

Peter Petros

The Female Pelvic Floor

Function, Dysfunction and Management According to the Integral Theory

Third Edition

Peter Petros

The Female Pelvic Floor

Function, Dysfunction and Management
According to the Integral Theory

With 365 Figures and 2 Tables

 Springer

PEP Petros MB BS (Syd) Dr. Med Sc (Uppsala) DSc DS (UWA) MB BS MD (Syd) FRCOG FRANZCOG CU

Dept of Gynaecology
Royal Perth Hospital
Western Australia

ISBN 978-3-642-03786-3 Springer-Verlag Berlin Heidelberg New York

Cataloging-in-Publication Data applied for
A catalog record for this book is available from the Library of Congress.

Bibliographic information published by Die Deutsche Nationalbibliothek
Die Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie;
detailed bibliographic data is available in the Internet at <http://dnb.d-nb.de>.

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilm or in any other way, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the German copyright Law of September 9, 1965, in its current version, and permission for use must always be obtained from Springer Medizin Verlag. Violations are liable for prosecution under the German Copyright Law.

Springer Medizin
Springer-Verlag GmbH
ein Unternehmen von Springer Science+Business Media
springer.com

© Springer-Verlag Berlin Heidelberg 2010
Printed in Germany

The use of general descriptive names, registered names, trademarks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.
Product liability: The publisher cannot guarantee the accuracy of any information about dosage and application thereof contained in this book. In every individual case the user must check such information by consulting the relevant literature.

SPIN 12743841
Cover Design: deblik Berlin, Germany
Typesetting: TypoStudio Tobias Schaedla, Heidelberg, Germany
Printer: Stürtz GmbH, Würzburg, Germany

Printed on acid free paper 18/5135/yb – 5 4 3 2 1 0

Cover design by Sam Blight, Rangs Graphics & Design

The three arrows represent the three major force vectors featured in the Integral Theory which control the tensioning of ligaments and membranes in the pelvic floor.

The enclosing circular brush stroke is inspired by the traditional 'enso' character in Zen calligraphy which represents non-duality or wholeness. This is to evoke the integrated approach covered in this book.

The butterfly represents the 'butterfly effect' concept from Chaos Theory, also known as 'sensitive dependence on initial conditions', which describes how small variations in a dynamic non-linear system (such as the pelvic floor) can produce a 'cascade' of events leading to a major change in the state of the system.

It also represents the freedom which this technology will give to women suffering from the many pelvic floor dysfunctions which can be cured by applying the Integral Theory System.

βίος βραχύς,
ὁ τέχνη μακρά,
ὁ καιρὸς ῥυτίς,
ὁ πειράσασθαι,
ὁ κρίσις χαλεπή

*Life is short,
[the] art long,
opportunity fleeting,
experiment dangerous,
judgment difficult.*

Hippocrates 460-377 BC

Science is the father of knowledge, but opinion breeds ignorance.

Hippocrates 460-377 BC

Preface to 3rd edition

Once more, I thank the growing number of colleagues around the world for their support of what has now become the “Integral System”.

Translations of the 2nd edition into German, Italian, Spanish, Polish, Romanian, Japanese, Chinese, and Korean lend growing international support to the concepts underlying this book.

A DVD, included for the first time, uses video to better explain function/dysfunction, diagnosis, ‘simulated operations’ and the tensioned mini-sling operations for incontinence and prolapse according to the “Integral System”. Since publication of the 2nd edition in 2006, there have been several important validations of the Integral Theory’s predictions. Bladder base stretch receptors have now been discovered in the urothelium. Dynamic 3D ultrasound and MRI have confirmed the lateral separation of hiatal structures, which the theory states is the major cause of organ prolapse. Validation that connective tissue, not muscle damage, is the prime cause of urinary and faecal incontinence has been documented by 3D ultrasound studies which show that, even in patients with torn pubovesical muscles, there was no increase in stress or faecal incontinence. Interstitial cystitis, vulvodynia, and pelvic pain symptoms and tenderness (Chapter 7) were relieved by local anaesthetic injected into the uterosacral ligaments, indicating that at least some of these conditions may be due to referred pain from uterosacral ligament laxity. Recently published works confirm many of the Theory’s predictions as regards idiopathic faecal incontinence causation by lax suspensory ligaments.

Xrays and EMGs added to Chapter 2 more clearly delineate the external striated muscle mechanism which opens the urethral tube for micturition, and closes it for continence. Chapters 3 and 4 (diagnosis and surgery) have been updated and expanded. Chapter 5 (pelvic floor rehabilitation) describes in more detail how symptoms such as pelvic pain, nocturia and urgency can be significantly improved with new, time-efficient exercises.

One of the major challenges identified in the preface to the 2nd edition, was how to address urinary and faecal incontinence in the ageing population. There has been steady progress in this domain, especially in Japan, using tensioned minisling methods. It is hoped that the anatomically based concepts presented in this 3rd edition will provide a basis for further progress in pelvic floor science and surgery.

Thanks to Joan McCredie for her assistance in the preparation of the text and to Sam Blight who has fulfilled a double role in this edition—editor and illustrator.

*Peter Papa Petros,
December 2009, Perth Western Australia.*

Foreword to the 3rd Edition

By Dr Bernhard Liedl, President, ICOPF (International Collaboration of Pelvic Floor Surgeons)

This book continues the development of the Integral System towards ever more minimal and effective methods for management of pelvic floor disorders. The Integral System is based on two major scientific discoveries. In the 1990s, an entirely new theory, the “Integral Theory”, by Petros (Australia) and Ulmsten (Sweden) proposed that bowel and bladder problems originate mainly from damaged vaginal ligaments, not from the bladder or bowel itself. The 2nd discovery by Petros and Papadimitriou, was a method for repairing these ligaments by creation of artificial ligaments. This had the effect of converting major operations with large incisions to relatively minor procedures performed through “keyhole incisions”.

Application of these twin discoveries has revolutionized the treatment of stress incontinence, with more than 1,500,000 operations performed to date. The experience of myself and other surgeons world-wide, confirms that this method can cure or improve many other conditions besides stress incontinence, for instance, prolapse, and symptoms such as urgency, nocturia, pelvic pain, bowel and bladder incontinence. Many of these conditions were previously considered incurable.

It takes many years for such a radical change in thinking to become widely known. This book is timely. It informs anyone interested in the pelvic floor how damaged vaginalligaments can cause specific problems, and how such problems can be cured or improved with a time efficient pelvic floor regime, or with state of the art minimally invasive surgery.

*Dr Bernhard Liedl,
President,
International Collaboration of Pelvic Floor Surgeons,
Munich, Germany, September 2009*

Foreword to the 2nd Edition

The initial objective of this work was to reduce stress incontinence surgery from a major surgical procedure (requiring up to ten days in hospital) to a minor day-care operation. From the beginning it was clear that the two major impediments to achieving this goal were post operative pain and urinary retention. Addressing these problems became a long and winding road and culminated in the Integral Theory.

The IVS 'tension-free' tape operation was inspired by Dr Robert Zacharin's anatomical studies. Though Zacharin suggested that the ligaments and muscles around the urethra were important for urinary continence control, he did not say how. The observation that implanted foreign materials created scar tissue led to the hypothesis that a plastic tape inserted in the position of the pubourethral ligament, would leave behind sufficient scar tissue to reinforce that ligament, which would then anchor the muscles for urethral closure.

In September 1986, two prototype Intravaginal Sling operations were performed. A Mersilene tape was inserted with neither tension nor elevation, in the position of the pubourethral ligament. Restoration of continence was immediate and both patients were discharged on the day following surgery without requirement for catheterization. There was minimal pain, and immediate restoration of continence. After six weeks the tapes were removed. Both patients were still continent at last review 10 years later. The results appeared to confirm the importance of a midurethral anchoring point. Furthermore, as there was no elevation of the bladder neck, the results cast doubt on the validity of the prevailing 'pressure equalization theory' of Enhorning.

In 1987, with Professor John Papadimitriou and colleagues from Royal Perth Hospital, a series of experimental animal studies was performed to scientifically analyse the safety, efficacy and *modus operandi* of a tape implantation. Tape implantation was found to be safe and it worked by creating a linear deposition of collagen in the position of implantation.

The first of 30 operations were performed at Royal Perth Hospital, Western Australia, between 1988 and 1989. An adjustable intravaginal Mersilene sling was sited at midurethra. The sling was set in an elevated position but this caused urgency and obstructed flow post-operatively. As the sling was lowered, these symptoms disappeared, yet most of the patients remained cured of their stress incontinence.

On comparing the pre-operative and post-operative x-rays, no elevation of bladder base was evident. This appeared to invalidate the 'Pressure Equalization Theory' for maintenance of urinary continence. Furthermore, when the midurethral tape was anchored by grasping it with a haemostat, the distal urethra was seen to move forward, but the Foley balloon catheter moved backwards and downwards around the midurethral point. From these observations the concept of two separate closure 'mechanisms' emerged. Over the space of a year, a theoretical framework that integrated these disparate findings with known anatomy was developed (the Integral Theory 1990). The key concepts were that the suspensory ligaments were essential for

normal bladder function, and that bladder dysfunction occurred because of connective tissue damage within these same ligaments.

In 1990 a collaboration with Professor Ulf Ulmsten began. Further studies were performed, and the first formulation of the Integral Theory was published:

For different reasons, stress and urge derive mainly from laxity in the vagina or its supporting ligaments, a result of altered collagen/elastin.

Separate urethral and bladder neck closure mechanisms were described. Abdominal ultrasound studies in 1990 demonstrated that the urethra was closed from behind by the hammock closure mechanism. Bladder instability in the non-neurological patient was defined as a premature activation of the micturition reflex.

In 1993 the second exposition of the Integral Theory presented radiological and urodynamic studies and brought a higher level of proof.

Five prototype suburethral sling operations for stress incontinence were analysed with reference to *modus operandi* and surgical methodology (1993 Integral Theory). A problem that remained was the relatively high rate of Mersilene tape erosion. This was largely solved in 1996 by Professor Ulmsten's Scandinavian group (Ulmsten et al. 1996) through use of a polypropylene mesh tape. The 'posterior fornix syndrome' was described (1993 Integral Theory). Reconstruction of the posterior ligaments improved symptoms of urge, nocturia, abnormal emptying and pelvic pain. These findings were seminal in the construction of the Pictorial Diagnostic Algorithm.

The ten years to 2003 has seen a consolidation and international acceptance of many parts of the Integral Theory, in particular, the treatment of stress incontinence with a midurethral sling. The Theory framework has expanded to include faecal incontinence, abnormal emptying, and some types of pelvic pain. New ultrasound and urodynamic techniques promise to improve diagnostic accuracy, especially when used with the 'simulated operations' technique described later in this book. Improvements in surgical methodology have been running on a parallel path with the expansion of the Integral Theory. These new methods were developed because traditional vaginal surgery methods of excision and approximation were unable to restore tissue strength sufficiently to restore structure, as described by the Integral Theory system. To overcome this deficiency, double layered techniques such as the 'bridge' repair, which recycles excess vaginal tissue (Petros 1998), and the Posterior IVS (Petros 2001) were developed. Tightening the suburethral hammock in addition to a midurethral sling has increased the cure rate for stress incontinence and intrinsic sphincter defect (Petros 1997). The posterior sling has been further improved and simplified.

In particular, the new tissue fixation system (TFS) appears to be a major advance on the existing 'tension-free tape' slings in that it is possible to repair any ligament or fascial defect in the pelvic floor. The TFS operations are more anatomical, far less invasive, and they are able to be performed *under direct vision*.

This book has been written in the hope that it will further clarify and disseminate the ideas of the Integral Theory and help provide the basis required for further

advances in theory, diagnosis and surgical techniques to alleviate problems in the female pelvic floor.

Chapter 1 is an introduction and overview of the Integral Theory. It outlines the 'problem' being addressed, that is, the various symptoms of pelvic floor dysfunction, current knowledge and treatments. The overview explains normal function, and introduces the causes of dysfunction, diagnosis of damaged structures and the principles of minimally invasive surgical repair according to the Integral Theory.

Chapter 2 aims to familiarize the reader with the roles of ligaments and muscle forces and describes how they work synergistically to maintain form and function of the pelvic organs. It describes the anatomy of the pelvic floor, the interrelated roles of bone, muscles, ligaments and organs in the context of structure, form and biomechanics. It describes the static and dynamic anatomy of the pelvic floor and the seminal role played by connective tissue in function and dysfunction. It introduces the concept of the 'three zones' of the vagina, which is a central part of the Integral Theory diagnostic system, surgical anatomy and techniques.

Chapter 3 describes the Integral Theory system for diagnosis of connective tissue damage in the three zones of the vagina. Two diagnostic pathways are discussed in detail: the Clinical Diagnostic pathway, suitable for the general clinician, and the Structured Assessment pathway for use in specialist pelvic floor clinics. The components of these pathways and their role in the diagnostic process are described thoroughly. The concept of the 'simulated operation', used for verification of diagnosis, is introduced. This is an invaluable part of the Integral Theory system. It is used for preoperative direct testing of the zone of diagnosed anatomical damage.

Chapter 4 discusses the conceptual basis for minimally invasive pelvic floor surgery and introduces a new perspective on the surgical anatomy of the three zones of the vagina. It presents the minimally invasive surgical techniques developed for addressing anatomical defects in each of the zones, in particular the 'tension-free' tape anterior and posterior slings, and introduces the tissue fixation system.

Chapter 5 explains the pelvic floor rehabilitation exercises that were developed from the Integral Theory approach. Originally these exercises were designed as an alternative to surgery, but it has been found that they also assist the patient in maintaining the benefits they have attained from surgery.

Chapter 6 gives an anatomical basis for the 'mapping' of connective tissue dysfunction and the anatomical basis for urodynamics is explained. Many of the internal contradictions within conventional urodynamics are explained using the Chaos Theory framework, non-linear methodology and Boolean algebra. Boolean algebra is used to explain the concept of switching between the closed and open phases of the bladder. There are descriptions of the expanded use of transperineal ultrasound to the middle and posterior zones.

Chapter 7 discusses current and emerging issues related to further enhancement of the Integral Theory system, in particular, faecal incontinence. The potential of the new scientific concepts, methodologies and technologies in making the diagnostic process more efficient is discussed. The Integral Theory Diagnostic System (ITDS), a computer based diagnostic system, incorporating the potential of a large data base

developed across the internet is presented. Chapter 8 is the conclusion. It briefly tracks the evolution of the Integral Theory from theory to working system and discusses the future importance of the internet for this new direction for pelvic floor science. The questionnaire and other tools used in the diagnostic process are included and described in Appendix 1. References and further reading are included in Appendix 2.

Foreword to the First Edition

I first encountered the Integral Theory system in the early 1990's at the Royal Perth Hospital laboratory in Western Australia where I was working on laparoscopic colposuspension. Even in prototype form, the IVS operation was so simple and effective that I adopted it immediately. Subsequently, based on my experiences, I wrote the following in the Medical Journal of Australia in October 1994:

(the operations) promise a new era for women, virtually pain-free cure of prolapse and incontinence without catheters, and return to normal activities within days.

Now, ten years later, more than 500,000 'tension-free' anterior or posterior sling operations have been performed.

One case in particular stands out from those early years. A woman patient in her mid-50's came to see me with a five year history of urinary retention which required an indwelling catheter. This woman had consulted more than a dozen medical specialists who had told her the same story: no cure was possible. Using the Structured Assessment of the Integral Theory it was deduced that she had a posterior zone defect. I performed a Posterior IVS. The next day the patient was voiding spontaneously with low residuals, and she has remained well since.

At first I was sceptical about some of the other predictions of the Integral Theory, in particular, surgical cure of nocturia, frequency, 'detrusor instability', chronic pelvic pain, intrinsic sphincter defect and 'idiopathic faecal incontinence. However, the high cure rate obtained by following the diagnostic system described in this book soon convinced me that the Integral Theory framework had much wider applications than those predicted in the original publications.

It is self-evident that the Integral Theory has now matured into an important medical Paradigm, every aspect of which is outlined in this book.

The original work on the Integral Theory was done at Royal Perth Hospital, Western Australia and the University of Uppsala, Sweden. However, the defining concepts concerning management and surgery were done at Royal Perth Hospital. It was here that the biomechanical and fluid dynamic principles developed at the University of Western Australia's Department of Mechanical and Materials Engineering and Fluid Dynamics were applied in practical form. For these works, Professor Petros received his Doctor of Surgery degree in 1999.

It should be emphasized that this book is mainly clinically based. Using the Diagnostic Algorithm and 'simulated operations', techniques which are thoroughly described herein, it is possible for the generalist to achieve a high degree of diagnostic accuracy and high cure rates. Furthermore most conditions can be treated at the clinical level without the use of expensive diagnostic equipment or surgical facilities. This means that the methods described in this book can be accessed by medical professionals in less developed countries where resources and equipment may not be readily available.

Peter Richardson FRCOG, FRANZCOG

Immediate Past Chairman, National Association of Specialist Obstetricians and Gynaecologists of Australia (NASOG).

Acknowledgments

It is now almost twenty years since the first threads of the Integral Theory arrived in my consciousness. This book brings together these and all the other threads which have materialized over these years. Throughout this time, I have had the unflinching support of my family, my wife Margaret, and children Eleni, Angela and Emanuel, my brother, Dr Sid Papapetros, my co-director of the Kvinno Centre, Dr Patricia M. Skilling, and the staff at the Kvinno Centre, Carole Yelas, Linda Casey, Maria O'Keefe, Margeurite Madigan and Joan McCredie. No enterprise can be achieved without passion, the interest of other colleagues, and above all, teamwork. My hospital, Royal Perth Hospital, has been immensely supportive. Much of the experimental work was done with internal hospital support. I am especially indebted to Dr Bill Beresford, Director of Medical Services, Drs Jim Anderson and Richard Mendelson, Department of Radiology, Mr Ed Scull and Dr Richard Fox Department of Medical Physics, Professor Mark Bush, Department of Mechanical and Materials Engineering, University of Western Australia (UWA), Professor Yianni Attikiouzel, Centre for Intelligence Processing, UWA, Professor Byron Kakulas from the Department of Neuropathology, Professor John Papadimitriou and Dr Len Matz from the Department of Pathology, Dr Ivor Surveyor from the Department of Nuclear Medicine, Mr Terry York Director of the animal laboratory, personnel from the Departments of Pathology, Morbid Anatomy, Bacteriology and Biochemistry, Dr John Chambers, Emeritus Gynaecologist, and Dr Graham Smith, Head of Department Gynaecology, colleagues from the Department of Surgery, UWA, in particular Professor Bruce Gray, and Dr G Hool. Several colleagues played a seminal role in the late 1980s and early 1990s. In Australia, Dr Peter Richardson, Chairman of the National Association of Specialist Obstetricians and Gynaecologists and Dr Colin Douglas Smith Emeritus Consultant from King Edward Hospital who made a prospective case by case assessment of 85 patients on behalf of the Hospital Benefits Fund of Western Australia. His conclusion that the surgical operations had largely fulfilled the predictions of the Integral Theory was a key factor in the wider propagation of the surgery. Since 1995, an ever-growing group of Gynaecological Surgeons belonging to the Association of Ambulatory Vaginal and Incontinence Surgeons (AAVIS) have used the Integral Theory diagnostic system and have learnt the various operations derived from the theory. I am indebted to the AAVIS President, Dr WB Molloy, Secretary, Dr Bruce Farnsworth, and Treasurer, Dr Laurie Boshell for their invaluable advice and assistance. I acknowledge a major intellectual debt to Dr Robert Zacharin whose 1961 anatomical works provided an inspirational starting point for the Integral Theory.

In December, 1989 I met the late Professor Ulf Ulmsten from the University of Uppsala. We began a close and productive collaboration lasting some years. During this time we published the 1990 and 1993 publications of the Integral Theory, and in time I became Associate Professor in his department. Coming from a clinical surgical background, it was a revelation for me to work in Uppsala in an environment which gave such emphasis to basic science, and I hungrily absorbed this scientific milieu until it became part of my being. Ulf Ulmsten opened the door to many Scandinavian works

on urodynamics, to which he himself had made some major contributions. I maintain a strong interest in urodynamics to this day. Through Ulf Ulmsten I met Professor Ingelman -Sundberg, the father of Urogynaecology whose writings I studied. In 1994 I met Professor Michael Swash who encouraged my interest in faecal incontinence, and with whom I later collaborated in studies of myogenic changes in patients with urinary incontinence. Another major intellectual influence in the development of the anatomically-based surgical techniques described in this book was the late Professor David Nichols, whom I knew and with whom I corresponded. Nichols in turn acknowledged his debt to major English, American, German and Austrian anatomists and surgeons, as do I. Over the years I have travelled widely in Europe, Asia, North and South America, teaching and being taught. To all these colleagues, I express my gratitude for affording me that privilege. In particular, I would like to thank Dr Victoria D'Abrera, FRCPath FRCPA and Carole Yelas for their invaluable scrutiny of the final text. The process of writing this book was managed by Mr Gary Burke. His insights have given the book a coherence which I hope translates into readability. Mr Sam Blight has added his creativity to the basic diagrams. Finally a special thanks to Yvonne Bell from Springer, whose assistance made this book possible.

Peter Papa Petros Perth, 2004

Contents

Preface to 3rd edition	VI
Foreword to the 3rd Edition	VII
Foreword to the 2nd Edition	VIII
Foreword to the First Edition	XII
Acknowledgments	XIII
Chapter 1: Overview	2
1.1 Introduction	2
1.1.1 The Problem	2
Urinary Incontinence	2
Frequency of Urination	2
Nocturia	3
Bowel Dysfunction	3
Abnormal Bladder Emptying	3
Chronic Pelvic Pain	3
Other Problems	3
1.1.3 A Summary Guide to the Diagrams Used in this Book	4
Series 1 Static Anatomy	4
Series 2 Dynamic Anatomy	7
Series 3 Functional Anatomy	8
1.2 Overview of Pelvic Floor Function and Dysfunction	9
1.2.1 Basic Tenets of the Integral Theory System	9
Structure and Form	11
Function and Dysfunction	11
Causes of Dysfunction - Delineating the Zones of Damage	11
Locating the damaged structures within the three zones	12
Diagnosis of Damage	13
Surgical Repair of Connective Tissue Structures	13
1.3 Summary Chapter 1	15
Chapter 2: The Anatomy and Dynamics of Pelvic Floor Function and Dysfunction ...	17
2.1 The Anatomy of Pelvic Floor Function	17
2.1.1 Introduction	17
2.1.2 The Role of Ligaments, Muscles and Fascia	18
2.1.3 The Role of Connective Tissue Structures	18
2.1.4 The Key Ligaments of the Pelvic Floor Structure	19
The Pubourethral Ligament (PUL)	19
The Arcus Tendineus Fascia Pelvis (ATFP)	20
The Cardinal Ligaments/Anterior Cervical Ring Complex	20
The Uterosacral Ligaments (USL)	20
The Pubovesical Ligament (PVL)	20
The Precervical Arc of Gilvernet	21
The Trigone	21
Fascial attachment of the vagina to ATFP	22
Organ Spaces	22
The Pubocervical Fascia	22
The Rectovaginal Fascia	23
The Cervical Ring	23
The Role of Proximal Cervical Ring Fascia	23
The Levator Hiatus	24

2.1.5	The Muscles of the Pelvic Floor	25
	The Upper Layer of Muscles	25
	The Middle (Connecting) Layer of Muscles	26
	The Lower Layer of Muscles	28
	The Special Case of the Puborectalis Muscle	29
2.2	The Dynamics of Pelvic Floor Function	30
2.2.1	The Dynamics of the Striated Pelvic Floor Muscles	30
	The Dynamics of Urethral Opening and Closure – Urethral Perspective	30
	The Dynamics of Urethral Closure and Opening – Vaginal Perspective	32
2.2.2	Pelvic Floor Dynamics - The 'Mechanical' Dimension	33
	Resting Closed	33
	Closure During Effort	34
	Urethral Opening by External Striated Muscle Forces During Micturition	36
	The Special Case of the Puborectalis Muscle	37
	Urethral Resistance	38
2.2.3	Pelvic floor dynamics - the neurological dimension	39
	Urethral Closure	39
	Urethral Opening (Micturition)	39
	The Role of Connective Tissue Tension	40
	Bladder Base Stretch Receptors	42
2.3	The Role of Connective Tissue in Pelvic Floor Function and Dysfunction	43
2.3.1	The Biomechanics of the Vagina	44
	The Effect of Pregnancy Hormones on Connective Tissue	46
	The Effect of Age on Connective Tissue	46
	The Role of Connective Tissue in Transmitting Muscle Forces	46
	The Positive Effect of Uterine Conservation in Preserving Ligament Integrity	47
2.3.2	The Role of Connective Tissue in the Maintenance of Form and Function	47
	The Causes of Damaged Connective Tissue	48
	Structural Effects of Damaged Connective Tissue	48
	Lax Connective Tissue and Diminution of the Force of Muscle Contraction	50
2.3.3	Role of Connective Tissue in Balance and Imbalance of Pelvic Muscle Forces	51
	The Anatomy and Pathogenesis of Prolapse	51
	Angle of the vaginal axis to the horizontal	53
	A Possible Mechanism for Widening the Hiatus	54
	Role of Pubovisceral Muscle Avulsion in Prolapse Causation	55
	Pathogenesis of rectocoele	56
2.3.4	The Role of Connective Tissue in Balance and Imbalance of Pelvic Muscle Forces – Effects on Micturition and Closure	57
	Closure at Rest and Effort	57
	Normal Micturition – A Controlled Temporary Unbalancing of the Closure System	58
	The Role of Damaged Connective Tissue in Incontinence Causation	59
	The Role of Damaged Connective Tissue in the Pathogeneses of Intrinsic Sphincter Defect	59
	The Role of Connective Tissue in Peripheral Neurological Imbalance – Bladder Instability	60
	The Role of Connective Tissue Damage in the Causation of Abnormal Bladder Emptying – A Mechanical Imbalance	61
	Symptomatic Manifestations of Imbalance Caused by Damaged Connective Tissue	62
2.3.5	The Role of Connective Tissue in Anorectal Opening, Closure and Idiopathic Faecal Incontinence	62
	A Musculo-Elastic Sphincter for Anorectal Closure (Continence)	62
	Tethered vagina syndrome	62
	A minor role for muscle damage in urinary incontinence?	64

Incontinence	64
A Musculo-Elastic Sphincter for Anorectal Closure (Continence)	65
A New Sphincter	65
The anatomical supports of the anorectum complex	65
Radiological correlations for normal function	67
Anorectal closure during straining, -normal patient	67
Anorectal closure during straining, faecal incontinence group (figs 2-57d&e)	69
During squeezing, faecal incontinence group	70
During defaecation, faecal incontinence group	70
Connective Tissue Laxity and Anorectal Dysfunction	71
The Role of m.puborectalis, external and internal anal sphincters in faecal incontinence causation	72
Dislocation of Anal Mucosa	74
Further reading on Nonsurgical and Surgical proofs of the Musculoelastic Theory	74
The related dynamics of anorectal and bladder function and dysfunction	74
2.4 Summary Chapter 2	76
Chapter 3: Diagnosis of Connective Tissue Damage	77
3.1 The Integral Theory Diagnostic System: Overview	77
3.2 The Integral Theory Diagnostic System	82
3.2.1 The Clinical Assessment Pathway	82
Using the Clinical Assessment Pathway in a Clinical Assessment	82
Phase 2 of Clinical Assessment Pathway - Examination	83
Anterior Zone Examination	84
Middle Zone	85
The special case of "Tethered Vagina" Defect	86
Posterior Zone Defect	87
Phase 3 of Clinical Assessment Pathway – Simulated Operations	89
'Simulated Operation' Technique: Anterior Zone	90
'Simulated Operation' Technique: Middle Zone	91
'Simulated Operation' Technique: Posterior Zone	92
Limitations of 'Simulated Operations'	92
3.2.2 The Structured Assessment Pathway	93
Introduction	93
Phase One of the Structured Assessment Pathway: Data Collection and Correlation	93
3.3 Working with Symptoms in the Integral Theory Diagnostic System	103
3.3.1 The Cerebral Cortex – the ultimate urodynamic machine	103
3.3.3 Assessing Probability: The Impact of Different Structures on the Variability of Incontinence Symptoms	105
3.3.4 The Anatomical Basis for the Diagnostic Summary Sheet	106
Anterior Zone Defect Symptoms	106
3.3.5 ICS Definitions and Descriptions expressed as dysfunctions of opening and closure	111
The Role of the Peripheral Neurological Control Mechanism in the 'Unstable Open' State ...	112
Motor Urgency (Anterior, Middle & Posterior Zones)	113
Nocturia – Posterior Defect	113
Sensory Urgency (Posterior, Middle, Anterior Zone Defects)	113
Unconscious Incontinence, Continuous Leakage (Anterior, Posterior Zone Defects)	114
Detrusor Instability (Posterior, Anterior, Middle Zone Defects)	114
Unstable Urethra (Posterior, Anterior, Middle Zone Damage)	114
Inability to Micturate with Neurological Damage	115
Change of Compliance (Posterior, Anterior, Middle Zone Defects)	115
Bladder Sensation (Posterior, Anterior, Middle Zone Defects)	115
Bladder Capacity	115

Urethral Function During Storage (Anterior, Posterior Zone Defects)	115
Genuine Stress Incontinence (Anterior Zone Defect)	116
Cough Activated Detrusor Instability	116
Reflex Incontinence	116
Detrusor Acontractility, Underactivity, Overflow Incontinence, Post-Micturition Dribble (Posterior, Middle Zone Defects)	117
Detrusor/Bladder Neck Dyssynergia (Anterior, Posterior Zone Defects)	117
3.4 Summary Chapter 3	117
Chapter 4: Reconstructive Pelvic Floor Surgery According to the Integral Theory ...	118
4.1 Introduction	118
4.2 The Integral Theory Approach to Reconstructive Pelvic Floor Surgery	118
4.2.1 The Conceptual Bases of Minimally Invasive Pelvic Floor Surgery	118
The Indications: Major Prolapse, or Major Symptoms with Minor Prolapse	119
The Tissues: Conservation and Reinforcement of Tissue	120
The Structure: The Synergistic Interaction of Connective Tissue Components	120
The Methods: Site-Specific Ligament Repair-Uterine and Vaginal Conservation	121
The Tools – A Tape and its Delivery Instrument	121
‘Tension-free tapes’ and their modus operandi	121
‘Tension-Free’ Tapes Attached to Large Mesh	122
A Clarification: ‘Tension-free’ Tapes are Not ‘Without Tension’	125
How a tensioned sling differs from a ‘tension-free’ mesh	125
4.2.2 The Surgical Principles of the Integral Theory	126
Introduction	126
Guiding Principles for Day-Care Vaginal Surgery	126
To minimise pain_	126
Conservation and Reinforcement of Tissue: Implications for Surgery	127
Adapting Surgical Technique for Wound Healing, Tissue Weakness and Scarring	128
Patient Care Issues Specific to Day-Care Pelvic Floor Surgery	129
4.2.3 Surgical Practice According to the Integral Theory	131
Correction of Connective Tissue Damage	131
Repair of Damaged Ligaments through Creation of Artificial Neoligaments	132
Repair of Damaged Fascia	138
4.3 Application of the Integral Theory Surgical System according to Zone of Damage	146
4.3.1 Surgery of the Anterior Zone	146
The Structures of the Anterior Zone	146
The Methods: Strengthening a Weakened Pubourethral Ligament with a Tape	148
Interpretation	152
Potential Intra-Operative Complications of Retropubic ‘Tension-Free’ Tape Slings	154
Bleeding	155
Difficulty with Passage of the Delivery Instrument with retropubic slings	155
Retropubic Fibrosis from Previous Incontinence Surgery	155
Scarring in the Rectus Sheath	155
Urethral Constriction by the Tape	156
Bladder Perforation	156
Testing for Continence at the End of Midurethral Tape Operations	156
Trans-Obturator Approach (TOT), Delorme 2001	156
“Tension-free” minislings	157
Complications	157
“Tensioned” mini sling	157
Outpatient Local Anaesthetic Technique	158
EUL and Hammock Tightening	158
EUL Reinforcement with a Small Segment of Polypropylene Tape	158

EUL reinforcement with a prepubic TFS sling, fig 4-37c, box, fig 4- 37d	159
Case history –EUL defect	160
Interpretations	160
4.3.2 Surgery of the Middle Zone	161
The Structures of the Middle Zone	161
Sites of damaged fascia	162
The Indications for Surgery in the Middle Zone	167
The Methods - Surgical Repair of the Middle Zone	167
Case report	178
Cure of “tethered vagina” with bladder neck skin graft	186
‘Tethered vagina’ after transobturator tape for cure of urinary stress incontinence	187
4.3.3 Surgery of the Posterior Zone	187
The Structures of the Posterior Zone	187
Indications for Posterior Zone Surgery: Damage to the Uterosacral Ligaments and Perineal Body	194
The Methods: Surgical Repair of the Posterior Zone	194
Simple level 1 repair of the posterior zone	195
Repair of Rectocele	202
The Posterior Fornix Syndrome addressed with TFS posterior sling	202
TFS perineal body repair of rectocele recurrence	208
Potential Complications of Posterior Zone Repair	209
Surgical cure of Idiopathic Faecal Incontinence by suspensory ligament repair	210
4.4 Post operative Monitoring: Strategies for Managing Recurrent or New Symptoms	211
The Origins of Subclinical Damage - How One Zone May Decompensate After Repair of Another Zone	211
The Dynamics of Symptom Formation	212
Managing Persisting Symptoms - An Anatomical Approach	213
Post-operative Middle Zone Symptoms	217
Post-operative Posterior Zone Symptoms	217
Future Directions for the Objective Diagnosis of Zone of Connective Tissue Damage	218
4.5 Summary Chapter 4	218

Chapter 5: Pelvic Floor Rehabilitation according to the Integral Theory

Towards a more time efficient method for pelvic floor rehabilitation and with a wider symptom scope 219

5.1 Introduction	219
The anatomy of traditional Kegel Exercises	219
The anatomical basis for the Integral Theory System for pelvic floor rehabilitation (PFR) ...	220
Why the Integral Theory System for pelvic floor rehabilitation was developed	221
Towards a more time efficient method for pelvic floor rehabilitation – use of a “fit ball” ...	221
Methodology for the 1st and 2nd studies, Tables I&II	221
5.2.1 Indications	223
Design	223
Comments	224
Conclusions	225

Chapter 6: Mapping the Dynamics of Connective Tissue Dysfunction 226

6.1 Mapping Function and Dysfunction of the Pelvic Floor	226
6.1.1 Urodynamics - An Anatomical Perspective	227
The Anatomical Basis of Urodynamic Measurement	228
Urethral Resistance and the Pressure-Flow Relationship	229
The Dynamics of Urethral Pressure Changes	230
Urethral Pressure	231

The Urodynamics of Micturition	233
Urodynamic Bladder Instability – Premature Activation of the Micturition Reflex	234
Voluntary Control of the Micturition Reflex	235
Normal Micturition and ‘After Contraction’ – A Sign of Normal Tissue Elasticity	237
‘Outflow Obstruction’	238
Limitations of Existing Tests: The Need for a Finite Element Model for Urodynamics	238
6.1.2 The Chaos Theory Framework – Its Impact on the Understanding of	
Bladder Control and Urodynamic Charting	239
Fractals	239
Extreme Sensitivity to Initial Conditions (The ‘Butterfly Effect’)	239
6.1.2 A Non-Linear Perspective of the Neurological Control of the Micturition Reflex	241
Normal Function	241
Dysfunction	242
Bladder Instability – A Struggle Between the Opening and Closure Reflexes	242
Mathematical Testing of Feedback Control of the Micturition Reflex	244
Example of Iterations of a Simple Feedback Equation (as per figure 6-25)	245
6.1.3 Transperineal Ultrasound	246
Ultrasound Assessment of the Anterior Zone	247
Ultrasound Assessment of the Middle Zone	247
Ultrasound Assessment of the Posterior Zone	249
6.1.4 The Role of X-rays in the Diagnosis of Ligamentous and Connective Tissue Defects	250
Anterior Zone X-rays	250
Middle and Posterior Zone X-rays	251
Abnormal Middle and Posterior Zone Anatomy X-rays	252
6.2.4 Dynamic Mapping with ‘Simulated Operations’: A Clinical Example	252
Background to the Clinical Example	252
The Intervention - ‘Simulated Operation’	253
The Post-Intervention Results – Anchoring One Structure at a Time	254
Post intervention Results – Two Structures Anchored Simultaneously	254
Comment	255
Conclusion	258
6.3 Summary Chapter 6	258
Chapter 7: Current and Emerging Research Issues	259
7.1 Introduction	259
7.2 Improvements in the Diagnostic Decision Path	261
7.3 The Integral Theory Diagnosis Support System (ITDS)	262
7.4 Possible Clinical Associations	262
7.4.1 Vulvar Vestibulitis (Vulvodynia)	262
7.4.2 Interstitial Cystitis	263
An objective office test to determine the role of the uterosacral ligaments in the causation	
of vulvodynia, pelvic pain and painful bladder syndrome (‘Interstitial Cystitis’)	264
Vulvodynia associated with chronic pelvic pain	264
Painful bladder syndrome, vulvodynia and chronic pelvic pain	264
Comments	265
7.4.3 Unresolved Nocturnal Enuresis and Daytime Incontinence	265
7.4.4 Vesico-Ureteric Reflux	266
Conclusion	267
Appendix 1 – Patient Questionnaires and Other Diagnostic Resource Tools	269
Patient Questionnaire	270
Quality of life grading	272
Explanatory Code for Physicians - Significance of ‘50% filter’ (column 3)	273

Explanatory Notes for the Numbers Preceding the Questionnaire Responses	273
Comprehensive 24 Hour Urinary Diary	274
'Objective' Tests	275
Pad tests	275
Pad Test Methodology Explanatory Notes	275
Example of a Completed Diagnostic Summary Sheet	279
Appendix 2 – References and Further Reading	283
Original works by the author which seek to validate the theory and its applications	284
Chapter 2: The Anatomy and Dynamics of Pelvic Floor Function and Dysfunction	293
Chapter 2: Further Reading	295
Chapter 3: The Diagnosis of Connective Tissue Damage	297
Chapter 4: Reconstructive Pelvic Floor Surgery	299
Chapter 4: Further Reading	302
Chapter 5: Pelvic Floor Rehabilitation	304
Chapter 6: Mapping the Dynamics of Connective Tissue Dysfunction	304
Chapter 6: Further Reading	306
Chapter 7: Current and Emerging Issues	307
Appendix 3 – Patient Information	308
Chapter 1: Understanding Your Vagina, Bladder, Bowel, and How They Work in a Normal Woman ...	309
Bladder, Bowel and Uterus	309
The importance of your ligaments	308
The Pelvic Muscles	312
A Symphony Orchestra	313
The brain and its nerves—a sophisticated feedback system	314
Chapter 2: How the Ligaments Become Loose to Cause Symptoms and Prolapse	315
The structure of ligaments	315
How ligaments are stretched and damaged during pregnancy and labour	315
The effect of age and menopause	316
Site of damage and its consequences	316
A perspective on organ prolapse	319
Index	323

List of Frequently Used Abbreviations and Acronyms

A	anus	LMA	longitudinal muscle of the anus
AAVIS	Association of Ambulatory Vaginal and Incontinence Surgeons	MUCP	maximal urethral closure pressure
ATFP	arcus tendineus fascia pelvis	N	nerve endings/stretch receptors
BN	bladder neck	O	opening phase of the bladder/urethra
BNE	bladder neck elevation	PB	perineal body
C	closure phase of the bladder/urethra	PM	perineal membrane
CL	cardinal ligament	PAP	post-anal plate
CP	closure pressure	POPQ	The ICS prolapse classification
CT	connective tissue	PCF	pubocervical fascia
CX	cervix	PCM	pubococcygeus muscle
CTR	cough transmission ratio	PNCT	pudendal nerve conduction times
DI	detrusor instability	PofD	Pouch of Douglas
EAS	external anal sphincter	PS	pubic symphysis
EUL	external urethral ligament	PRM	puborectalis muscle
F	fascia	PUL	pubourethral ligament
FI	faecal incontinence	PUSM	periurethral striated muscle
GAGS	glycosaminoglycans	PVL	pubovesical ligament
GSI	genuine stress incontinence	RVF	rectovaginal fascia
H	suburethral vagina (hammock)	R	rectum
ICS	International Continence Society	S	sacrum
IS	ischial spine	SI	stress incontinence
ISD	intrinsic sphincter defect	T	Tapes
ITDS	Integral Theory Diagnostic Support System	TFS	tissue fixation system
IVS	Intravaginal slingplasty	U	urethra
LA	levator ani – anterior portion of PCM	USL	uterosacral ligament
LP	levator plate	UT	uterus
		V	vagina
		ZCE	zone of critical elasticity

Overview

1.1 Introduction

1.1.1 The Problem

Female pelvic floor dysfunctions form an extensive, if well hidden problem. Urinary incontinence is perhaps the best known of these dysfunctions but prolapses, faecal incontinence and pelvic pain affect a significant number of women. Even with urinary incontinence, the conventional approaches leave many bladder conditions deemed as 'incurable'.

The problem of 'conventional' surgical correction is a case in point. When performed in the usual manner, bladder neck elevation (BNE) surgery for stress incontinence is characterized by long hospital stays, post-operative pain, urinary retention, neourgency, increasing surgical failure with time, and an incidence of enterocoele of up to 20%. BNE surgery is not generally advised for situations where there is mixed incontinence. Moreover, it cannot cure other pelvic floor dysfunctions.

It is the contention of this book that pelvic floor dysfunctions are largely caused (for different reasons) by damaged connective tissue in the suspensory ligaments of the pelvic floor. Treatment according to the Integral Theory is based on the principle that *'restoration of form (structure) leads to restoration of function'*. Hence, repair of damaged ligaments makes it possible to cure not only organ herniations and prolapses, but many conditions currently deemed 'incurable' by conventional approaches to incontinence. These are listed below.

Urinary Incontinence

In simple terms, urinary incontinence can be defined as involuntary urine loss. The prevalence in women as reported varies between 10 and 60%. It has two main components, stress (SI) and urge (UI) incontinence. UI increases with age. Only SI is said to be surgically curable. UI or mixed SI and UI are treated with drugs or bladder training. Drugs are rarely tolerated in the longer term because of side effects.

Frequency of Urination

Frequency of urination is defined as a problem when it occurs more than eight times per day. Causation is mostly unknown and it is treated with drugs or bladder training, both of which are not effective in the longer term.

Nocturia

Nocturia is defined as a problem when it occurs more than two times per night. Causation is mostly unknown and it is treated with drugs or bladder training, both of which are not effective in the longer term.

Bowel Dysfunction

Bowel dysfunction has two elements, difficulty with evacuation ('constipation') and incontinence, involuntary loss of wind or faeces (FI). FI causation is unknown, but is thought to be due to anal sphincter or pelvic muscle damage. The prevalence of all bowel dysfunctions in women varies between 10 and 20%. Treatment usually consists of drugs to slow down the bowel action, diet and operations such as levatorplasty. None of these treatments are particularly effective.

Abnormal Bladder Emptying

Abnormal bladder emptying can be defined as difficulty in bladder evacuation. It has specific symptoms and can present as chronic urinary infection due to a high residual urine. Conventionally it is treated with urethral dilatation, even though there is no obstruction and the treatment is not very effective.

Chronic Pelvic Pain

Chronic pelvic pain is characterized by a one-sided 'dragging' pain, of varying severity. The incidence can be as high as 20% of women. The cause is unknown but is thought to be psychological.

Other Problems

'Interstitial Cystitis' is a debilitating condition. The cause is unknown and no long term effective treatment is known. 'Vulvodynia' may occur in 10% of women. Symptoms can be severe in affected women. Causation is unknown. Treatment is empirical, and not always effective.

Relationship of prolapse to symptoms

Uterine prolapse, herniations of the anterior vaginal wall (cystocoele), vaginal apex, and posterior vaginal wall (rectocoele) may occur with or without the above symptoms. Conversely, some symptoms such as pelvic pain and urgency, may occur with minimal prolapse.

1.1.2 The Integral Theory - A New Perspective

The Integral Theory explains the above problems in terms of connective tissue damage to the pelvic ligaments and fascia. The Theory has evolved into the Integral System, which has 4 elements:

- Function
- Dysfunction
- Diagnosis
- Management

In the pages that follow, the scientific framework and contemporary practical applications of these 4 elements is presented. In particular, how accurate reconstruction of these structures according to the Integral System, may significantly improve both organ prolapse and symptoms.

1.1.3 A Summary Guide to the Diagrams Used in this Book

Many diagrams are used in this book to illustrate the components of various aspects of pelvic floor function and dysfunction. The purpose of the following series of diagrams is to familiarize the reader with the anatomical structures as well as the abbreviations and acronyms used. It is hoped that the reader will spend a few minutes contemplating these generic diagrams so that the general flow of the text can be more easily followed as the diagrams become more complex.

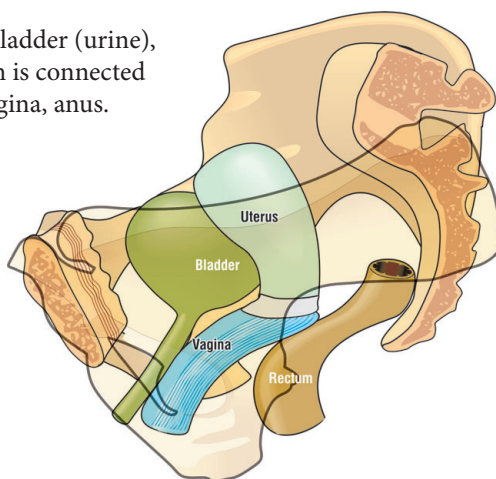
Series 1 Static Anatomy

Figures 1-01 to 1-04 illustrate the organs and connective tissue structures.

The Organs

Think of the organs as receptacles, bladder (urine), rectum (faeces) uterus (foetus). Each is connected to the exterior by a tube, urethra, vagina, anus.

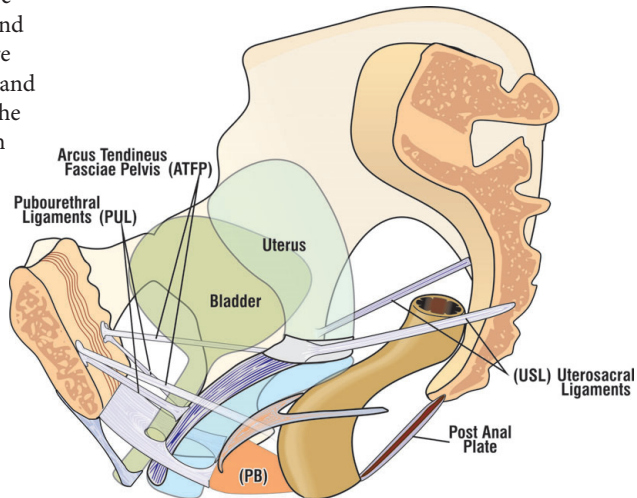
Fig. 1-01 (right) Pelvis with organs: urethra and bladder are green, vagina is blue and rectum is brown.



The Ligaments

Think of the organs as interconnected, and suspended by ligaments like a suspension bridge.

Fig. 1-02 (below) Pelvis with organs and connective tissues. The ligamentous and membranous structures are indicated by grey colours, and the fascial thickenings of the vagina, PCF and RVE, with darker colouring.

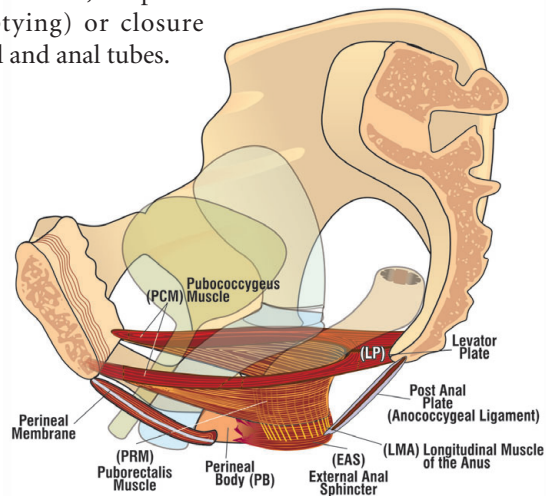


The Muscles

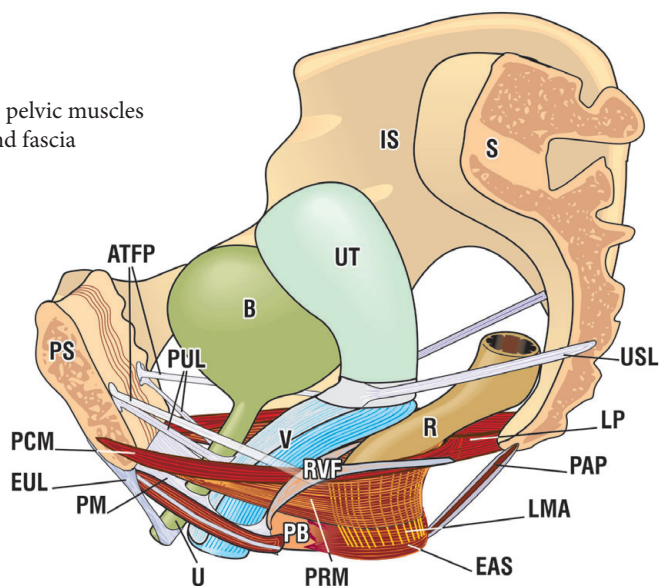
The muscles have two main functions.

1. To provide structural support for the organs by stretching them against the suspensory ligaments, thus creating shape and strength (like a suspension bridge).
2. By selective relaxation or contraction, the pelvic muscles assist opening (emptying) or closure (storage) of the urethral, vaginal and anal tubes.

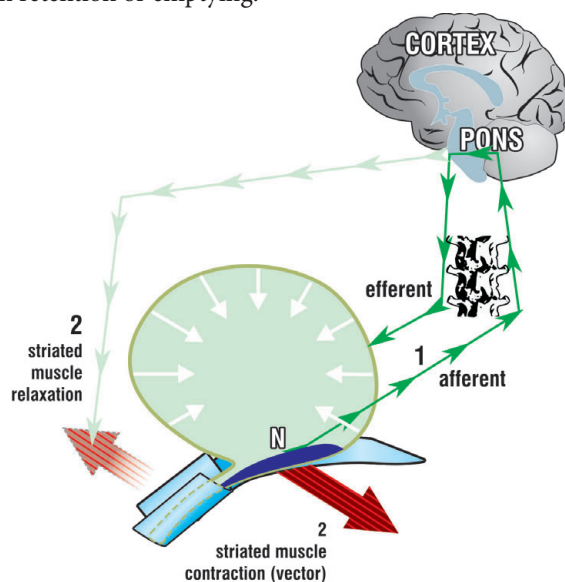
Fig. 1-03 Pelvis with organs and muscles – Muscles are brown colours with striations.



The relationship of the pelvic muscles to organs, ligaments and fascia



The nerves have two main functions, as a sensor of organ fullness or muscle tension, and as a 'motor' to co-ordinate and accelerate the complex series of events involved in organ retention or emptying.



Function of nerves- as a sensor of bladder fullness “1”, or as a co-ordinator for muscle action during emptying or retention “2”.

Series 2 Dynamic Anatomy

Figure 1-05 shows the components involved in the transition from static to dynamic anatomy.

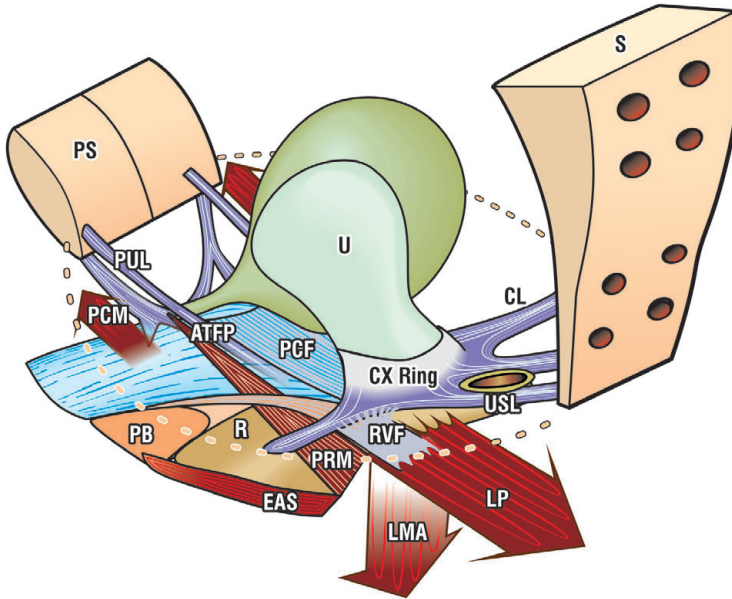


Fig. 1-05 Transition diagram, from static to dynamic - The arrows represent the directional closure forces and are marked according to their derivation. These forces act against the suspensory ligaments PUL, ATFP, CL and USL to stretch the three organs.

Bone:

PS = pubic symphysis;

S = sacrum.

Suspensory ligaments:

PUL = pubourethral ligament;

ATFP = arcus tendineus fascia pelvis;

USL = uterosacral ligament;

CL = cardinal ligament.

Muscle forces:

PCM = pubococcygeus muscle;

LP = levator plate;

LMA = longitudinal muscle of the anus;

PRM = puborectalis muscle.

Supporting fascia:

PCF = pubocervical fascia;

RVF = rectovaginal fascia.

Perineal anchoring structures:

PB = perineal body;

EAS = external anal sphincter.

Series 3 Functional Anatomy

Figures 1-06 and 1-07 illustrate the transition from dynamic to functional anatomy in the bladder.

They show three pelvic muscle forces acting during normal closure (fig 1-06), and two pelvic muscle forces acting during normal opening (micturition) (fig 1-07). A similar system of co-ordinated muscle relaxation and contraction activates anorectal closure and opening (defaecation).

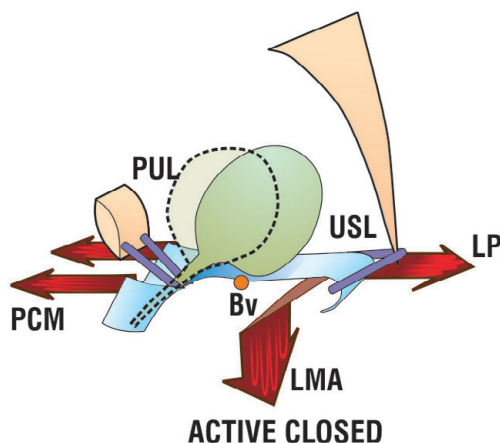


Fig. 1-06 Active Closure. This diagram shows how three muscle forces stretch and close the urethra and bladder neck. Arrows = muscle forces. Blue = vagina; green = bladder and urethra; yellow = bone. Bv = attachment of bladder base to vagina.

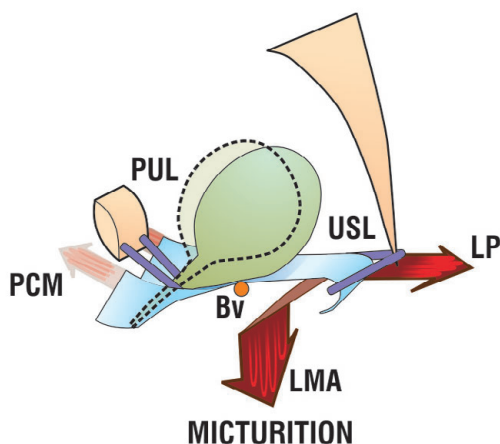


Fig. 1-07 Micturition. This diagram shows how two muscle forces (red arrows) open out the urethra once the anterior muscle force (PCM) relaxes.

1.2 Overview of Pelvic Floor Function and Dysfunction According to the Integral Theory System

As the name suggests, the Integral Theory is an interrelated and dynamic anatomical framework for understanding pelvic floor function and dysfunction. The pelvic floor is an interrelated system of organs, muscles, nerves and connective tissue structures, where the whole is greater than the sum of the parts. The fundamental principle of the Integral Theory System is that the *'restoration of form (structure) leads to restoration of function'*. Although 'form' and 'structure' are used interchangeably throughout the book, they are slightly different. 'Structure' is a static concept. 'Form' is a dynamic concept and carries the connotation that damaged connective tissue structures may cause loss of form (prolapse) and therefore, function. Hence the importance of an accurate diagnosis of the location of the damaged structure prior to surgery. The Integral Theory (1993) was stated thus:

Symptoms of stress, urge, and abnormal emptying mainly derive, for different reasons, from laxity in the vagina or its supporting ligaments, a result of altered connective tissue.

More recently, the Theory has been expanded to include idiopathic faecal incontinence and some types of pelvic pain.

1.2.1 Basic Tenets of the Integral Theory System

Structure (prolapse) and function (symptoms) are related.

"Repair the structure and you will improve the function."

The Integral Theory emphasizes the role of the connective tissue of the vagina and its supporting ligaments in both function and dysfunction, as well as in surgical correction. The Integral Theory views normal pelvic floor function as a balanced, interrelated system composed of muscle, connective tissue (CT) and nerve components, with connective tissue being the most vulnerable to damage.

To help explain the Integral Theory, two key analogies are used, the suspension bridge analogy for structure, and the trampoline analogy for function.

The clinical application of the Integral Theory system culminates in the Pictorial Diagnostic Algorithm (fig. 1-11). This algorithm provides the surgeon with a guide to the anatomical causes of dysfunction and the damaged structures that may need repairing. The surgical techniques developed from the Integral Theory focus on reinforcing damaged ligaments and fascia with polypropylene tapes, and preserving vaginal tissue and elasticity, especially in the bladder neck area of the vagina. This approach reduces pain and urinary retention and allows the surgery to be performed on a day-care or overnight stay basis with early return to normal activities.

The Integral Theory System, when applied to pelvic floor rehabilitation, focuses on strengthening structures of the pelvic floor - muscle, nerve and connective tissue – all of which work synergistically as a dynamic system.

Form, Structure and Function

1

Fig. 1-05 Form – This diagram illustrates the synergism of the pelvic floor structures. It shows how the organs are suspended by ligaments and stretched by muscle forces acting against these same ligaments to create form and strength.

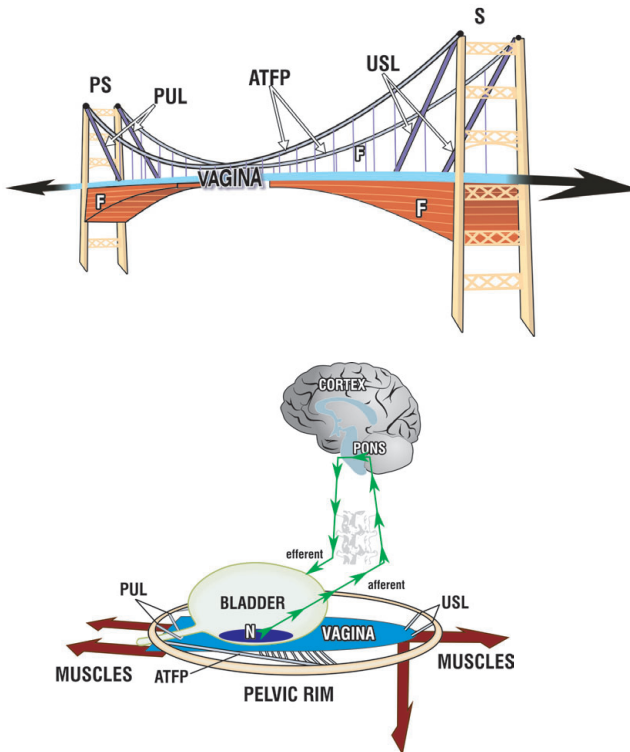
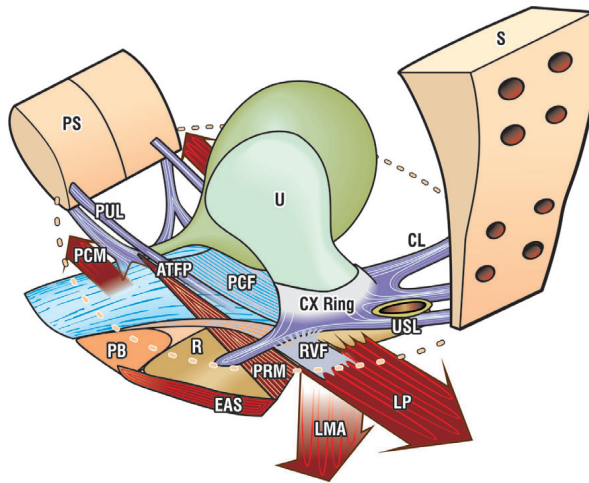


Fig. 1-08 Structure - The suspension bridge analogy. The suspension bridge analogy illustrates how the pelvic structures are inter-dependent. In a suspension bridge, strength is maintained through tensioning of suspensory steel wires (arrows). Weakening any one part of the structure may disturb the equilibrium, strength and function of the whole. Relating the analogy to figure 1-05, form (ie shape and strength) is achieved because the vagina and bladder are suspended from the bony pelvis by ligaments (PUL, USL, ATFP) and fascia (F). The structural dimension develops when these are stretched by muscle forces (arrows).

Fig. 1-08a Trampoline analogy- Function. How the muscle forces control peripheral neurological function. Like a trampoline, laxity in even one suspensory ligament, PUL, ATFP or USL, may prevent the muscle forces (arrows) from tensioning the vaginal membrane. The stretch receptors 'N' cannot be supported, and fire off prematurely. The cortex perceives the afferent impulses as urge symptoms.

Structure and Form

Structure and form in the pelvic floor arise from the interaction of muscles, nerves and ligaments acting on the pelvic organs. The vagina and ligaments must be stretched to their limit of extension to attain the strength required to carry loads. Unequal balance of the forces may stretch the system one way or the other, thereby affecting organ support and/or function. The 'suspension bridge' and 'trampoline' analogies (figs 1-05, 1-08, 1-08a) are used to illustrate how structure and form (and thereby function) arise from a system in balanced tension.

Function and Dysfunction

The Integral Theory describes normal bladder and anorectal function as having only two stable states: closed (continence) and opening (micturition or defaecation). These states are deemed to be stable because they are the resultants of a balance of forces.

For example, three muscle forces interact during bladder closure (fig 1-06) and two muscle forces interact during bladder opening (fig 1-07). If the efficacy or balance of these muscle forces is disrupted through damage to their ligamentous anchoring points (fig 1-09), dysfunction may result in both closure (incontinence) or opening (abnormal emptying).

Causes of Dysfunction - Delineating the Zones of Damage

The damaged suspensory ligaments and associated fascia are sited in three zones: anterior, middle and posterior (fig 1-09). The anterior zone extends from the external urethral meatus to the bladder neck, and contains *three structures* which may be

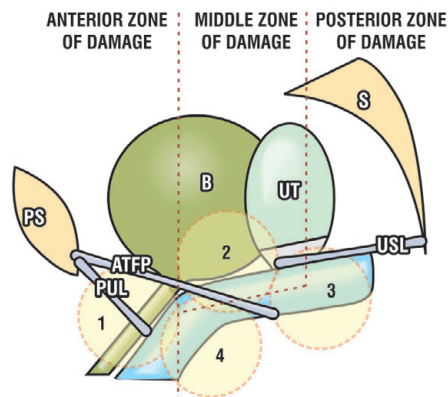


Fig. 1-09 The causes of dysfunction: the zones of damage. The circles represent the foetal head descending through the birth canal. '1' stress incontinence, '2' cystocele, '3' uterine/apical prolapse, '4' rectocele. Damage to one or more ligaments may imbalance the system causing dysfunction, expressed as prolapse, symptoms (1-11) or both. Congenitally defective collagen may also cause dysfunction.

damaged: the pubourethral ligament (PUL), the suburethral hammock, and the external urethral ligament (EUL) (see figs 2-03 and fig 2-04).

The middle zone extends from the bladder neck to the cervix or hysterectomy scar. It contains *three structures* which may be damaged: the pubocervical fascia (PCF), the arcus tendineus fasciae pelvis (ATFP), and the cervical ring/cardinal ligament.

The posterior zone extends from the cervix or hysterectomy scar to the perineal body. The uterosacral ligaments (USL), rectovaginal fascia (RVF) and perineal body (PB) are the key posterior zone structures which may be damaged.

Locating the damaged structures within the three zones

Within each zone are three connective tissue structures which facilitate normal pelvic floor function. If any of these is damaged, dysfunction may result. The Integral Theory delineates nine key structures in which damage may occur. The three zones each contain three main structures which may be damaged (fig 1-10). They are:

Anterior Zone

Excess Laxity

1. External urethral ligament (EUL)
2. Suburethral vagina (hammock)
3. Pubourethral ligament (PUL)

Middle Zone

Excess Laxity

4. Arcus tendineus fascia pelvis (ATFP) (lateral defect)
5. Pubocervical fascia (PCF) (midline defect - cystocele)
6. Cardinal ligament/cervical ring attachment of PCF (high cystocele)

Excessive tightness

‘ZCE’ - Excessive tightness in the ‘Zone of critical elasticity’ (ZCE) (cause: excess scarring; excess elevation with colposuspension)

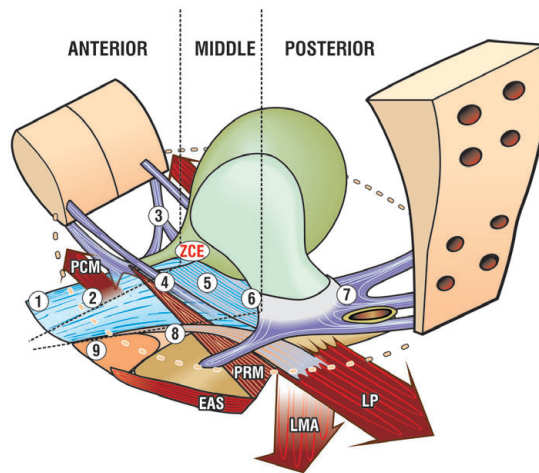
Posterior Zone

Excess Laxity

7. Uterosacral ligaments (USL) (uterine/apical prolapse)
8. Rectovaginal fascia (RVF) (mid/high rectocele)
9. Perineal body (PB) (low rectocele)

Note that the ZCE is part of the PCF. It is included here as a separate structure to emphasize the importance of maintaining elasticity at the bladder neck area of the vagina (ZCE) during surgery. It is in the ZCE where the ‘tethered vagina syndrome’ originates. The ‘tethered vagina syndrome’ is described fully later in this book. Briefly, it is caused by loss of elasticity at ZCE from vaginal or bladder neck elevation surgery due to scarring or excessive bladder neck elevation. It is entirely iatrogenic.

Fig. 1-10 The nine main connective tissue structures potentially needing surgical repair. All nine structures work synergistically with the muscle forces to maintain structure and function.



Diagnosis of Damage

The Pictorial Diagnostic Algorithm (fig 1-11) provides an efficient method for locating and remedying structural damage or pelvic floor dysfunction. It summarizes in graphical form the relationship between structural damage (prolapse) in the three zones and symptoms of dysfunction. By using the ‘simulated operations’ technique (Chapter 3), and other empirical research, it has been found that certain symptoms occur more frequently in one zone than another. The Pictorial Diagnostic Algorithm illustrates these varying probabilities. Most importantly, it shows that *almost any symptom may be caused by dysfunction in any zone*, even if the probability is very small. The Pictorial Diagnostic Algorithm is the key to the clinical application of the Integral Theory system.

Surgical Repair of Connective Tissue Structures

Reconstructive pelvic floor surgery according to the Integral Theory System differs from conventional surgery in four ways:

1. It is minimally invasive (day-care).
2. It is based on specific surgical principles which minimise risk, pain and discomfort to the patient.
 - avoid over-tensioning the structures
 - avoid vaginal excision and hysterectomy if possible
 - use polypropylene tapes to repair damaged ligaments
3. It takes a holistic approach to pelvic floor dysfunction by isolating the contribution(s) of each zone of the vagina to dysfunction.
4. It has a symptom-based emphasis (the Pictorial Diagnostic Algorithm) which expands the surgical indicators beyond major prolapse to include cases with major symptoms and only minimal prolapse.

In keeping with the overall framework of the Integral Theory, the surgical techniques are organised by zone. The zones consist of nine key structures which

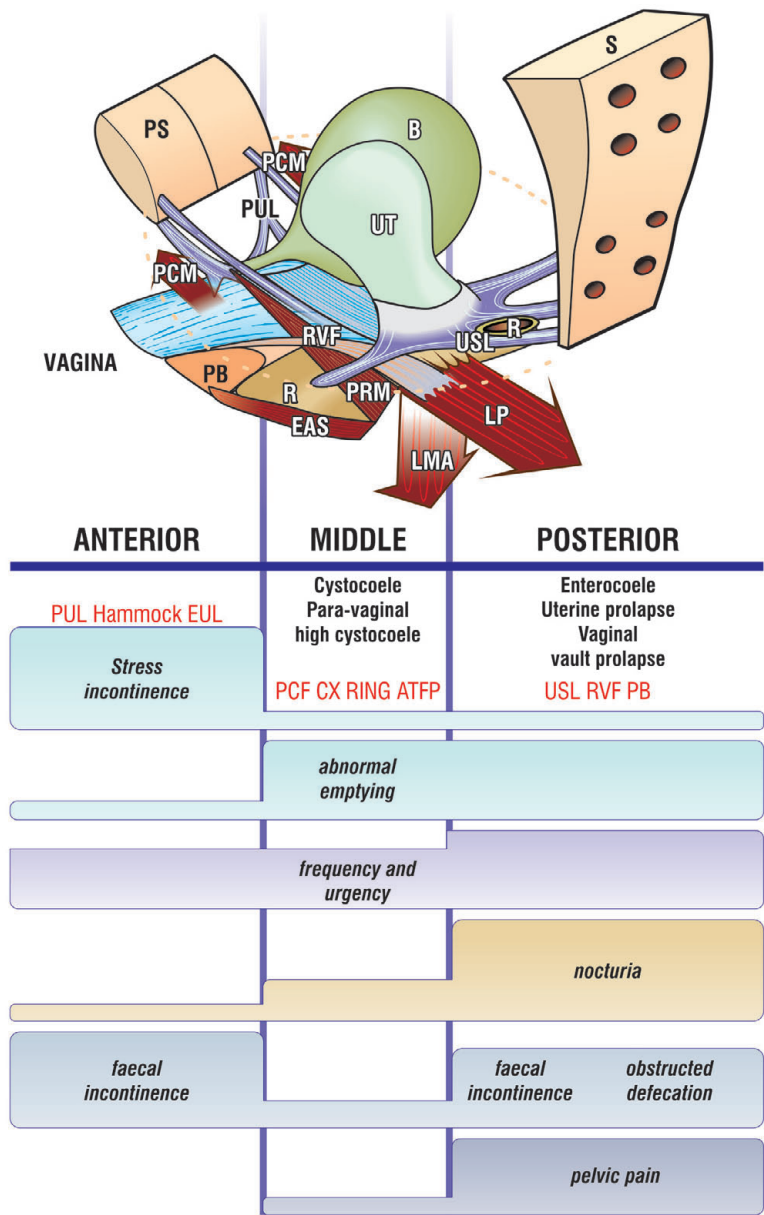
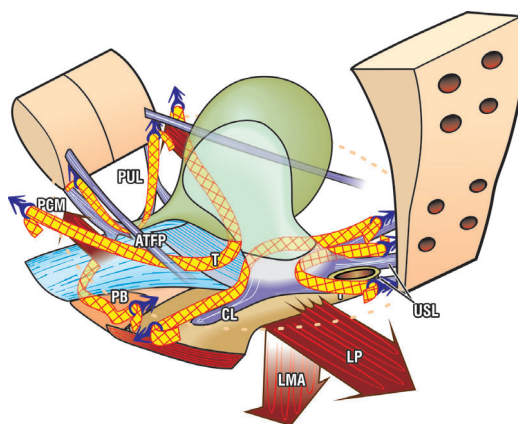


Fig. 1-11 The Pictorial Diagnostic Algorithm summarizes the relationships between structural damage (prolapse) in the three zones and function (symptoms). The size of the bar gives an approximate indication of the prevalence (probability) of the symptom. Laxities (red lettering) which can be repaired: pubourethral ligament (PUL); external urethral ligament (EUL); pubocervical fascia (PCF); CX ring/cardinal ligament; arcus tendineus fascia pelvis (ATFP); uterosacral ligament (USL); rectovaginal fascia (RVF); perineal body (PB).

Fig. 1-12 Polypropylene tapes 'T' may be used to reinforce the main suspensory structures – pubourethral (PUL), uterosacral (USL) and arcus tendineus fascia pelvis (ATFP), Cardinal (CL), and perineal body (PB).



potentially need repair in pelvic reconstructive surgery (fig 1-10). Using a special delivery system, polypropylene tapes are inserted as an anterior sling at midurethra, a posterior sling in the position of the USLs, and other positions according to which structure in which zone has been damaged (fig 1-12).

The uterus needs to be conserved wherever possible. It is the central anchoring point for the posterior ligaments (USL), the rectovaginal fascia (RVF) and the pubocervical fascia (PCF). The descending branch of the uterine artery is a major blood supply for these structures, and should be conserved where possible even if subtotal hysterectomy is performed.

1.3 Summary Chapter 1

The pelvic floor consists of an interrelated system of muscles, ligaments and nerves, with connective tissue being the most vulnerable to damage.

The Integral Theory specifies that damaged connective tissue in the suspensory ligaments or fascia may cause prolapse and/or the following symptoms:

- stress incontinence
- urge incontinence
- frequency
- nocturia
- abnormal emptying
- faecal incontinence
- pelvic pain.

The Pictorial Diagnostic Algorithm is based on a relationship between specific symptoms and connective tissue damage in three zones of the vagina. It indicates which connective tissue structures have been damaged. The main structures damaged are the pubourethral ligament in the anterior zone, cardinal ligaments and pubocervical fascia in the middle zone, and uterosacral ligaments and perineal body in the posterior zone. Minimally invasive surgical operations repair the damaged ligaments and abnormal symptoms by precise insertion of polypropylene tapes in the position of the damaged ligaments. This is based on the surgical principle that restoration of form leads to restoration of function.

Change in axis according to position

The axis of the pelvic structures alters according to the position of the body.
Note the direction of ligaments with the patient in the supine position.

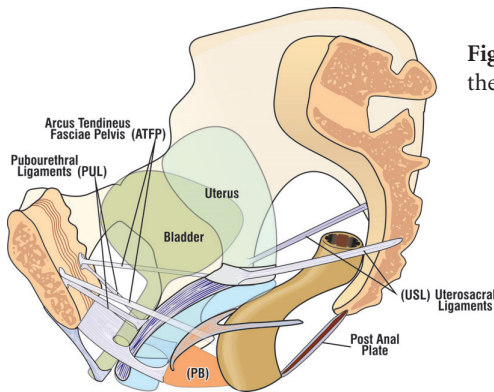


Fig. 1-02 Position of the organs in the sitting position

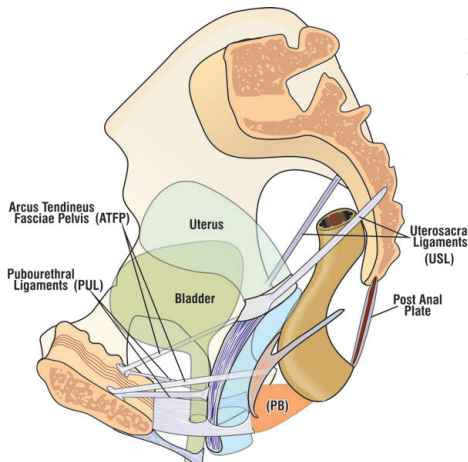


Fig. 1-02a Position of the organs in the standing (anatomical) position

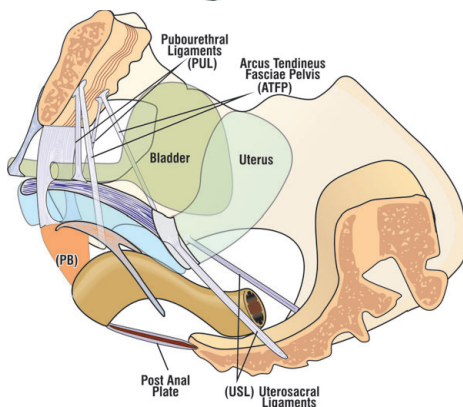


Fig. 1-02b Position of the organs in the supine position. In the lithotomy position, a few degrees extra clockwise rotation would occur.

The Anatomy and Dynamics of Pelvic Floor Function and Dysfunction

2.1 The Anatomy of Pelvic Floor Function

2.1.1 Introduction

Pelvic anatomy may be defined as those bones, muscles, ligaments and organs which contribute to normal pelvic floor function.

Ligaments, muscles and fascia constitute a musculo-elastic system which gives form and function to the organs of the pelvic floor.

Connective tissue is a generic term generally applied to tissues which contain collagen, proteoglycans and sometimes elastin.

Fascia is defined as that fibromuscular tissue which suspends or strengthens the organs, or connects them to muscles. Fascia is composed of smooth muscle, collagen, elastin, nerves and blood vessels and may form part of the wall of the vagina. Fascia is the main structural component of the vagina. Discrete thickenings may be termed ligaments.

The organs of the pelvis are the bladder, vagina and rectum. None of these has any inherent shape or strength (fig 2-01). While the role of fascia is to strengthen and support the organs, the role of the ligaments is to suspend the organs and act as anchoring points for the muscles. Muscle forces stretch the organs to contribute to their shape, form and strength.

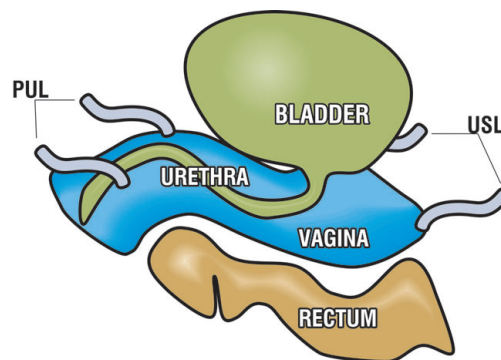


Fig. 2-01 The organs have no inherent shape or strength when the suspensory ligaments are severed. Likewise, loose ligaments weaken the muscle forces which provide form and function to healthy organs. PUL = pubourethral ligament; USL = uterosacral ligament.

2.1.2 The Role of Ligaments, Muscles and Fascia in Creating Form, Strength and Function

The pelvic organs, urethra, vagina and rectum, have no inherent form, structure or strength. Form, structure and strength are created by the synergistic action of ligaments, fascia and muscles. *Normal* function of these pelvic organs is directly dependent on the integrity of the pelvic floor structure.

2.1.3 The Role of Connective Tissue Structures

Bones and connective tissue are the main structural components of the pelvis. The connective tissue consists of ligaments and fascia. The critical elements of connective tissue are collagen and elastin, both of which are changed during pregnancy, childbirth and ageing. These changes may weaken the ligaments and fascia, thereby affecting the structural integrity of the pelvic floor. This may result in prolapse and affect organ function. The ligaments suspend the pelvic organs from above in the manner of a tensioned suspension bridge. Other connective tissue structures (fig 2-02) such as perineal body, perineal membrane, post-anal plate anchor the organs horizontally and inferiorly.

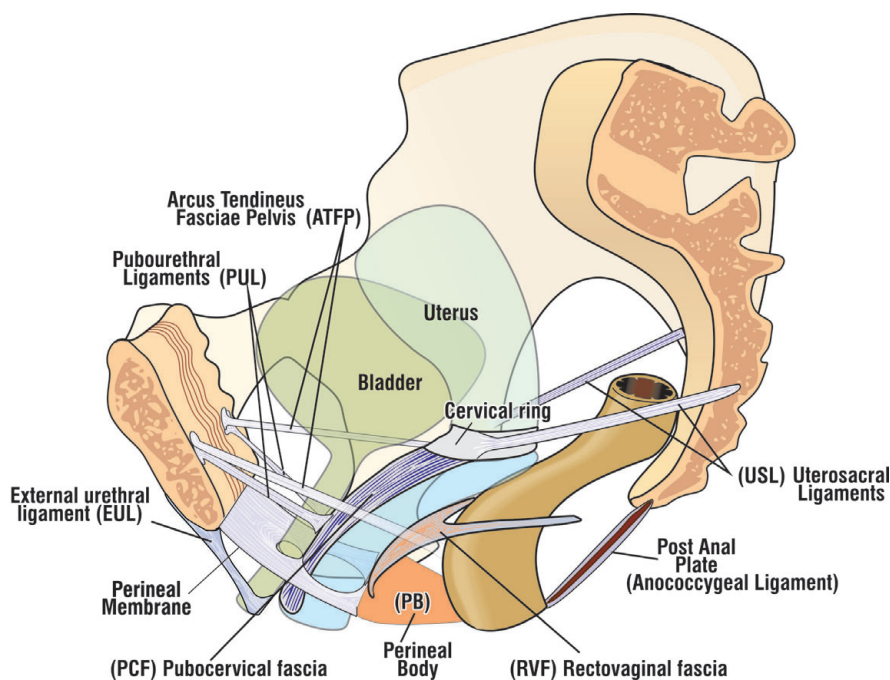


Fig. 2-02 Connective tissue levels - This is a schematic 3D sagittal section of the main connective tissue structures of the pelvis, showing their relationship to the organs and pelvic bones.

2.1.4 The Key Ligaments of the Pelvic Floor Structure

The key ligaments of the pelvic floor are the external urethral ligament (EUL), which is sited anterior to the perineal membrane, the pubourethral ligament (PUL), which lies behind the perineal membrane (urogenital diaphragm), the arcus tendineus fasciae pelvis (ATFP), the cardinal and uterosacral ligaments (USL) and the pubovesical ligament (PVL). The composition of all the suspensory ligaments and fascia is similar (fig 2-05). The presence of nerves (N), smooth muscle (Sm) and blood vessels (Vs) indicates that ligaments are active contractile structures, as is the fascial layer of the organs. The perineal body also contains striated muscle.

The Pubourethral Ligament (PUL)

The pubourethral ligament (PUL) (figs 2-03 & 2-04) originates from the lower end of the posterior surface of the pubic symphysis and descends like a fan to insert (fig 2-03) medially (M) into the midurethra and laterally (L) into the pubococcygeus muscle and vaginal wall (Zacharin 1963, Petros 1998).

The external urethral ligament (EUL) (fig 2-03 and fig 2-04) anchors the external urethral meatus to the anterior surface of the descending pubic ramus. It extends upwards to the clitoris and downwards to PUL. It is approximately equivalent to Robert Zacharin's anterior pubourethral ligament.

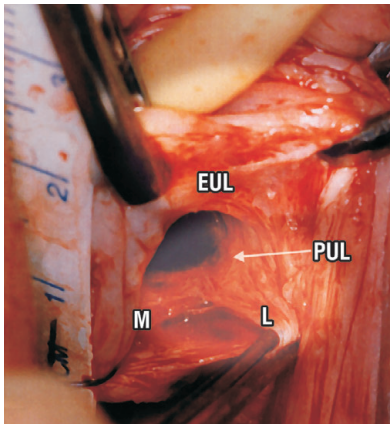


Fig. 2-03 (Above) The suspensory ligaments of urethra - a live anatomical study. Perspective: Looking into the vagina. Incision: left paraurethral sulcus. EUL = external urethral ligament; PUL = pubourethral ligament; M = medial part; L = lateral part.

Fig. 2-05 (Right) Biopsy of a pubourethral ligament. Cn = collagen; E = elastin; Vs = vessel; Sm = smooth muscle.

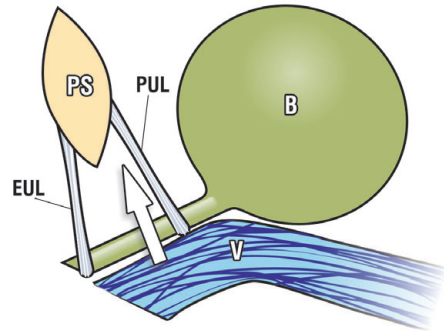
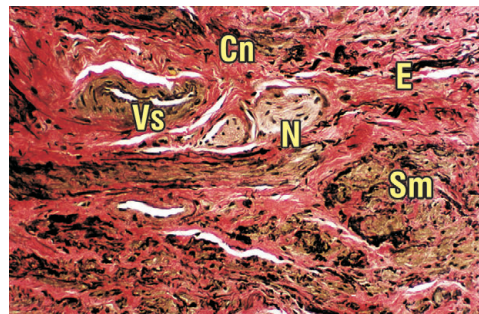


Fig. 2-04 Sagittal view of fig 2-03. Arrow = muscle force



The Arcus Tendineus Fascia Pelvis (ATFP)

The ATFP (fig. 2-02) are horizontal ligaments which arise just superior to the pubourethral ligament (PUL) at the pubic symphysis and insert into the ischial spine (IS). The vagina is suspended from the ATFP by its fascia, much like a sheet slung across two washing lines (Nichols 1989). The muscle force of the levator plate and adjacent muscles tension the ATFP ligament and the vagina itself.

The Cardinal Ligaments/Anterior Cervical Ring Complex

The cardinal ligaments are attached to the anterior cervical ring and pubocervical fascia (fig. 2-07). They extend laterally towards and above the ischial spine.

The Uterosacral Ligaments (USL)

The uterosacral ligaments (USL) (fig. 2-02) suspend the apex of the vagina and are the effective insertion points of the downward muscle force, the longitudinal muscle of the anus (LMA). The USL arises from the sacral vertebrae S2,3,4 and attaches to the cervical ring posteriorly. Its main vascular supply is the descending branch of the uterine artery.

The Pubovesical Ligament (PVL)

The pubovesical ligament (PVL) was described by Ingelman-Sundberg (1949) as the main structural support of the anterior wall of the bladder. It inserts into the transverse precervical arc of Gilvernet, a stiff fibromuscular structure on the anterior bladder wall (fig 2-06). PVL brings rigidity to the anterior wall of bladder.

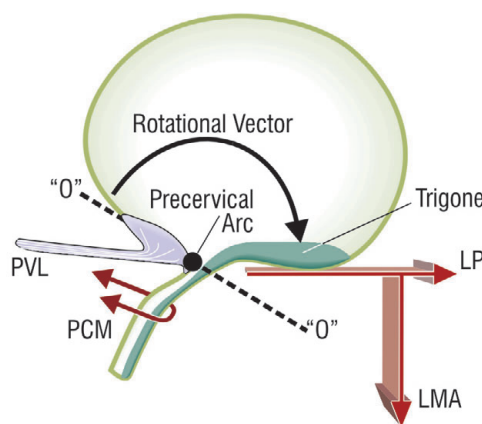


Fig. 2-06 The role of the trigone and precervical arc (PVL) in bladder neck closure. Sagittal section. Arrows represent the directional closure forces. Relaxation of PCM allows the LP/LMA vector to open out the outflow tract.

During effort, pubococcygeus muscle (PCM) contraction stretches the hammock forwards. This anchors the urethra, and helps create the internal urethral meatus at 'O'-'O'. Levator plate (LP) and longitudinal muscle of the anus (LMA) vectors rotate the upper vagina and trigone in a plane ('O'-'O') around PVL insertion point like a ball valve, to create bladder neck closure. As this ligament is sited well away from the passage of the head in childbirth, it is rarely injured.

The Precervical Arc of Gilvernet

The precervical arc of Gilvernet (fig 2-06) is essentially a thickened insertion of PVL in the anterior wall of the bladder. This structure limits posterior displacement of the anterior bladder wall. It prevents inward collapse of the anterior bladder wall during micturition and it is rotated downwards to close off the bladder neck during stress.

The Trigone

The trigone (fig 2-06) forms part of the bladder base and is composed mainly of smooth muscle. It extends down the posterior wall of the urethra to the external meatus. Although it is not a ligament, it behaves like one. The trigonal extension creates a 'back-bone' for the hammock muscles to pull forward in order to close off the urethra from behind. During micturition, the trigone splints the posterior urethral wall facilitating the backward stretching by LP and LMA that is required to expand the outflow tract.

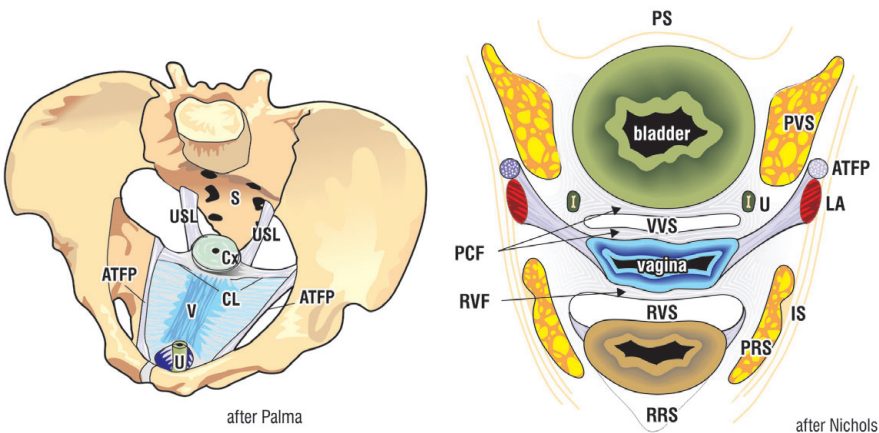


Fig. 2-07 (Above left): Vaginal attachments to ATFP. The vagina is suspended like a trampoline membrane between the Arcus Tendineus Fascia Pelvis (ATFP) ligaments laterally, the anterior part of the cervical ring, and its collagenous extensions onto the cardinal ligament (CL).

Fig. 2-08 (Above right): The connective tissue spaces. Perspective: transverse section, horizontal part of vagina just anterior to cervix. PVS = paravesical space; VVS = vesicovaginal space; RVS = rectovaginal space; RRS = retrorectal space; RVF = rectovaginal fascia; U = ureter; PCF = pubocervical fascia; ATFP = Arcus Tendineus Fascia Pelvis; IS = ischial spine; LA = m. levator ani.

Fascial attachment of the vagina to ATFP

The vagina is suspended like a trampoline between the two Arcus tendineus Fascia Pelvis (ATFP) ligaments, by lateral fascial extensions (fig 2-07). These lateral extensions fuse with the pubocervical fascia superiorly, and the rectovaginal fascia inferiorly (fig 2-08).

Organ Spaces

The fascial components of the organs are separated from each other by spaces (fig 2-08), and these spaces allow the organs to move independently of each other during organ opening, closure and especially, during intercourse. These spaces provide an avascular dissection plane during surgery.

The Pubocervical Fascia

The pubocervical fascia (PCF) stretches from the lateral sulci to the anterior part of the cervical ring (fig 1-05). The anterior part of the cervical ring in turn fuses with the cardinal ligament. Separation of the fascia from the ring may cause a high cystocele, or even an anterior enterocoele.

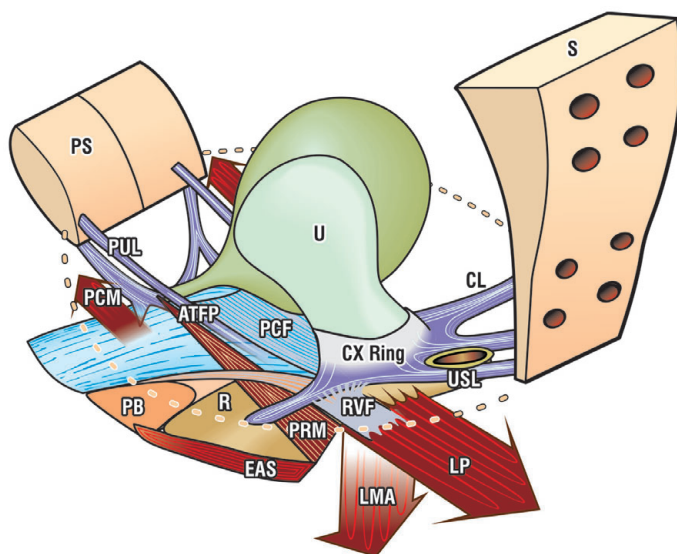


Fig. 1-05 Fascial attachments and tensioning mechanism. Anteriorly, vaginal fascia connects the vaginal membrane to the muscles and pubourethral ligaments (PUL), laterally to the Arcus Tendineus Fascia Pelvis (ATFP) and the cervical ring/cardinal ligament complex, posteriorly to the uterosacral ligaments (USL) and inferiorly, to the perineal body (PB). PB is tensioned by the external anal sphincter (EAS). Like a rope suspension bridge, all the ligamentous and fascial structures in fig.1-05 are tensioned by the three directional muscle forces (arrows), to provide structural support to the organs.

The Rectovaginal Fascia

The rectovaginal fascia or Fascia of Denonvilliers, extends as a sheet between the lateral rectal pillars, from the perineal body below to the levator plate above (fig 1-05). It is attached to the uterosacral ligaments (USL) and the fascia surrounding the cervix.

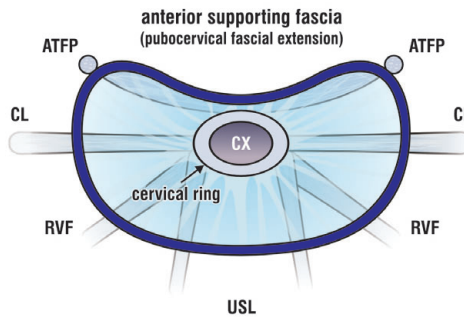


Fig. 2-09 Role of the cervical ring in the connectedness of pelvic fascia. All fascial and ligamentous structures insert directly or indirectly into the cervical ring. Perspective: 3D view, looking into the posterior fornix of the vagina. CL = Cardinal ligament, RVF = rectovaginal fascia, USL = uterosacral ligament, and ATFP = Arcus Tendineus Fascia Pelvis.

The Cervical Ring

The cervical ring surrounds the cervix and acts as an attachment point for the cardinal and uterosacral ligaments, and also, the pubocervical and rectovaginal fascia. It consists mainly of collagen.

The Role of Proximal Cervical Ring Fascia in Preventing Everting Vaginal Prolapse

The pubocervical and rectovaginal fascia around the cervical ring act as an adjunctive structural support to the upper walls of the vagina. Collapse of the upper vaginal walls is an essential element in the pathogenesis of uterovaginal prolapse, which is really a type of intussusception. Therefore simple reinforcement of the uterosacral ligaments may not be sufficient to restore the prolapse. Approximation of the laterally displaced fascia below and lateral to the uterosacral ligaments inferiorly, and above and lateral to the cardinal ligaments superiorly, may be needed to restore tension (and therefore structural support) to the side walls of the vagina.

The Role of Proximal Cervical Ring Fascia in Preventing Peripheral Neurologically Derived Symptoms

Symptoms of urge, frequency, nocturia and pelvic pain are attributed to failure of connective tissue to support the bladder base stretch receptors, and unmyelinated nerve endings of the uterosacral ligaments.

These are peripheral neurologically derived symptoms, so it is highly likely that

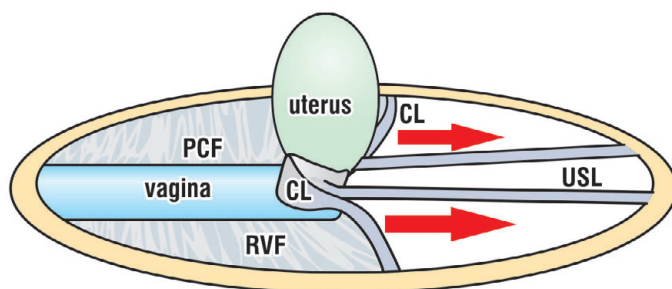


Fig. 2-10 Fascial re-inforcement of the upper walls of the vagina. The pubocervical fascia 'PCF' and rectovaginal fascia 'RVF' form a critical mass to support the upper part of the vagina, thus preventing its intussusception. CL = cardinal ligament; USL = uterosacral ligament.

they may be triggered by fairly minor degrees of connective tissue laxity. The cure rate for these symptoms with the posterior sling operation is in the region of 80%, (Petros 1997, Farnsworth 2002). Anecdotal evidence is emerging with use of the TFS (Chapter 4), that tightening the proximal parts of the pubocervical and rectovaginal fascia with a tensioned tape may be important in better restoring function as regards these neurologically derived symptoms.

The Levator Hiatus

The levator hiatus (white arrow, figs 2-10a). is that space bounded by the pubovisceral muscle complex (pubococcygeus /puborectalis muscles). It contains the urethra, vagina and rectum, fig. 2-10b. The organs are attached to each other and to the adjacent muscles with connective tissue, constituting a musculofascial support system.

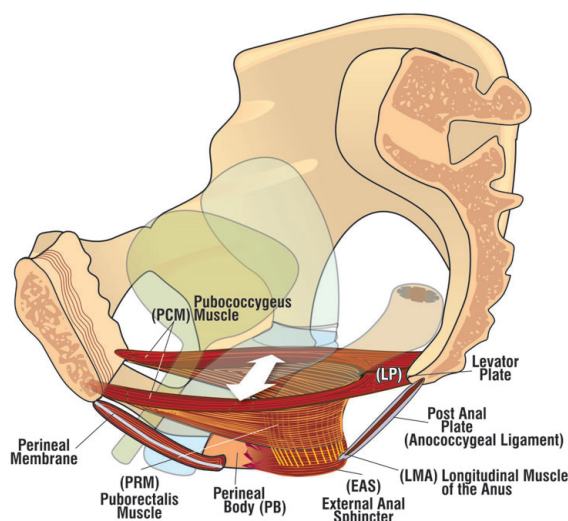


Fig. 2-10a The striated pelvic muscles and organs of the pelvic floor- schematic 3D sagittal view. The white arrows represent the levator hiatus which is occupied by the organs.

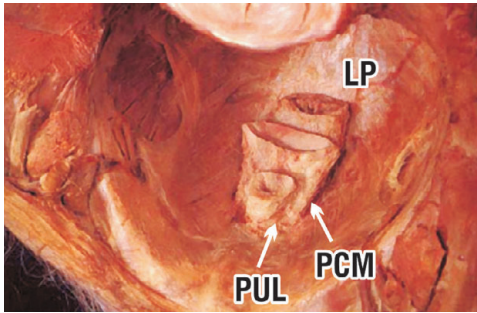


Fig. 2-10b Interconnectedness of organs and levator crus by connective tissue –view from above. Cadaveric specimen, organ section at upper urethra, in order, front to back, urethra, vagina and rectum. PUL=pubourethral ligament; PCM=pubococcygeal muscle; LP=levator plate.

2.1.5 The Muscles of the Pelvic Floor

In broad terms, the pelvic muscles form three layers: upper, middle and lower (fig 2-10a) (Petros & Ulmsten, 1997). The upper layer consists of the anterior part of pubococcygeus muscle (PCM) anteriorly, and levator plate (LP) posteriorly. The middle layer consists of the longitudinal muscle of the anus (LMA), a short striated muscle which connects the upper and lower muscle layers. The lower layer consists of the muscles sited on the perineal membrane (PM), external anal sphincter (EAS) and postanal plate (PAP).

It is important to note that the three muscle layers do not necessarily correspond to the three levels of connective tissue structures. This is explained further below.

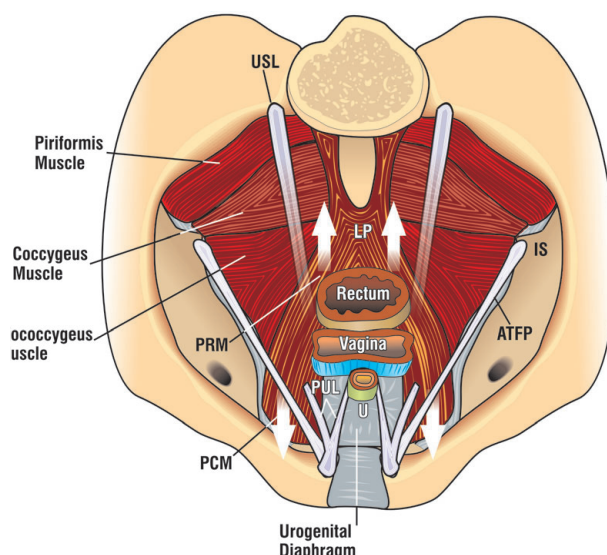
The Upper Layer of Muscles

The upper layer of muscles is horizontal in orientation. This layer of muscles stretches the organs forwards or backwards. Its pubococcygeus component (PCM) creates a forward force. The posterior segment of this layer, the levator plate (LP) attaches to the posterior wall of rectum and creates the backward force.

The upper layer of muscles have a dual function; organ support and opening and closure of the urethra, vagina and anus. The anterior portion of pubococcygeus muscle (PCM) has its origin approximately 1.5 cm above the lower border of pubic symphysis, and its insertion into the lateral wall of the distal vagina (fig 2-11) (Zacharin 1963). The lateral parts of pubococcygeus sweep behind the rectum to join with each other and fibres from coccygeus and iliococcygeus to form the levator plate (LP). The levator plate inserts into the posterior wall of the rectum, and so plays a major role in the backward movement of this organ.

The arrows (fig 2-11) indicate the direction of muscle forces. The anterior portion of pubococcygeus muscle, attached to the lateral walls of vagina constitutes the forward force. The levator plate, attached to the posterior wall of the rectum, constitutes the posterior force.

Fig. 2-11 Upper layer of muscles of the pelvic floor (after Netter 1989).



The Middle (Connecting) Layer of Muscles

The longitudinal muscle of the anus (LMA) (Courtney 1950) is a striated muscle which constitutes the middle layer (fig 2-12). The LMA is a vertically oriented muscle which creates the downward force for bladder neck closure during effort, and stretches open the outflow tract during micturition. It takes fibres superiorly from the levator plate (LP), lateral part of the pubococcygeus muscle and puborectalis. Inferiorly it inserts into the deep and superficial external anal sphincter (EAS). It needs to be distinguished from the longitudinal muscle of the rectum, a smooth muscle which forms part of the rectal wall.

It follows from the anatomy that if LMA is well anchored by EAS, then LP will be pulled downwards. As LP inserts into the posterior wall of rectum (R), then the rectum will also be angulated downwards by LMA contraction.

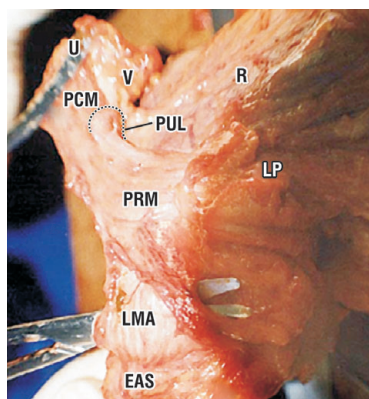


Fig. 2-12 Longitudinal muscle of the anus (LMA) – origins and insertions. This is an anatomical specimen from a female cadaver, cut away from its bony insertions. Bladder and vagina have been excised at the level of bladder neck.

U = urethra; V = vagina. PCM = anterior and lateral portion of the pubococcygeus muscle. These sweep behind the rectum (R) and merge with the contralateral side to form part of the levator plate (LP). PRM = puborectalis muscle; PUL = insertion of pubourethral ligament into PCM; EAS = external anal sphincter.

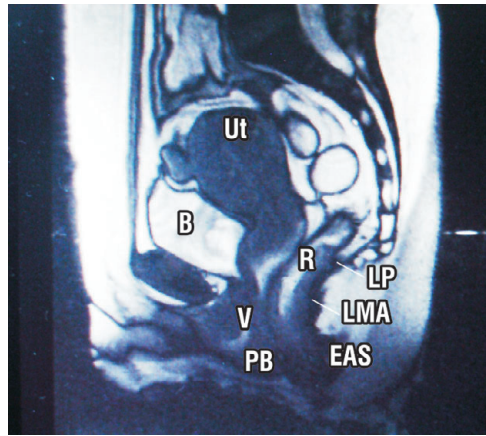


Fig. 2-12a MRI of LMA and LP Sagittal view of pelvic organs, levator plate (LP) and longitudinal muscle of the anus (LMA), resting state, inserting into external anal sphincter. PB=perineal body; EAS=external anal sphincter; V=vagina; B=bladder; PS=pubic symphysis. By permission, Prof E Petri.

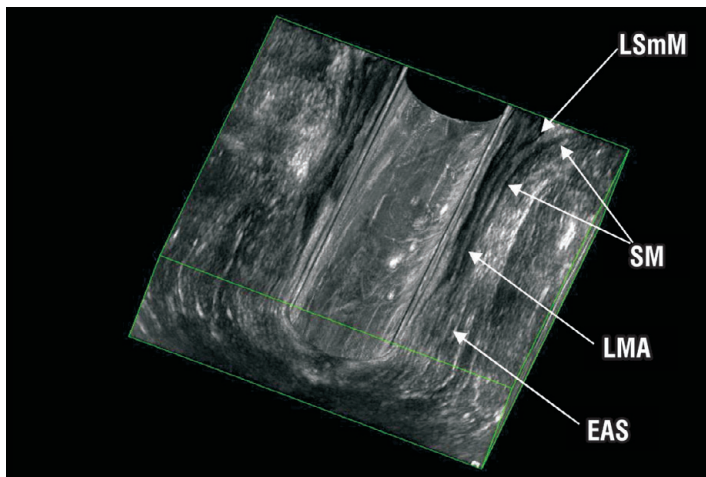


Fig. 2-12b 3D intra-anal ultrasound. The smooth muscle longitudinal muscle of the anus (LSmM) joins with the striated muscle reflections (SM) to form the conjoint longitudinal muscle of the anus (LMA) which then inserts into the external anal sphincter (EAS). From Santoro, by permission.

The Lower Layer of Muscles

The lower layer of muscles is the anchoring layer. It is composed of the perineal membrane and its component muscles: bulbocavernosus, ischiocavernosus and the deep and superficial transverse perinei muscles (fig 2-13).

The lower layer contracts to stabilize the distal parts of the urethra, vagina and anus. It also helps to contain the abdominal contents, but they (the muscles) also appear to exert a downward force on the distal parts of the urethra, vagina and (probably) the anus as well (see the x-rays in Chapter 5, Pelvic Floor Rehabilitation).

The perineal body is the key anchoring point for contraction of bulbocavernosus and the external anal sphincter (EAS) (Petros 2002). The deep transverse perinei anchors the upper part of the perineal body to the descending ramus. It is a strong muscle and it stabilizes the perineal body laterally. EAS acts as the tensor of the perineal body and it is the principal insertion point of the longitudinal muscle of the anus. The bulbocavernosus stretches and anchors the distal part of the urethra. The ischiocavernosus helps stabilize the perineal membrane and may act to stretch the external urethral meatus laterally *via* its effect on the bulbocavernosus. Between EAS and the coccyx is the postanal plate, a tendinous structure which also contains striated muscle inserting into EAS.

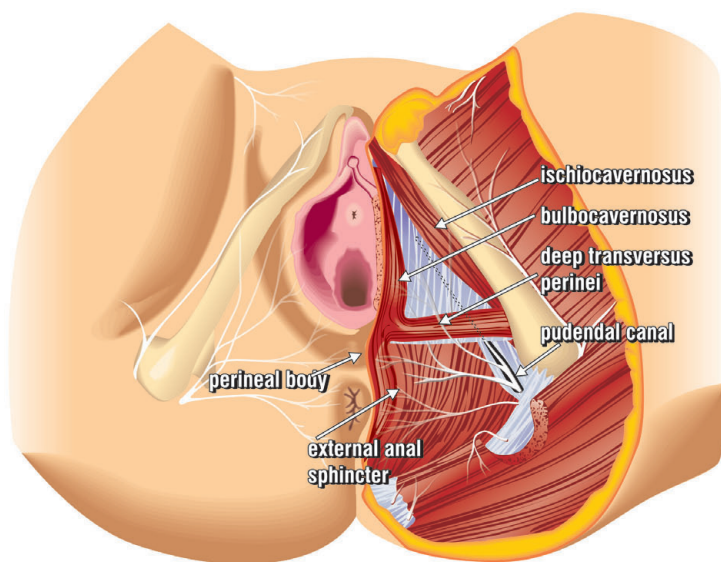


Fig. 2-13 Lower layer muscles of the pelvic floor anchor the organs distally (after Netter 1989).

The Special Case of the Puborectalis Muscle

The puborectalis muscle (PRM) (fig. 2-14) originates just medially to PCM and traverses all three muscle layers. It is included in the upper layer of muscles, even though it extends down to the middle layer. It is oriented vertically and runs forward medially below PCM. It is closely applied to the lateral walls of the rectum and surrounds it (Courtney 1950)

Whereas PCM is a flat, horizontally placed muscle, PRM is more vertical and runs medial to, and partly below, PCM. As well as its pivotal role in anorectal closure, the puborectalis muscle is the voluntary muscle activated during 'squeezing' when it elevates the whole levator plate (LP) (See the section on pelvic floor rehabilitation later in this book). 'Squeezing' refers to the action that occurs when a patient crosses her legs and contracts the pelvic muscles upwards

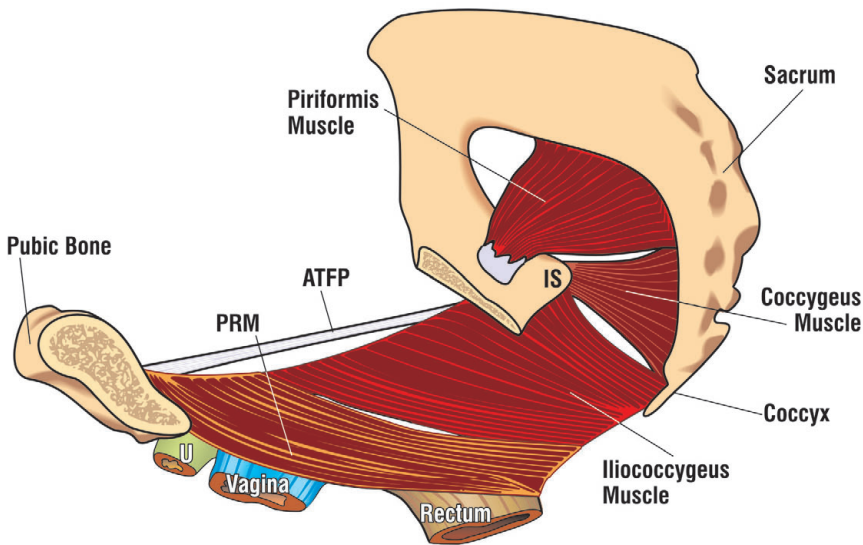


Fig. 2-14 Puborectalis muscle (PRM) (after Netter 1989)

2.2 The Dynamics of Pelvic Floor Function

2.2.1 The Dynamics of the Striated Pelvic Floor Muscles

The pelvic floor muscles contain mainly slow-twitch fibres essential for their roles of containing the intra-abdominal contents and maintenance of pelvic organ shape, structure and closure. The pelvic floor muscles work in a co-ordinated manner to stretch and angulate the pelvic organs backwards and downwards (arrows, fig 2-15) so that they are compressed by intra-abdominal pressure. This helps prevent prolapse. The same muscle actions assist closure of the urethra and anus.

The lower two thirds of the urethra is densely adherent to the anterior vaginal wall. The distal part of posterior vaginal wall is densely adherent to the perineal body and the anterior wall of rectum. The upper parts of the urethra (U), vagina (V) and rectum (R) are not attached to each other. This freedom of movement allows the stretching of the organ which is so essential for opening and closure.

The Dynamics of Urethral Opening and Closure – Urethral Perspective

Urethral closure or opening is determined by contraction or relaxation of one muscle, the pubococcygeus.

A urethra adequately anchored by PUL and the forward muscles PCM, allows the backward acting muscles LP and LMA to stretch and close the proximal urethral cavity to 'C' (fig 2-16). Relaxation of PCM allows LP and LMA to stretch open the urethral cavity to 'O' during micturition.

Figure 2-16 is a schematic 3D view of the vagina (broken lines), urethra and bladder. The shared longitudinal smooth muscle of bladder and urethra is represented by thin black lines. Extension of this smooth muscle by the pelvic muscles is a prerequisite to closure 'C' and opening 'O'. An adequately tight pubourethral ligament (PUL) is needed to anchor all three muscle forces (arrows). The pubococcygeus muscle (PCM) also requires an adequately tight hammock 'H' to effectively close the urethra. If PUL is lax, the urethra is pulled into the 'open' position 'O' by levator plate (LP) and the longitudinal muscle of the anus (LMA) during effort. Anything which provides a firm anchoring point at PUL (e.g. a haemostat or a surgically implanted tape) will enable the 3 directional forces to close urethra from 'O' to 'C' during effort. This is the basis of the 'simulated operation' which involves anchoring the midurethra unilaterally (so as not to obstruct it) and asking the patient to cough (Petros & Von Kony 1999).

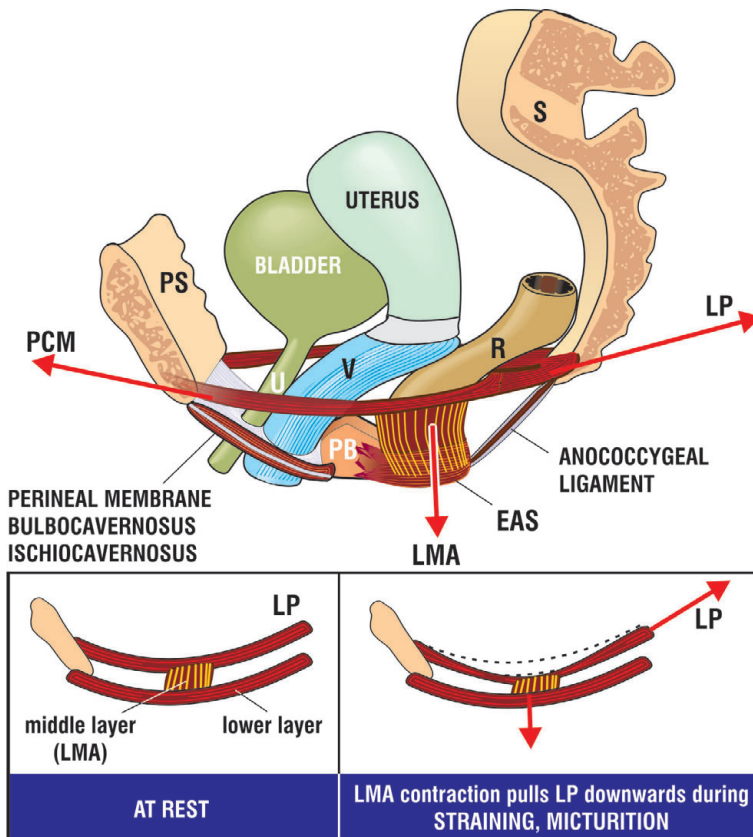


Fig. 2-15 Interaction of the upper and lower muscles of the pelvic floor.

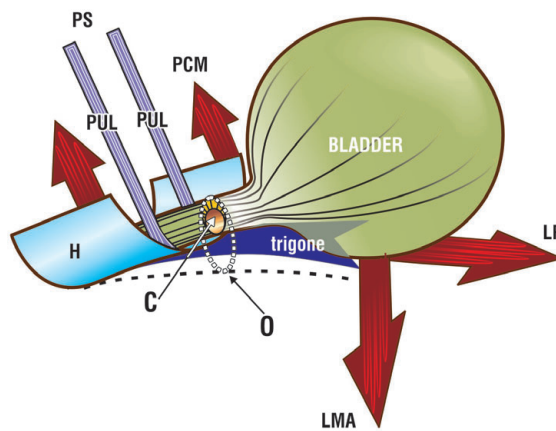


Fig. 2-16 Smooth muscle in the dynamics of urethral opening and closure

The Dynamics of Urethral Closure and Opening – Vaginal Perspective

Damage in the connective tissue of the ligaments or vagina may weaken muscle contraction, causing dysfunctional closure or opening of the outflow tract.

During effort (fig 2-17) the distal vagina is stretched forwards by PCM. The upper vagina and bladder base are stretched down and back by LP and LMA. PCM and LP contract against the pubourethral ligament (PUL). LMA contracts against the uterosacral ligaments (USL). The broken lines represent the resting position of the bladder.

During micturition (fig. 2-18), PCM relaxes. The stretch receptors activate the micturition reflex. The whole system is stretched down and back by LP and LMA, opening out the outflow tract. The detrusor contracts to expel urine. The broken lines represent the closed position of the bladder.

Note that, although the terms 'opening' and 'micturition' are used interchangeably, they are not exactly the same. 'Micturition' is driven by a neurological reflex whereas the 'open' state of the urethra may result from entirely mechanical factors, for example, 'genuine stress incontinence'.

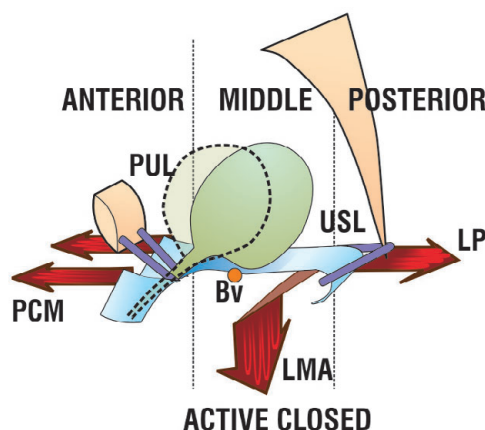


Fig. 2-17 Active Closure.

Bv = attachment of bladder base to vagina.

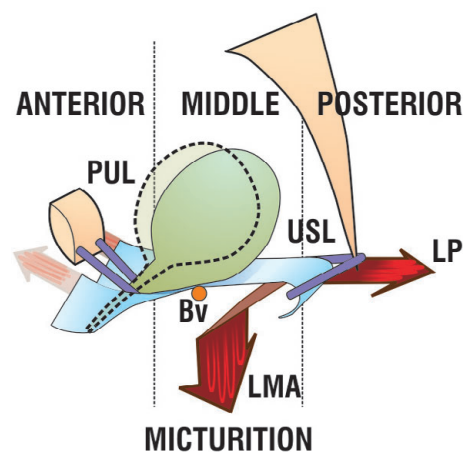


Fig. 2-18 Micturition

2.2.2 Pelvic Floor Dynamics - The 'Mechanical' Dimension

There are three normal states of the urethra: resting closed, closure during effort, and opening during micturition. Each state is a resultant of muscle forces acting mainly against anterior pubourethral ligament (PUL) or posterior uterosacral suspensory ligaments (USL). In this section, these states are demonstrated radiologically, using x-rays from the same patient in each of the three states.

Resting Closed

In the resting closed state (fig 2-19) the slow twitch fibres of 3 directional muscles Stretch vagina against pubourethral ligaments (PUL) anteriorly, and uterosacral ligaments (USL) posteriorly, like a suspension bridge. The white interrupted horizontal and vertical lines are drawn between fixed bony points. The backward angulation of the urethra and vagina at PUL clearly illustrates the effect of a backward force, the levator plate (LP).

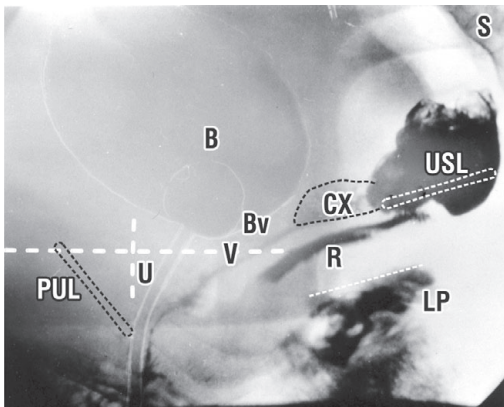


Fig. 2-19 Resting Closed.

Sitting lateral x-ray.

U = urethra; V = vagina;

B = bladder; Bv = fascial attachment of bladder base to vagina;

CX = cervix; LP = levator plate.

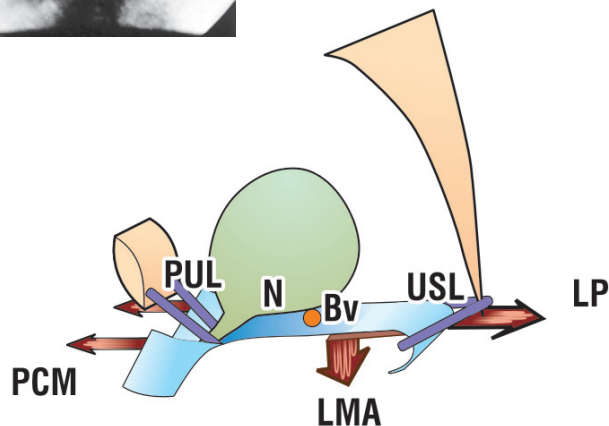


Fig. 2-20 Schematic model of urethrovesical unit at rest, corresponding to the x-ray shown in figure 2-19. N = stretch receptors; Bv = attachment of bladder base to vagina.

Figure 2-20 schematically represents a 3D sagittal section of the bladder and urethra nestled in the anterior vaginal wall ('hammock'). It corresponds to figure 2-19. The distal part of vagina is tensioned by the anterior part of pubococcygeus muscle (PCM), and the proximal part by the levator plate (LP) and the longitudinal muscle of the anus (LMA). Inherent vaginal elasticity and slow-twitch muscle contraction maintains urethral closure.

Closure During Effort

There are 2 distinct but related closure mechanisms, the distal urethral closure mechanism (forward arrow), and the bladder neck closure mechanism (backward/downward arrows), fig. 2-21. The former stretches the distal vagina, (hammock) forwards against the pubourethral ligament (PUL) to close the distal urethra. The latter stretches the proximal vagina backwards and downwards around PUL, thereby 'kinking' the proximal urethra. The downward force (arrow) acts directly against USL. The small downward arrows below 'V' indicate presumed contraction of the superficial and deep perineal muscles. The small arrows above 'R' (fig. 2-21) signify the vector of the backward and downward forces. Maintenance of continence in many patients after excision of the distal urethra indicates the bladder neck closure mechanism is of primary importance.

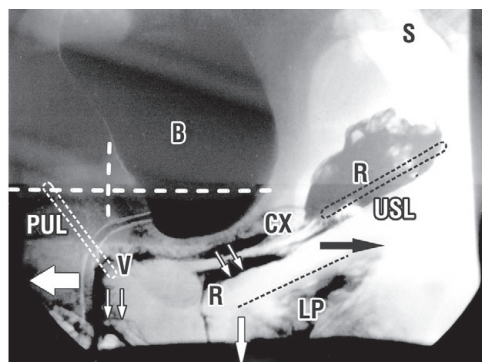


Fig. 2-21 Urethral closure during effort (coughing or straining). Compared to fig. 2-19 (same patient), the forward muscle force (arrow) stretches the distal vagina (V) forwards against the pubourethral ligament (PUL) to close the distal urethra, 'urethral closure mechanism'; the backwards and downwards muscle forces (arrows), stretch and angulate the upper vagina and urethra around PUL to 'kink' the proximal urethra, 'bladder neck closure mechanism'.

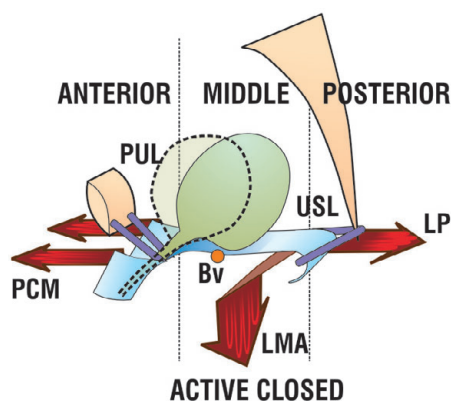


Fig. 2-22 The vagina transmits muscle forces to close urethra and bladder neck. This figure relates to figure 2-21. In comparison to figure 2-20 (resting state), the fast-twitch fibres of the three directional muscle forces PCM, LP and LMA stretch and rotate the vagina and bladder base in a plane around PUL to 'kink' the bladder neck, PCM closes the urethra along its length. The resting closed position is outlined with dotted lines.

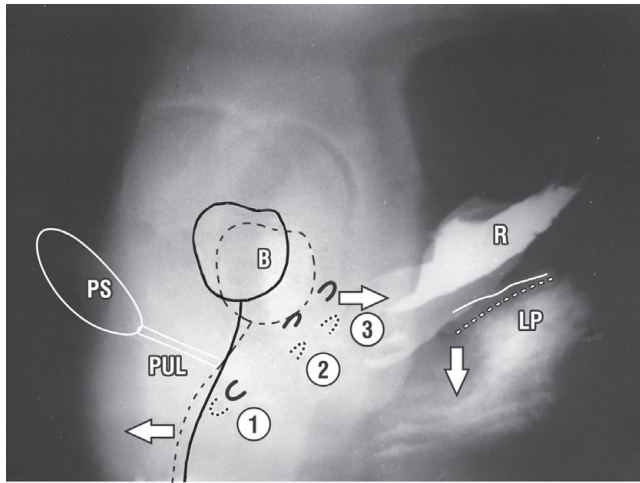


Fig. 2-22a Straining (broken lines) xray superimposed on resting xray (unbroken lines). Clips have been applied to the anterior vaginal wall, '1', midurethra, '2' bladder neck, '3' bladder base. Note downward and forward movement of clip '1' and downward/backward displacement of clips '2' & '3'. The levator plate (LP) and rectum (R) are angulated downwards. PUL=estimated position of the pubourethral ligament.

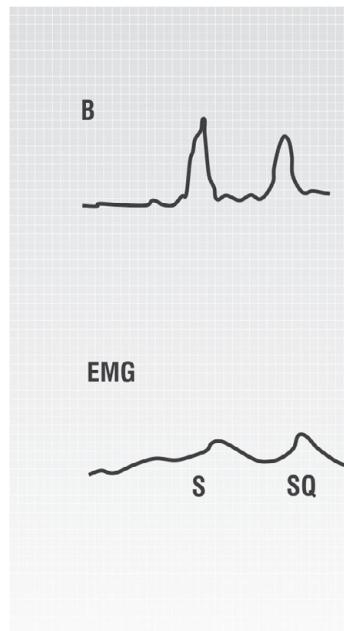


Fig. 2-22b EMG in posterior fornix of vagina simultaneous with bladder pressure measurement (B) demonstrates muscle activity both during straining (S) and squeezing (SQ).

Urethral Opening by External Striated Muscle Forces During Micturition

In comparison to figure 2-19, figure 2-23 shows that the urethra and bladder neck appear to have been opened out by the downward angulation of levator plate (LP) causing downward stretching of the vagina (V) and rectum (R). The directional stretchings of upper vagina, bladder, rectum, and levator plate appear identical to those in the 'closure during effort' position (fig 2-21). Note how the urethra is now well behind the vertical white line, consistent with PCM relaxation.

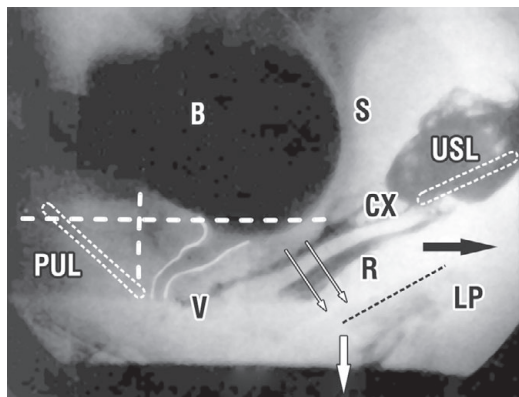


Fig. 2-23 Urethral opening during micturition. Same labelling as in figure 2-19.

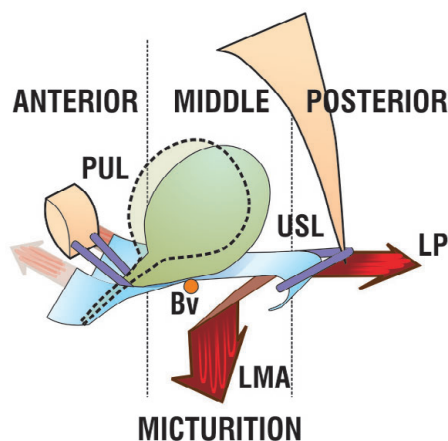


Fig. 2-24 Micturition (Schematic)
This figure corresponds with the situation shown in figure 2-23.

In figure 2-24, relaxation of the forward force allows the backward and downward forces to open out the outflow tract. As the urethral resistance is inversely proportional to the 4th power of the radius (Poiseuille's Law, see 'Urethral resistance and the pressure-flow relationship' in Chapter 6), this action vastly decreases the detrusor pressure required to expel urine. The dotted lines (fig 2-24) indicate the resting position of the bladder.

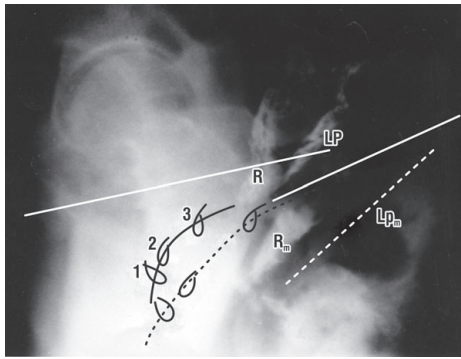


Fig. 2-24a Micturition (broken lines) xray superimposed on resting xray (unbroken lines). Clips have been applied to the anterior vaginal wall, '1', midurethra, '2' bladder neck, '3' bladder base. Note downward/backward displacement of clips '1,2&3'. The levator plate (LP) and rectum (R) are angulated downwards. Downward movement of clip '1' may indicate active contraction of the lower level muscles of the pelvic floor, such as bulbocavernosus and ischiocavernosus, opening out the posterior wall of the distal urethra.. The subscript 'M' indicates the micturition position of R and LP.

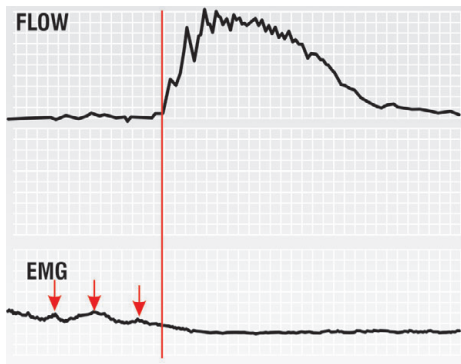


Fig. 2-24b EMG in the posterior fornix of the vagina demonstrates commencement of muscle contraction (arrows) prior to commencement of voiding. This observation is consistent with active opening out of the outflow tract so as to decrease resistance to flow. See also Ch 6.

The Special Case of the Puborectalis Muscle

The evidence from dynamic ultrasound and contraction of the xray imaging studies indicate that that the voluntary “squeeze” component of Kegel exercises is activated by puborectalis muscle. Rectum and vagina are stretched upwards and forwards as is the levator plate, figs 2-24c and 2-24d.

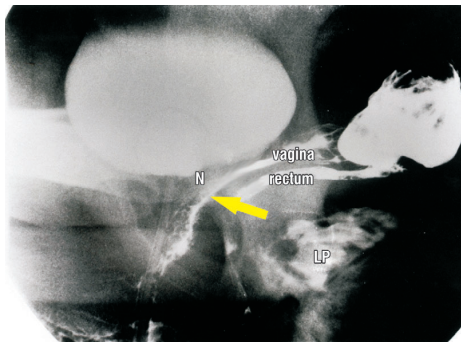


Fig. 2-24c Sitting xray “Squeezing”. Same patient as 2-19, 2-21 and 2-23. Levator plate (LP) rectum and vagina are all lifted forwards and upwards (arrow). Only voluntary contraction of m.puborectalis can explain these observations.

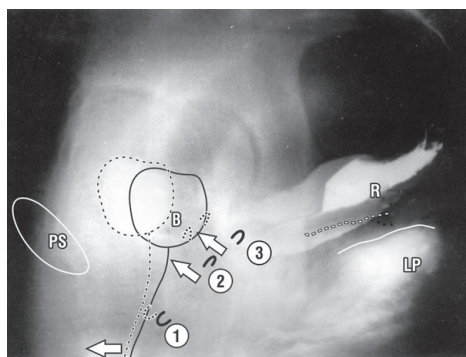


Fig. 2-24d Same patient as 2-22a. “Squeezing” xray (broken lines) superimposed on resting xray (unbroken lines). Clips have been applied to the anterior vaginal wall, ‘1’, midurethra, ‘2’ bladder neck, ‘3’ bladder base. Note upward and forward movement of clips ‘1’, ‘2’ & ‘3’. Only voluntary contraction of m. puborectalis can explain these observations.

Urethral Resistance

— the ultimate pathway to continence, incontinence and ‘obstructed micturition’.

The external striated muscle mechanism, by exponentially increasing and decreasing the urethral resistance, gives an almost instantaneous control for closure, and emptying. It follows, that if the external opening mechanism is not working during micturition, then the flow rate would be much slower, and the patient would complain of emptying symptoms such as ‘dribbling’ and slow flow. Non-function of this mechanism during closure causes incontinence.

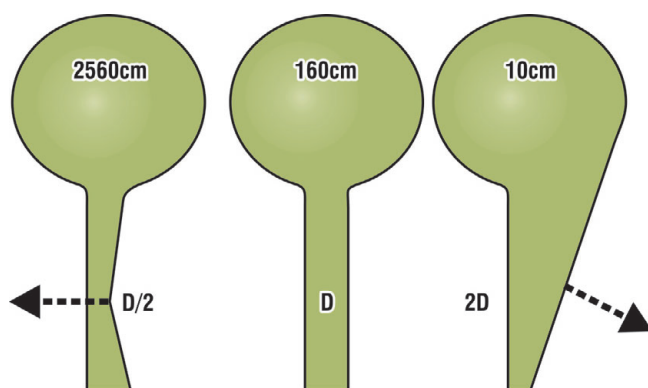


Fig. 2-24e Role of the external striated muscle mechanism in urethral resistance, continence and evacuation. The arrows represent simplified vector forces which close the urethra during continence (forward arrow) or open it during micturition (backward arrow). The pressures required to drive the urine through the changed diameter, are nominally based on a pressure of 160cm for diameter ‘D’. Pressures to expel through diameters $D/2$ (closure) and $2D$ (micturition) are calculated using the 4th power law. Halving the diameter ($D/2$) increases the expulsion force required by a factor of 16, to 2560 cm H₂O. Doubling the diameter ($2D$), decreases that force by a factor of 16 to 10cm H₂O.

2.2.3 Pelvic floor dynamics - the neurological dimension

Urethral Closure

In simple terms, the central nervous system co-ordinates and controls all the structures involved in opening and closure of the urethra and anus. The presence of nerve endings in ligaments and fascia indicates that they too are co-ordinated. The mechanical aspects of opening and closure of the urethra require that a critical tension is maintained in the vaginal membrane (fig 2-19) so that any force applied can pull open or close the urethra. Discovery of a muscle spindle (fig 2-25, Petros PE, Kakulas B and Swash MM - unpublished data) indicates the presence of a complex, balanced, finely-tuned control system.

Muscle spindles (fig 2-25) found in the anterior portion of pubococcygeus muscle suggest that a precise feedback system controls the tension in the vaginal membrane. Adequate tension of the tissues is essential if the woman is to maintain continence at rest.

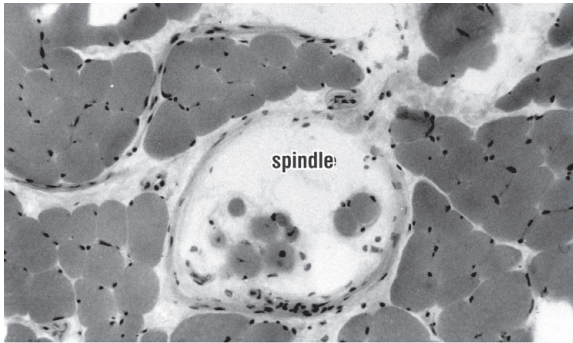


Fig. 2-25 Vaginal tension is controlled by muscle spindles. Muscle spindle found in the anterior portion of the pubococcygeus muscle.

Urethral Opening (Micturition)

Normal micturition may be defined as the controlled emptying of the bladder on demand and rapid restoration of the closed state on completion.

The micturition reflex is activated by both stretch and volume receptors at the bladder base. These vary in sensitivity from patient to patient. The control of the micturition reflex is essentially by a neurological feedback system which operates *via* these receptors. The normal micturition reflex is co-ordinated by the central nervous system and has four main components (fig 2-26):

1. The hydrostatic pressure of a full bladder activates the stretch receptors (N) which send afferent signals to the cortex.
2. The anterior striated muscles relax.
3. The posterior striated muscles (fast-twitch component) stretch open the outflow tract, greatly reducing urethral resistance, thereby allowing the expulsion of urine.
4. The detrusor contracts, creating a smooth muscle spasm to expel urine.

Because electrical transmission is from smooth muscle (Creed 1979) to smooth muscle, the detrusor 'spasms' to expel the urine. This can be seen on video x-ray studies.

It can be helpful to conceptualise the inhibitory centres as 'trapdoors' which can be opened or closed by cortical direction, thereby facilitating or blocking afferent impulses from the bladder base stretch receptors (fig 2-27). When the afferent stimulus ceases, the fast-twitch posterior muscle fibres relax. The stretched tissues 'rebound' to close the urethra. The anterior muscles contract.

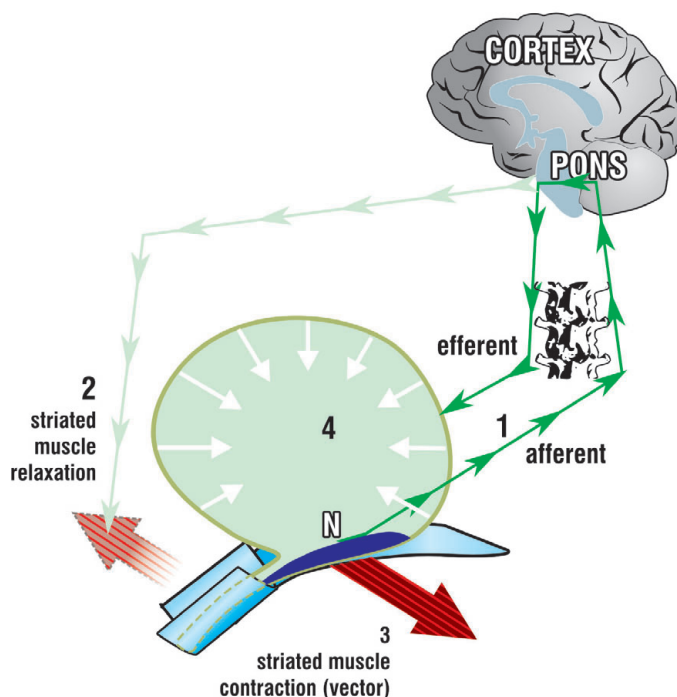


Fig. 2-26 The normal micturition reflex. The normal micturition reflex is activated by peripheral and volume receptors 'N' at bladder base.

The Role of Connective Tissue Tension in the Peripheral Neurological Control Mechanism for Micturition

In a functional sense, there are two neurological mechanisms for controlling inappropriate activation of the micturition reflex: central and peripheral. The central mechanism 'C' arises from the cortex and it acts through the micturition inhibitory centre (fig 2-27). The peripheral neurological control mechanism is a musculo-elastic complex which requires competent suspensory ligaments to work properly (fig 2-28 'trampoline analogy').

With reference to figure 2-27, spindle cells in the pelvic muscles (arrows) sense the tension of the membrane and the system is balanced by the cortex. As the bladder

fills, the stretch receptors (N) send afferent impulses to the cortex. These are reflexly suppressed by activation of the central inhibitory centres (broken red lines). The central inhibitory centres have only a limited ability to suppress the micturition reflex, especially if the vaginal membrane is too lax to support 'N'. As with a trampoline, even if one ligament (spring) is lax, the vaginal membrane cannot be stretched by the muscle forces. The hydrostatic pressure of the urine cannot be supported and 'N' may 'fire off' to initiate micturition at a lower volume. For the patient, these afferent impulses may be interpreted symptomatically as frequency, urgency and nocturia. Urodynamically, the patient may display a phasic pattern in the bladder or urethra ('detrusor' or urethral' instability) or a 'low bladder capacity'.

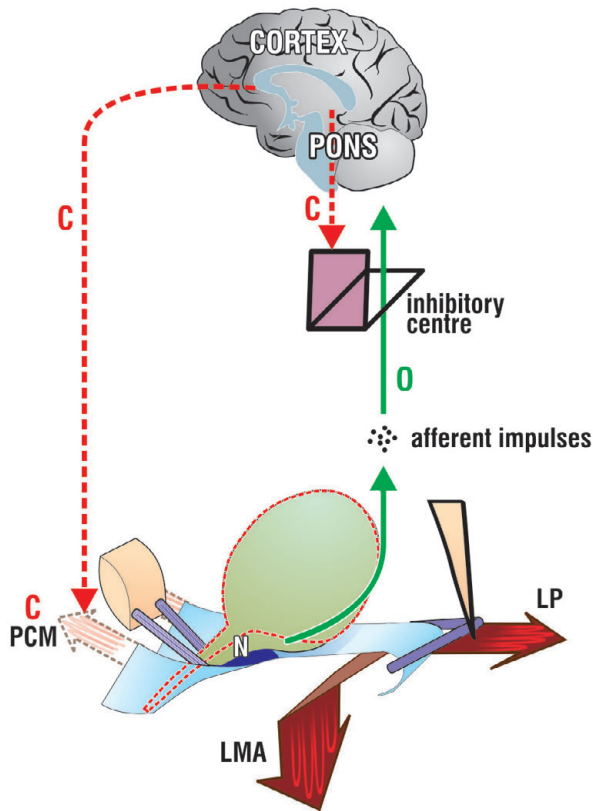


Fig. 2-27 Bladder control - the neurological dimension. Bladder in 'open' position. The closed phase 'C' is indicated by broken lines and the open phase 'O' by unbroken lines. Afferent impulses 'O' activate the cascade of events for micturition: relaxation of the PCM and de-activation of the inhibitory centre and closure reflex 'C'. 'C' activates the cascade of events for closure: activation of the inhibitory centres and contraction of PCM. Note the identical position of LP and LMA in closure and micturition. N = stretch receptors, PCM = pubococcygeus muscle, LMA = longitudinal muscle of the anus, LP = levator plate.

Bladder Base Stretch Receptors

In the human, sensory nerves form a plexus immediately below the urothelium. The urothelium, with its sensory nerves, acts as a mechanosensor. It controls the activity of the afferent nerves, and therefore, the micturition reflex, via specific neurotransmitters, for example, acetyl choline, noradrenalin, NO, ATP, VIP (vasoactive intestinal peptide) (Wyndaele et al. 2008).

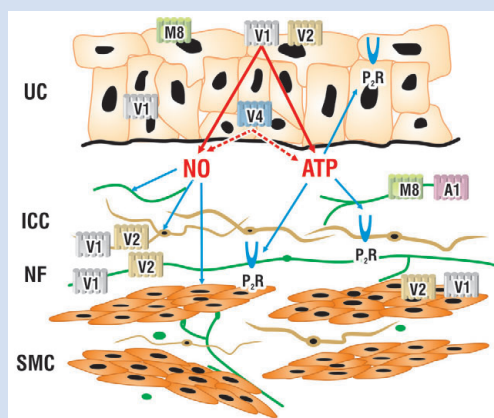


Fig. 2-27a Distribution of Transient Receptor Potential (TRP) channels throughout the bladder wall. Most TRP channels are present on nerve fibres in both the suburothelium, and the muscularis, making them sensitive to different stimuli. Activation of urothelial TRPV1 (V1) and TRPV4 (V4) induces ATP and NO release by the urothelial cells. ATP can activate afferent nerves by acting on specific receptors. NO activates smooth muscle cells (SMC), interstitial cells (IC), and nerve fibres (NF). V1, V2, V4, A1, M8 signify different types of TRPs. From Everaerts et al *Neurourol & Urod.* 2008, by permission.

The pathways to the sensory nerves include TRPs (transient receptor potential channels), Calcium ion permeable cation channels. TRPs channels function as multifunctional sensors at a cellular level. They can be activated by heat, cold, mechanical stress, and by altered pH and osmolality (Everaerts et al 2008).

The sensory nerves supplying the bladder are either thin myelinated A-delta fibres, or unmyelinated C-fibres. A-delta fibres constitute the afferent limb of the micturition reflex. These remain silent until a volume threshold is reached. They may become more sensitive in the presence of inflammatory states. Unmyelinated C-fibres are not normally mechanosensitive, but may become so during inflammation, unmasking a new afferent pathway to express urge and pain symptoms experienced at low bladder volume (Wyndaele et al. 2008). Bladder afferents travel via S2-4 (parasympathetic) or via the hypogastric plexus T11-12 (sympathetic) (Wyndaele et al. 2008).

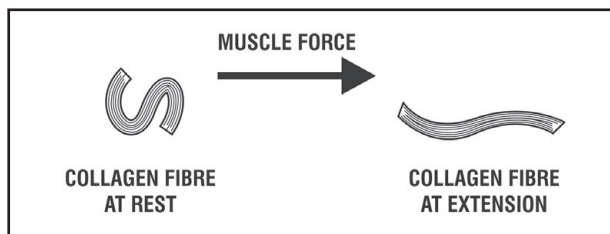
Generally, pelvic floor surgery only addresses damaged connective tissue. Understanding how connective tissue weakens and alters the closure forces that act on the organs of the pelvic floor is, therefore, of vital importance when choosing a particular surgical technique. Biomechanics is the application of principles of physics and engineering to body function. It is used to mathematically analyse all the components that contribute to function, e.g. tissue quality, strength and direction of muscle force.

Structurally, collagen has an 'S' shaped fibril (fig 2-29). Once the curves are straightened out by distension, collagen acts as a rigid rod, preventing further distension. At this point, any force applied is transmitted directly. Thus the distensibility of a tissue depends entirely on the configuration of these collagen fibrils. In a tendon, there is no extensibility, as all fibrils are parallel. A ligament has limited distension, but skin and the vaginal membrane have much more.

The pelvic ligaments suspend the organs from the bony pelvis. They are strong, active structures and are only minimally distensible.

The muscle forces are transmitted to the bony pelvis by means of ligaments (estimated breaking strain approximately 300 mg/mm² (Yamada 1970)). If the ligament is excessively weak, it cannot be repaired, and needs to be reinforced by a tape. This stimulates the deposition of collagen which forms an artificial neoligament.

Fig. 2-29



2.3.1 The Biomechanics of the Vagina

The vagina has an estimated breaking strain of approximately 60 mg/mm² (Yamada 1970). It is essentially an elastic membrane. Inherent elasticity provides a low energy urethral closure force applied from behind. The vaginal membrane has little inherent strength. It derives strength from its fascial layer, and, in a normal patient this is strongest in the area of ligamentous insertions, for example, the apex. The vagina stretches to transmit muscle forces for urethral opening and closure. This stretching counteracts the hydrostatic pressure at the bladder base and so prevents displacement of the stretch receptors which initiate the micturition reflex. The vagina is an organ which cannot regenerate once it is excised. Surgical excision, stretching and tightening of the cut edges of the vagina only serve to further weaken what is essentially a weak elastic membrane. Conceptually, vaginal prolapse is much like an intussusception of a visceral organ. During repair, there is a critical length along the side walls which may need to be reinforced in order to prevent further prolapse.

Elastic fibres occur in tissues which are subject to repeated distortional forces such as skin, vagina, certain ligaments, and large arteries. Their purpose is to restore original contour after a distorting force ceases to act. Elastin fibres are associated closely with collagen fibres and embedded in a ground substance matrix, fig. 2-05. The elastic fibres restore the original network in a typical hysteresis loop when the stretching force is released. This principle is particularly important in providing a low-energy closure for the urethra and ano-rectum, and for restoring the shape and position of the organs following stretching by pelvic muscle contraction. The number of elastic fibres decreases with age.

Thus aged vaginal tissue becomes loose and baggy because the collagen network becomes oriented by gravity or by muscular pull, and there is little or no restoring force. In a scar, where there are few elastic fibres, and where collagen fibres become oriented primarily along lines of tension, there is little give and stretching and relaxation are not possible. This accounts for the rigidity of scar tissue and its inability to undergo repeated deformation (Peacock (1984). For example, the extensive scar tissue created by large mesh insertion along the length of the posterior vaginal wall would limit the vaginal stretching seen in fig 2-29a. Scar tissue contraction with age would create even more rigidity, and this may interfere with any organ function, which relies on adequate vaginal elasticity.

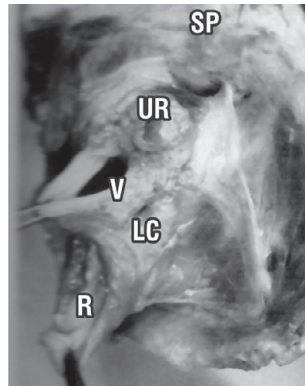


Fig. 2-29a Fresh cadaver specimen- demonstration of vaginal elasticity. The vagina 'V' has been stretched backwards. In the live patient pelvic muscle forces perform this function. Note the intimate connective tissue attachments of vagina to levator crus (LC), urethra (UR) and rectum (R). SP=symphysis pubis. From Zacharin (1985), by permission.

The Effect of Pregnancy Hormones on Connective Tissue

Connective tissue in the area of the urogenital organs is sensitive to hormones. During pregnancy, collagen is depolymerized by placental hormones, and the ratios of the glycosaminoglycans change. (The term 'proteoglycans' is used here interchangeably with 'glycosaminoglycans'.) The vaginal membrane becomes more distensible, allowing dilatation of the birth canal during delivery. There is a concomitant loss of structural strength in the suspensory ligaments. This explains the uterovaginal prolapse so often seen during pregnancy. Laxity in the hammock may remove the elastic closure force, causing urine loss on effort. This condition is described as stress incontinence. Loss of membranous support may cause gravity to stimulate the nerve endings (N) at the bladder base, so causing premature activation of the micturition reflex, expressed as symptoms of 'bladder instability'. This condition is perceived by the pregnant patient as frequency, urgency and nocturia. Laxity may also cause pelvic pain, due to loss of structural support for the unmyelinated nerve fibres contained in the posterior ligaments. The action of gravity on these nerves causes a 'dragging' pain. Removal of the placenta restores connective tissue integrity and the symptoms rapidly disappear in a large percentage of patients.

The Effect of Age on Connective Tissue

In younger patients, the 'S' shaped collagen (fig 2-29) easily extends. In older patients, the increased inter and intramolecular cross-bonding of the collagen stiffens the 'S' and so the tissue may shrink. Age related loss of elastin may cause tissues to 'droop' due to the effect of gravity realigning the collagen fibrils.

Though the individual collagen fibrils strengthen up to 400% with age, the total tensile strength of the urogenital tissues decreases to about 60% (Yamada, 1970). Excision and stretching of vaginal tissue during surgery may weaken it further. Therefore it is advisable to avoid excision of vaginal tissue during surgery where possible.

Loss of elasticity may take away the low energy elastic component of urethral closure. This explains the slow insensible urine leak often seen in patients with low urethral pressure ('intrinsic sphincter defect'). The patient must rely on the slow twitch component of the anterior closure force to close the urethra in a low effort situation, hence the frequent complaint of leakage after 20 minutes walking in patients with no demonstrable stress incontinence. The slow twitch closure muscles simply tire and urine leaks out. Oestrogen may prevent collagen loss and so is recommended as a preventative measure postmenopausally, at least as vaginal pessaries.

The Role of Connective Tissue in Transmitting Muscle Forces – The Sail Analogy

The muscle forces needed to close the urethra require adequately tightened connective tissues for proper functioning. The sail analogy (fig 2-30) is a simplistic illustration of this point: unless the sail and its holding ropes are firm, the force of the wind is not transmitted to drive the boat forward. The analogy drawn is that if the holding ropes (ligaments) are loose, the sail (vagina) flaps in the breeze. Just as a boat without

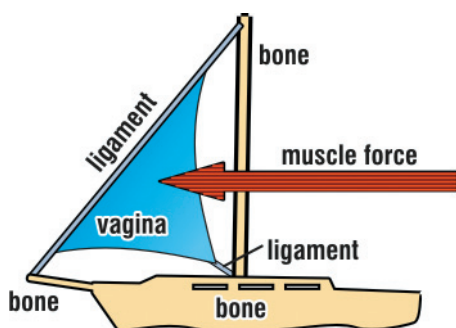


Fig. 2-30 The 'sail analogy' – a loose vagina cannot be tensioned sufficiently to close off the urethra.

a taut sail cannot be driven forwards, so an untensioned vagina cannot be stretched forward to close off the urethra, or support the stretch receptors.

The Positive Effect of Uterine Conservation in Preserving Ligament Integrity

Patients undergoing hysterectomy are much more likely to suffer from urinary dysfunction later in life, and the incontinence is likely to be more severe (Brown 2000).

It follows that the uterus should be conserved where possible in vaginal surgery. The uterus occupies a central structural role in the pelvis, much like the keystone of an arch. The cervix is non-distensible and is a pure collagen structure with an estimated breaking strain of approximately 1500 mg/mm² (Yamada 1970). Because it is connected directly and indirectly with almost every pelvic ligament, any intra-abdominal force impacting on the cervix is distributed to these ligaments as a trophic force. Hysterectomy potentially removes this dispersion of forces, and results in the force being imposed on a weak vaginal membrane to cause herniation. Cervical conservation (subtotal hysterectomy) may be helpful, especially if the descending branch of the uterine artery, the main blood supply for the uterosacral ligament (USL), is conserved. Where cervical removal is essential, intrafascial hysterectomy, using a purse string suture pulls in the cardinal and uterosacral ligaments, and creates a fibrous plug in the centre.

2.3.2 The Role of Connective Tissue in the Maintenance of Form (Structure) and Function

'Function follows form, and dysfunction follows loss of form'.

A normal structure has form, function and balance. Dysfunction may be defined as abnormal symptoms consequent on damaged (unbalanced) structures. Damaged or unbalanced structures lose form and hence normal, healthy function.

Dysfunction is different from biomechanics because not all patients with damaged structures have symptoms. Dysfunction is different to anatomical prolapse in that symptoms may occur as a consequence of minor, barely detectable, anatomical abnormalities. Jeffcoate, in 1962, observed that some patients with gross degrees of

prolapse had no symptoms at all. Others with minor degrees of prolapse complained bitterly of symptoms such as pelvic pain. The aim of this section is to demonstrate how connective tissue damage to key anatomical structures may cause abnormal symptoms.

The Causes of Damaged Connective Tissue

Childbirth is accepted as a major cause of uterovaginal prolapse, bladder and bowel dysfunction. Age and congenital collagen defects are also causal factors. Figure 2-31 schematically demonstrates how childbirth may damage specific connective tissue structures. Damage can be categorised as being of the anterior, middle and posterior zone.

Structural Effects of Damaged Connective Tissue

The circles (fig 2-31) represent the baby's head descending down the vagina damaging connective tissue (CT) thereby causing laxity. This, in turn, may cause urogenital prolapse, and urinary or bowel dysfunction. The numbers 1 through 4 in figure 2-31 represent connective tissue damage to the following structures:

1. Hammock, pubourethral ligament and external ligament laxity
2. Cystocoele and arcus tendineus fasciae pelvis defect
3. Uterine prolapse, enterocoele
4. Rectocoele, anal mucosal prolapse, perineal body and external anal sphincter damage.

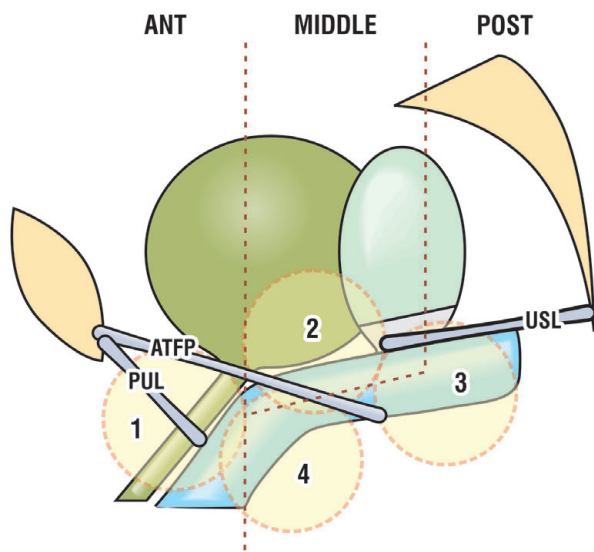


Fig. 2-31 Schematic representation of zones and structures of connective tissue damage at childbirth (circles). 1. PUL = pubourethral ligament (stress incontinence). 2. ATRP = arcus tendineus fasciae pelvis, cardinal ligament and pubocervical fascia (cystocoele). 3. USL = uterosacral ligament (uterine prolapse). 4. Perineal body/rectovaginal fascia (rectocoele). Surgery in one area, may, in time, cause dislocation and prolapse in another subclinically damaged area.

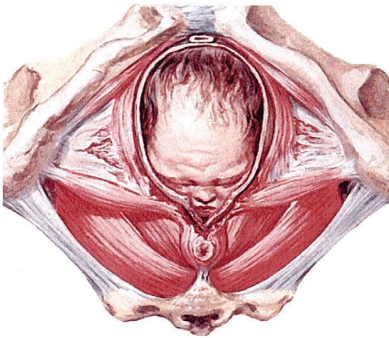


Fig. 2-31a Childbirth. Forcible lateral displacement of hiatal and perineal structures. The head has turned 90 degrees and has descended below the ischial spines to distend the middle and distal parts of urethra, rectovaginal fascia, and perineal body. The A-P diameter of the pelvis is 12-13 cm. A flexed head measures 9.4cm, and a deflexed head 11.2 cm. After Santoro, by permission.

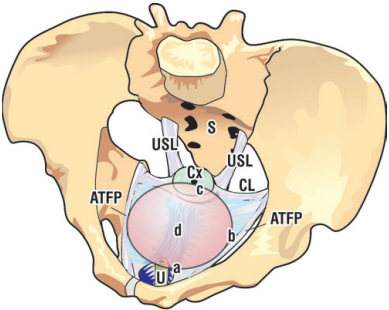


Fig. 2-31b Childbirth. Forcible lateral displacement of connective tissue structures by the foetal head (circle) at the level of the ischial spines may cause ligamentous laxity at 'a'(pubourethral), 'b' (AFTP), 'c' (cardinal/cervical ring), 'd' (pubocervical fascia) causing prolapse and incontinence.

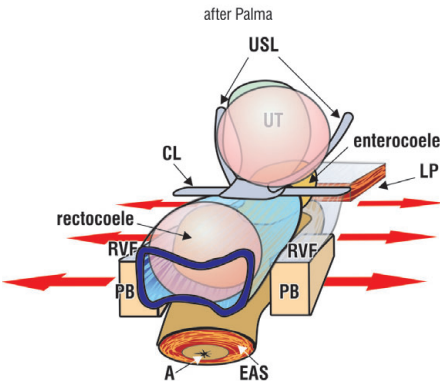


Fig. 2-31c Childbirth. Forcible lateral displacement of uterosacral ligaments (USL), perineal body (PB) and rectovaginal fascia (RVF) by the foetal head above and below the ischial spines (circles) causing connective tissue laxity, and protrusion of enterocoele and rectocoele .

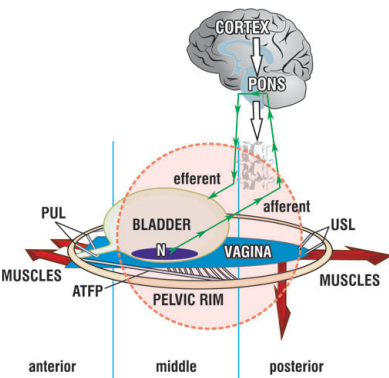


Fig. 2-31d Schematic representation of a foetal head pressing into the pelvic brim, against the vagina and its suspensory ligaments, uterosacral (USL), pubourethral (PUL) and Arcus Tendineus Fascia Pelvis (AFTP). There may be no major separation of ligaments. Even minor damage may cause urgency, as this symptom is neurologically determined; a lax vaginal membrane may not be able to support sensitive stretch receptors "N", so that these activate the micturition reflex prematurely. The patient senses this as urgency and frequency, and at night, nocturia.

Lax Connective Tissue and Diminution of the Force of Muscle Contraction

Even at rest, sufficient tension is required in the vaginal membrane to close the urethra and support the stretch receptors (N) (fig 2-32) to prevent their 'firing off' prematurely. Vaginal tension is maintained by tissue elasticity and slow-twitch pelvic muscle contraction.

Connective tissue laxity 'L' (lower part, fig 2-32) may cause dysfunction. As the 'trampoline analogy' shows, laxity in the ligaments (springs) or vagina (trampoline membrane) will not permit tensioning of the vagina (trampoline membrane) by the muscles.

The muscle forces (arrows) can only be transmitted to open or close the urethra when point 'SE' has been reached on the stress-extension curve (upper part, fig 2-32). With damaged connective tissue, the muscle forces (arrows) must first 'take up the slack' (L) before sufficient tensioning of the vaginal membrane can be reached at SE_L . As a muscle can only contract over a finite length (E), SE_L cannot be reached, the muscle forces cannot close the urethra, and stress incontinence occurs. A lax vaginal membrane cannot support the stretch receptors (N), so these may prematurely activate the micturition reflex: 'detrusor instability'.

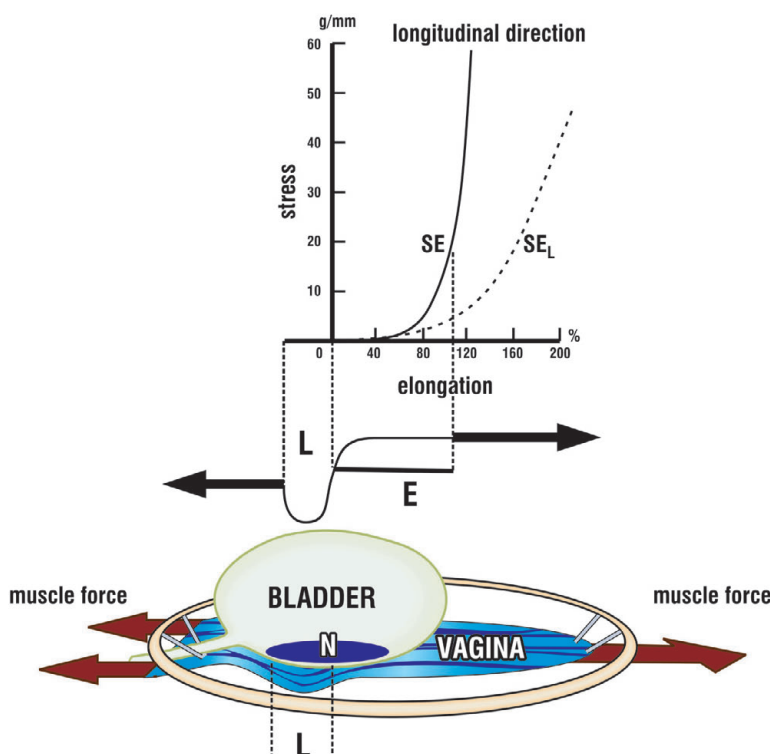


Fig. 2-32 Vaginal or ligamentous laxity may inactivate a muscle contraction. SE_L = stress-extension curve for lax tissues; SE = stress extension curve for normal tissues. (After Yamada 1970)

2.3.3 Role of Connective Tissue in Balance and Imbalance of Pelvic Muscle Forces-Effects on Prolapse,

Pelvic connective tissue and pelvic muscles act synergistically as a neurologically co-ordinated system to support the organs and to prevent prolapse. There is no laxity between the organs and the adjacent muscles in fig.2-33, so that any muscle contraction from the hiatal muscles is immediately transmitted via the connective tissue attachments at levator crus (LC) to stretch the organs and maintain structure, position and form, much like a wire suspension bridge. Of the two components, muscle and connective tissue (CT), the latter is the most vulnerable to damage, causing laxity, weakening of muscle forces, as demonstrated in fig. 2-32.

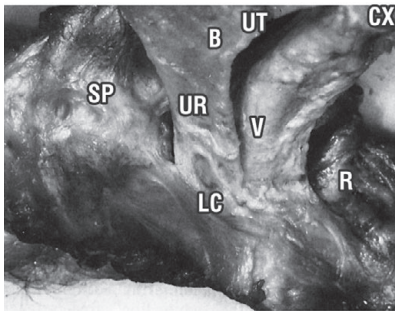
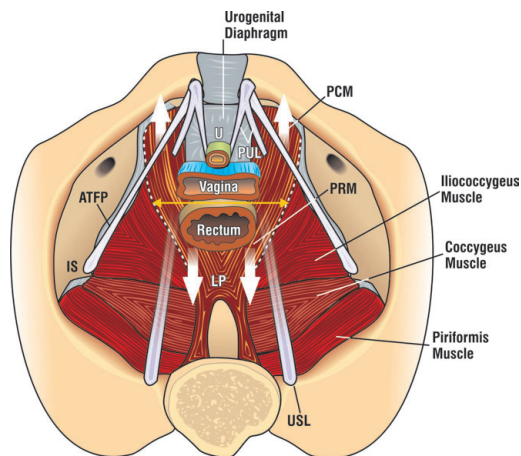


Fig. 2-33 Normal interconnectedness of organs and levator crus by connective tissue –lateral view cadaveric specimen. The vagina 'V', urethra 'U', rectum 'R' are tightly bound to each other and to the levator crus 'LC' by connective tissue. UT=uterus; CX = cervix; SP=symphysis pubis. From Zacharin 1985, by permission.

The Anatomy and Pathogenesis of Prolapse – The Role of a Widened Levator Hiatus

The levator hiatus is the space between the bodies of the pubococcygeus and puborectalis muscles (yellow arrow), fig. 2-34. The mean diameter of the LH is approximately 4 cm at rest. The hiatal area in nulliparous patients varies widely, from 6.34 to 18.06 (mean 11.25) cm² at rest, increasing to a mean of 14.05 cm² on Valsalva manoeuvre, where there is an even wider variation, (from 6.67–35.01cm²), Dietz et al 2005.

Fig. 2-34 Levator hiatus (yellow arrow) is the space between the bodies of the pubococcygeus (PCM) and puborectalis (PRM) muscles.



Strong connective tissue (fig.2-33), binds the organs and medial borders of the pubovesical muscle (PVM) to each other so that the muscle bellies are horizontal. Lax connective tissue allows the muscle bellies to 'droop', fig.2-34a, widening the levator hiatus and creating a "funnel" shape which may per se accelerate the prolapse. * the pubovesical muscle (PVM) is a relatively new term applied to the pubococcygeus and puborectalis muscle bellies as seen on 3D ultrasound or MRI.

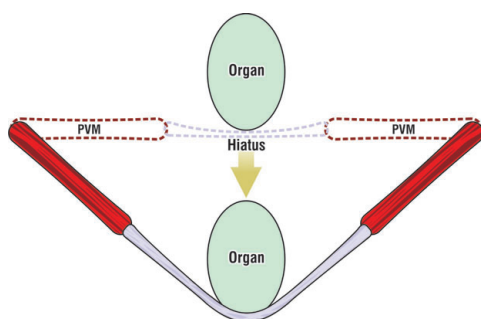
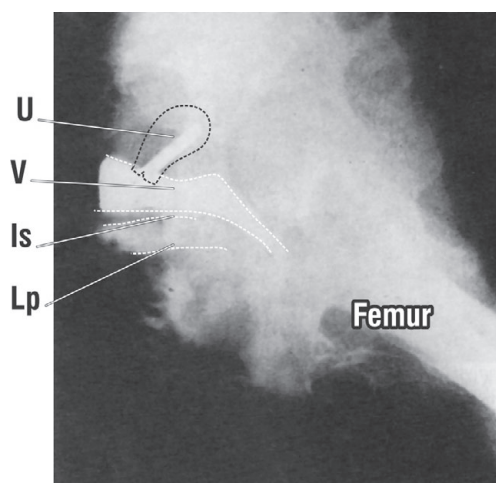


Fig. 2-34a A wide hiatus predisposes to organ prolapse. PVM=pubovesical muscle. Light purple lines represent connective tissue binding the organ and PVMs to each other. If this tissue is weak (bent lines), PVM cannot resist the downward muscle forces acting on it (cf figs 2-40, 2-41), the hiatus widens, and the organ prolapses (arrow).

Berglas & Rubin (1956) and more recently, Dietz et al (2005-2008), have emphasized the importance of a widened levator hiatus (LH) in uterine prolapse causation. Fig 2-35 demonstrates how a uterus positioned in its correct anatomical position directly above levator plate, will be angled forwards during straining, preventing prolapse into the hiatus. If the connective tissue binding the organs together is weak or lax, the organ may shift from its normal position directly above the levator plate, figure 2-35, to incline downwards into the hiatus, even in the nullipara, figs 2-36 & 2-37. The uterus descends on straining, in contrast to fig. 2-35, where the uterus and rectum are stretched even further onto the levator plate.

Fig. 2-35 Position of the uterus (U) above the levator plate (LP). Vagina (V) is horizontal and sited over LP and ischial spine (IS). This geometry is consistent with organs tightly bound to the muscles of the hiatus as in fig 2-33. From Berglas & Rubin (1956), by permission.



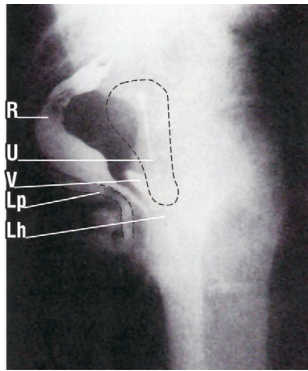


Fig. 2-36 Nulliparous patient with prolapsed uterus at rest (left). Uterus (U) and vagina (V) are inclined into the levator hiatus (LH). R=rectum. However, levator plate 'LP' is horizontal, signifying no paralysis or damage. This geometry is consistent with organs loosely bound to the muscles of the hiatus. From Berglas & Rubin (1956), by permission.

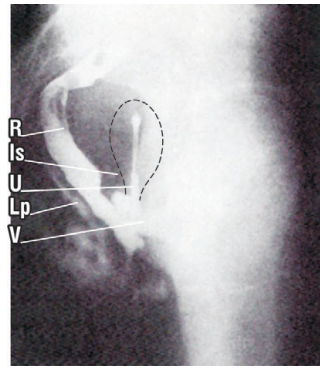


Fig. 2-37 Same patient as fig.2-36- straining (right), LP is pulled downwards, and the vagina (V), rectum (R) and uterus all appear to slide downward into the hiatal space, well below the ischial spine (IS). From Berglas & Rubin (1956), by permission.

"*Ballooning*" (Dietz 2005-8) is defined as a very wide separation of the levator hiatus (LH) muscle bodies on straining. It is more frequent in patients with PVM avulsion, but it may occur even in nulliparous patients. Patients with "ballooning" are more likely to have cystocele and uterovaginal prolapse of at least grade II (Dietz 2005-2008), fig.2-38.

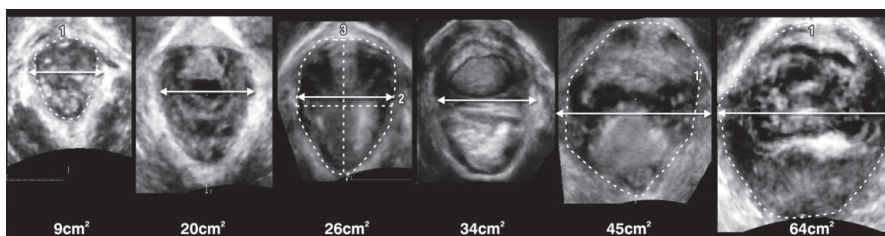


Fig. 2-38 demonstrates a dramatic widening of the levator hiatus "ballooning", in a patient during straining (Valsalva), from 9cm² at rest, to 64cm². (After Dietz HP, by permission). The arrows define the hiatal space between the pubovesical muscles.

Angle of the vaginal axis to the horizontal

The angle of the vaginal axis to the horizontal needs to be more than 45 degrees for the vagina to be compressed down against the rectum and levator plate, fig 2-38a. It was demonstrated using levator myogram xrays at rest and straining, (Petros 2001), that the levator muscles were contracting normally, even in patients with a vertically

inclined vagina, suggesting that lax connective tissue, rather than muscle damage, may have been the prime cause of organ prolapse. The series of MRI images, figs 2-39-2-41, appear to confirm those xray findings.

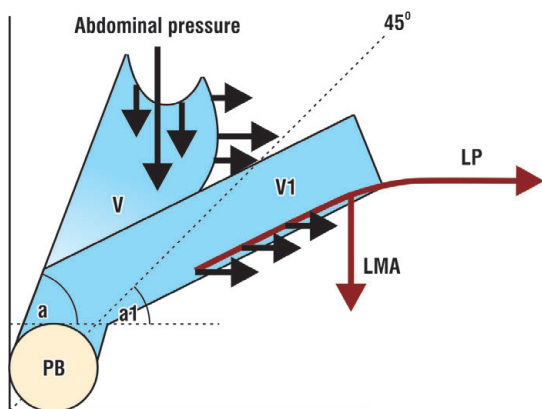
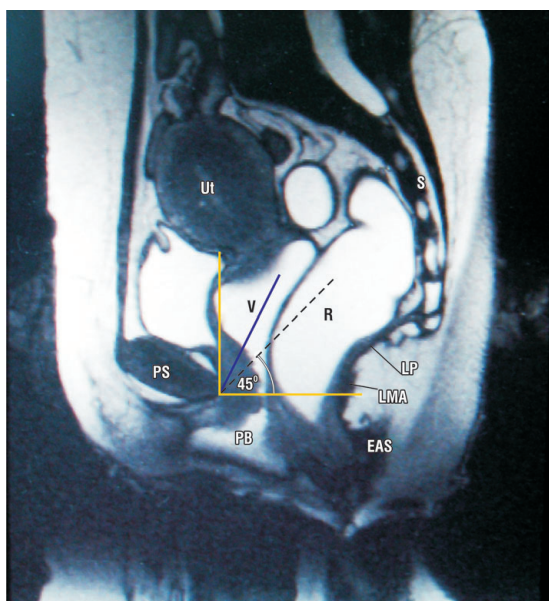


Fig. 2-38a Vaginal axis and prolapse formation. A vertically inclined vagina with an axis to the horizontal >45 degrees, cannot be compressed downwards by muscle forces LP/LMA. The intraabdominal forces (vertical arrows) then accelerate prolapse and herniation.

A Possible Mechanism for Widening the Hiatus and Causation of Organ Prolapse

The video MRI sequence from which figs. 2-39-2-41 are taken, appears to confirm the mechanism proposed in the diagram, fig. 2-40a: lax connective tissue binding between the muscle bodies of the crus allows the muscles to be stretched laterally, widening the hiatus ('ballooning'); LP and the organs are pulled down into the hiatal space by LMA contraction. Even at rest, lax connective tissue does not allow the vagina to be angulated below the 45 degree line, fig 2-39.

Fig. 2-39 Dynamic MRI sagittal view, at rest. The vagina (V) is vertically inclined, >45 degrees to the horizontal, and so cannot be angulated downwards. LMA (longitudinal muscle of the anus) is clearly attached to the anterior border of LP. Ut=uterus; PB= the perineal body. From Petri E, by permission.



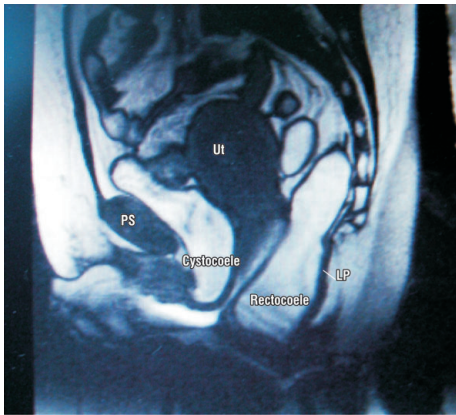


Fig. 2-40 Dynamic MRI sagittal view, early straining. There is an obvious cystocele and rectocele protrusion. The uterus has commenced its descent. LP has been markedly angulated downwards by LMA. From Petri E, by permission.

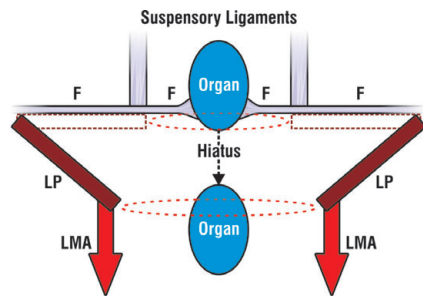


Fig. 2-40a Schematic coronal view of fig. 2-40 (straining). During straining, the levator plate LP is angulated downwards by the LMA vector, opening out the levator hiatus. If the suspensory ligaments and attached fascia (f) are weak, the organs prolapse through the widened hiatus. As the elastin and collagen weaken with time, the prolapsed position becomes permanent.

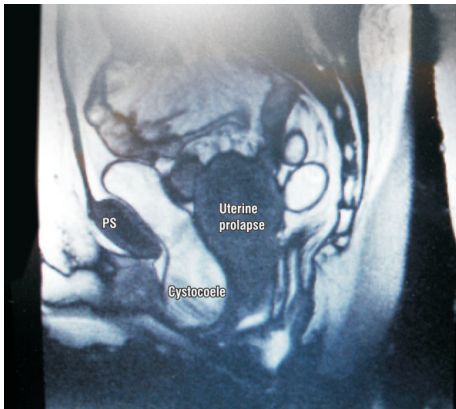


Fig. 2-41 Dynamic MRI sagittal view, late straining. The uterus is now everting outside the introitus. From Petri E, by permission.

Role of Pubovisceral Muscle Avulsion in Prolapse Causation

Pubovisceral muscle (PVM) avulsion has been anecdotally described for over 60 years, but its effect on uterovaginal prolapse and abnormal symptoms has only recently been quantified. Patients with PVM avulsion are far more likely to have lateral displacement of PVM (“ballooning”) on straining (Dietz 2008), and therefore, genital prolapse. In a large retrospective study in 781 patients, Dietz et al (2008) demonstrated that women with levator avulsion defects (figure 2- 42) were twice as likely to have cystocele and uterine prolapse of stage II or higher than those without. This data is consistent with damage from the foetal head to the structures in the hiatal area.

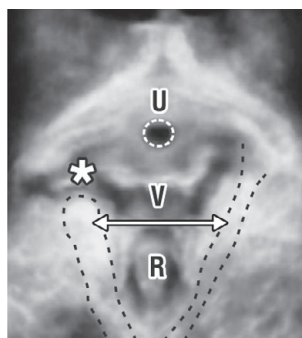


Fig. 2-42 Pubovisceral muscle defect (PVM). View from above of levator hiatus (arrows). The asterisk denotes a left-sided avulsion of PVM from its bony insertion point. PVM is outlined by broken lines. U=urethra; V=vagina; R=rectum. From Dietz HP, by permission.

Pathogenesis of rectocele.

A rectocele is sited below the levator hiatus, fig 2-44. Its pathogenesis, therefore, is different from that for cystocele and uterine prolapse. The rectovaginal fascia (RVF), and perineal body are the major structural components of the posterior vaginal wall. RVF extends from the perineal body to levator plate, and it is attached to the uterosacral ligaments and cardinal ligaments, figure 2-33b. The perineal body supports at least 50% of the posterior vaginal wall, fig. 2-43. Backward and downward stretching of vagina and rectum by the posterior muscle forces (arrows) fig. 2-43, brings the cervix and rectum over the levator plate, so that the intraabdominal pressure will compress both organs onto the levator plate. Separation of the perineal bodies (PB) and uterosacral ligaments (USL) exposes the rectovaginal fascia (RVF) to protrusion of the rectum into the posterior vaginal wall (rectocele), figure 2-44.

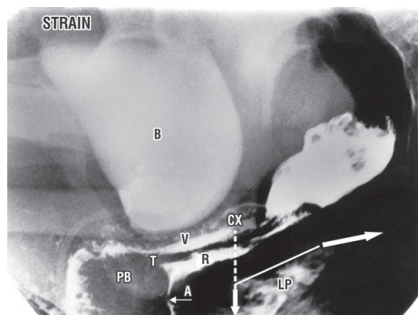


Fig. 2-43 Sitting lateral xray, straining. The perineal body (PB) supports > 50% of the posterior vaginal wall. (V). Arrows indicate muscle forces stretching V, CX (cervix) and R (rectum) backwards over LP (levator plate); 'A' = indentation of the posterior rectal wall by m.puborectalis. T = attachment of anterior rectal wall to PB, from Abendstein et al. (2008).

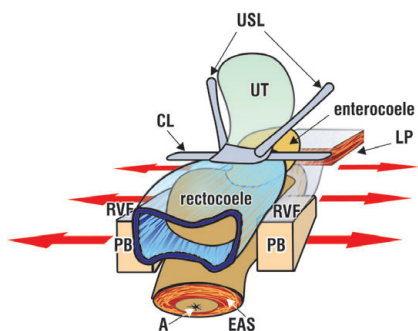


Fig. 2-44 Pathogenesis of rectocele and enterocele. Separation of perineal body (PB) below and uterosacral ligaments (USL) above create potential defects for rectocele and enterocele.

2.3.4 The Role of Connective Tissue in Balance and Imbalance of Pelvic Muscle Forces – Effects on Micturition and Closure

'Balance is a sign of health, imbalance, a harbinger of disease.' Hippocrates

Competent connective tissue is required for normal opening and closure of the bladder. Normal function is only achieved through a balance of the three directional muscle forces, PCM, LP and LMA (fig 2-45). Weakness in any muscle force may unbalance the system, causing dysfunctions of opening (micturition) or closure (continence). A series of diagrams is presented in this section, each illustrating a situation of balance or imbalance between the muscle forces within the three zones of the pelvic floor.

Closure at Rest and Effort

Closure at rest results from inherent elasticity and slow-twitch muscle contraction (fig 2-45). The bladder neck area of vagina must be elastic to allow the anterior and posterior muscle forces to function separately. This is called the 'zone of critical elasticity' (ZCE). The ZCE extends between midurethra and bladder base, and is stretched during effort and micturition. During effort, the fast-twitch muscle fibres of all three muscles are recruited to close the system further.

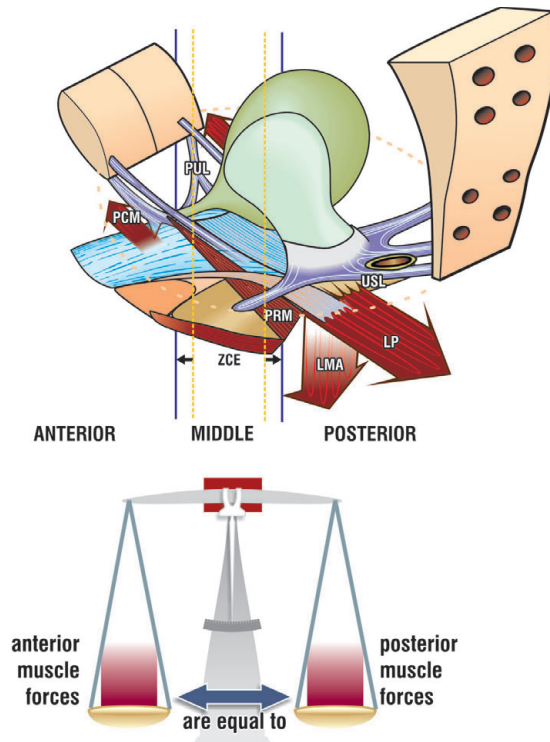


Fig. 2-45 Closure at rest - a balanced system

Normal Micturition – A Controlled Temporary Unbalancing of the Closure System

Competent connective tissue is also required for the normal micturition process (fig 2-46). Relaxation of the forward muscle pubococcygeus (PCM) causes the posterior muscles (levator plate (LP) and longitudinal muscle of the anus (LMA) to stretch the system backwards to the limit of tissue elasticity, expanding the outflow tract backwards, thereby decreasing intraurethral resistance to flow. At the end of micturition, the tissues recoil to close the urethra.

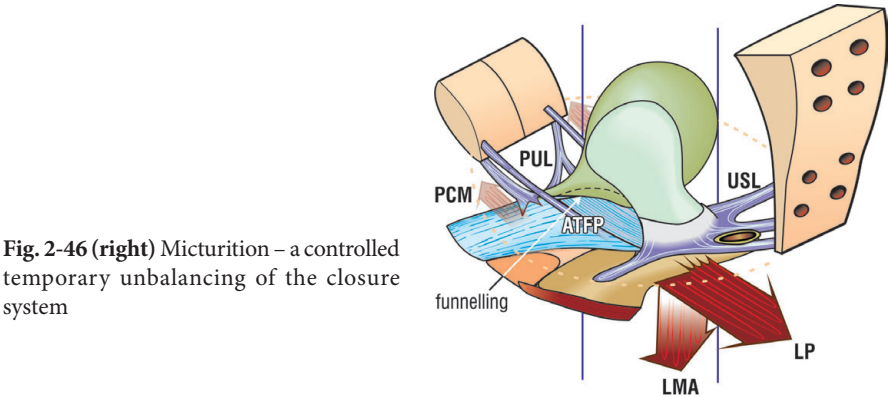


Fig. 2-46 (right) Micturition – a controlled temporary unbalancing of the closure system

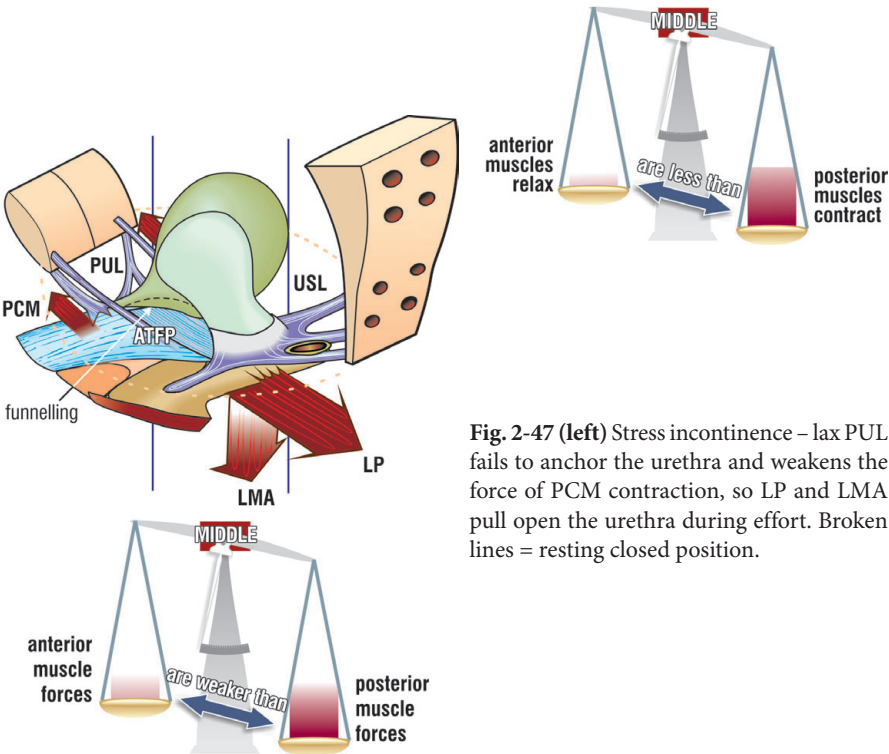


Fig. 2-47 (left) Stress incontinence – lax PUL fails to anchor the urethra and weakens the force of PCM contraction, so LP and LMA pull open the urethra during effort. Broken lines = resting closed position.

The Role of Damaged Connective Tissue in Incontinence Causation

'Mechanical' Imbalance

Stress Incontinence – A 'Mechanical' Imbalance

The cause of stress incontinence is mechanical failure of the connective tissue structures (fig 2-47). A lax pubourethral ligament (PUL) may unbalance the system by allowing LP to stretch open the outflow tract on effort, similar to that which happens during micturition.

The Role of Damaged Connective Tissue in the Pathogenesis of Intrinsic Sphincter Defect

Intraurethral pressure, as measured in one segment of the urethra, is equal to all the forces impacting on that segment divided by the area over which the forces are exerted ($\text{Pressure} = \text{force}/\text{area}$). The three directional muscle forces stretch the trigone to narrow the urethral lumen 'a', and cut off the venous return so that the vascular plexus swells into 'a' (fig 2-48). The horseshoe muscle, "rabd sphincter", contracts to seal the lumen 'a'. These components insert into the connective tissue of the vagina or pubourethral ligament (PUL).

Childbirth stretches connective tissue and ageing causes atrophy. Elastin begins to diminish in a female from her mid-twenties. This weakens the connective tissue of PUL, vagina, the urethral wall, and vascular plexus. The lumen 'a' loses its passive closure forces and dilates. The pubococcygeus (PCM) and the horseshoe muscles insert into connective tissue. As the connective tissue of the vagina and PUL atrophies, these muscles lose their contractile strength and may even atrophy to the extreme found by Huisman (1983). The combination of the diminished closure forces and the dilated lumen lower the intraurethral pressure: 'intrinsic sphincter defect'.

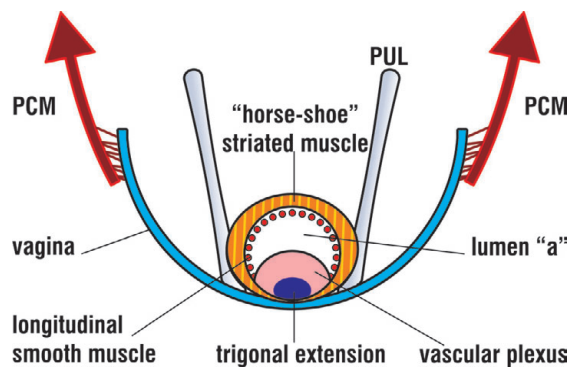


Fig. 2-48 The components of urethral closure. Perspective: vagina at midurethra

The Role of Connective Tissue in Peripheral Neurological Imbalance – Bladder Instability'

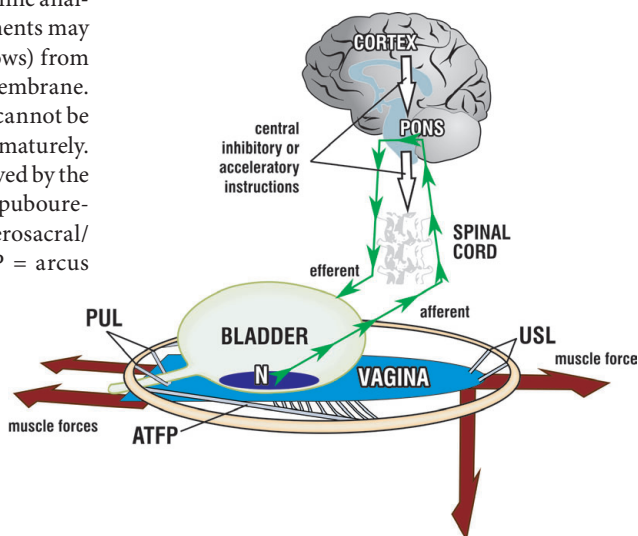
Connective tissue laxity in the suspensory ligaments or vaginal membrane (fig 2-49), may unbalance the peripheral neurological control mechanism, so that the stretch receptors (N) 'fire off' prematurely, causing manifestations of bladder (detrusor) instability.

The bladder lies on top of the vagina (cf. trampoline membrane), which is suspended from the pelvic girdle by the anterior, middle and posterior ligaments (cf. trampoline springs). As the bladder fills, the pelvic muscles reflexly stretch the vaginal membrane. This supports the hydrostatic pressure exerted by the urine column on the stretch receptors (N). It also explains the rise in urethral pressure observed during filling.

Laxity in the ligaments (cf. trampoline springs) or in the vagina (cf. trampoline membrane) (fig 2-49) may not transmit the forces applied and so the vagina cannot be adequately stretched. The stretch receptors may 'fire off' at a lower hydrostatic pressure (smaller bladder volume) and the cortex interprets this as urgency. The patient empties the bladder more frequently during the day (frequency). At night, there is nocturia. The sensitivity of the stretch receptors is clearly an important variable. Because a loose hammock may diminish the contribution of the forward forces to vaginal tensioning, hammock tightening is advised for patients undergoing anterior sling surgery for mixed incontinence.

This musculoelastic mechanism cannot counter bladder instability caused by damage to the cortical inhibitory circuits (white arrows, fig 2-49) say by multiple sclerosis, or excessive stimulation of 'N' by tumour or inflammation.

Fig. 2-49 Peripheral control of micturition – The trampoline analogy. Lax suspensory ligaments may prevent the muscles (arrows) from stretching the vaginal membrane. The stretch receptors 'N' cannot be supported, and fire off prematurely. These impulses are perceived by the cortex as urgency. PUL = pubourethral ligament; USL = uterosacral/cardinal ligament; ATFP = arcus tendineus fascia pelvis.



This process is further illustrated in the series of figures 6-15 to 6-18 in Chapter 6. Figure 6-18 shows how contraction of the puborectalis muscle (yellow arrow) can stretch the vagina forwards to support N and thereby restore balance in the system. This action can control an activated micturition reflex (fig 6-17).

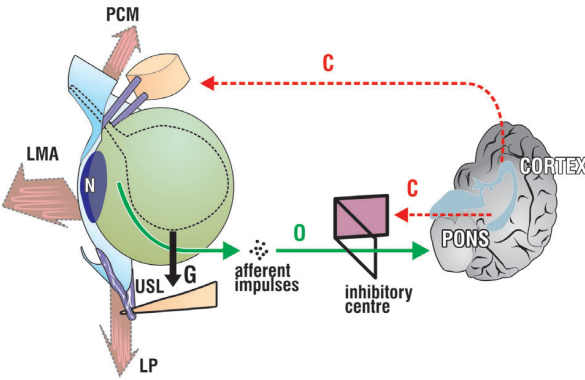


Fig. 2-50 Mechanical origin of nocturia- patient asleep. Pelvic muscles (arrows) are relaxed. As the bladder (broken outline) fills, it is distended downwards by gravity G. If the uterosacral ligaments (USL) are weak it continues to descend until the stretch receptors 'N' are stimulated, activating the micturition reflex once the closure reflex 'C' has been overcome.

The Role of Connective Tissue Damage in the Causation of Abnormal Bladder Emptying – A Mechanical Imbalance

Laxity in the ATRP, pubocervical fascia, cardinal or uterosacral ligaments may unbalance the external opening mechanism. Inability to stretch open ('funnel') the outflow tract may fail to lower the intra-urethral resistance to urine flow. As the urethral resistance varies with the 4th power of the diameter of the urethra, a high pressure may be needed to expel the urine. The clinical picture is one of obstructed micturition (Bush et al. 1997).

Symptoms for this condition are slow flow, 'stopping and starting', difficulty in initiating micturition, feeling of not having emptied, post-micturition dribble. A urodynamic demonstration of the consequences of inability of LMA and LP to open out the outflow tract, that is, a prolonged and slow micturition is shown in the series of figures 6-19, 6-20 and 6-21 in Chapter 6 of this book.

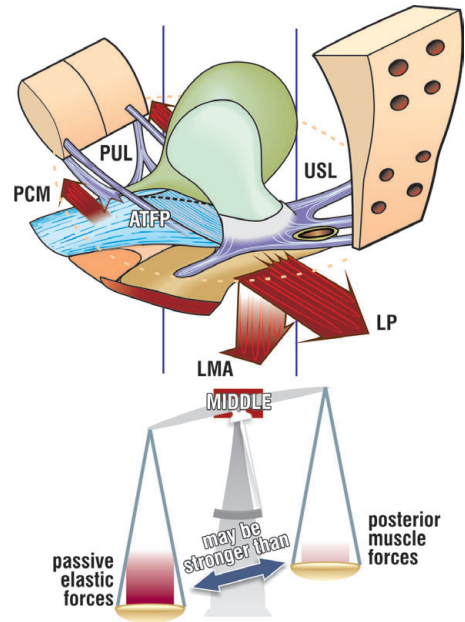


Fig. 2-51 Abnormal bladder emptying –inability to activate the external opening mechanism. A lax USL may inactivate the LMA contraction required to stretch open the outflow tract. A cystocele may inactivate LP contraction. Broken lines indicate normal open position of bladder neck during micturition.

Symptomatic Manifestations of Imbalance Caused by Damaged Connective Tissue

Proper functioning of the urethral tube requires firm connective tissue to be stretched open or closed by the pelvic muscles. Lax connective tissue therefore may result in a *mechanical* inability to open or close the urethra (cf. sail analogy). Failure of connective tissue to support bladder stretch receptors or pain fibres may result in *neurologically-based* dysfunctions, such as pelvic pain or premature activation of the micturition reflex (cf. trampoline analogy).

Mechanical Closure Defects

Symptoms of genuine stress incontinence, unconscious incontinence, continuous leakage and dribble incontinence (some types) are all consistent with a pathogenesis whereby lax anterior zone structures (PUL, hammock) may not permit urethral closure by the forward force, PCM.

Mechanical Opening Defects

Cystocele or lax uterosacral ligaments may prevent the outflow tract being opened out by the backward muscle forces (LP and LMA). Inability to stretch open the urethra greatly increases the resistance to flow (to the 4th power) creating, in effect a functional obstruction. The patient perceives this as slow flow, feeling of not having emptied, post-micturition dribble, interrupted flow, dribble incontinence (some types), overflow incontinence, and difficulty in initiation of flow.

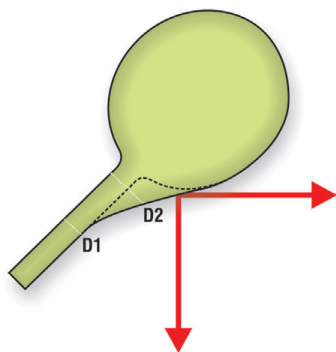


Fig. 2-52 Normally the urethra is stretched open by an external striated muscle mechanism (arrows), from D1 to D2. Because of the 4th power law, even a minor inability to actively open the urethra during micturition may cause symptoms of “obstructed micturition”.

Tethered vagina syndrome

Tethered vagina syndrome is an iatrogenic scar causing forcible opening of the outflow tract. This is an iatrogenic condition usually caused by scar tissue in the bladder neck area of vagina, but it may be caused by excessive bladder neck elevation from a Burch colposuspension. It is addressed in detail in Chapter 4. With reference to fig. 2-53, the scar tissue at the ‘Zone of Critical Elasticity’ (ZCE) “tethers” the stronger posterior force to the weaker anterior force (arrows). This unbalances the urethral closure system, and forcibly opens out the outflow tract with any effort requiring prolonged contraction of the pelvic floor. The classical symptom is massive urine loss immediately the patient’s foot is placed on the floor on getting out of bed in the morning.

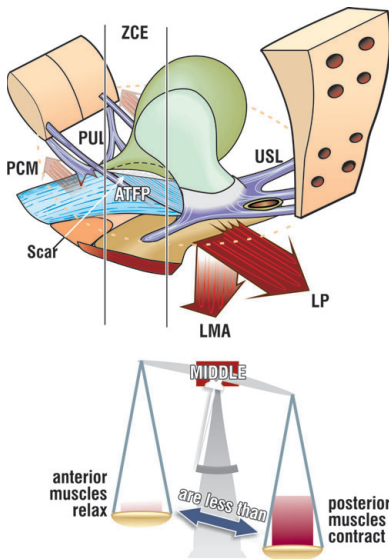


Fig. 2-53 Tethered Vagina. The scar tissue at ZCE ('zone of critical elasticity') tethers the more powerful posterior force to the weaker anterior force (arrows) forcibly opening the outflow tract, much as occurs in micturition, but is driven mechanically, not neurologically. Broken lines indicate closed position of the bladder neck.

Peripheral Neurological Defects Caused by Connective Tissue Laxity

Lax connective tissue may cause the stretch receptors at bladder base to 'fire off' and activate the cascade of events which occur with micturition: sensory urgency, relaxation of PCM, opening out of the outflow tract, and detrusor contraction. Other causes of inappropriate activation of the micturition reflex are malignancy at bladder base, inflammation or even pressure on the stretch receptors by fibroids. The patient may present with symptoms of detrusor instability, low bladder capacity, sensory urgency, frequency, nocturia and motor urgency. All these symptoms are consistent with this pathogenesis. Poor sensitivity in the bladder base stretch receptors may prevent adequate activation of the micturition reflex. Hence the outflow tract has to be opened out by mechanical means only, that is by straining. This condition is described as 'detrusor acontractility' or 'under-activity'.

Pelvic Pain Caused by Connective Tissue Laxity

Pelvic pain related to laxity of the uterosacral ligaments (USL) is characterized by low dragging abdominal pain, (often one-sided), deep dyspareunia, and often, low sacral backache (Petros 1996). It can vary in intensity. Sometimes it can be sufficiently severe for the patient to present as an emergency. It is often relieved on lying down, and usually exists as part of the 'posterior fornix syndrome' (posterior zone defect, fig 1-11) which may include urge, frequency, nocturia and abnormal emptying. The pain may occur with only minor degrees of prolapse. This pain can be reproduced ('simulated') by digital palpation of the USLs. It is hypothesized that the pain relief obtained after posterior IVS surgery is related to the physical support given to the S2-4 unmyelinated nerve fibres carried along the uterosacral ligaments. Ligamentous laxity may be causally linked to birth trauma in the multipara, or may arise in the nullipara soon after menarche.

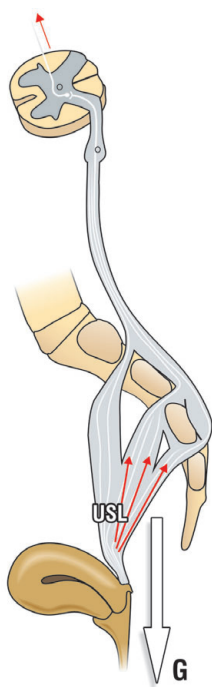


Fig. 2-54 The anatomy of uterosacral ligament (USL) referred pelvic pain. If the uterosacral ligaments (red arrows) cannot provide adequate anatomical support for the unmyelinated afferent nerves (thin white lines) the force of gravity (G) may stretch them, causing referred abdominal and sacral pain. After Goeschen, by permission.

A minor role for muscle damage in urinary incontinence?

Bedwell & Dietz 2008 assessed 420 patients, 104 of whom had pubovesical muscle (PVM) avulsion from their pubic bone insertions. The PVM avulsion group were less likely to have stress incontinence, and more likely to have bladder emptying symptoms and prolapse. There was no correlation between symptoms of urgency and nocturia with PVM avulsion. These findings support the Integral Theory's prediction, that the bladder dysfunction derive mainly from connective tissue damage rather than muscle damage.

2.3.5 The Role of Connective Tissue in Anorectal Opening, Closure, and Idiopathic Faecal Incontinence

This section is based on clinical and experimental studies which indicate that idiopathic faecal incontinence and evacuation disorders have the same causation as urinary dysfunction: connective tissue damage in the suspensory ligaments. See Musculoelastic Theory, Petros & Swash, *Pelviperrineology*, 2008, www.pelviperineology.org. The original impetus for these works was the repeated observation that patients with stress incontinence (SI), treated with a suburethral sling, volunteered that their FI had also been cured (Petros 1999). Patients who did not have SI, but who had posterior zone defects also reported improvement of their FI.

A Musculo-Elastic Sphincter for Anorectal Closure (Continence)

Described for the first time (see box below) is a musculo-elastic sphincter for anorectal closure. This mechanism is powered by the same two posterior muscle forces which activate bladder neck closure, levator plate (LP) and longitudinal muscle of the anus (LMA). Because these muscles contract against the pubourethral and uterosacral suspensory ligaments, laxity in these ligaments may cause faecal incontinence.

A New Sphincter

A new complex musculo-elastic sphincter is presented. Its mechanism is similar to that for bladder neck closure. Directional muscle forces stretch the rectum backwards and downwards around an anus firmly anchored by the puborectalis muscle (Petros & Swash 2008).

In its simplest form, anorectal closure occurs when the backward muscle forces LP (levator plate) and LMA (longitudinal muscle of the anus) stretch the rectum like a rubber tube, around an anus anchored by m.puborectalis (PRM) contraction. On relaxation of PRM, LP/LMA vectors open out the anal canal for evacuation to occur.

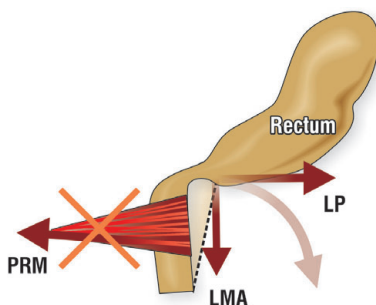


Fig. 2-55 Simplification of the anorectal closure (continence) and evacuation (defaecation) mechanisms. Closure (continence, small arrows): LP (levator plate) and LMA (longitudinal muscle of the anus) stretch the rectum around an anus anchored by m.puborectalis (PRM) contraction. Opening (defaecation): PRM relaxes (large 'X'); the anorectal canal is pulled open (broken lines).

The anatomical supports of the anorectum complex

Upper and middle supports

The rectum is supported postero-inferiorly by the levator plate, and anteriorly by its connective tissue attachments 'CT' to the vagina and uterosacral ligaments, figs. 2-56 & 2-57. The rectovaginal fascia (RVF) (fig 2-56) is a dynamic middle support. It attaches to the perineal body (PB) inferiorly and levator plate (LP) superiorly (Nichols 1989). It is stretched during anorectal closure and defaecation.

The levator plate (LP) inserts directly into the posterior wall of rectum. The smooth muscle longitudinal muscle of the rectum inserts into striated muscle arising from

levator plate, the lateral part of m.pubococcygeus (PCM), and m.puborectalis (PRM) to become the conjoint longitudinal muscle of the anus (LMA). PRM (fig 2-56) runs vertically below and medial to PCM, around the rectum, from which it is separated by a type of bursa (Courtney 1950), to insert into the lower part of the pubic bone. It effectively compresses the sides of the anus and anchors its posterior wall. The perineal body (PB) and pubourethral ligaments anchor LP contraction, and the uterosacral ligaments anchor LP/LMA contraction (fig 2-56).

Lower supports, figs 2-56, 2-57

The anus is a soft tissue tube with little inherent strength. Its walls must be stretched firmly and anchored superiorly and inferiorly so that anorectal opening and closure may take place. Dense fibromuscular tissue surrounds the lower 2-3 cm of vagina and anus. The perineal body (PB) is a key anchoring point for the distal vagina and anus. Contraction of the anterior part of pubococcygeus muscle (PCM), perineal membrane muscles, external anal sphincter (EAS), and postanal plate, anchor the anus distally. The superficial and deep transverse perineal muscles fig.2-57a help anchor the upper part of PB to the descending ramus of the pubis.

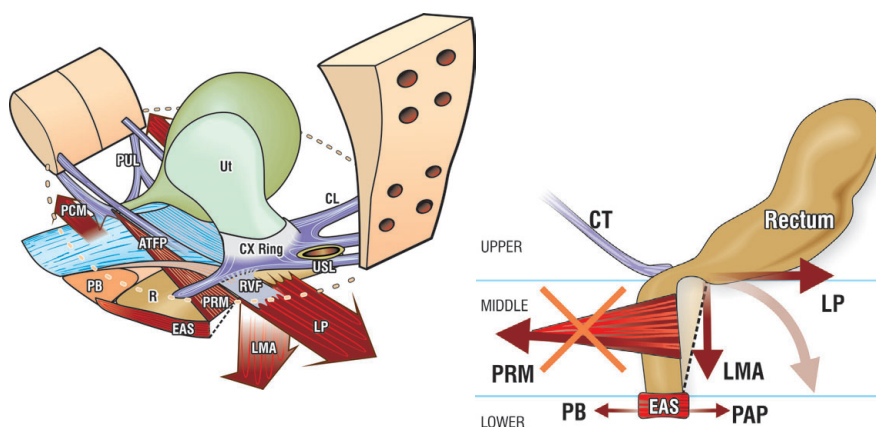


Fig. 2-56 Anatomical supports of the anorectum complex, schematic 3D view. Anorectum in closed position. Upper supports levator plate (LP); uterosacral ligaments (USL) Middle supports m.puborectalis (PRM); longitudinal muscle of the anus (LMA) rectovaginal fascia (RVF); Lower supports perineal body (PB); external anal sphincter (EAS), postanal plate (not shown). Defaecation PRM relaxes; PCM tensions the perineal body and anterior wall of rectum; LP/LMA open out the anorectal tube (broken lines) ; rectum contracts to evacuate faeces.

Fig. 2-57 Anatomical supports of the anorectum complex, schematic sagittal view. The upper and lower supports stabilize the rectal tube, allowing closure and evacuation (broken lines) on PRM relaxation. Upper supports: levator plate (LP); connective tissue attachment to vagina and uterosacral ligament (CT). Middle supports m.puborectalis (PRM); longitudinal muscle of the anus (LMA). Lower supports External anal sphincter (EAS) perineal body (PB); post-anal plate (PAP); horizontal arrows from PB represent anterior and posterior anchoring muscle forces.

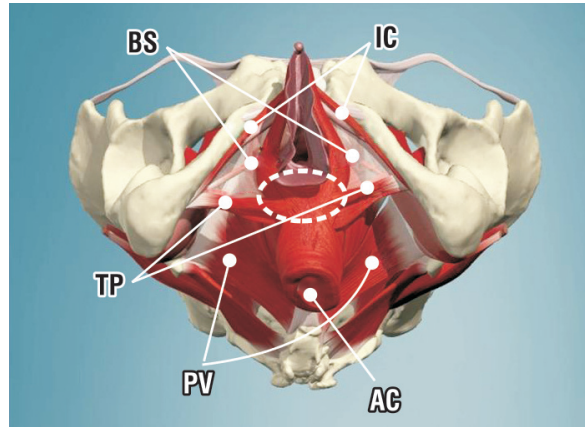


Fig. 2-57a Anatomy of perineal body. The broken circle represents the central tendon of the perineal body. It is the insertion point of the bulbospongiosus muscle (BS), and deep and superficial transverse perinei muscles (TP). PV=pubovaginalis; AC=anal canal; IC=ischioanal canal; AC=anal canal. From Santoro G, by permission.

Radiological correlations for normal function

The xrays which follow, aim to demonstrate the directional movements by the 4 muscle forces, and the ligamentous insertion points against which they contract. One set of xrays, figs 2-57b&c, is from a normal nulliparous patient, and these illustrate the dynamics of anorectal closure. The other set of xrays, figs 2-57d-g, is from a patient with idiopathic faecal incontinence, and it illustrates the dynamics of both closure and defaecation. The major difference is an apparent laxity of the vagina, and a significantly altered vaginal axis both at rest, and during straining.

Anorectal closure during straining, -normal patient

On comparing the resting films (fig 2-57b), with the straining films (fig 2-57c), four directional forces become evident (arrows). These appear to stretch the vagina and rectum between 'X' and 'Y', the exact positions of the pubourethral and uterosacral ligaments, much like a trampoline. The perineal body provides anatomical support for more than 50% of the posterior vaginal wall. The perineal body, distal parts of the vagina and midurethra appear to be pulled forwards (forward arrow). There is a distinct indentation of the anal wall, consistent with a force applied from behind, consistent with puborectalis muscle contraction (curved arrow). The rectum and upper part of the vagina are stretched backwards against "X" and downwards against "Y", arrows (fig 2-57c). In addition, the anterior part of the levator plate becomes angulated downwards. These video studies indicated a clear relationship between

the downward angulation of levator plate and downward displacement of the vagina and rectum, consistent with the fascial attachments of the organs to these ligaments (fig 2-57b). Like an elastic membrane, the rectum was markedly altered in shape and position during pelvic floor or pelvic organ movement. Thus it was stretched upwards and forwards during “squeezing” (“lifting up”) (as in fig 2-57f), but backwards and downwards during straining. Coughing caused an identical, but much faster organ movement than that observed during straining.

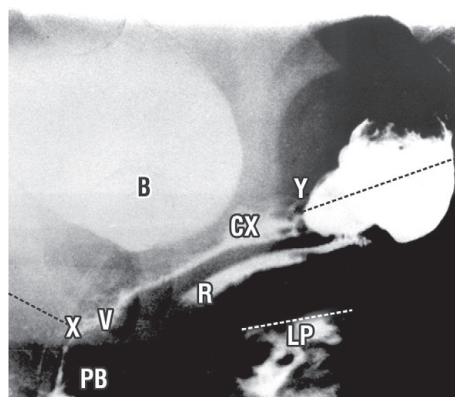


Fig. 2-57b Patient continent of urine and faeces. Sitting lateral X-Ray, with radio-opaque dye in bladder (B), vagina (V), rectum (R) and levator plate (LP). A white diagonal line represents the superior border of LP. PB= perineal body; R=rectum; CX=cervix; 'X' & Y= insertion of the pubourethral and uterosacral ligaments (black broken lines).

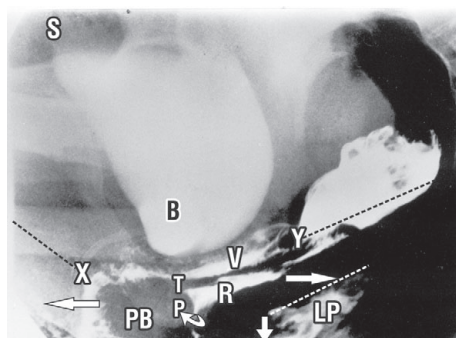


Fig. 2-57c Straining, normal patient anorectal closure—same patient and labelling as fig.2-57b. With reference to fig 2-57b, arrows denote directional movement of the organs; P (curved arrow) =action of m.puborectalis; the forward and backward directional arrows pull against “X” (pubourethral ligament), and the downward arrow against “Y”(uterosacral ligament). The anterior wall of rectum appears to be anchored at “T”, the site of insertion of m.deep transversus perinei. The rectum ‘R’ is stretched backwards and rotated around an anus firmly anchored by m. puborectalis ‘P’.

Anorectal closure during straining, faecal incontinence group (figs 2-57d&e)

The same directional muscle forces appear to be acting on the organs as in fig.2-57c, anteriorly, posteriorly and inferiorly. Compared to the nulliparous xrays, the vagina in the FI group is almost vertical at rest (fig.2-57d), and on straining (fig.2-57e), a stark contrast to the horizontal angulation obvious in the nulliparous straining xray (fig.2-57c). The perineal body is not nearly as prominent in fig.2-57e as in fig. 2-57c. Relative to the resting xray, fig. 2-57d, the posterior wall of the rectum appears to have been pulled forwards to the vertical position during straining (fig. 2-57e), consistent with contraction of the puborectalis muscle, accentuating the anorectal angle, but not as much as in the nulliparous xray, fig 2-57c. Inferiorly, angulation downwards of the anterior border of levator plate (LP) is seen, (downward arrow, straining xray, Fig. 2-57e), and this is consistent with contraction of the longitudinal muscle of the anus.

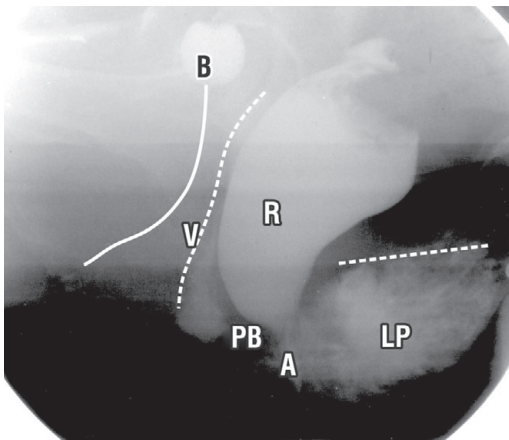


Fig. 2-57d Resting position–faecal incontinence patient Sitting position. Labelling as per fig. 2-57b. A=anus; white broken horizontal line = superior border of LP. Vertical broken lines “V”=vagina; unbroken vertical line=urethra; B=bladder; R= rectum.

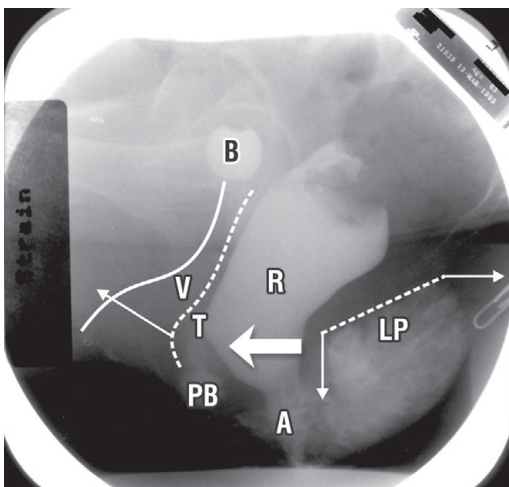


Fig. 2-57e Anorectal closure–“Pre-Evacuation strain” Same patient & labelling as fig 2-57d, sitting position. With reference to the resting state, fig.2-57d, note: forward stretching of distal vagina “V”; downward angulation of anterior border of levator plate (LP); the distal part of the posterior rectal wall has become vertical, consistent with forward contraction of puborectalis (black arrow); entry of material into anus “A”, consistent with the diagnosis of faecal incontinence; “pinching” of anterior rectal wall at “T”, consistent with anchoring by m. deep transversus perinei.

During squeezing, faecal incontinence group (fig.2-57f)

All the organs have been pulled upwards and forwards, apparently by contraction of the puborectalis muscle, PRM, which lies below the levator plate muscles.

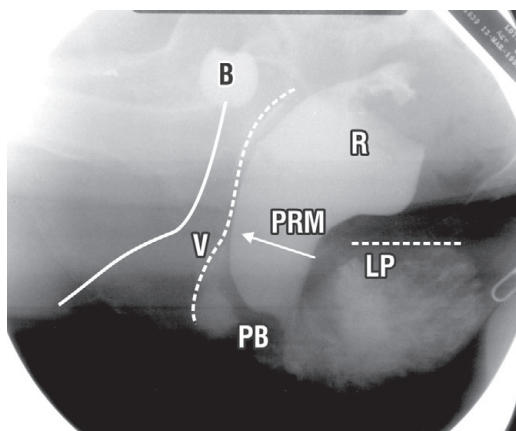


Fig. 2-57f Squeezing—Same patient as fig 2-57d, sitting position. All the organs and LP have been pulled upwards and forwards, consistent with contraction of the puborectalis muscle, PRM.

During defaecation, faecal incontinence group (fig2-57g)

The same three directional muscle forces seen during straining, seem to be acting on the walls of the anus and rectum: the distal vagina is pulled forwards; the rectum and proximal vagina have been pulled backwards; levator plate is angulated downwards; The anus has been opened out, consistent with puborectalis muscle 'PRM' relaxation. As in fig. 2-57e, 'T', the insertion of the deep transversus perinei, and "X", the insertion of the pubourethral ligament appear to be acting as firm anchoring points for backward stretching of bladder, vagina and rectum by LP.

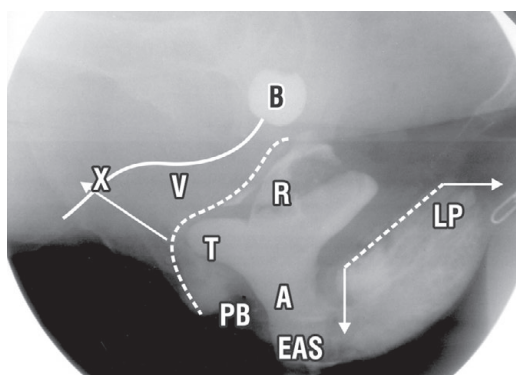


Fig. 2-57g Defaecation—Same patient and labelling as fig 2-57d, sitting position. Arrows denote directional movement of the organs consistent with stretching by muscle forces. Note: forward stretching of distal vagina "V"; backward stretching of proximal vagina, bladder (B) and rectum (R); downward angulation of levator plate (LP); marked widening of the anal canal (A); bulge at "T" consistent with anchoring by m. deep transversus perinei. EAS = position of external anal sphincter.

Connective Tissue Laxity and Anorectal Dysfunction

Anal dysfunction is defined as the inability to evacuate ('constipation') or to contain the rectal contents ('incontinence'). Incontinence is graded (in increasing degrees of severity) as wind, liquid or solid incontinence. Observational data collected from patients undergoing anterior and posterior sling operations for FI suggest that anal sensation may work in a similar manner to the bladder: anorectal stretch and volume receptors may initiate a defaecation reflex which can be controlled by puborectalis muscle (PRM) contraction. Defaecation is different to anorectal opening. Like micturition, defaecation is driven by a neurological reflex which coordinates all the elements required to produce efficient evacuation.

Because the main anorectal closure muscles, PCM, LP & LMA effectively contract around the pubourethral (PUL) and uterosacral (USL) suspensory ligaments, fig. 2-56, any laxity in these ligaments may invalidate the muscle forces, causing difficulties in both closure (incontinence) or opening ('constipation'). As urinary and other pelvic symptoms often co-exist, such symptoms as depicted in the pictorial algorithm are used to diagnose which damaged ligaments require reinforcement with plastic tapes.

If the uterosacral ligaments, perineal body and rectovaginal fascia are damaged, the anterior wall of rectum cannot be stretched, and defaecation difficulties may occur. The perineal body is an insertion point for the external anal sphincter, which is the major insertion point for the longitudinal muscle of the anus, the major muscle for the external anorectal opening mechanism, figs 2-55-2-57. This same laxity may also be an important cause of haemorrhoids. The inward collapse of the anterior rectal wall may inhibit the venous return, distending the veins and creating backward pressure which may cause pain and bleeding. It has often been observed that haemorrhoids disappear after a three level posterior sling repair.

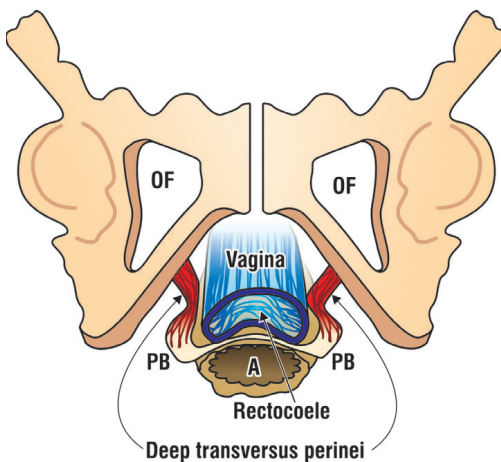


Fig. 257h. Stretched and damaged perineal body. The muscles, in particular the transverse perineal muscles (TP) have separated laterally and prolapsed. The anus (A) and rectum protrude into the vagina (V). OF=obturator fossa.

The Role of m.puborectalis, external and internal anal sphincters in faecal incontinence causation

A damaged external anal sphincter (EAS) is a major correctable cause of faecal incontinence (FI). It may contribute to FI in two ways. Firstly, through its direct effect on distal closure of the anus, and secondly, by its inactivation of LMA contraction. EAS is the insertion point of LMA, fig. 2-56. LMA is a key element in creation of the anorectal angle. Because the pelvic muscles, PCM, LP, LMA (arrows, fig 2-56) effectively insert into the pelvic ligaments, lax ligamentous anchoring points may inactivate these muscles, causing FI and/or evacuation disorders. The impact of damaged pelvic muscles on FI is likely to be minor, given the greater than 80% improvement rate following PUL or USL reinforcement with polypropylene tapes (see last page Ch4 and also, www.pelvip erineology.org Vol 27). The exact contribution of damaged m.puborectalis to anorectal closure and FI is yet to be fully defined. However, recent data from Chantarasorn & Dietz 2008 appears to indicate that the function of PRM is to stabilize the anus for closure by the LP/LMA sphincter, figs 2-55-7, rather than acting as a closure muscle per se. Chantarasorn & Dietz found that a torn m.puborectalis has no correlation with symptoms of FI. Neither is internal anal sphincter (IAS) damage likely to be a major cause of FI. In a prospective ultrasound study, Petros & Anderson (2005) found that only 28% of patients with both urinary stress incontinence and idiopathic faecal incontinence had thinned IAS. The remaining 72% had normal IAS.

'Constipation'

For the purposes of this chapter, 'constipation' is synonymous with *obstructed defaecation*. With reference to (fig 2-56), during defaecation, LP stretches the rectovaginal fascia (RVF) against the perineal body (PB) and RVF is then pulled downwards by LMA against USL, to open out the anorectal junction. Connective tissue laxity in USL, RVF or PB may weaken the opening forces causing 'straining at the stool' and 'constipation'.

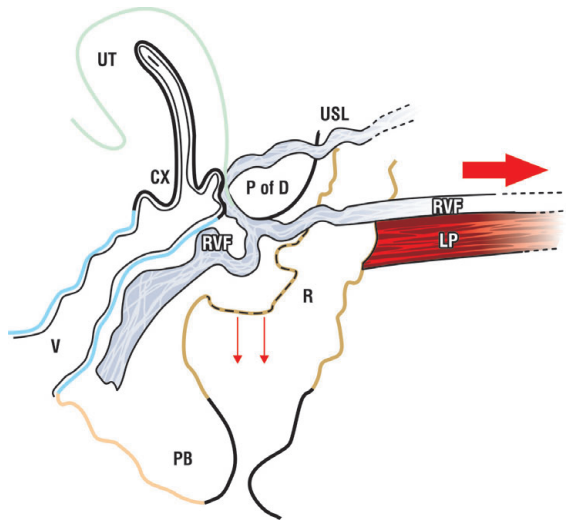
Inability of the perineal body complex to splint the anterior wall of the anus explains difficulty in rectal evacuation ('constipation') in some patients, and why digital pressure on the perineum by the patient is often required to aid defaecation. Digital pressure anchors the perineal body. The anchoring effect of PB can often be demonstrated using synchronous perineal ultrasound. A lax PB may reduce the downward angulation of levator plate seen during straining to a mere flicker, while LP contracts exaggeratedly upwards and backwards. Anchoring PB can reduce the latter movement, and restore the downward angulation of the anterior portion of levator plate (Petros 2002). It is known that connective tissue weakens and loses elasticity with age, thus preventing the rectum being stretched to the semirigid tube required for evacuation. This may explain the increasing incidence of 'constipation' with age.

Relationship of "obstructed defaecation" to anterior rectal wall intussusception and lax perineal body.

Abendstein et al (2008) used pre and post-operative defaecating proctograms to monitor changes in anterior rectal wall intussusception in patients presenting with

rectocele, and symptoms of “obstructed defaecation”. A posterior sling was used to repair the uterosacral ligaments simultaneously with repair of the rectovaginal fascia and perineal body. Almost all patients were cured of both anterior rectal wall intussusception, and defaecation symptoms. Fig. 2-58 represents the pathogenesis of apical prolapse and anterior anorectal wall intussusception. A lax uterosacral ligament and perineal body may prevent the stretching of the rectal tube so necessary for evacuation. Furthermore, the intussusception may narrow the cavity and vastly increase the intracavity resistance according to the 4th power law of Poisseuille (Petros, DCR 2008).

Fig. 2-58 Pathogenesis of rectal intussusception. With lax uterosacral ligaments (USL), levator plate (LP) cannot tension the rectovaginal fascia (RVF). The force of gravity (small arrows) causes the rectal wall (R) to prolapse inwards, much like a tent whose apex is not firmly attached to the pole, “rectal intussusception”.



The key role of the uterosacral ligaments was demonstrated by Abendstein et al (2008) using postoperative single contrast defecating proctography in 19 patients. Following a posterior IVS sling, normal anatomy of the rectum and no intussusception (figs. 2-58 a&b) was demonstrated in 17/19 patients (89%). In 2/19 (11%) patients a minimal residual intussusception could be detected. However, all rectoceles disappeared.

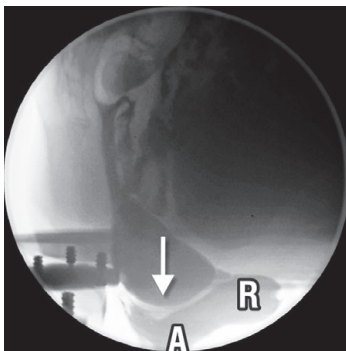
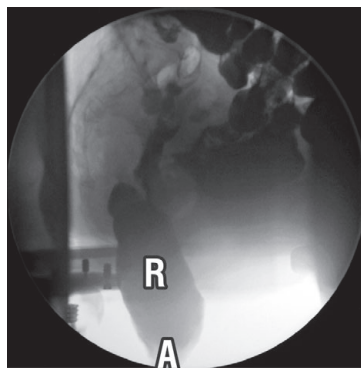


Fig. 2-58a Pre-operative defecating proctogram Sagittal view, straining. Arrow indicates site of intussusception. R=rectum; A=anus. “rectal intussusception”.

Fig. 2-58b Post-operative defecating proctogram Sagittal view, straining. The intussusception has disappeared. R=rectum; A=anus.



Dislocation of Anal Mucosa

In time, prolapse of rectal wall, fig.2-58, may cause congestion, and the anal mucosa may even dislocate from the serosal layer. Congestion may cause ulceration and bleeding. This pathogenesis may correlate with some types of 'solitary rectal ulcer'. The same process may stimulate sensory nerve endings to cause faecal incontinence. Reconstruction of the uterosacral ligaments, repair of rectovaginal fascia and perineal body restores the dynamic anatomical supports, and prevent the 'sagging' and the rectal intussusception often found with this condition (Abendstein et al.2008).

Further reading on Nonsurgical and Surgical proofs of the Musculoelastic Theory

See Petros PE, Swash M, The Musculoelastic Theory of anorectal function and dysfunction 2008, J. Pelviperineology, 27; 89-121 at www.pelviperineology.org

The related dynamics of anorectal and bladder function and dysfunction

The same posterior forces, LP & LMA, fig 2-59, are involved in anorectal and urethrovesical closure (continence), and also, bladder and rectal evacuation. The only difference between bladder and rectal evacuation is that PCM relaxes for bladder evacuation, and PRM relaxes for rectal evacuation.

Anorectal closure

The rectovaginal fascia (RVF) inserts into perineal body (PB), levator plate (LP) and the uterosacral ligaments (USL). Contraction of LP stiffens RVF and both walls of rectum. Contraction of LMA (longitudinal muscle of the anus) against USL stretches the rectum around puborectalis muscle (PRM), to create the anorectal angle and closure.

Defaecation

PRM relaxes. LMA/LP vectors open out the anorectal angle (broken lines); pubococcygeus (PCM) vector stiffens PB and anterior wall of anus; rectum (R) empties.

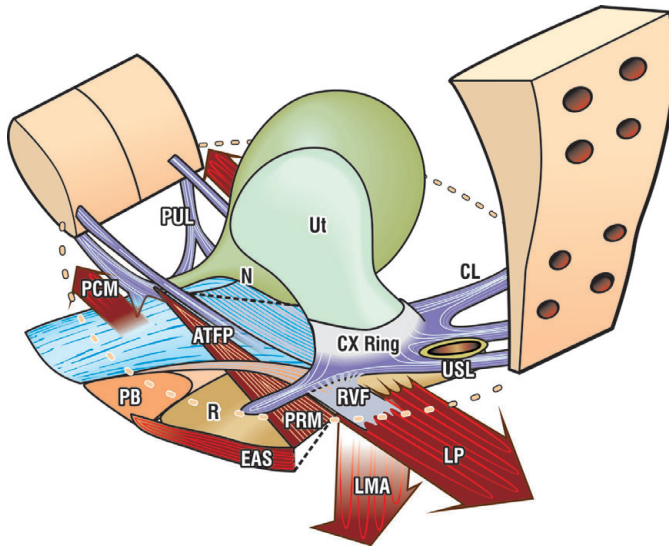


Fig. 2-59 The related dynamics of anorectal and bladder function and dysfunction.

Arrows denote directional muscle forces. ATFP=arcus tendineus fascia pelvis; CL=cardinal ligament; circular broken lines = pelvic brim.

Urethral/bladder neck closure

The forward vector (PCM) closes urethra from behind; LP/LMA vectors rotate bladder around pubourethral ligaments (PUL) to close off bladder neck.

Micturition

Forward vector (PCM) relaxes. Posterior vectors (LP/LMA) stretch open posterior urethral wall (broken lines). Bladder contracts.

Pathogenesis

Damaged ligaments decrease the force of opening and closure vectors for urethra and anus.

Surgery according to this theory

Reinforcement of damaged ligaments with implanted polypropylene tapes.

2.4 Summary Chapter 2

2

The suspensory ligaments and fascia are described in three zones:

Anterior, Middle, Posterior.

Three directional muscle forces, anterior portion of the pubococcygeus muscle (PCM), levator plate (LP) and longitudinal muscle of the anus (LMA) activate urethral and anal canal closure and help retain the position of the organs. LP and LMA open out the urethra during micturition when PCM relaxes and the anal canal during defaecation when PRM (puborectalis muscle) relaxes. The puborectalis muscle works independently of the three directional muscle forces and is presented as a special case.

The ligaments and muscles constitute an integrated balanced system which has mechanical and peripheral neurological components. The bladder base stretch receptors and the unmyelinated nerves comprise the neurological components of the system. These require a competent connective tissue support below them to prevent them firing off prematurely to cause urgency or pelvic pain. Connective tissue damage may unbalance both the mechanical and peripheral neurological components of the system and, depending on the sensitivity of the nerve endings, may cause some or all of the bladder, bowel, or pelvic pain symptoms described in Chapter 1. In this context, the nerve endings act as an 'engine' so that even minor degrees of prolapse in the three zones of the vagina may cause quite major symptoms.

Diagnosis of Connective Tissue Damage

3.1 The Integral Theory Diagnostic System: Overview

The Integral Theory Diagnostic System aims to locate and identify which ligaments or fascia of the pelvic floor have been damaged (fig 1-10). The Integral Theory holds that damage to one or more connective tissue structures may cause prolapse, or dysfunction in organ closure or opening. That is, prolapse and other pelvic floor symptoms are related. They are differing expressions of connective tissue defects.

The Integral Theory Diagnostic System uses a three zone approach to disentangle the complexity of symptoms. By isolating the damaged connective tissue structures which mainly cause these symptoms (fig 1-10), this approach enables the surgeon to deduce the appropriate surgical techniques to use to repair each damaged structure. Generally the damage to connective tissue structures results in excess laxity, except for the special case of excessive tightness in the middle zone in the 'Zone of Critical Elasticity'. This 'tethered vagina syndrome' is usually the result of previous surgery ('ZCE' fig 1-10). Notwithstanding this special case, the nine main structures potentially needing surgical repair are:

Anterior Zone

Excess Laxity

1. External urethral ligament (EUL)
2. Suburethral vagina (hammock)
3. Pubourethral ligament (PUL)

Middle Zone

Excess Laxity

4. Arcus tendineus fascia pelvis (ATFP)
5. Pubocervical fascia (PCF) (midline defect - cystocoele)
6. Cardinal ligament/cervical ring attachment of PCF (high cystocoele) 'transverse defect'

Excessive tightness

'ZCE' - Excessive tightness in the 'Zone of critical elasticity' (ZCE) (Iatrogenic cause: excess scarring; excess elevation with colposuspension)

Posterior Zone

Excess Laxity

7. Uterosacral ligaments (USL)
8. Rectovaginal fascia (RVF)
9. Perineal body (PB).

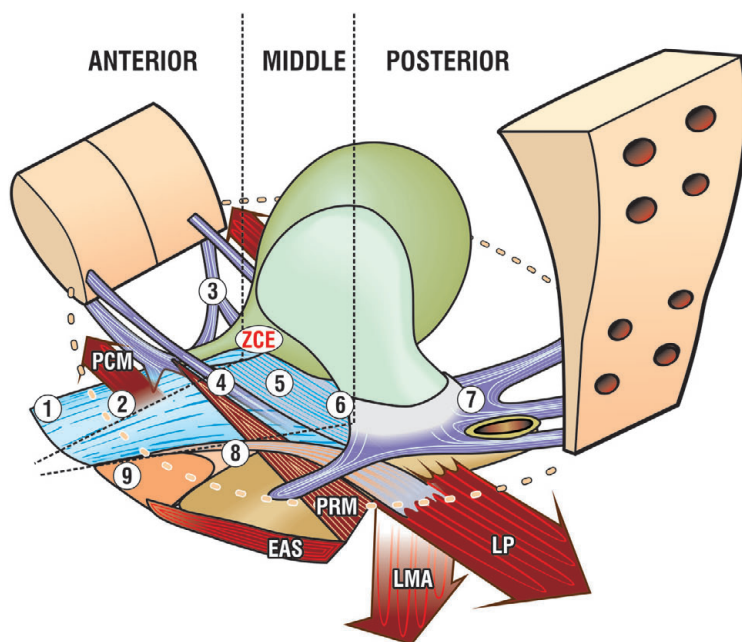


Fig 1-10 The three zone structure of the pelvic floor according to the Integral Theory showing the nine main structures and the special case 'ZCE' potentially needing surgical repair. A 3D view of the pelvis from above and behind. The dotted lines represent the pelvic brim. PCM = anterior portion of pubococcygeus muscle; LP = levator plate; LMA = longitudinal muscle of the anus; PRM = puborectalis muscle; EAS = external anal sphincter. 'ZCE' = 'Tethered vagina' - excessive tightness caused by previous surgery.

The Integral Theory Diagnostic System is an iterative process based on the perspectives of the pelvic floor anatomy and dynamics presented thus far in this book. There are two pathways: Clinical Assessment (fig.3-01), and the Structured Assessment (fig.3-02).

The Structured Assessment System, fig. 3-02 is identical to fig. 3-01, except that it applies a structured questionnaire, a 24 hour urinary diary, pad tests, transperineal ultrasound, and urodynamics.

Which pathway?

From a purely diagnostic perspective, the Clinical Assessment pathway (fig.3-01) is sufficient for most clinical surgeons. The Structured Assessment pathway (fig.3-02) is useful in assessing more complex cases such as 'tethered vagina syndrome', and it provides the more thorough documentation essential for tertiary referral clinics.

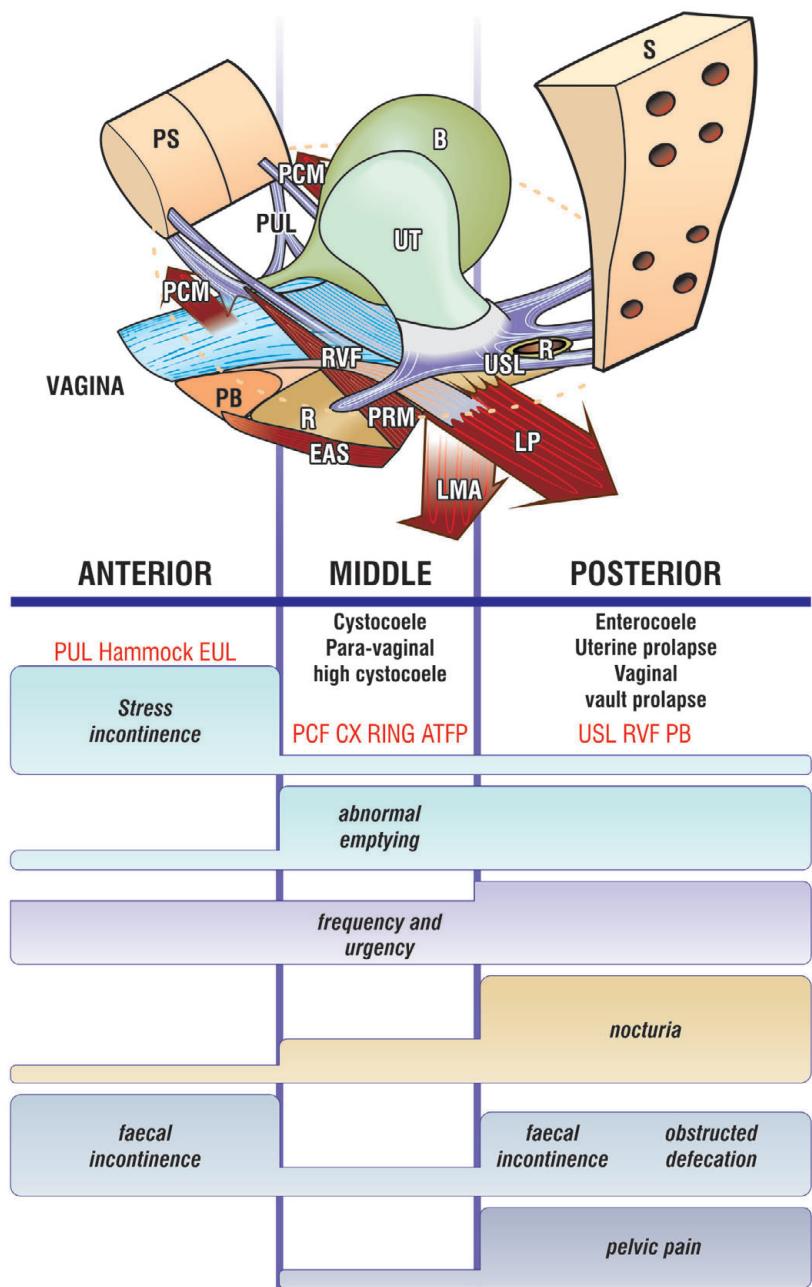


Fig. 1-11 The Pictorial Diagnostic Algorithm. This is a summary guide to causation and management of pelvic floor conditions. The area of the symptom rectangles indicates the estimated frequency of symptom causation occurring in each zone. The main connective tissue structures causing the symptoms are summarized in each zone, in order of importance. Note that there is no correlation between degree of prolapse and the severity of symptoms.

3

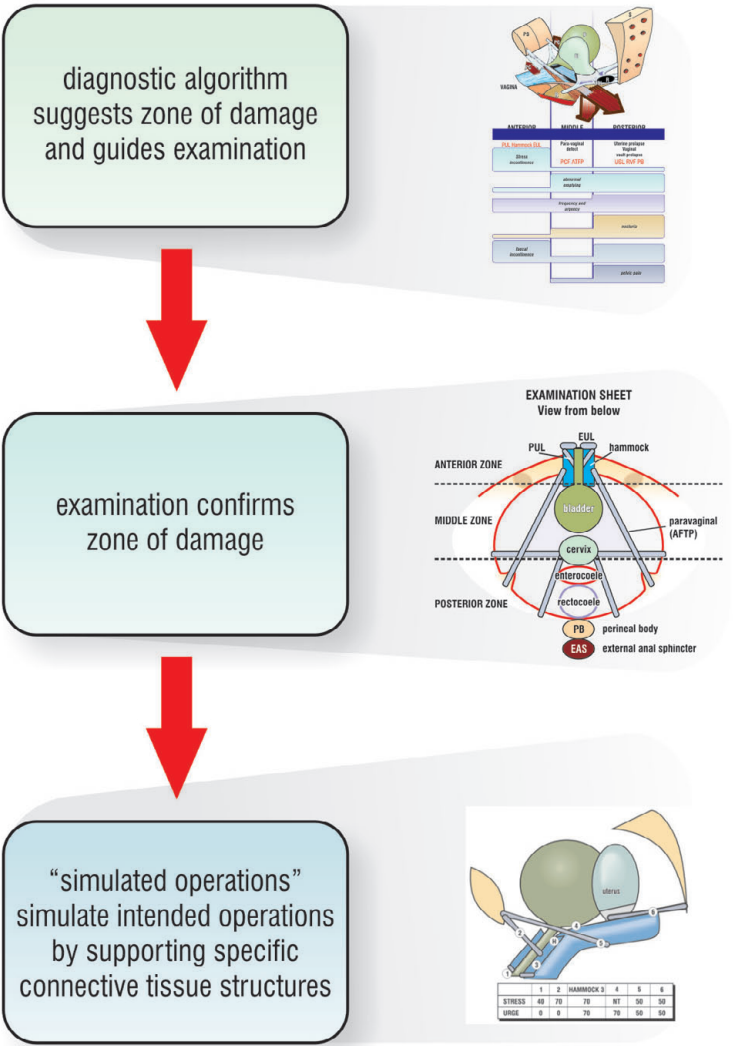


Fig 3-01 The Clinical Assessment Pathway. This figure shows the relationship between the Pictorial Diagnostic Algorithm, the Structured Assessment Diagram and the ‘Simulated Operations’ Validation Table.

3.2 The Integral Theory Diagnostic System

3.2.1 The Clinical Assessment Pathway

The Pictorial Diagnostic Algorithm (fig. 3-03a) is the starting point of the Integral Theory diagnostic system for the generalist surgeon. It provides a framework for symptom assessment, a guide to the examination of the patient (fig. 3-04), and a guide to use of the 'simulated operations' technique for detailed localization of the origin of stress or urge symptoms, Fig. 3-09a.

Using the Clinical Assessment Pathway in a Clinical Assessment

Phase of 1 of Clinical Assessment Pathway -symptoms.

The Pictorial Diagnostic Algorithm (fig. 3-03a) is the starting point of the Integral Theory diagnostic system for the generalist surgeon. It provides a framework for symptom assessment, a guide to the examination of the patient (fig. 3-04), and a guide to use of the 'simulated operations' technique for detailed localization of the origin of stress or urge symptoms, Fig. 3-09a.

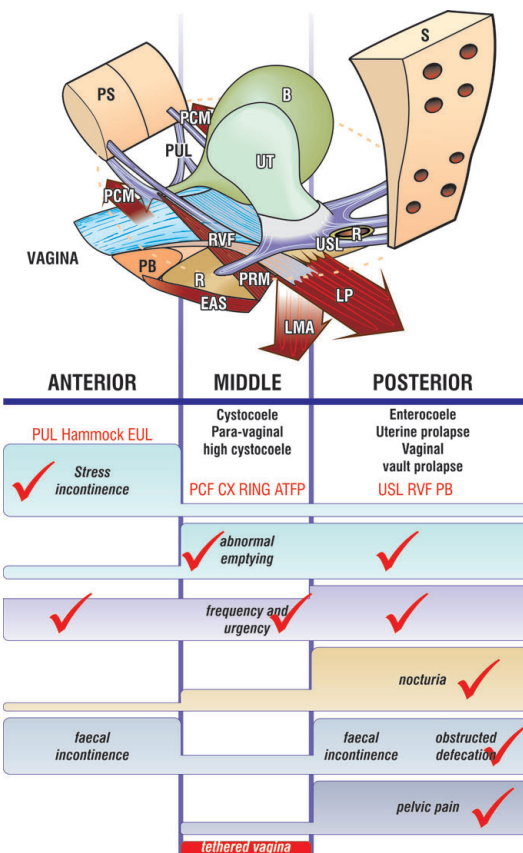


Fig. 3-03a The Pictorial Diagnostic Algorithm. A summary guide to causation and management of pelvic floor conditions. Because symptoms such as urgency and abnormal emptying may be caused by ligament damage in more than one zone, all rectangles for that symptom should be ticked. The area of the symptom rectangles indicates the estimated frequency of symptom causation occurring in each zone. The main connective tissue structures causing the symptoms and prolapse in each zone are indicated in red capital letters. PUL=pubourethral ligament; EUL=external urethral ligament; PCF=pubocervical fascia; Cx ring=cervical ring/cardinal ligament complex; USL=uterosacral ligament; RVF=rectovaginal fascia; PB=perineal body. There is no correlation between degree of prolapse and symptom severity. Actual case example-positive symptoms have been ticked. A clear diagram for copying and clinical usage can be found in Appendix 1.

Phase 2 of Clinical Assessment Pathway - Examination

The aim of the examination stage is to confirm the potential sites of damage in the three zones of the vagina. Using the Halfway Classification system (Fig 3-04b), these sites are recorded as 1st, 2nd, 3rd or 4th degree prolapse on the Clinical Examination Sheet (Fig 3-04a). The examination should always be conducted with a full bladder.

NOTE: Experience has shown that accurate diagnosis of some anatomical defects (especially in the posterior zone) is not always possible in a clinical examination setting. Often the final diagnosis can only be made once the patient is examined in the Operating Room.

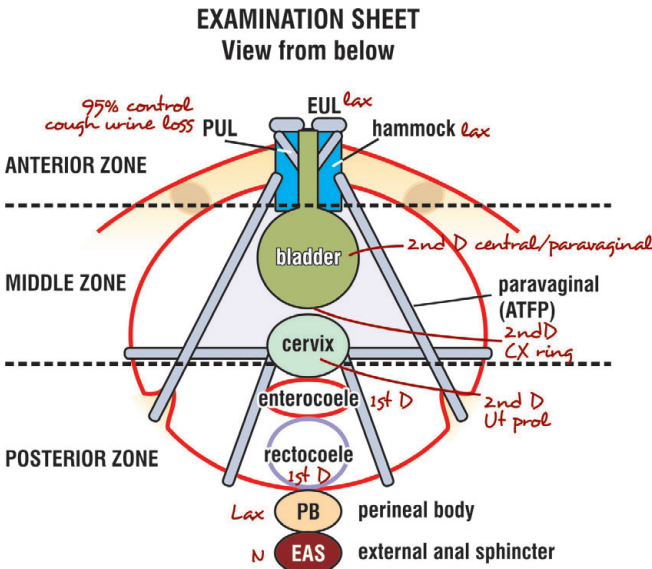


Fig. 3-04a An example of a completed Clinical Examination Sheet (Mrs H). The Clinical Examination Sheet is designed to be copied and used by the clinician as a record. Each structure is assessed and notated, if possible as 1st, 2nd or 3rd degree prolapse, or for PUL and EUL, 'normal' or 'lax'. A clear diagram for copying and clinical usage can be found in Appendix 1.

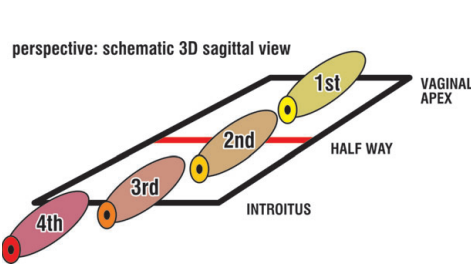


Fig. 3-04b Halfway Classification System. Perspective: schematic 3D sagittal view. The Halfway Classification System is used for prolapse from grades 1-4. Prolapse assessment is best performed under gentle traction, preferably in the operating room: 1st degree = prolapse to the halfway point; 2nd degree = prolapse between the halfway point and introitus, but not beyond; 3rd degree = prolapse beyond introitus; 4th degree = total eversion of either uterus or vaginal vault with traction.

Anterior Zone Examination

The anterior zone extends from the external urethral meatus to bladder neck. Three structures are tested: the external urethral ligament (EUL), the pubourethral ligament (PUL) and the vaginal hammock. A 'pouting' (open) external urethral meatus generally signals laxity in the EULs, especially if associated with eversion of the urethral mucosa, fig.305c. The test for a damaged PUL involves two essential stages (Petros & Von Konsky 1999). The first is for the patient to demonstrate urine loss in the supine position on coughing. Then a finger or a haemostat is placed at midurethra on one side and the cough is repeated. Control of urine loss signifies a weak PUL. The EUL can be similarly tested.

A lax hammock is evident on inspection, but it can also be tested by the 'pinch' test, taking a unilateral fold of the hammock with a haemostat (Petros & Ulmsten 1990). Diminution of urine loss during this test demonstrates the importance of an adequately tight hammock for urethral closure. These manoeuvres are an essential part of the vaginal examination. They also form part of the 'simulated operations' technique.

Testing for Vulvar Vestibulitis when Indicated

A cotton bud is gently applied at 0.5 cm intervals to the hymenal area of introitus in a circle. A hypersensitive reaction confirms a diagnosis of vulvar vestibulitis.

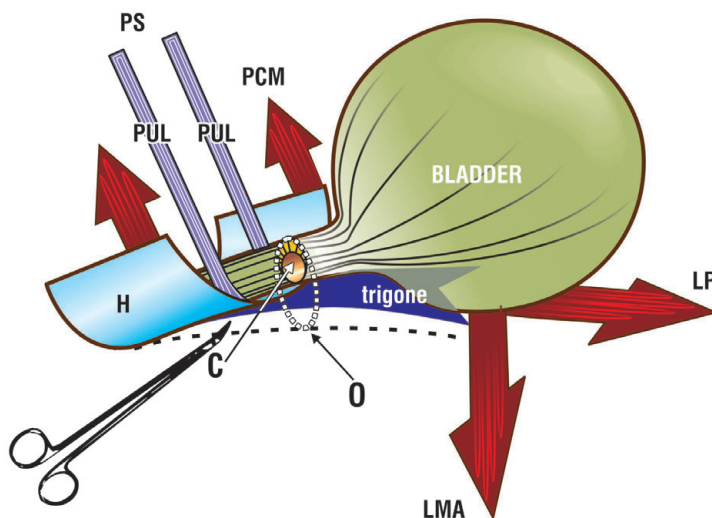


Fig. 3-05a Unilateral anchoring at midurethra is the only method possible for diagnosing a damaged pubourethral ligament (PUL). Cessation of urine loss on coughing confirms a lax PUL. Schematic 3D view of distal vaginal hammock (H), urethra and bladder. A haemostat applied unilaterally at midurethra mimics the effect of a midurethral sling. Midurethral anchoring restores the closure forces which narrow the urethra from 'O' (stress incontinence) to 'C' (continence) during coughing. Taking a fold of vagina 'H' ('pinch' test) generally also decreases urine loss.

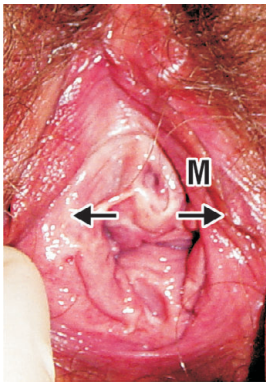


Fig. 3-05b Normal external urethral ligament (EUL). The urethral meatus (M) is well supported horizontally by the EUL (arrows). The hammock is in the normal plane.

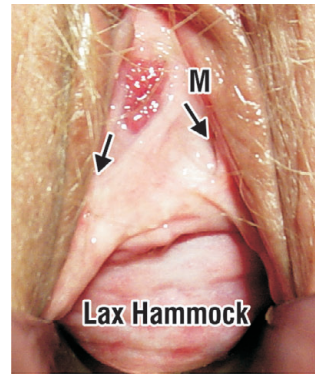


Fig. 3-05c Lax EUL and hammock. The urethral meatus (M) is lax, and the urethral mucosa is everted. The lateral EUL supports are seen "drooping" downwards (arrows). The hammock is lax and angulated downwards.

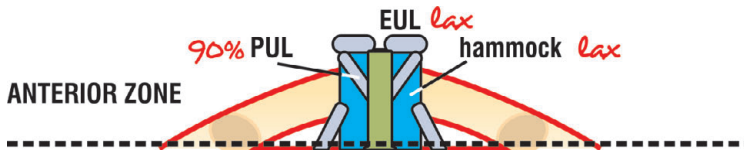


Fig. 3-05d Notation of fig 3-05c in a patient with urinary stress incontinence (SI). On midurethral anchoring, decrease of urine loss on coughing was estimated at 90%. The EUL and hammock, fig. 3-05c are recorded as lax. If the physician wishes to demonstrate the impact of the EUL and hammock in controlling SI in a particular patient, these can also be anchored while the patient coughs, and the percentage decrease annotated.

Middle Zone

The middle zone extends from bladder neck to the anterior lip of the cervix or hysterectomy scar. It has 3 connective tissue defects, central, lateral ('paravaginal'), and cardinal ligament/anterior cervical ring defect ('high cystocele', 'transverse defect'). A central defect typically is shiny, and it frequently extends laterally. A central cystocele can be differentiated from a paravaginal defect by placing ring forceps in the lateral sulci to support the ATRF and asking the patient to strain. Often, however, a patient has both midline and lateral defects. The cardinal ligaments insert anteriorly into the cervical ring. Tearing of this insertion may dislocate the pubocervical fascia, creating a characteristic lateral extension of the bladder fascia around the cervix (arrows), figs.3-06, 4-63. This is known as a 'high cystocele' or 'transverse defect' and it is often accompanied by a retroverted or prolapsed uterus. An isolated cervical ring defect may have rugae.

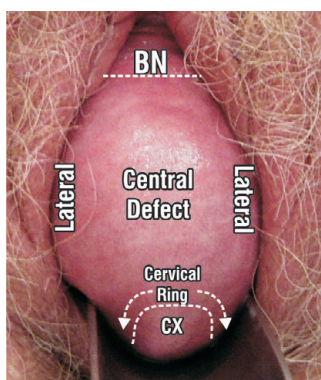


Fig. 3-06 Prolapse, 3rd degree, of bladder and uterus. A large central defect extends laterally. Prolapse of bladder around cervix (CX) (curved arrows) is characteristic of CL/cervical ring defect. The central defect remained after the Allis forceps test (see below). BN=bladder neck.

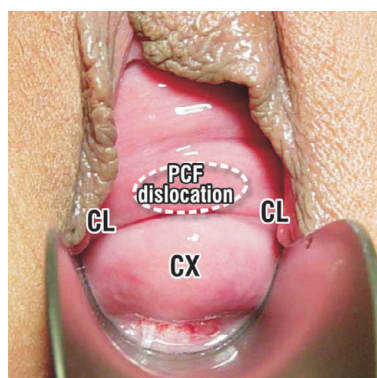


Fig. 4-63 Cardinal ligament/cervical ring defect. The dislocated cardinal ligaments (CL) 'droop' laterally around the cervix (CX). The central bulge labelled 'PCF dislocation' disappears on approximation medially of 2 Allis forceps applied at 'CL'. This is the definitive test for a cervical ring/CL defect.

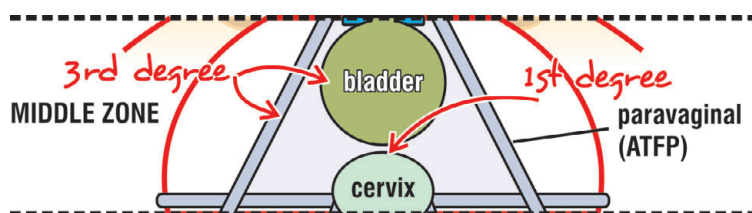


Fig. 3-06a Notation of fig 3-06. The patient has 3rd degree central and lateral defects, and 1st degree cardinal ligament/cervical ring defect.

The special case of "Tethered Vagina" Defect

The "Tethered Vagina" defect is addressed formally in the Structured Assessment protocol. In patients with previous vaginal or bladder neck elevation surgery, and who leak immediately on getting out of bed in the morning, it is important to check for scarring, or excessive tightness in the bladder neck area of vagina, and this should be noted on the Clinical Examination Sheet. Often there is no urine loss on coughing, and minimum bladder base descent on straining on transperineal ultrasound. However, gently stretching the vaginal tissue behind bladder neck simultaneously with coughing, will usually provoke urine loss. This sign is also positive in patients with low elasticity, and no previous surgery.

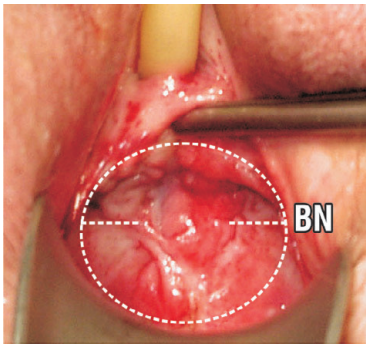


Fig. 3-07 Extensive scarring across the bladder neck (BN) area of vagina.

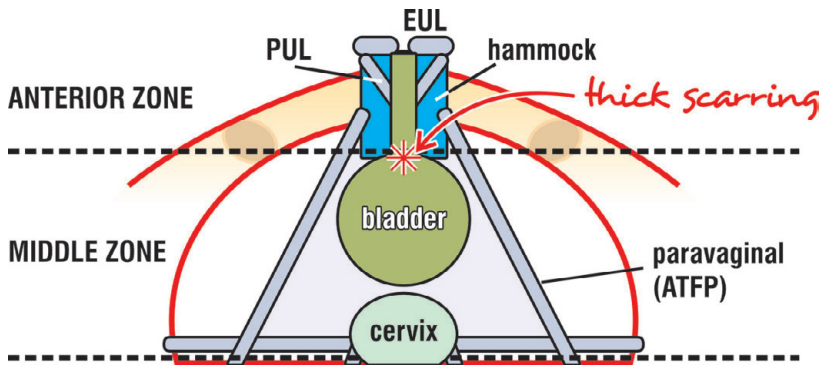


Fig. 3-07a Notation of scarring in the bladder neck area of vagina.

Posterior Zone Defect

The posterior zone extends from the cervix/hysterectomy scar to the perineal body. Evidence of a bulge at the apex, vaginal wall or perineal body should be looked for during straining. Small degrees of prolapse in the apex of the vagina are easily missed. Therefore, when examining in the supine position, always support the lateral sulci of the vagina with ring forceps and ask the patient to strain when examining the posterior zone. Alternatively, examination in the left lateral position may be helpful. The posterior vaginal wall is tested for defects in the rectovaginal fascia (rectocele) by asking the patient to strain, and also by digital rectal examination. The perineal body and external anal sphincter are tested by digital examination. Major posterior zone defects are frequently accompanied by other defects. For example the patient,

fig.3-08a most likely has a cardinal ligament/cervical ring defect, a central cystocele, lax and separated uterosacral ligaments with an enterocele, and probably lax rectovaginal fascia.

3



Fig. 3-08a Everting 4th degree vault prolapse. X denotes the line of the hysterectomy scar.

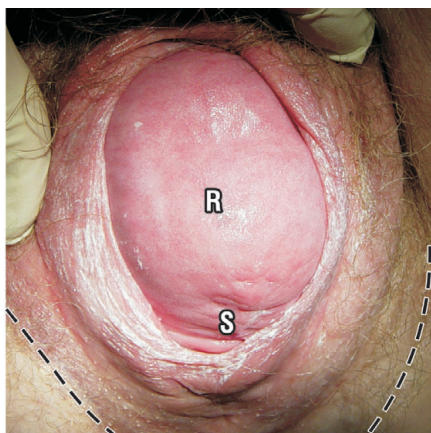


Fig. 3-08b Large rectocele (R), and deficient perineal body (broken lines) revealed by rectal examination.

Note scar 'S' from previous surgery for rectocele.

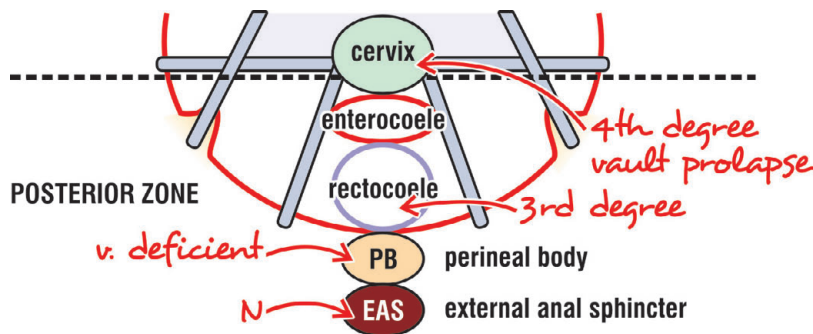


Fig. 3-08c Notation of findings figs 3-08a&b.

Phase 3 of Clinical Assessment Pathway – Simulated Operations

The ‘Simulated Operations’ technique is especially useful to help delineate the cause of urgency symptoms. It can give the surgeon an understanding of the contribution of each connective tissue structure to symptom causation. It must be performed with a bladder sufficiently full to provoke stress or urgency in the supine position.

Simulated operations- an overview

Specific connective tissue structures fig.3-09a, are supported digitally or with forceps, and the percentage change in urge or stress symptoms noted in the table. Fig 3-09a specifies 6 separate structures. However, testing for the 3 principal structures (red squares), pubourethral ligament “2”, cardinal ligament/cervical ring “4”, and uterosacral ligament “6” is sufficient to more fully diagnose the origin of the stress or urge symptoms. Testing all 6 structures will provide significant insights into the synergistic mechanisms for symptom control. For example, laxity in the posterior ligaments may contribute to SI causation, especially if the stress incontinence began after hysterectomy. See Ch6 for an example of a 6 structure ‘simulated operation’ assessment which includes urodynamics and ultrasound.

Indications for ‘Simulated Operations’

Stress incontinence (SI) The unilateral midurethral anchor test, fig 3-05a, is part of the standard vaginal examination chart, fig 3-04a. It is the only method possible to diagnose a lax pubourethral ligament, the principal cause of SI. Anchoring the external urethral ligament (EUL), and plicating the hammock with a haemostat may also decrease urine loss with coughing, demonstrating that SI control is a complex synergistic mechanism.

Latent stress incontinence

Patients with a cystocele or enterocoele should always be examined with a full bladder and asked to cough before and after reduction of the prolapse, so as to uncover ‘latent’ stress incontinence.

Urge symptoms

As urgency symptoms may be caused by laxity in any zone, testing in all three zones is required to delineate the cause of urgency symptoms, figs 3-05a, 3-09b, 3-09c.

Cough activated detrusor instability

This can usually be controlled with the midurethral anchor test, fig. 3-05a.

Pelvic pain

In patients with lower abdominal or pelvic pain, palpation of the posterior fornix with ring forceps, or digitally, usually reproduces the pain complained of by the patient.

3

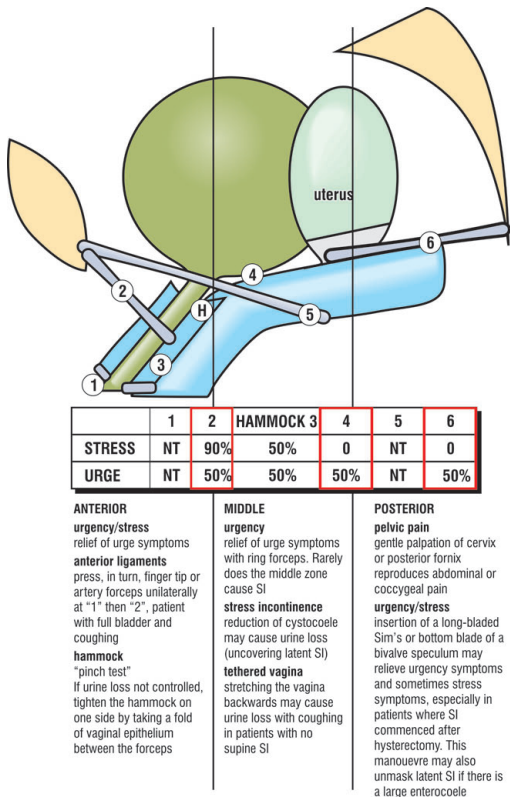


Fig. 3-09a Simulated Operations Table directly assesses the contribution of structures in each zone to urge, stress and even pelvic pain causation. A clear diagram for copying and clinical usage can be found in Appendix 1. The red squares outline the 3 main ligaments which need to be tested: pubourethral ligament, "2"; cardinal ligament/cervical ring, "4" (bladder base); uterosacral ligament, "6". The other 3 structures, "1"=external urethral ligament; "3"-suburethral vaginal hammock; "5"= ATFP (paravaginal sulcus), are adjunctive rather than causative. Actual test for Mrs H. NT=not tested.

‘Simulated Operation’ Technique: Anterior Zone

The aim is to support the pubourethral ligament. The patient should always be tested with a full bladder. An artery forceps or finger tip is applied unilaterally, immediately behind the pubic bone, at the site of the pubourethral ligament (PUL) ('2' in fig. 3-09a) during coughing, in a patient with stress incontinence. This action controls urine loss in the vast majority of patients, and often relieves urge symptoms as well, if the patient has mixed incontinence. This test will usually also control cough activated 'detrusor instability' (OAB). The 'pinch test' (taking up a fold of vaginal epithelium unilaterally) '3' may control stress incontinence (SI) completely in up to 30% of patients and demonstrates the importance of an adequately tight hammock for continence (Petros 2003). In about 10% of patients, anchoring EUL may diminish urine loss or urge*. Anchoring PUL and hammock simultaneously ('2' and '3', fig 3-09a), almost invariably completely controls urine loss during coughing, demonstrating the importance of tightening the hammock during midurethral sling surgery.

* Diminution of urgency on supporting EUL does not necessarily imply that EUL laxity is causing the urgency. There is a well described reflex historically, whereby touching the suprapubic or vulval area, temporarily suppresses the micturition reflex (and therefore, urgency).

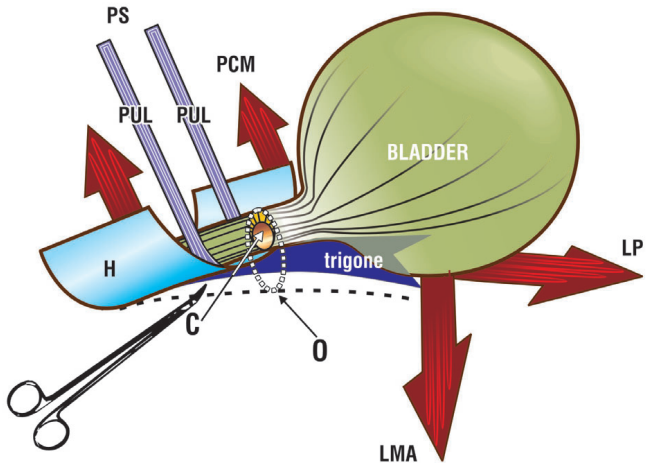


Fig. 3-05a Anterior Zone Simulated operation A finger or haemostat is placed at midurethra, site No2, fig. 3-09a, and the % diminution of urge symptoms, and % diminution of urine loss on coughing annotated in fig.3-09a..

'Simulated Operation' Technique: Middle Zone

The aim is to support the bladder base, effectively the insertion of pubocervical fascia to the cervical ring /cardinal ligament complex. The patient should always be tested with a full bladder. Two fingers or ring forceps are placed gently below bladder base, site No4, fig. 3-09a, and the percentage diminution of urge symptoms is annotated in fig.3-09a. The area of bladder base is the site controlled by the cervical ring/cardinal ligament structures.

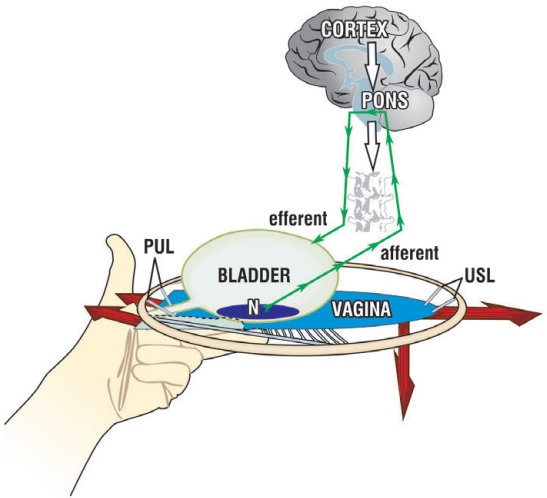


Fig 3-09b Middle Zone Simulated operation

Simulated Operation' Technique: Posterior Zone

The aim is to support the lax uterosacral ligaments. The patient should always be tested with a full bladder. A long speculum or ring forceps is placed very gently in the posterior vaginal fornix, site No 6, fig. 3-09a, and the % diminution of urge symptoms, and % diminution of urine loss on coughing annotated in fig.3-09a. Alternatively, a tampon can be gently inserted into the posterior fornix. In patients with pelvic pain, gentle insertion of an examining finger generally reproduces that pain.

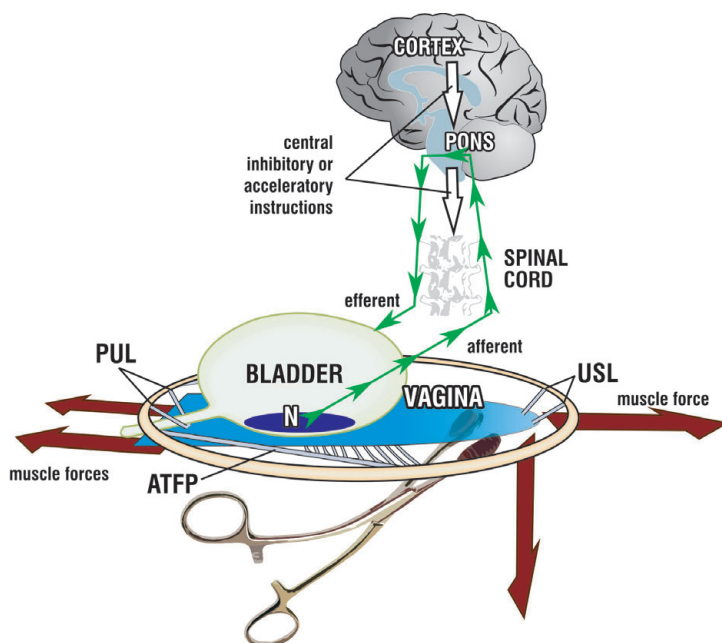


Fig. 3-09c Posterior Zone Simulated operation A speculum, tampon, finger, or ring forceps is placed very gently in the posterior vaginal fornix, and the % diminution of urge symptoms, and % diminution of urine loss on coughing annotated. In patients with pelvic pain, gentle insertion of an examining finger generally reproduces that pain.

Limitations of 'Simulated Operations'

Not all patients with a history of urge symptoms can reproduce their urge symptoms even with a full bladder when lying in the supine position. Occasionally the serial anchoring of specific structures listed in fig. 3-09a makes no impact on the urge symptoms. In such patients, other causes such as bladder cancer should be rigorously excluded before proceeding. In younger women, pelvic inflammatory disease or endometriosis is need to be excluded in patients with a positive pain response to palpation.

3.2.2 The Structured Assessment Pathway

Introduction

The Structured Assessment Pathway (fig 3-02) has been designed for use in clinics which specialise in pelvic floor disorders. It is essentially a clinically based process, although it uses ultrasound and urodynamics. Its vaginal examination and Simulated Operations components are identical to the Clinical Assessment pathway.

The Structured Assessment Pathway is an iterative process consisting of three stages: Collection and correlation of data, analysis of the data, and verification (or not) of provisional diagnosis.

Data is collected from the questionnaire, the urinary diary, the vaginal examination, pad tests, urodynamics and perineal ultrasound. (To remove bias, it is best if the questionnaire is completed by the patient.) Relevant data is transcribed on to the Diagnostic Summary Sheet (fig 3-03).

The Diagnostic Summary Sheet consists of four groupings which list the specific conditions which form the basis for diagnosing the zone(s) of damage. The groupings are:

- symptoms
- examination
- urodynamics
- ultrasound.

The data from these 4 groupings is entered (ticked) against a copy of the Diagnostic Summary Sheet, fig. 3-12.

Phase One of the Structured Assessment Pathway: Data Collection and Correlation

Symptoms - the Patient Questionnaire

(Appendix I, or visit www.integraltheory.org) is completed by the patient in her own time. The questions relate to specific zones of connective tissue damage, anterior, middle, posterior and these are identified by the letters 'A', 'M' and 'P' on the left. Also on the left of each question is a number in parenthesis which relates to the notes at the end of the questionnaire. These notes explain the anatomical basis of the symptoms, and possible other cause(s) of that symptom. The physician collates the responses from the questionnaire into the Diagnostic Summary Sheet (fig 3-12) by ticking the symptoms listed in the columns where they appear in each applicable zone. For example, urgency is ticked in all 3 zones, and emptying in both the middle and posterior zones. Why a 'sometimes' response is regarded as a positive response is explained in the section, "The Human Urodynamic Machine" later in this chapter. When the patient attends for an interview, the clinician clarifies any areas of doubt in the questionnaire and writes on the sheet in his/her own hand.

The questionnaire presented below is from an actual case. (Mrs H). Notes (in red) in the margin, denote symptom progress at the 6 week review after an anterior and posterior polypropylene sling.

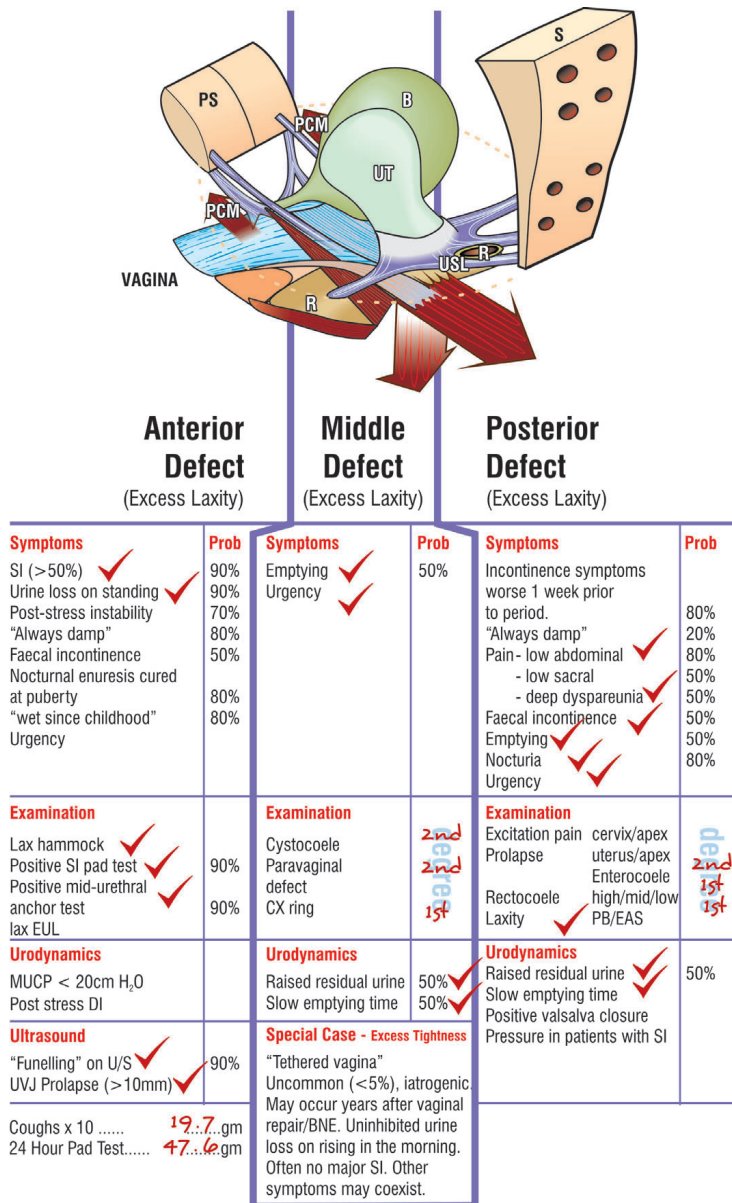


Fig. 3-12 The Diagnostic Summary Sheet as used in the Structured Assessment Pathway. It is designed to be copied by the physician and used as a record. Each condition is checked against the data gathered and ticked when appropriate. The probabilities listed against some symptoms indicate the likelihood that damage within that zone is causing that particular condition. The physician may record other relevant data onto the Diagnostic Summary Sheet, such as degree of prolapse, urge incontinence episodes per day, etc., as a record summary. Actual case, Mrs H. A clear copy of a Diagnostic Summary Sheet can be found in the Appendix.

Patient Questionnaire

Self administered patient questionnaire

Part I Personal Details

Name: _____ Date: _____
 Address: _____ Date of birth : _____
 Weight : _____ kg Telephone: _____
 Number of vaginal deliveries ()
 Number of caesarean sections ()

Part II Symptoms

Describe in your own words your main urinary symptoms and duration:

I can't hold on. Get up 4-5 times a night.
I lose urine on coughing.
I have pain in my lower abdomen

All sections: tick appropriate square. ☐ Write extra details if you wish.

*Ant & post sling
31-1-08 rectocele P/B* *Post-op
8-5-08*

A. Stress Incontinence (SI) Symptoms		No	Yes some- times	Yes 50% or more
Do you lose urine during:				
(A)	Sneezing	☐	☐	☒ *
(A)	Coughing	☐	☐	☒ * <i>dry</i>
(A)	Exercise	☐	☐	☒ *
	(1) Walking	☒	☐	☐
(A)	(2) Stooping, squatting or getting up from a chair	☐	☒	☐
(P,M) Symptoms of deficient emptying				
(3)	Do you feel that your bladder isn't emptying properly?	☒	☐	☐
(3)	Do you ever have difficulty starting off your stream?	☐	☒	☐
(3)	Is it a slow stream?	☐	☒	☐
(3)	Does it stop and start involuntarily?	☐	☒	☐

good stream

* Note to physician: the filter '50% or more' (column 3) has a proven correlation for SI being caused by anterior zone defect. For all other symptoms a 'sometimes' notation is sufficient to attribute a symptom to a particular zone. 'A', 'M' and 'P' indicate the zone of causation and where the symptoms should be transcribed on the Diagnostic Summary Sheet (fig 3-03). Numbers in parentheses refer to notes at the end of the questionnaire.

		No	Yes some- times	Yes 50% or more
Urge symptoms:				
Do you ever have an uncontrollable desire to pass urine?		☐	☐	☒
If so, do you wet before arriving at toilet?		☐	☐	☒
If so, how many times a day do you wet? (Write number)		<i>Can hold on</i>		
Good day		— — <i>1-2</i>		
Bad day		— — <i>3-5</i>		
How much?	A few drops	No	Yes	
	A teaspoon full	No	Yes	
	A tablespoon or more	No	Yes	☒
(4) Do you have pain while passing urine?		☒ No	Yes	
(P) How many times during the night do you get up to pass urine?		<i>Nx1</i>	<i>3-5</i>	
How many times do you pass urine during the day? (Write number)		<i>8-10</i>		
(A, M) (5) In the morning do you wet immediately on getting out of bed?		☒	☐	☐
(A) (5a) Did you wet the bed as a child but not after puberty?		☒ No	Yes	
(P) (5b) Did your problems begin soon after puberty?		☒ No	Yes	
(P) (5c) Are your symptoms worse before a period?		No	Yes	☒
Bowel symptoms:		<i>improved</i>		
(A, P) (6a) Do you have difficulty evacuating your bowels?		No	Yes	☒
(A, P) (6b) Do you ever soil yourself (faeces)?		☒ No	Yes	
	wind	☒ No	Yes	
	liquid faeces	☒ No	Yes	
	solid faeces	☒ No	Yes	
Social inconvenience:				
(A, P) (7) Are you 'moist' with urine much of the time?		No	Yes	☒
(8) Do you leave puddles on the floor?		No	Yes	☒
Do you lose urine in bed at night?		No	Yes	☒
Do you wear a pad or liner on going out? (Circle) Never /sometimes /always				
If so, how many pads/liners per day? (Write number)		<i>3-5 dry</i>		
Previous operations: (circle the answer which matches)				
(P) (9) Have you had a hysterectomy?		☒	No	Yes
If so, when? (write date) — — — —				
(10) Have you had previous surgery for incontinence?		☒	No	Yes
If so, when? (write date) — — — —				
Are you <u>better</u> or <u>worse</u> since? (Circle)			Worse	Better
(10) Have you had previous vaginal surgery?		☒	No	Yes
If so, when? (write date) — — — —				

(P)(11) Pelvic pain	No	Yes some- times	Yes 50% or more
Do you have deep pain on intercourse?	☐	☒	☐
Do you have a pain down at the bottom of your spine?	☐	☒	☐
Do you have a pain down at the bottom of your abdomen?	☐	☒	☐
(12) Do you have pain at the entrance to your vagina?	☒	☐	☐

pain cured 100%

Quality of life grading

Please circle a grading between 1 and 5 to describe the effect that incontinence has on your normal activities. 1 is low impact, 5 is high impact.

1 = normal
2 = mild, no effect on lifestyle
3 = can't drink, must locate toilets on going out
4 = always wears pads, very restricted social life
5 = totally housebound.

Vaginal examination and Simulated Operations See Clinical Assessment pathway.

The 24 Hour Urinary Diary

The information entered into the 24 hour urinary diary by the patient provides a check on the patient's historical accuracy. In particular, it excludes excessive fluid intake as a cause of frequency. The diary is not used directly in the diagnostic decision tree.

Pad Tests

Pad tests are a simple and effective means for assessing severity of incontinence and the results of intervention. A rapid cough stress test (cough x 10) can confirm (or not) the likelihood of an anterior zone defect. The 24 hour pad test is performed in the same time period as the 24 hour diary. It is used to determine the severity of the incontinence problem.

Urodynamics

In the urodynamic process, only the residual urine (>30 ml), emptying time (>60 secs) and maximal urethral closure pressure are used in the Diagnostic Summary Sheet (fig 3-12). Although it is useful to know if there is a low maximal urethral closure pressure (MUCP) (20 cm or less) and 'detrusor instability' (DI), now 'overactive bladder' (OAB), it is not so relevant clinically because 1. A 2006 Cochrane Collaboration demonstrated that pre-operative urodynamics has no predictive value for surgical outcomes (Glazener et al 2006, Palma & Herrmann 2007).

2. These conditions are potentially curable surgically using the techniques described in Chapter 4. A valid clinical test for low MUCP is the 'slow leak speculum sign': placing a Sim's speculum in the introitus, with very gentle downward pressure, usually causes a slow steady leak of urine, which is relieved on removing the speculum (Petros &

'Objective' Tests

Actual urodynamics and pad test result from Mrs H

Pad tests

(A) Cough X 10

(197) gm

Handwashing Test (30 Seconds)

(0) gm

*24 Hr Pad Test

(474) gm

*indicate with a tick: good day () average day (x) bad day ()

Perineal Ultrasound

(A) Bladder neck descent

(19) mm

(A) Funnelling

No / Yes✓

(A) Prevention of funnelling with midurethral anchor Test:

No / Yes✓

Urodynamics

Bladder capacity

(350) ml

(M) (P) Emptying time (>60 seconds)

(72) secs

(M) (P) Residual urine (>30 ml)

(60) ml

Detrusor instability

✓ No / Yes

(A) Maximal urethral closure pressure (MUCP)

(85)

A = anterior zone; M = middle zone; P = posterior zone

Ulmsten 1990).

Transperineal Ultrasound

Transperineal ultrasound is used to confirm bladder neck opening or excessive descent on straining which helps to verify the diagnosis of stress incontinence. The ultrasound probe required (3.5 MHz) is the same as that used in antenatal diagnosis and so is usually readily accessible.

Two observations are used: bladder neck opening 'funnelling' and excessive descent (>10 mm) on straining. Both are signs of a damaged PUL. However, especially after bladder neck elevation surgery, there may be no change in geometry on straining, even though the patient may leak very significant amounts of urine on coughing

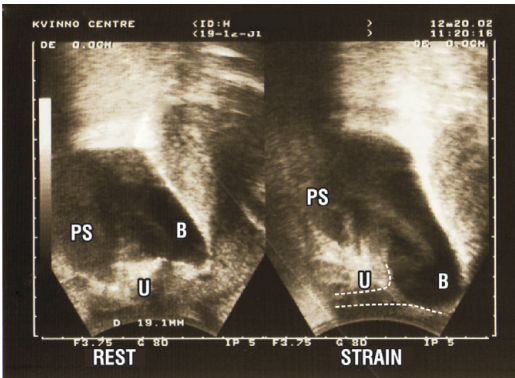


Fig. 3-10 Transperineal 2D ultrasound at rest and straining Bladder base rotation, descent (19.1mm) and funnelling (broken lines) diagnose pubourethral ligament laxity, (see fig. 3-05a, position "O"). PS=pubic symphysis; B=bladder; U=urethra. Actual case (Mrs H).

(Petros, Neurourol. & Urod. 2003).

Objective verification of ligamentous laxity using ‘Simulated Operations’

The final phase of the Structured Assessment Pathway applies the technique of ‘simulated operations’, pressure applied to specific connective tissue structures during urodynamic, ultrasound and other objective test procedures. Examples of ‘simulated operations’ using ultrasound and urethral pressure changes to determine ligamentous laxity are presented below. More detailed examples are presented in Ch6.

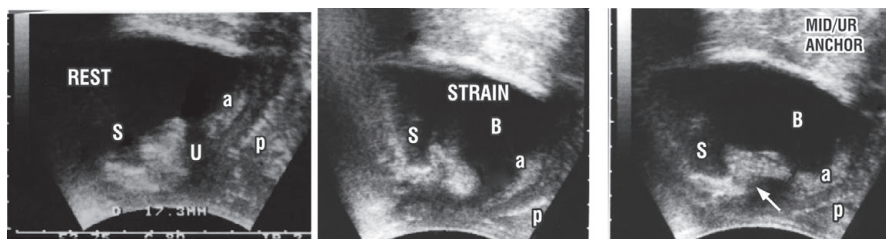


Fig. 3-11 Objective diagnosis of pubourethral ligament laxity. Simulated operation carried out under video ultrasound control. On straining, the bladder neck and proximal urethra demonstrate ‘funnelling’, and urine is lost. ‘Funnelling’ is reversed on application of a haemostat at the midurethra, the insertion site of the pubourethral ligament (arrow). Anterior ‘a’ and posterior ‘b’ vaginal wall are stretched backwards on straining, and are clearly stretched during midurethral anchoring. From Petros & Von Kinsky (1999). Midurethral anchoring controlled urine loss during coughing in this patient.



Fig. 3-11a Objective diagnosis of pubourethral ligament laxity. Increased closure pressure and continence with midurethral anchoring. A twin Gaeltec electrode was placed in the bladder and also, at midurethra. During coughing (left graph), the closure pressure was negative, and the patient lost urine. Following pressure applied in the position of the pubourethral ligament, both the maximal urethral pressure, and closure pressure during coughing increased, and no urine was lost.

Other uses of ultrasound

Ultrasound is the most important tool as regards understanding the dynamic anatomy of the pelvic floor. Since 1995, the author has routinely applied 2D ultrasound in thousands of patients- in every clinical examination- at rest, straining, squeezing, with and without the anchoring of specific ligaments. Organ prolapse, muscles, and directional movements are easily identified. Examples are given in Chapters 2,4, 6 and 7. 3D and 4D ultrasound have taken dynamic anatomical investigations to another level. Despite the rich anatomical knowledge which ultrasound imparts, the Integral System diagnostic decision tree remains essentially clinically based.

Phase Two of the Structured Assessment Pathway: Data Analysis

This section describes how the physician uses the data that has been entered on the Diagnostic Summary Sheet (fig 3-12) to deduce a provisional diagnosis. The discussion presents options in two broad possibilities: when a diagnosis is clear cut, and when the diagnosis is not so clear cut.

3

Anterior Defect (Excess Laxity)		Middle Defect (Excess Laxity)		Posterior Defect (Excess Laxity)	
Symptoms	Prob	Symptoms	Prob	Symptoms	Prob
SI (>50%) ✓	90%	Emptying ✓	50%	Incontinence symptoms worse 1 week prior to period.	80%
Urine loss on standing ✓	90%	Urgency ✓		"Always damp" ✓	20%
Post-stress instability	70%			Pain - low abdominal	80%
"Always damp"	80%			- low sacral	50%
Faecal incontinence	50%			- deep dyspareunia ✓	50%
Nocturnal enuresis cured at puberty	80%			Faecal incontinence ✓	50%
"wet since childhood" ✓	80%			Emptying ✓	50%
Urgency				Nocturia ✓	80%
				Urgency ✓	
Examination		Examination		Examination	
Lax hammock ✓		Cystocele ✓	2nd	Excitation pain cervix/apex	20
Positive SI pad test ✓	90%	Paravaginal defect ✓	2nd	Prolapse uterus/apex	2nd
Positive mid-urethral anchor test ✓	90%	CX ring ✓	1st	Enterocoele	1st
lax EUL				Rectocoele high/mid/low	
				Laxity ✓	PB/EAS
Urodynamics		Urodynamics		Urodynamics	
MUCP < 20cm H ₂ O		Raised residual urine	50% ✓	Raised residual urine ✓	50%
Post stress DI		Slow emptying time	50% ✓	Slow emptying time ✓	
Ultrasound		Special Case - Excess Tightness		Positive valsalva closure	
"Funelling" on U/S ✓	90%	"Tethered vagina"		Pressure in patients with SI	
UVJ Prolapse (>10mm) ✓		Uncommon (<5%), iatrogenic			
		May occur years after vaginal repair/BNE. Uninhibited urine loss on rising in the morning. Often no major SI. Other symptoms may coexist.			
Coughs x 10 19.7 gm					
24 Hour Pad Test..... 47.6 gm					

Fig. 3-12 The Diagnostic Summary Sheet as used in the Structured Assessment Pathway. It is designed to be copied by the physician and used as a record. Each condition is checked against the data gathered and ticked when appropriate. The probabilities listed against some symptoms indicate the likelihood that damage within that zone is causing that particular condition. The physician may record other relevant data onto the Diagnostic Summary Sheet, such as degree of prolapse, urge incontinence episodes per day, etc., as a record summary. Actual case, Mrs H. A clear copy of a Diagnostic Summary Sheet can be found in the Appendix.

A 'Clear' Diagnosis

Used correctly, the Diagnostic Summary Sheet usually allows the clinician to make a clear diagnosis in more than 80% of cases. A 'tick' in a particular column indicates that there may be damage in the corresponding zone. The more 'ticks' in a column, the greater likelihood that damage has occurred in that zone of the vagina. The probability ranking at the right of some conditions listed in the columns indicates the likelihood of that condition being caused by damage in the corresponding zone. This probability ranking is based on the author's experience over several thousand cases. It is for use as a reference point only, to be modified by clinicians according to their own experience and judgement. A large data base and computer based diagnostic system, the Integral Theory Diagnostic Support tool (ITDS) has been developed to provide ongoing improvement to the accuracy of the Structured Assessment Pathway. (The ITDS is described in Chapter 7.)

Although a patient will generally have several conditions present at the same time, sometimes only one condition will be present; for example, 'genuine stress incontinence' (anterior zone defect), or simply a prolapse with no symptoms.

A 'Less-Clear' Diagnosis. What to do if the algorithm fails to give a definite direction?

Urgency only

If a patient has urgency symptoms only, all 3 zones are ticked. This scenario is rare. The zone of damage that is actually causing urgency may be inferred from the presence of other conditions in a particular zone. A 'simulated operation' is the only means of localizing the zone causing the urgency symptoms. If this is negative, other causes such as malignancy, infection, fibroids pressing on bladder base, need to be excluded, especially if there is no evident laxity in any zone, on vaginal examination.

'Insensible' leakage with no demonstrable SI

In patients who leak some urine, but who have no demonstrable stress incontinence, particular attention needs to be paid to laxity in the external urethral ligaments (EUL), hammock or uterosacral ligaments (USL), because these structures make a significant contribution to the urethral closure mechanism. A typical symptom of EUL defect is leakage on sudden movement, experiencing a 'feeling of urine in the urethra', or a "bubble" released with the urine.

Patients who continue to leak after multiple surgical operations

The "tethered vagina syndrome" needs to be excluded. The cardinal sign of this condition is sudden uncontrollable leakage of urine immediately the patient's foot touches the floor on getting out of bed in the morning. Older patients (>70 years) may also lose urine on getting up in the morning due to a weak pubourethral ligament. Such cases generally take a few steps before the urine runs out. It is necessary to confirm tightness and/or scarring in the bladder neck area of vagina prior to surgically restoring elasticity in this area.

If there is little laxity to find on vaginal examination

It is emphasized that there is no correlation between quantum of prolapse and quantum of symptoms. Prolapse may exist without symptoms and no symptom is

Practical Application of the Structured Assessment

The structured assessment is best performed in two visits. The protocol outlined is that followed by the author. It can be altered according to the physician's or clinic's needs. It is advisable to perform Structured Assessment even in patients presenting with prolapse and few apparent symptoms. This process will generally reveal the presence of some accompanying dysfunction.

*First Visit**The History*

Prior to the first visit, the questionnaire is mailed to the patient to be completed by her at home. She then attends with a comfortably full bladder. The physician checks the questionnaire and completes the first part of Diagnostic Summary Sheet (fig 3-12). The information from the questionnaire guides the physician as to where to look during the examination.

The Examination

Using the Clinical Examination Sheet (fig 3-04a) as a guide, the physician checks the three zones for evidence of connective tissue laxity. The findings are noted on the Clinical Examination Sheet. During the examination, patients with stress incontinence are asked to cough, and the midurethral anchor and 'pinch tests' are carried out to confirm PUL and hammock laxity. There is no other reliable way to test for these defects. If transperineal ultrasound is available, the patient may be tested for bladder neck descent and funnelling. All these findings are entered into the Diagnostic Summary Sheet (fig 3-12).

If the patient has urgency in the supine position, 'simulated operations' can be done whereby the six connective tissue structures are anchored in turn to assess the contribution of each structure to the urge symptoms.

Prior to leaving the clinic, the patient is instructed by the nurse on how to do a 24 hour pad test and how to complete a 24 hour urinary diary which are done during the 24 hours preceding the second visit. Both are used to check for consistency in the questionnaire responses.

Second Visit

Ensure the patient attends with a comfortably full bladder.

24 Hour Pad Tests

The nurse weighs the used pads from the 24 hour pad test. Then the nurse administers the cough stress test and the 30 second hand-washing test. In the cough stress test, the patient is in the standing position and urine loss during 10 coughs is measured. If available, urodynamic testing is performed at this stage.

Review of Data, Diagnosis and Treatment Decisions

The physician reviews the patient along with all her data and then completes the Diagnostic Summary Sheet (fig 3-12) which is used to assess which zone(s) may have been damaged. The 'simulated operations' or the ultrasound may be repeated if clarification is required. On the basis of the quantum of urine lost, or the patient's needs, she may be referred for Pelvic Floor Rehabilitation or surgery.

necessarily present in a particular zone. There is no quantum of prolapse specified in the Pictorial Algorithm because the same operation is performed whether the prolapse is first or fourth degree. For example, patients with posterior zone symptoms, (pelvic pain, urgency, nocturia and abnormal emptying) frequently have only minimal prolapse.

3.3 Working with Symptoms in the Integral Theory Diagnostic System

3.3.1 The Cerebral Cortex -- the ultimate urodynamic machine

It is a major thesis of this book, that all the different afferent impulses are expressed as symptoms, that such symptoms are not only reliable, they are the ultimate criterion for assessment of bladder, bowel, and pelvic floor function and dysfunction. It is in this context, that the brain is presented as the ultimate urodynamic machine. The nervous system constitutes its “wiring”, specific nuclei its relay stations. All these structures transmit impulses to the cortex from multiple types of sensory receptors, for heat, cold, pain, mechanical stress, tension. At a lower level, the various centres of the brain function automatically via a myriad of feedback loops. These were first described by Barrington in 1921.

The Reliability of Symptoms

Symptoms are the sentinels of the body and inform the cortex that something has gone wrong. The brain stores symptoms, orders them, and averages them out, and so presents the patient’s collective experience over a period of time. From Hippocrates onwards, symptoms have been an essential element in a medical diagnosis. The symptoms displayed in fig. 3-03a or fig. 3-12 are essential for the diagnostic process with the Integral Theory System. For example, a patient with symptoms of pelvic pain, nocturia, abnormal emptying and urgency (‘posterior fornix syndrome’, Petros & Ulmsten, 1993) has a greater than 80% probability of cure following reconstruction of the posterior zone with a posterior sling operation.

The “Unreliability” of Symptoms -- the rise of “objective” urodynamics

Beginning in 1976 (Bates et al. 1976, Abrams et al. 1988), urodynamics has been presented as the “objective” answer to the “unreliability” of symptoms. The rationale for this appeared to be that a urodynamic “detrusor instability” or “overactive bladder” (OAB) pattern (Abrams et al. 2002), was only present in less than 50% of patients with urge symptoms. An equally logical explanation is possible, that the urodynamic assessment was not sufficiently sensitive. Urodynamic machines measure singular parameters, pressure or flow rate, a snapshot in time. Even these objective measurements require care in interpretation. Pressure is the force per unit area, and it is different from closure. Patients may be continent with low urethral pressures, or leak with high pressures (Petros & Ulmsten 1995). It is the contention of this book, that all

urodynamic tests, and even the variability thereof, are functions of the intraurethral resistance, not pressure, (Poisseeuille's Law). The power Law of Poisseuille states that resistance within a tube (e.g., urethra) is inversely proportional to the 4th power of the radius. This makes a single flow reading highly unreliable, as even a minor alteration in radius exponentially alters (to the 4th power) resistance, and therefore, flow rate. Pressure is more reproducible, as it measures the force per unit area. An "unstable" detrusor pressure pattern is not recorded unless there is some degree of urethral resistance. If the micturition reflex causes the outflow tract to be fully pulled open by external muscle forces (see pressure/flow graphs, Ch6), so that the resistance to flow is negligible, there may be no recordable pressure, even though the patient is demonstrably leaking urine from an unstable contraction (Griffiths 1991, Bush et al. 1997, Petros & Bush 1998). This subject is explored in greater detail in Chapter 6.

- Because symptoms varied from day to day, and were subject to a patient's memory, they were deemed "unreliable".

3.3.2 The Variability of Symptoms in Patients with Similar Anatomical Defects

Specific symptoms do not always correlate exactly with the zones represented in the Pictorial Diagnostic Algorithm (fig 1-11). For instance, not all posterior zone symptoms are necessarily present in a given case of posterior zone prolapse, and these may vary from day to day. When symptoms vary from day to day, it means only that they may be the resultant of a complex series of events. The problem of symptom variability is overcome with the help of the patient's memory of a symptom, that is, referring to the 'sometimes' category from the questionnaire and applying it in the Diagnostic Summary Sheet (fig 3-12). 'Good day', 'bad day' (see patient questionnaire) bring further accuracy by specifying a range. The clinician can achieve a reasonably accurate clinical picture by checking the responses in the questionnaire against the urinary diary and the 24 hour pad test.

A urodynamic test for detrusor instability (DI) presents a 'snapshot' only at one point of time. Yet in answer to the question 'how many times do you get up at night to pass urine', a patient may unhesitatingly answer '3 or 4 times on average'. It is not surprising therefore that the correlation of the DI testing with the patient's history of urge, frequency and nocturia symptoms is rarely greater than 50%. From a scientific point of view, it can be argued that bladder instability symptoms (frequency, urgency and nocturia) are more reliable than urodynamically diagnosed DI because of 'logging' by the cortex. For DI testing to achieve the same 'accuracy' or level of probability as that obtained from a patient's 'logging' of urgency symptoms in her memory bank, the urodynamic test would have to be repeated hundreds of times, clearly not a feasible option.

3.3.3 Assessing Probability: The Impact of Different Structures on the Variability of Incontinence Symptoms

The pelvic floor functions optimally as a balanced system, with important contributions from muscles, nerves and connective tissues (CT). However, it is the connective tissues (CT) which are the most vulnerable part of the system. Each CT component of the overall structure - pubourethral ligament (PUL), hammock, arcus tendineus fascia pelvis (ATFP), uterosacral ligament (USL) and external urethral ligament (EUL) - contributes differently to the maintenance of continence. These contributions to stress incontinence can be represented in a normal probability curve (fig 3-09).

A damaged PUL is overwhelmingly the major cause of stress incontinence (SI). However, other structures - hammock, ATFP, USL and EUL - add variable contributions, depending on the patient. This difference in contribution explains the variable cure rate for SI that is obtained from the Kelly operation (hammock repair), the paravaginal repair (Richardson 1981), the EUL and PUL repair (Zacharin 1963, Petros & Ulmsten 1993), and the USL repair in some patients with post-hysterectomy incontinence (Petros 1997). From the viewpoint of restoration of function, it follows that restoration of damage to the whole system is desirable, if possible. As it requires only two more sutures to tighten the hammock and external urethral ligaments, both important components of the urethral closure mechanism, it is recommended these steps be added to reinforcement of PUL in surgery for cure of stress incontinence.

The concept of synergy also applies in patients with urge and abnormal emptying symptoms. The individual muscles, ligaments and stretch receptors contribute collectively to bladder closure and opening, but each structure has a different weight for each person.

Extreme examples are:

- a) severe urgency in one patient may be caused by a cystocoele stretching very sensitive stretch receptors;
- b) another patient with very insensitive stretch receptors and an equivalent cystocoele may have to empty by abdominal pressure because LP and LMA cannot gain sufficient 'traction' on the posterior urethral wall to open out the outflow tract;
- c) in yet another patient, the cystocoele may stretch the hammock downwards sufficiently to tighten it during stress, creating the condition of 'latent stress incontinence' - appearing after surgical repair of the cystocoele.

Some insights into this concept of differential contribution to continence can be obtained by performing 'simulated operations', anchoring each supporting structure in turn and measuring the effect, e.g. diminution of urine loss on coughing, or diminution of urgency sensation in a patient with a full bladder, or reducing the cystocoele and asking the patient to cough. (See the section 'Simulated operations - case reports in the Diagnosis section.)

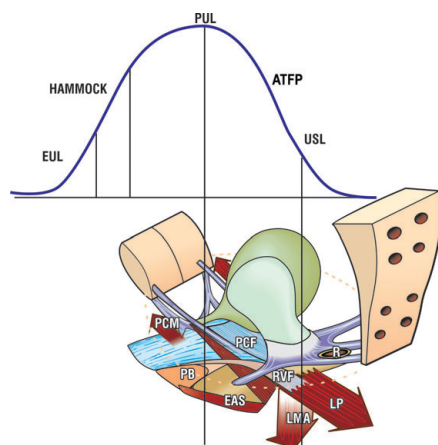


Fig. 3-13 Different structures impact synergistically to control stress incontinence in the individual patient. The impact of each structure differs between patients. The variance follows a normal distribution curve. This perspective is derived from application of the concepts of non-linearity to the dynamics of the pelvic floor (see Ch 6 for more detailed examples).

3.3.4 The Anatomical Basis for the Diagnostic Summary Sheet

The following section describes the components of the Diagnostic Summary Sheet (fig 3-03). The anatomical basis for these dysfunctions are presented according to the zone in which the dysfunction occurs.

Anterior Zone Defect Symptoms

A lax pubourethral ligament (PUL) allows the posterior directional forces to pull open the posterior urethral wall on effort to the 'open' position, fig. 3-19. Stimulation of the stretch receptors 'N' by this movement may activate the micturition reflex to cause urgency, or continued urine loss after coughing ceases ('cough activated OAB').

Manifestations of a lax PUL include:

- *Stress Incontinence*
- *Urine Loss on Standing (in the older person)*
- *Post-Stress Instability ('cough activated OAB')*
- *Urgency If the stretch receptors 'N' are stimulated ('mixed incontinence')*
- *Faecal Incontinence (associated with SI)*
- *Nocturnal Enuresis Cured at Puberty*

Many patients who report nocturnal enuresis plus daily wetting up till puberty have a familial history of this, which also includes the male members. Improvement at puberty can reasonably be attributed to thickening of PUL under pubertal hormonal influence. Many patients only partly improve at puberty and these respond well to an anterior midurethral sling. This type of 'complicated' nocturnal enuresis is to be distinguished from the normal childhood wetting at night only.

- *Funnelling on ultrasound*
- *Urethrovaginal junction (UVJ) prolapse >10mm*

This is caused by rotation of bladder base. It should be used only as a guide to look further. It is not possible to arbitrarily diagnose damaged PUL at 10.1 mm and intact PUL at 9.9 mm.

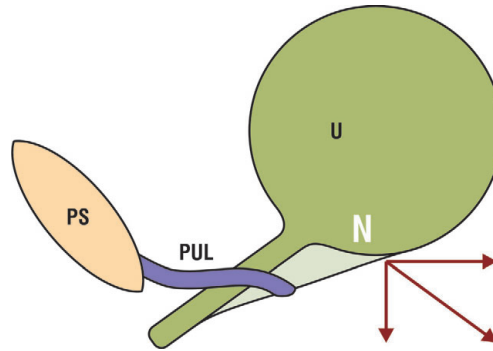


Fig. 3-14 Lax PUL allows the posterior directional forces to pull open the posterior urethral wall on effort.

Manifestations of a lax EUL include:

'Always Damp'

In the absence of fistula, constant dampness may indicate Intrinsic Sphincter Defect (ISD), caused by inability of slow-twitch PCM (arrow, Fig 3-15), to close the urethra because of possible damaged EUL, PUL and suburethral connective tissues. Significant decrease in measured urine loss on inserting a tampon suggests EUL laxity.

Stress incontinence

Up to 20-30% of patients require tightening of the hammock ('pinch test') in addition to a midurethral anchoring to control urine loss on coughing when tested with 'simulated operations' (Petros & Von Kinsky 1999). This demonstrates the synergy of these structures in urethral closure as well as the importance of tightening the hammock in addition to placement of a midurethral sling.

No SI, but urine loss on sudden movement

In the absence of any significant stress incontinence, lax EUL may manifest as a light leakage 'like a bubble', or on sudden movement. This is the classic symptom of lax EUL.

Urethral Closure Pressure (UCP) < 20cm water

This confirms the diagnosis of intrinsic sphincter defect (ISD). The precise anatomical cause is probably a degeneration of all 3 structures, EUL, PUL and hammock. ISD can usually be diagnosed without urodynamics using the 'slow leak speculum sign' (Petros & Ulmsten, Integral Theory, 1990), observation of a slow steady leak of urine on placing a Sims speculum into the vagina during examination. The speculum stretches the vaginal tissue downward to provide a counter force to the slow-twitch PCM-hammock closure mechanism, so that urine simply trickles out.

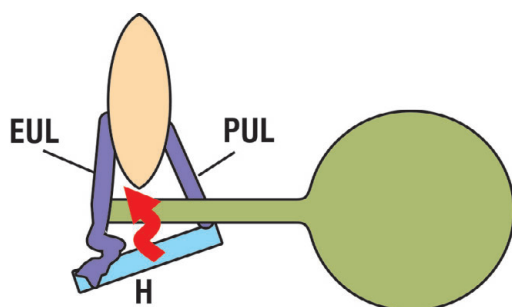


Fig. 3-15 The hammock (H) and external urethral ligament (EUL) constitute part of the urethral sealing mechanism. Wavy arrow indicates weakened muscle force.

Middle zone defect symptoms

Manifestations of a lax middle zone structures may include:

Abnormal Emptying

A cystocele may not allow the muscle forces (arrows), fig 3-16, to stretch open the outflow tract, so that the detrusor has to empty against greatly increased urethral resistance.

Urgency

If the stretch receptors 'N' are stimulated (usually with a 'high' cystocele- cardinal ligament/cervical ring laxity).

"Lump" and discomfort

If the prolapse is large, the patient complains of a 'dragging' pain.

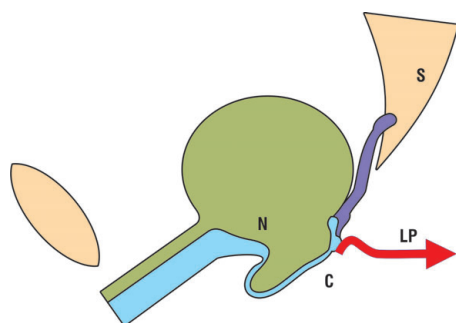


Fig. 3-16 Cystocele (C) may prevent LP (wavy arrow indicates weakened muscle force) from stretching open the urethra, causing "obstructed flow". Flow is exponentially diminished if the urethral diameter cannot be expanded (Poisseeuille's Law). If 'N' (stretch receptors) are stimulated, the patient may experience urgency also.

Posterior zone defect symptoms

Laxity in the uterosacral ligaments (USL), fig. 3-17 may inactivate the posterior muscle forces (arrows), fig. 3-17, preventing opening out of the posterior urethral wall by the muscles forces (wavy arrows indicate weakened muscle forces). If the stretch receptors 'N' are stimulated, the patient may have urgency, frequency and nocturia.

Manifestations of lax posterior zone structures may include:

Posterior zone symptoms worse one week prior to periods

The cervix softens under the influence of hormones to allow egress of blood at period time, also loosening the uterosacral ligaments.

'Always damp'

USL is the anchoring point for slow-twitch LMA muscles (downward arrow, fig. 3-17), which stretch the bladder base down and around PUL to achieve watertight closure in the proximal urethra.

Abnormal emptying, raised residual urine and prolonged emptying time

The uterosacral ligament (USL) is the effective anchoring point of the downward muscle forces, fig. 3-17, which stretch open the outflow tract. A lax USL will weaken the downward forces (wavy arrow) so that the detrusor has to empty against greatly increased urethral resistance, causing 'obstructed flow'.

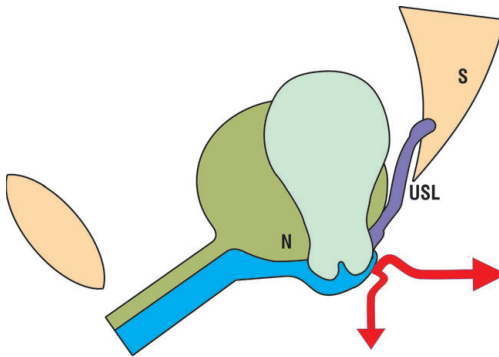
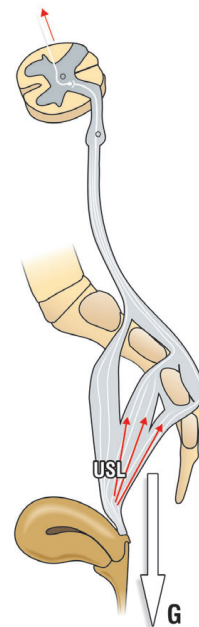


Fig. 3-17 Laxity in the uterosacral ligaments (USL), may inactivate the posterior muscle forces (wavy arrows). N= stretch receptors.

Pelvic Pain

Insufficient connective tissue support for the non-myelinated nerve endings which course along the uterosacral ligaments, may cause referred low abdominal pain or sacral backache (fig 2-54). Deep dyspareunia may cause pain by pressure on these nerves. The lower abdominal pain and sacral backache may be reproduced by gently touching the posterior fornix digitally, or with a ring forceps. This is described as 'cervical' or 'vaginal' 'excitation pain'.

Fig. 2-54 The anatomy of uterosacral ligament (USL) referred pelvic pain. If the uterosacral ligaments (red arrows) cannot provide adequate anatomical support for the unmyelinated afferent nerves (thin white lines) the force of gravity (G) may stretch them, causing referred abdominal and sacral pain. After Goeschen, by permission.



Nocturia

When the patient is asleep, the bladder base is pulled down by the force of gravity, and is contained by firm elastic uterosacral ligaments. If the weakened posterior ligaments cannot ‘hold’ the bladder base, the stretch receptors may be stimulated, and this is perceived as night urgency, nocturia.

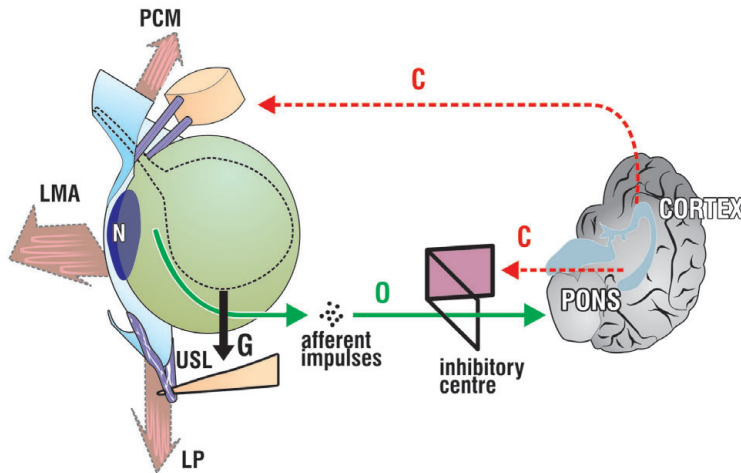


Fig. 2-50 Mechanical origin of nocturia- patient asleep. Pelvic muscles (arrows) are relaxed. As the bladder fills, it is distended downwards by gravity G. If the uterosacral ligaments (USL) are weak it continues to descend until the stretch receptors ‘N’ are stimulated, activating the micturition reflex once the closure reflex ‘C’ has been overcome.

Prolapse

Given the non-linear nature of bladder emptying, arbitrary limits to residual urines, such as ‘30 ml’ (the limit used by the author) have little meaning. Strictly speaking, any urine remaining after micturition is abnormal.

Abnormal Emptying Time

A time limit of 60 seconds is generally used, but the same limitations as in the case of residual urine apply.

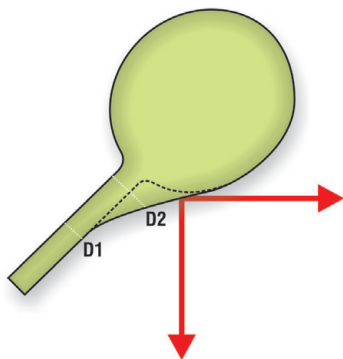


Fig. 2-52 Physical origin of abnormal emptying symptoms. Urethral resistance decreases by the fourth power of the diameter. D2 is twice the diameter at D1, therefore urethral resistance at D2 is 1/16th of the resistance at D1. ($2^4 = 16$)

3.3.5 ICS Definitions and Descriptions expressed as dysfunctions of opening and closure

In this section the definitions and descriptions of the International Continence Society are explained anatomically in terms of defective closure and opening of the bladder. In a normal patient, there are only two normal bladder states, stable closed and stable open. Muscle energy is required to pull open the outflow tract to the ‘open’ state and to close it. There are specific connective tissue structures in each zone which play a key role in these dynamics (ie opening and closure). In simple terms, the structures in the anterior zone are mainly concerned with closure, and those in the middle and posterior zones are mainly concerned with opening (fig 3-18).

The main connective tissue structures in each zone are printed in red (fig 3-18). These are listed in order of importance. The specific incontinence symptoms associated with damage to these structures, as defined by the ICS, are detailed in the columns representing each zone. The height of the rectangle in each zone represents an approximation of the probability of that symptom’s occurrence in that zone.

These incontinence symptoms may be designated as dysfunctions of closure (‘stress incontinence’) or of opening (‘abnormal emptying’). Dysfunctional closure occurs in the anterior zone, dysfunctional opening occurs in the middle and posterior zones. Bladder instability symptoms (‘urgency’, ‘frequency’, etc) may occur in all three zones.

ANTERIOR	MIDDLE	POSTERIOR
Urethrocoele PUL Hammock EUL <i>stress incontinence</i> “unconscious” urine loss, ISD, cough-activated DI	Cystocoele Para-vaginal defect CL/Cerv. Ring PCF ATPF	Enterocoele Uterine prolapse Vaginal vault prolapse USL RVF PB
	abnormal emptying slow flow, hesitancy, “detrusor acontractility”, “dyssynergia”, overflow, dribble incontinence	
frequency and urgency sensory urgency, urge incontinence, low compliance bladder, urethra instability, detrusor instability, low bladder capacity		
		nocturia

Fig. 3-18 ICS Symptom definitions allocated to the three anatomical zones, expressed as dysfunctions of closure or opening. Note the synergistic relationships between the middle and posterior zones.

The Role of the Peripheral Neurological Control Mechanism in the 'Unstable Open' State

In the normal patient, the peripheral neurological control mechanism consists of a musculo-elastic complex which controls afferent impulses from the stretch receptors 'N' (fig 3-19). This neuro-musculo-elastic complex is known as the 'micturition reflex'. This reflex acts as an 'engine' to accelerate opening out of the outflow tract. This is a non-linear mechanism with precise feedback control. It is explained more fully in the urodynamics section, Ch6. The combination of damaged connective tissue and oversensitive nerve endings may lead to excessive afferent impulses from 'N' which may result in inappropriate activation of the micturition reflex at low bladder volume. This may be interpreted by the cortex as frequency, urgency and nocturia symptoms.

The afferent impulses activate the micturition reflex. Usually, the normal response to afferent impulses is the contraction of PCM, which pulls the hammock forward to stabilize the urethra and support 'N'. However, once activated sufficiently to override the inhibitory centres 'C' (fig 3-19), the micturition reflex drives the external musculo-elastic opening mechanism 'O' such that PCM relaxes, the urethra is opened out, the bladder contracts, and urine is expelled.

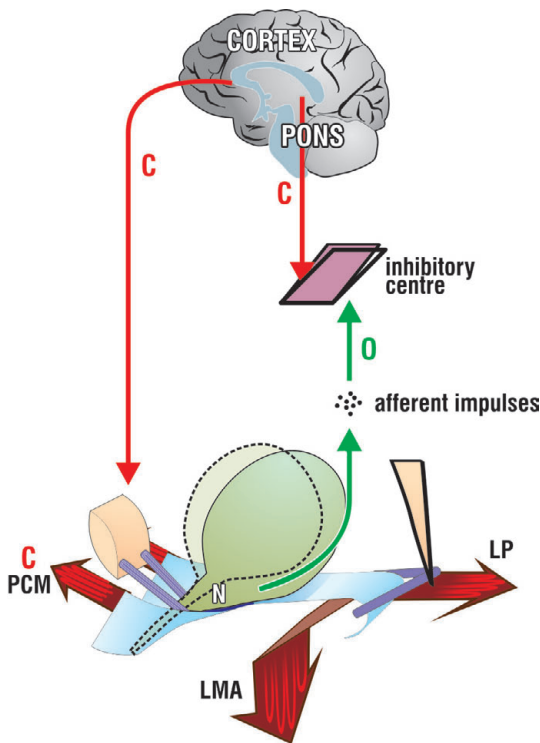


Fig. 3-19 The bladder is shown in the 'open' (micturition) phase. During micturition, the closure reflex 'C' (shown in red) is overcome by the opening reflex 'O', (shown in green). During closure, 'C' dominates. The inhibitory centre 'trapdoor' closes, PCM contracts to close the urethra and supporting 'N', thereby diminishing the number of afferent impulses.

Conversely, a patient with insensitive nerve endings in the presence of connective tissue damage may present with bladder emptying problems or even urinary retention.

In the section below, the anatomical zones in which the symptoms originate are denoted in parentheses where relevant (Petros & Ulmsten, 1998, 1999). The terms used are as defined by the International Continence Society (ICS 1998).

‘Detrusor instability’ and ‘bladder instability’ are used interchangeably. In the Integral Theory framework they are both manifestations of a normal but prematurely activated micturition reflex.

Motor Urgency (Anterior, Middle & Posterior Zones)

According to the Integral Theory, motor urgency is mainly an uninhibited micturition. In patients with anterior ligamentous defect (PUL), the forward forces (PCM), (fig 3-19) cannot anchor the urethra. Instead, on being given the signal to close (e.g. when a patient stands up), the powerful backward forces (LP and LMA) open out the outflow tract much as occurs during micturition. This action further stimulates the stretch receptors ‘N’, already activated by urine in the bladder. The sheer quantity of afferent impulses may overcome the inhibitory centre. The micturition reflex is activated and massive urine loss ensues. These symptoms often commence after 70 years of age, and are presumably caused by PUL atrophy. In a patient with previous surgery, scar-based ‘tethering’ of the forward and backward forces may work in a similar way. The more powerful backward forces (fig 3-19) overcome the forward force to forcibly open the outflow tract resulting in urine loss. This may be entirely mechanical or have an urge component. Patients with these symptoms and previous surgery are unlikely to have the ‘tethered vagina’ syndrome if there is an absence of a fixed scarred bladder neck. A combination of sensitive stretch receptors and lax posterior ligaments may sometimes present a similar clinical picture.

Nocturia – Posterior Defect

The anatomical basis for nocturia is best understood by turning figure 3-19 clockwise through 90 degrees to represent the sleeping position (fig 2-50). As the bladder fills at night, the bladder fluid, assisted by the force of gravity, stretches the proximal vagina downward. If USL is strong, it will prevent excess stretching and will support the stretch receptors ‘N’. If USL is weak, ‘N’ may ‘fire off’ at a low volume. This is interpreted as nocturia – that is, waking to pass urine. With very sensitive stretch receptors the micturition reflex may be activated and the patient may wet prior to arrival at the toilet. Alternatively, with insensitive stretch receptors and lax inelastic tissues, the urine may simply leak out so the patient wets her bed.

Sensory Urgency (Posterior, Middle, Anterior Zone Defects)

As the bladder fills, the afferent impulses from the stretch receptors ‘N’ reach the cortex and are interpreted as a full bladder, sensory urgency - the first warning of

the activated micturition reflex. Central inhibition 'C' (fig 3-19) combined with vaginal stretching to support the stretch receptors usually prevents urine loss. If these are insufficient and the patient wets, the symptom is termed 'urge incontinence'. Intravesical lesions (cancer), chronic cystitis and extrinsic pressure (uterine fibroids) need to be excluded.

Unconscious Incontinence, Continuous Leakage (Anterior, Posterior Zone Defects)

Unconscious incontinence and continuous leakage is evidence of the inability of the urethral closure muscles PCM (fig 3-19) to stretch the vagina sufficiently for urine-tight urethral closure. Unconscious leakage may be mainly due to anterior zone laxity, but it may occasionally be due to inability of the slow-twitch backward and downward muscles to close off the bladder neck. Other cases, such as bladder fistula and multiple sclerosis need to be excluded.

Detrusor Instability (Posterior, Anterior, Middle Zone Defects)

Detrusor instability (DI), now known as (Overactive Bladder 'OAB'), is an abnormal phasic rise in bladder pressure. It is purely a urodynamic diagnosis, and may be present in normal women. This contradiction disappears entirely if DI is considered as being part of an uninhibited, prematurely activated, but otherwise normal, micturition reflex (Integral Theory 1993). This perspective of a premature micturition reflex was supported by use of a provocative handwashing test. Handwashing may work by counteracting central inhibition (Mayer et al. 1991) of afferent impulses from the bladder base stretch receptors. The sequence of events observed in a group of 115 patients presenting with urge incontinence was, generally speaking, what one would find during normal micturition: a feeling of urgency within a few seconds of commencement of the test (108 patients), then, fall in urethral pressure (91 patients), rise in detrusor pressure (56 patients), and finally, loss of urine (52 patients) (Petros & Ulmsten 1993). The classical sinusoidal curve of DI can be explained as a 'battle' between two feedback systems: the micturition (opening) reflex 'O' (fig 3-19), and the closing reflex 'C'. In other words, the micturition reflex struggles to open the outflow tract, and the brain struggles to counteract this reflex by increasing central inhibitory impulses, and by contracting the pelvic floor, which, in turn, closes the urethra. If the detrusor is contracting at this point, detrusor pressure rises. If the outflow tract is being pulled open at this point, the detrusor pressure falls. The time delay in the transition between the 'open' and 'closed' is expressed urodynamically as a sinusoidal pressure curve indicating 'detrusor instability'.

Unstable Urethra (Posterior, Anterior, Middle Zone Damage)

The same explanation for the phasic contraction of the bladder applies for the urethra: both share the same smooth muscle and so both respond to the same feedback system. The fibre to fibre transmission of bladder smooth muscle (Creed 1979) not

only precludes independent innervation of the bladder and urethra, but means that all the fibres contract ‘as one’ to expel the urine.

Inability to Micturate with Neurological Damage

This is explained by the spinal cord transection preventing working of the extrinsic opening mechanism. Therefore the detrusor contracts reflexly against an unopened outflow tract. As the urethral resistance varies inversely with the fourth power of the radius (r^4), a much higher detrusor pressure is required to expel the urine.

Change of Compliance (Posterior, Anterior, Middle Zone Defects)

‘Low compliance’ during cystometric filling is consistent with a micturition reflex activated by bladder filling, partly controlled by cortical inhibition ‘C’ (fig 3-19) and pelvic floor contraction (Petros Neurrol 1999). Pelvic floor contraction compresses the urethra thereby increasing the urethral resistance. This, in turn, increases the detrusor pressure. The latter is interpreted as ‘low compliance’.

Bladder Sensation (Posterior, Anterior, Middle Zone Defects)

According to the ICS, bladder sensation is classified as ‘normal’, ‘increased’, ‘decreased’ and ‘absent’. It was demonstrated, that the sensation of urgency, was the first and most constant manifestation of a micturition reflex prematurely activated by handwashing (Petros & Ulmsten 1993). Because of the complex feedback system, it is inevitable that these sensations will vary in intensity and frequency even within the same patient. Variable sensitivity of stretch receptors in patients with connective tissue damage may explain the ICS classification.

Bladder Capacity

The variables for bladder capacity are sensitivity of the stretch receptors ‘N’ (fig 3-19), competence of the central inhibitory mechanism, and competence of the musculo-elastic mechanism in stretching the vaginal membrane. How these merge is reflected as a particular bladder capacity on the day of testing.

Urethral Function During Storage (Anterior, Posterior Zone Defects)

In a normal patient, the urethral pressure rises during urodynamic bladder filling. Urine leakage in the absence of a detrusor contraction reflects the inability of the PCM/hammock (fig 3-19) complex to close off the urethra. A higher rate of cure for low urethral pressure incontinence, ‘intrinsic sphincter defect’ (ISD), or ‘Type III’ incontinence with the anterior midurethral sling procedure has been demonstrated when the hammock is also tightened. The importance of this mechanism has also been demonstrated when the hammock is surgically disconnected from the closure

muscles. Urine may leak even in the presence of raised 'cough transmission ratio' (CTR) (Petros & Ulmsten, 1995).

Genuine Stress Incontinence (Anterior Zone Defect)

3

According to the ICS definition (1988), genuine stress incontinence (GSI) is strictly demarcated from mixed incontinence, and implies that there is urine loss coincident with stress in the absence of a detrusor contraction. GSI is a confusing definition, as it attempts to separate conditions which, according to the Integral Theory's anatomical classification, derive from the same source, viz. laxity in the vagina or its ligaments. Indeed, the presence of DI was not a negative prognostic factor for the IVS operation (Petros 1997) or conventional bladder neck elevation surgery (Black 1997). Though testing for DI appears to be of little practical use in the Integral Theory decision path for surgery, dynamic urethral pressures, urine flow and residual urine determinations are of considerable assistance in improving the diagnostic accuracy of the basic pictorial algorithm.

Cough Activated Detrusor Instability

Although patients with symptoms of stress incontinence usually lose urine coincident with coughing, it is not always the case. Many previous investigators have observed that a cough may sometimes activate a detrusor contraction, so that leaking continues many seconds after the cough has ceased. This observation has been a key factor in the ICS labelling stress incontinence symptoms as unreliable.

However, an alternative explanation for this occurrence is as follows. A lax PUL (fig 3-19) may fail to anchor the urethra. The result of this is that LP and LMA stretch the bladder base backwards to stimulate the stretch receptors 'N' which activates the micturition reflex. This causes the bladder to contract, so that urine is lost after cessation of coughing. Urodynamic testing in this situation may show a phasic rise in pressure: detrusor instability. A midurethral sling usually cures this condition, but there has been at least one patient in the author's experience where a posterior sling was needed.

Although urgency and frequency may occur with damage in any zone, in the author's experience it is more likely to be caused by posterior zone defects, especially in older patients.

Reflex Incontinence

According to the ICS (1988), reflex incontinence describes urine leak in the absence of sensation. Neurological damage is equated with this condition. This concept is consistent with a neurological lesion such as multiple sclerosis which interferes with cortical or spinal cord inhibitory centres 'C' (fig 3-19). As the afferent impulses cannot be suppressed, they activate the cascade of events which form the micturition reflex 'O' (fig 3-19). However, patients with intrinsic sphincter defect and a very lax hammock can also leak urine without sensation. In this case the cause is purely mechanical.

Detrusor Acontractility, Underactivity, Overflow Incontinence, Post-Micturition Dribble (Posterior, Middle Zone Defects)

Normal bladder evacuation requires competent mechanical and neurological components. Relatively insensitive stretch receptors 'N' (fig 3-19) plus connective tissue laxity in the middle or posterior zones of the vagina may cause detrusor acontractility, underactivity, overflow incontinence, post-micturition dribble, or even urinary retention. The author has seen several older patients presenting with retention of urine and vaginal vault prolapse whose ability to micturate was restored by correction of the prolapse by a posterior IVS operation and/or cystocele repair. Insensitive stretch receptors may explain 'abdominal micturition': the forward force relaxes and urine is expelled by opening out the outflow tract with a Valsalva manoeuvre. This activates the two posterior forces.

Detrusor/Bladder Neck Dyssynergia (Anterior, Posterior Zone Defects)

Laxity in either the anterior or posterior ligaments may prevent adequate activation of the two posterior striated muscle opening forces. It follows that the urethra cannot be opened out adequately. As the urethral resistance is inversely proportional to the 4th power of the radius (r^4), even a minor degree of vaginal laxity may cause the detrusor to contract against a higher urethral resistance (fig 3-12). As the detrusor pressure recorded is entirely a reflection of the urethral resistance, a pattern of 'dyssynergia' may be recorded.

3.4 Summary Chapter 3

Two pathways to diagnosis of damaged structures are described, the simpler clinical pathway and the structured assessment pathway, designed for a specialist clinic. Both are based on diagnosing connective tissue damage in the three zones of the vagina. Both use the same examination technique and both use the 'simulated operations' technique to verify which connective tissue structure(s) may be causing the stress or urge symptoms. Though the structured assessment technique uses specific transperineal ultrasound and urodynamic parameters to assist the diagnosis, adequate diagnosis and management can be achieved in most cases by just using the patient questionnaire, 24 hour diary, cough stress test and 24 hour pad test, vaginal examination and 'simulated operation' techniques.

Reconstructive Pelvic Floor Surgery According to the Integral Theory

It is helpful for the modern pelvic floor surgeon to think firstly as an architect, secondly as an engineer: as an architect, to design the form of the reconstruction; as an engineer, so the construction can withstand the pelvic forces imposed upon it.

4.1 Introduction

The Integral Theory approach to reconstructive pelvic floor surgery differs from conventional surgery in four main ways:

1. It is minimally invasive and oriented to day-care treatment.
2. It takes an holistic approach to pelvic floor dysfunction by isolating the contribution(s) of connective tissue in each zone of the vagina to dysfunction.
3. It has a symptom-based emphasis (the Pictorial Diagnostic Algorithm) which allows surgical indicators to include cases where major symptoms can be the result of only a minimal prolapse.
4. It is based on a set of surgical principles which aim to minimize risk, pain and discomfort to the patient.

The surgical approach described in this chapter has developed from the anatomical and diagnostic perspectives described in the previous chapters. The Integral Theory emphasizes the role of competent ligaments and fascia in pelvic floor function; the Integral Theory approach to surgery focuses on the repair of these structures.

Section 4.2 describes the concepts, principles, and practice which underpin this approach. Section 4.3 describes how this surgical approach is applied to repairing connective tissue damage in the three zones of the vagina. The final section describes strategies for managing recurrent and emerging symptoms.

4.2 The Integral Theory Approach to Reconstructive Pelvic Floor Surgery

4.2.1 The Conceptual Bases of Minimally Invasive Pelvic Floor Surgery

In Chaos Theory (Gleick 1987), natural systems are regarded as being a series of interconnected components in which even *minor* alterations in initial conditions

may create a 'cascade' of *major* events (the 'butterfly effect'). The symptom-based emphasis of the Integral Theory stems from the fact that even minor degrees of ligamentous laxity (prolapse) may cause quite severe symptoms. For example, as explained earlier, in a patient with very sensitive nerve endings even minimal ligamentous laxity may cause the peripheral 'neurological' control mechanism to 'fire-off' at a low threshold.

The cascade of events which follow from this low threshold may be expressed as quite major symptoms such as urge incontinence, pelvic pain, cough-activated detrusor instability, etc. In surgery, some 'major events' (for example, thrombosis, haemorrhage and infection) are potentially fatal, yet their origins may be traced to apparently 'minor' events.

Accordingly, the Integral Theory system for surgery emphasizes a minimalist approach, with safety built-in to the techniques. For instance, wherever possible, conservation of the uterus and vaginal tissue is advised so as to avoid longer term complications for the patient. (These are explained later in this book). This approach is in keeping with the Chaos Theory perspective, as well as the historical concept that the consequences of surgery can not always be fully foreseen.

The Integral Theory surgical system introduces a specific methodology to the five elements which are characteristic of all surgery. These are:

1. Indications
2. Tissues
3. Structure
4. Methods
5. Tools.

By using the Integral System methodology in surgical practice, many conditions previously considered to be complex become treatable on a day-care basis.

The Indications: Major Prolapse, or Major Symptoms with Minor Prolapse

The diagnostic framework of the Integral System is summarised in the Pictorial Diagnostic Algorithm (fig 1-11). The Pictorial Diagnostic Algorithm brings together the key concepts at the core of this method:

- that restoration of structure will also restore function
- that even minor degrees of prolapse may cause dysfunction in the pelvic floor
- that the same minimally invasive surgical techniques can be applied regardless of the scale of damage to that structure.

This has meant, for instance, that patients with only minor degrees of damage and so-called 'incurable' symptoms such as frequency, urgency, nocturia, abnormal emptying and pelvic pain can now benefit from a posterior sling, even though its original indication was for utero-vaginal prolapse.

In the following sections, both structural and functional indications will be given for the surgical techniques described. Note that the same operations described for major degrees of prolapse may also be applied to improve symptoms associated with minimal anatomical defect.

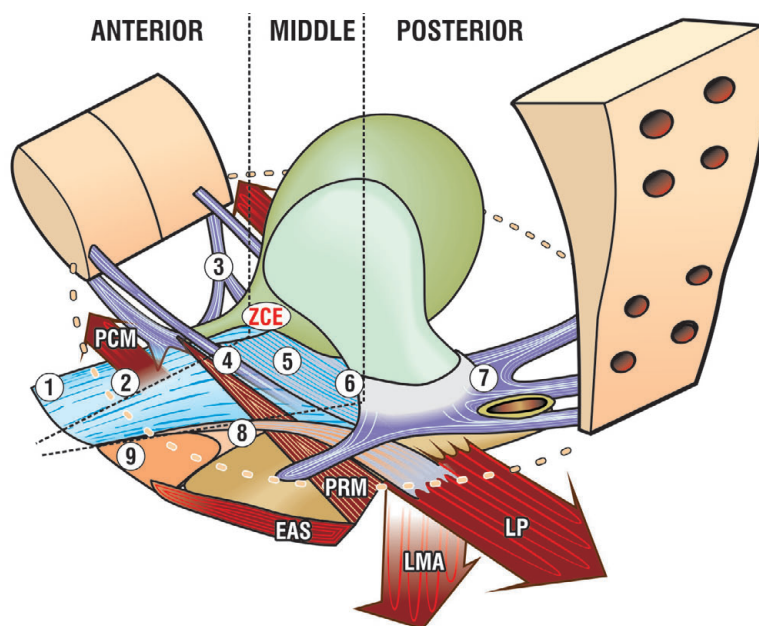


Fig. 1-10 The key connective tissue structures of the pelvic floor. Perspective: view from above and behind, level of pelvic brim. PCM = pubococcygeus muscle force; LP = levator plate muscle force; LMA = longitudinal muscle of the anus force; ZCE = Zone of Critical Elasticity.

The Tissues: Conservation and Reinforcement of Tissue

Conservation and reinforcement of tissue is the key to ambulatory surgery. Connective tissue loses strength with age. The vagina is an organ and cannot regenerate. To avoid vaginal shortening and dyspareunia, the Integral Theory approach recommends minimal and preferably no vaginal tissue be excised. Where required, damaged suspensory ligaments can be reinforced by using tapes, precisely inserted to create artificial collagenous neoligaments. Tissue conservation and a 'tension-free' technique while suturing will minimise post-operative pain. By avoiding surgery at the bladder neck area of the vagina 'zone of critical elasticity' (ZCE, fig 1-10), sufficient elasticity for funnelling during micturition is retained, thus minimising post-operative urinary retention.

The Structure: The Synergistic Interaction of Connective Tissue Components

There are nine main connective tissue structures which may contribute to pelvic floor dysfunction (fig 1-10). They are:

Anterior zone

- 1 = external urethral ligament (EUL)
- 2 = pubourethral ligament (PUL)
- 3 = suburethral vagina (hammock)

Middle zone

4 = arcus tendineus fascia pelvis (ATFP)

5 = pubocervical fascia (PCF)

6 = anterior cervical ring/cardinal ligament (CL)

ZCE = excess tightness, usually scar tissue below bladder neck ('tethered vagina')

Posterior zone

7 = uterosacral ligament (USL)

8 = rectovaginal fascia (RVF)

9 = perineal body (PB).

Three muscle forces stretch these structures (fig 1-10). As illustrated in the suspension bridge analogy, it is the 'tensioning' of the connective tissues that gives the pelvic floor system its structure and form.

Laxity in some or all of these connective tissue structures may affect position or function of the organs. Therefore the surgeon needs to address all damaged structures within each zone and across all three zones (fig 1-10).

The Methods: Site-Specific Ligament Repair-Uterine and Vaginal Conservation

David Nichols (1989) stated that there may be multiple sites requiring repair, and therefore, it was important to address the construction needs of each damaged site. From the perspective of this book, this means repairing the 9 structures detailed in figure 1-10, using tapes to reinforce damaged ligaments, restore tissue tension by approximation of laterally displaced ligaments, and conservation of the uterus and vaginal tissue wherever possible. As all the pelvic structures work collaboratively, the surgeon needs to be aware as to how the reconstruction itself may alter the dynamics of pelvic floor structure and function. The best known example is post-operative pain, urinary retention, neourgency and enterocoele formation after a Burch colposuspension. Other less common examples are possible sequelae from excision of vaginal tissue ('tethered vagina syndrome'), hysterectomy (vault prolapse), and excessive tightness of tapes and sutures (pain and urinary retention).

The Tools – A Tape and its Delivery Instrument

The surgical operations based on the Integral Theory System generally require special instruments to insert tapes in a minimally invasive way to reinforce damaged ligaments or fascia (Petros & Ulmsten, 1990,1993), figs 4-01, 4-02.

'Tension-free tapes' and their modus operandi

The tape is ideally 6-10 mm wide, and is placed in the exact position required to create an artificial collagenous neoligament, as demonstrated in experimental animal studies (Petros, Ulmsten & Papadimitriou, 1990). The 1st application, a retropubic midurethral sling, was first used for cure of stress incontinence at Royal Perth Hospital in 1986, figs 4-01,4-02. The 2nd application, a posterior sling, 'infracoccygeal

sacropexy', was used for cure of uterine/apical prolapse, also at Royal Perth Hospital, in 1992. Delorme applied the midurethral principle via the transobturator approach (TOT) in 2001.

4

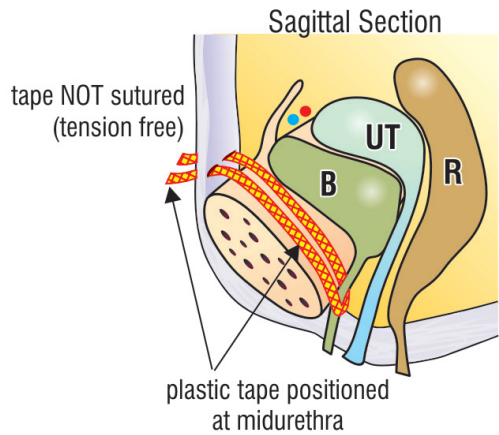


Fig. 4-01 The midurethral plastic mesh tape reinforces the pubourethral ligament.

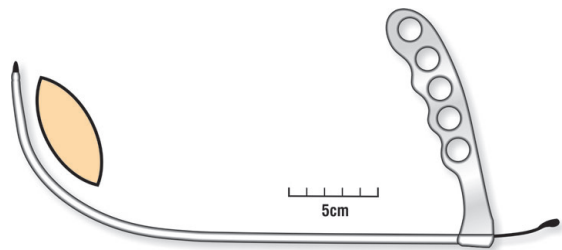


Fig. 4-02 Current insertion instruments derive, in some way, from this prototype, 1st used for a midurethral sling in 1986.

'Tension-Free' Tapes Attached to Large Mesh

This method has been applied to cystocele repair, using a large mesh with 'arms', usually via the transobturator (TOT) approach . A large mesh attached to 'arms' also been applied for rectocele repair, via the same perineal approach as the infracoccygeal sacropexy. However, it has been demonstrated with 3D ultrasound (HP Dietz, personal communication, 2008), that such meshes create only a barrier, which may be incomplete. For example, the TOT mesh configuration, fig. 4-03b, cannot physically extend to the vaginal apex, even when the arms are passed into the ATRF. Dietz has demonstrated that such meshes do not prevent separation of the levator hiatus seen during straining, fig 4-03a. Neither do they adequately restore function. Farnsworth & Parodi (2005) reported inferior symptom cure with large mesh to that achieved

previously by using the infracoccygeal sacropexy alone. Other problems faced by such meshes, such as change in the vaginal axis, alteration in the anatomy of other structures, and shrinkage are outlined later in this chapter.

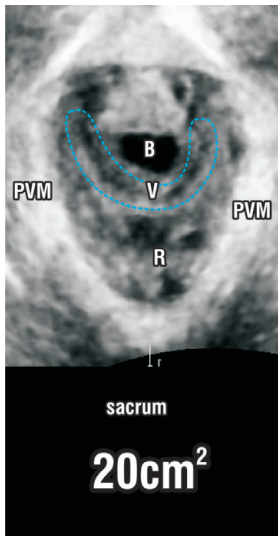


Fig. 4-03a Separation (“ballooning”) of the pubovisceral muscles (PVM) during straining. 3D ultrasound, view from above. The vagina V is outlined with broken lines. B=bladder; R=rectum. From Dietz HP (2008), by permission.

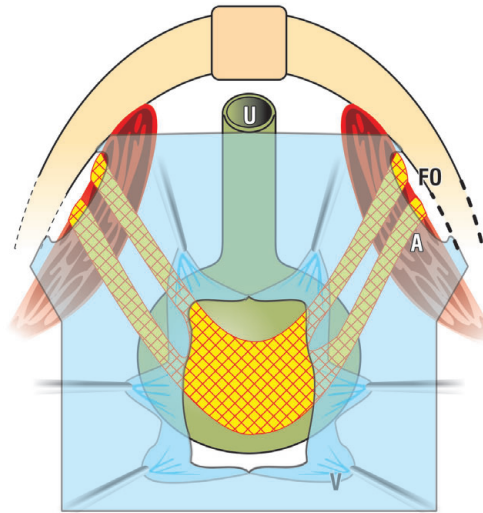


Fig. 4-03b Transobturator placement of anterior mesh for cystocele repair using 2 arms. The white space indicates an unavoidable gap between the mesh and the vaginal apex.

“Tension-free minislings”

Two arrows connected by a small segment of tape are pushed upwards around the urethra. Initial results indicate an inferior cure rate for SI with some minislings.

Tensioned minislings, fig.1-12

The TFS (Tissue Fixation System) is described here, as it is the only tensioned minisling available to date. It consists of twin 4 pronged anchors, fig. 4-04, connected by a non-stretch monofilament polypropylene tape, passing through a one way tensioning system at each base. The anchors are inserted upwards around the urethra and the tape is precisely tightened. The 3 year cure rate for SI is equivalent to the retropubic slings (Petros & Richardson 2008). A high cure in patients with ISD has been confirmed (Sekiguchi J Urol 2009).

Tensioning a sling uses the same engineering principle as a suspension bridge: only a tensioned wire is capable of structural support, (fig 4-05). The TFS was designed to approximate laterally displaced ligaments and fascia to restore tissue tension, and therefore, function (fig4-05b). Therefore it is also effective in the repair of cystocele, uterovaginal prolapse and rectocele (Petros & Richardson 2005,2009). Because

the tapes are laterally applied, fig 1–12, there is little possibility of anteroposterior shrinkage, a major problem with large mesh implantation. In fig 4-05, TFS tapes and anchors (arrows) have been superimposed schematically on a 3D ultrasound photo with pubovesical muscles already separated during straining. The arrows indicate the direction of tensioning. Once the “slack” has been taken out of the connective tissue during tightening of the tape, a resistance is felt, evidence that the slow-twitch contraction/connective tissue dynamic of the adjacent muscle forces has been restored.

4

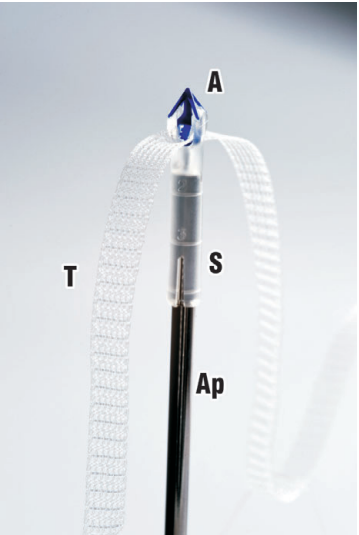


Fig. 4-04 TFS applicator (Ap). The monofilament tape (T) passes through a one-way trapdoor at the base of the anchor (A) which sits on the saddle (S), which fits onto the applicator.

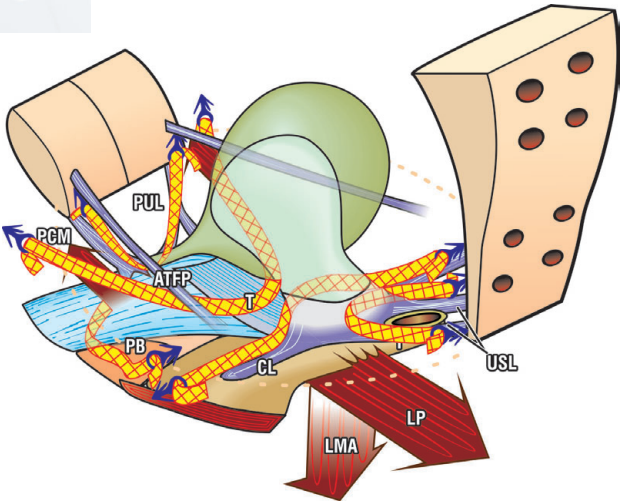


Fig. 1-12 Tensioned minimeshing tapes approximate and tension, laterally displaced ligaments and fascia. The laterally positioned tapes do not limit the backward stretching of the muscle forces (arrows), and act much like a suspension bridge to provide tensioned support for prolapsed organs.

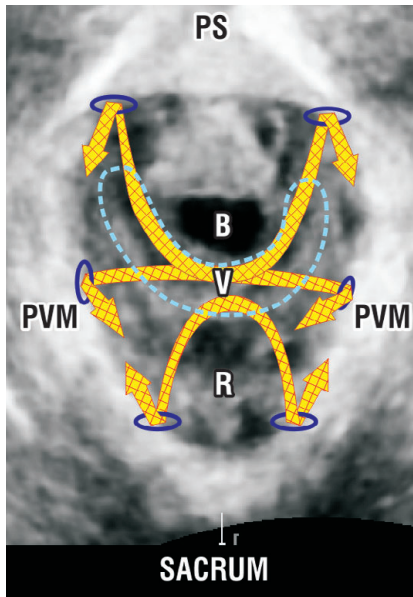


Fig. 4-05 Modus operandi of the “tensioned tape” surgical system- Schematic view. Arrows indicate the direction of tensioning through the one-way system (blue ovoid circles). Tensioned tapes approximate and bind together laterally displaced ligaments and fascia to the hiatal muscles (PVM), restoring tissue tension and function. From above, TFS U-Sling reinforces central and lateral defects. Cardinal ligament TFS restores attachments to anterior cervical ring (high cystocele). Posterior TFS sling (uterosacral ligament) restores apical/uterine prolapse.

A Clarification: ‘Tension-free’ Tapes are Not ‘Without Tension’

The term ‘tension-free’ tape surgery was first used in a 1994 (Ulmsten & Petros 1994). At the time, ‘tension-free’ was used to mean that the tape should not be applied under tension to the urethra. It is a term that, subsequently, has often been misinterpreted.

With ‘tension-free’ tape operations, the two ends of the tape are free. They ‘grip’ into the anterior abdominal wall muscles so that the sling provides a fixed anchoring point for the midurethra. This prevents the urethra being opened out during effort. Indeed, an essential element in the original descriptions of this technique (Petros & Ulmsten 1993, Ulmsten et al 1996, Petros 1996) was the insertion of 300 ml in the bladder, and pulling the tape upwards to tighten it sufficiently to prevent urine loss while the patient coughed.

How a tensioned sling differs from a ‘tension-free’ mesh

The foetal head displaces ligaments and fascia laterally as it descends down the birth canal. A tensioned sling re-locates and tensions these structures, restoring muscle effectiveness. Unlike large mesh, a tensioned sling does not inhibit the antero-posterior (A-P) organ movement so essential for opening and closure. ‘Tension-free’ meshes glue the organs together, inhibiting A-P movements and in some cases, function.

4.2.2 The Surgical Principles of the Integral Theory

Introduction

'Restoration of function follows restoration of form (structure).'

A central principle of the Integral Theory is that connective tissue damage in the fascia and ligaments of the three zones of the vagina may cause both prolapse and abnormal pelvic floor symptoms. Moreover, even minor connective tissue defects may cause abnormal symptoms.

Two major consequences follow from this: firstly, the same operation that is described for major prolapse surgery may be used for patients who, although exhibiting major symptoms, actually have only minor degrees of prolapse; secondly, symptoms become a major indicator for surgery. Hence the emphasis in the Integral Theory on the diagnostic system.

Before choosing a particular surgical technique however, the surgeon should try to assess the strength or weakness of a connective tissue structure, and contemplate the likely response of the functional anatomy to the intervention.

Guiding Principles for Day-Care Vaginal Surgery

To avoid urinary retention

- Avoid tightness in bladder neck area of vagina
- Avoid indentation of the urethra with a midurethral sling.

To minimise pain

- Avoid tension when suturing the vagina
- Avoid vaginal excision
- Avoid surgery to the perineal skin

The vagina is innervated by the parasympathetic nervous system, except for its introital portion, which is somatically innervated. Like the intestine, vaginal pain is elicited only by applying pressure, grasping or crushing.

Stretching and suturing the cut edges of vagina tightly potentially causes immediate, or longer-term pain by stimulating the parasympathetic nervous system. This explains the chronic post-operative pain experienced in up to 20% of patients after Burch Colposuspension. In particular, excess tightening of the cardinal and uterosacral ligaments during surgery is a potent source of post-operative pain, so one should be careful not to pull transvaginal holding sutures together very tightly. Avoidance of surgery to the perineal skin, and restricting vaginal incisions to within 1.0 cm of the introitus avoids post-operative somatic nerve pain.

The fibromuscular layer of the vaginal 'fascia' forms part of the vaginal wall. Therefore incisions need to be full thickness, avoiding surgical separation of the 'fascia' from the epithelium.

The midurethral sling must not indent (constrict) the urethra. Tightness at the bladder neck area of the vagina following vaginal repair may prevent the active stretching open of the outflow tract which occurs during micturition. This may result in diminished urine flow or even urinary retention.

Conservation and Reinforcement of Tissue: Implications for Surgery

The principles of conservation and reinforcement of tissue are fundamental to achieving connective tissue strength.

The vagina is essentially a tubular elastic membrane which derives strength from its fibromuscular layer. However, the elastic component of this layer is weak and susceptible to rupture. Once the elastin has been broken, (for example, through childbirth), the collagen fibres re-align along the lines of tension and may prolapse with gravity, resulting in herniation (rectocele, enterocele, cystocele).

A high incidence of dyspareunia and apareunia has been reported (Jeffcoate 1962) following traditional vaginal repairs. These methods usually comprise excision of vaginal epithelium. It is important, therefore, to avoid excision of vagina where possible. As an organ, the vagina cannot regenerate. Stretching of urogenital tissue may weaken it by almost 30% (Yamada 1970). Thus it is best to avoid stretching of the vagina during surgery.

In patients with grossly redundant tissue, the surgeon can use a double layering technique such that the redundant tissue is used instead of mesh. This safely doubles the strength of the repair, while retaining elasticity.

In patients with poor tissues where surgery has failed, some form of polypropylene mesh or heterologous biological implant may be the best option available.

Collagen fibres within ligaments provide strong structural support. Unlike the vagina, ligaments have only limited stretching capacity (Yamada 1970). However, the breaking strength of these ligaments is far stronger than that of the vagina. The breaking strength of a pure collagen ligament (e.g. cervix) is approximately 1500 mg/mm² (Yamada 1970). In childbirth, just before delivery, the collagen of the cervix (and probably its associated ligaments) depolymerize, reducing their structural strength to a fraction of normal strength. Delivery may overstretch these tissues so that they 'reset' in an extended state. A stretched ligamentous anchoring point cannot adequately anchor the organ or the muscle force acting on it. Neither can it be shortened by suturing as it is already too weak. For these reasons, implanted polypropylene mesh tapes are used to create collagenous tissue to reinforce the ligament.

Post-operative Structural Adaption

A new group of symptoms occurring weeks, or even days after successful surgery is suggestive of another herniation. As shown in figure 1-10, 'Key connective tissue structures of the pelvic floor', all the components of the pelvic floor interact as part of a system for organ closure. It may be that strengthening one part of the system only diverts the muscle forces to another, weaker part of the system. This explains Shull's observations (1992) that herniations, usually in other parts of the vagina, occur in up to 38% of patients following vaginal surgery.

Adapting Surgical Technique for Wound Healing, Tissue Weakness and Scarring

Correct dissection technique can avoid much organ injury, especially in patients who have had previous surgery. The single most important dissection technique is to stretch the tissues to full extension prior to cutting. Once elastic tissue is cut under tension, it automatically retracts to reveal the dissection plane. With scarring from previous surgery, for example where vagina and rectum are fused by thick scar tissue, it is critical to precisely identify the organs and to cut the scar only while the organs (e.g. rectum and vagina) are being stretched in opposite directions by traction forceps. Stretching tensions the scar collagen, so that cutting it causes it to retract, revealing the plane between rectum and vagina, or bladder and vagina. Finger-tip dissection in patients with previous vaginal surgery should be avoided, as the organ often tears before the scar tissue separates.

In the early stages of setting, scar tissue has little strength (fig 4-06). The healing wound has very little structural strength during the first two weeks. During this time, the wound relies on the integrity of the suture in order to withstand the muscular forces pulling on the vagina. (The pressure needed to tear a suture out of the fascial layer of the vagina is approximately 8 lbs/sq inch (Van Winkle 1972).)

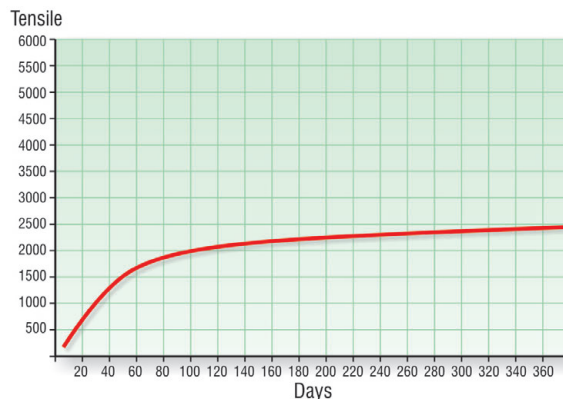


Fig. 4-06 Tensile Strength of healing fascia. (After Douglas)

As it is not possible to inhibit all natural reflex functions with bed rest, the surgical procedures themselves must contain the methodology to withstand such vaginal stretching.

Excessively tight sutures may compress the vagina and cause severe pain because of the sensitivity of visceral nerves to compression. Therefore, such sutures should be applied without excess tension.

Use of transvaginal 'holding sutures' help protect the healing wound for sufficient time until cross-bonding of the scar tissue collagen helps the wound to withstand herniation of the repaired tissue. The transvaginal holding suture derives its strength

by penetrating the full thickness of the vagina. The new TFS soft tissue anchor system more strongly approximates laterally displaced tissues as the anchors have a 'tear out' resistance of up to three kilogram force.

Video observations show that some parts of the vagina may be stretched considerably during straining, micturition, and defaecation. In some instances, even a relatively low force may cause post operative tearing out of the retaining sutures, especially in a tight vaginal repair, where devascularization and restorative musculoelastic forces can combine to tear sutures out. Tearing out of sutures may cause wound dehiscence and recurrence of vaginal herniations.

For patients with previous surgery and poor tissues, mesh is often effective (when correctly used) in addressing patients with large herniations. However, it is technically difficult to restore the correct tissue tension using mesh, especially in patients with high cystocele and high rectocele. In such cases, restoration of correct tissue tension may be crucial if abnormal symptoms such as urge, frequency, nocturia, abnormal bladder emptying, even faecal incontinence are to be addressed (cf Chapters 2 & 3). The use of a tensioned sling to approximate laterally displaced fascia is proving to be effective in restoring tissue tension, and therefore, function.

Patient Care Issues Specific to Day-Care Pelvic Floor Surgery

With day-care surgery, special precautions need to be taken because the patient may be some distance from medical help if something was to go wrong. It is imperative that systems be in place to deal with any potential problems. These include ready accessibility to the surgeon, access to a hospital, as well as instructions such as immediately commencing a nil-by-mouth regime with acute emergencies such as post-operative haemorrhage.

Primary Haemorrhage

The vagina is a vascular organ, especially in the premenopausal female and the patient with previous surgery. Very small vessels may initially constrict only to bleed later. Suturing the vagina under tension may cause sutures to tear within 72 hours and this may result in considerable blood loss if there is delay in reaching a hospital. Therefore haemostasis must be meticulous, and sutures inserted without tension.

Cease aspirin and other analgesics which may alter blood clotting 10 days prior to surgery, and avoid pre-operative heparin if possible.

Adequate Fluid Replacement

Old or diabetic patients having their operation in the afternoon of a day admission list may already be 12 hours behind in their fluids. Dehydration may predispose to thrombosis and embolism. Arranging intravenous fluids on admission rather than during surgery may be useful.

Pre-operative Antibiotics

Where possible, all patients are given Tinidazole 2 gm pre-operatively, orally or 1gm Flagyl, rectally in the morning of the operation and a broad spectrum antibiotic such as

a cephalosporin intravenously injected as a single dose at commencement of anaesthesia. Pre-operative vaginal swab cultures help to locate pathogenic bacteria such as staphylococci and beta haemolytic streptococci which should be treated before surgery.

Post-Operative Instructions

In general, the operations have been designed so that the patient can, within reason, return to fairly normal activities, such as household duties, driving a car, even employment within days. However, the patient should avoid spreading her legs and bearing down, exercise and sport as this may cause dislocation of tapes and tearing out of sutures.

Post-Operative Follow-Up

Wound infections and delayed haematomas are uncommon. Patients who can pass between 200 - 250 ml of urine post-operatively very rarely have post-operative retention problems.

Local Anaesthetic Sedation Technique

It is possible to use local anaesthetic sedation techniques for all operations described in this book.

Under midazolam (dosage 5mg-12mg) administered by an anaesthetist, up to 80-160 ml of prilocaine (or xylocaine) 0.25% are infiltrated into relevant muscles, the vagina at the site of operation and the ligamentous insertions (by the operating surgeon). Where relevant, pudendal block using a guarded needle, can be used. For a cervical block, the cervix is grasped gently, without pressure, with a pair of Littlewood's forceps and gently pulled upwards, placing the uterosacral ligaments under tension. The vagina at the site of operation and the ligamentous insertions are liberally infiltrated. Ten minutes are allowed for the local anaesthetic to exert its effect. Use of propafol at key points of the operation for example, during insertion of LA and during tunnelling, is helpful. The LA technique is especially well tolerated in the older age group. Younger women, especially those under 50 years of age generally may not tolerate local anaesthetic well, with up to 1 in 4 experiencing pain. A three point suburethral sling repair, tightening of external urethral ligament, hammock and insertion of a midurethral tape 'spreads the load' and makes the tension imposed on the tape less critical, so that good results are obtained even under general anaesthesia.

Potential Longer-Term Complications

Longer-term complications such as deep vein thrombosis and infection, though quite rare with these operations, may occur at up to 0-15 days post-operatively.

The main complication is a change in the structural balance of the three zones. A midurethral sling may divert the pelvic muscle forces on to subclinically weakened middle or posterior zone to cause a cystocele, enterocele or one or more posterior zone symptoms (fig 1-11) with only minimal prolapse. Such dysfunction may occur within days, weeks or months after surgery. Mesh tapes may create a foreign body reaction sometimes years after the insertion and this may present as a sterile abscess

either just below the abdominal skin, or occasionally in the vagina. If the foreign body reaction is dense and attached to an organ such as the urethra, bladder or rectum, the patient may present with pain or abnormal function, depending on the anatomical distortion caused by the fibrosis.

4.2.3 Surgical Practice According to the Integral Theory

Correction of Connective Tissue Damage

There are two main categories of connective tissue damage: ligaments and fascia. In the repair of damaged ligaments, special delivery instruments are used to position tapes in a minimally invasive way; the foreign-body response is used in a positive way to create an artificial collagenous neoligament. There are two main types of fascial repair. Firstly, simple repair of damaged fascia is done by cutting and suturing, using natural scarring as the 'glue'. Secondly, reinforcement of fascial tissue is done using homologous tissue, mesh, or heterologous tissue.

Whatever surgical technique used needs to allow for the inherent properties of collagen and the mechanical consequences of foreign body-induced scarring, especially in areas where the organs need to move independently of each other.

Collagen, including scar tissue, forms a living structure and is constantly broken down and recreated. Immunologically different protein will be re-absorbed at some stage, while non-absorbable irritants such as polypropylene create a permanent neoligament to support damaged ligaments and fascia, fig 1-12 (Bailey et al 1973). Polypropylene may sometimes create problems by mechanical erosion due to 'slippage', foreign body reaction, excessive scarring or (rarely) infection.

Collagen contracts with age. Thus a polypropylene sling which may restore function perfectly in a 30 year old woman may become the cause of urethral constriction when she is 70 years old due to scar contraction at the site of the sling.

Weakened vaginal tissue may be strengthened with polypropylene mesh sheets. The long term effect of inserting sheets of fibrogenic mesh on pelvic floor function is still being monitored. It is possible that increasing fibrosis around the mesh over time may create a tight and inelastic vagina. It is clear that the rectum and posterior vaginal wall must be sufficiently elastic to move freely of each other, otherwise dyspareunia may occur. Similarly, the vagina and proximal urethra must be able to move independently of each other. Structurally, tapes positioned transversely between the ATFPs, or the perineal bodies, can potentially achieve the same effect as mesh by reinforcing weakened pubocervical (PCF) or rectovaginal fascia (RVF), much like ceiling joists hold up the plasterboard (vaginal epithelium).

The history of the Integral Theory surgical system has been an evolution towards safer and simpler surgical techniques to provide stronger, more effective repair to the connective tissues of the pelvic floor. The common theme has been the use of special precision instruments to insert mesh tapes to reinforce fascial and ligamentous defects in the three zones of the vagina (fig 1-12). In the next sections, options for surgical correction of connective tissue damage are explained, as well as the issues arising

from these surgical correction techniques, particularly the use of mesh tapes, mesh, and the delivery instruments.

Repair of Damaged Ligaments through Creation of Artificial Neoligaments

A striated muscle requires a firm anchoring point to function optimally. It is the collagen component which gives a ligament strength. Once weakened or damaged, suspensory ligament such as PUL, ATRP or USL cannot be successfully repaired by suturing. Placement of a polypropylene tape in the position of these ligaments can strengthen them. The implanted tapes irritate the tissues causing a collagenous neoligament to form around the tapes. This linear deposition of collagen acts as an artificial neoligament (Petros et al (1990), Petros (1999), Doctor of Surgery thesis).

Principles and Research Underpinning the Strategy of Creation of Artificial Neoligaments

Very early in the development of the Integral Theory, it became clear that the characteristics and behaviour of the tapes to be used were critical to the practical success of surgery based on the Theory. A brief overview of the issues encountered is now provided, together with summaries of laboratory and other research undertaken to assess the characteristics of, and the histological reactions to the tapes used to create artificial neoligaments.

Eliciting a Useful 'Foreign Body' Tissue Reaction to Implanted Tapes

An early challenge was to determine if the foreign body tissue reaction elicited by the tape could be used in a positive way to reinforce the pubourethral ligament. Mersilene tapes were implanted between rectus abdominis and midurethra in 13 canines for periods of 6 to 12 weeks. Both tape ends were left lying free in the vaginal cavity (Petros, Ulmsten & Papadimitriou 1990). In all cases, a linear deposition of collagen



Fig. 4-07 (Above left) Tissue Reaction to implanted Mersilene tapes. Specimen from an experimental animal in which a tape had been implanted around urethra with ends free in the vagina for 12 weeks. The tape 'T' is surrounded by a layer of granulation tissue, then by a layer of collagen.

Fig 4-08 (Above right) Collagenous neoligaments 6 weeks after removal of the tape. Canine specimen. Arrows indicate the collagenous neoligament. V = vagina; B = bladder.

was observed around the implanted tape, (fig 4-07), which persisted after the tape was removed (fig 4-08). Macrophages were observed in the tape interstices. There was no evident discomfort, pyrexia, change in appetite, or raised white cell count in the animals (Petros (1999), Doctor of Surgery thesis) or, subsequently, in the patients who had the prototype intravaginal sling procedures (Petros & Ulmsten, 1990, 1993).

Assessing Different Tape Materials

Ulmsten et al. (1996) demonstrated that polypropylene mesh is better tolerated in human tissues (such as Mersilene, Teflon, PTFE). Polypropylene has low erosion rates and proven inertness, even in the presence of infection (Iglesia et al. 1997). It is the preferred material for reconstructive vaginal surgery.

Whatever the material, a mesh should not fray when trimmed because the frayed parts may exit through the vaginal epithelium to cause dyspareunia, or even perforate an organ to cause a fistula.

Mechanical Properties of Various Tapes

Both monofilament and multifilament tapes have been successfully used in incontinence surgery.

Monofilament mesh (fig 4-09) is very distensible, has thicker fibrils (100-150 μ) than multifilament mesh, with relatively large diamond-shaped spaces between the fibrils. Monofilament mesh tape can be stretched under tension to a narrow string-like configuration. This stretching under tension greatly increases the pressure (force per unit area) that is applied, so that soft atrophic tissues such as the urethra may be easily transected (as reported by Koelbl et al (2001)). A distensible monofilament tape must always be set loosely under the urethra when used in stress incontinence surgery.

Multifilament mesh (fig 4-10) has more and smaller fibrils (20-30 μ) and smaller spaces between the fibrils than monofilament tape. It is also softer and non-distensible.

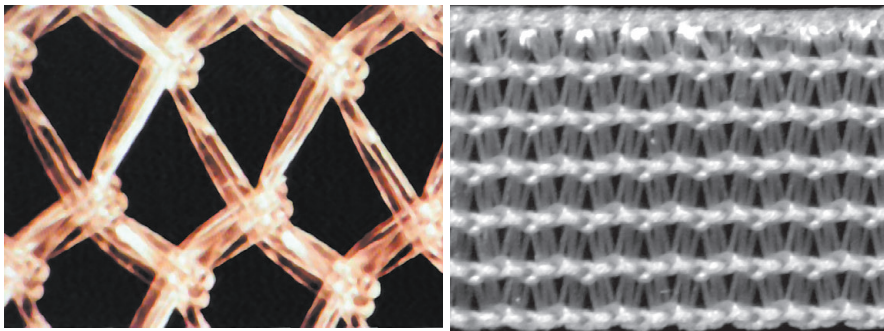


Fig 4-09 (Above left) Monofilament tape. The monofilaments are 100-150 microns thick. The spaces are relatively large. The diamond-shape allows the tape to be stretched into thin string which may transect the urethra.

Fig 4-10 (Above right) Multifilament tape. The tape is soft, non-elastic and non-distensible, and applies a smaller force per unit area to the urethra. The filaments are 20-30 microns thick. The spaces are 55 to 75 microns, significantly smaller than monofilament tape.

Multifilament mesh has a greater surface area to apply to the urethra, thereby vastly diminishing the pressure applied (force per unit area) and thus the possibility of perforation is reduced. When used in stress incontinence surgery, multifilament needs to just touch the urethra without indentation to be effective.

"Next generation" macropore monofilament tapes

More recently, non-stretch purpose knitted, "next generation" tapes with smaller diameter fibrils have been developed. More evidence is required, however to determine whether there is any significant reduction in foreign body reaction.

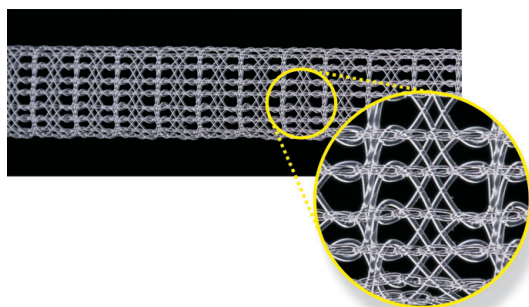


Fig. 4-11 The TFS tape, an example of 'next generation' non-stretch monofilament tape. Such tapes are purpose knitted, not cut from sheets, with finer fibrils, and less weight per unit area. They do not fragment, and are less likely to surface in the wound.

The Impact of Fibril Diameter on Tissue Reaction

The multifilament fibrils (20-30 microns) elicit much smaller individual tissue reactions and create a collagenous cylinder which surrounds the tape with fine, interconnecting collagen or glycosaminoglycan fibrils. The thicker monofilament fibrils (100-150 microns) create a much denser collagen reaction around fibrils, a characteristic which may make surgical removal difficult. A multifilament tape is much easier to remove because it is encased in a collagen cylinder.



Fig. 4-11a A 'monofilament tape' becomes densely adherent to organs, and is difficult to remove.

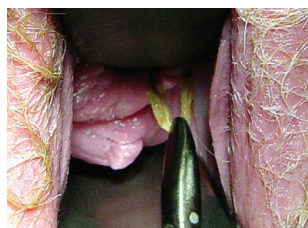


Fig. 4-11b A 'multifilament tape' is covered by collagen and is easily removed.

The Impact of Time on Tissue Reaction

Baessler et al (2005), Balakrishnan (2007) reported patients presenting with sterile abscess caused by delayed foreign body reaction to the IVS "multifilament" tape.

Ward and Hilton (2008) reported an additional 3% (3/98) monofilament erosions at 5 year TVT review. None of this is surprising. All mesh/tape implantations are foreign bodies, and like a splinter, may be rejected. Any pain experienced by the patient is a consequence of the redness and swelling accompanying the foreign body reaction, and, again, like a splinter, settle immediately the tape is removed. Any pus or abscess is invariably sterile. It is emphasized that foreign body inflammations are benign, and are different to bacterial infections, which may not be benign.

The Impact of Weave Density

Testing of monofilament and multifilament tapes at the School of Materials Engineering, University of Western Australia (unpublished data, 1999), showed that the multifilament tape was twice as dense per surface area as the monofilament tape, suggesting that a denser tissue reaction is more likely. This was confirmed histologically (Papadimitriou et al 2005).

In terms of the Integral Theory, the type of fibrotic reaction elicited by a non-stretch tape is advantageous in ligament reconstruction because the ligaments are anchoring points for the three directional muscle forces that are the key to the structural integrity of the pelvic floor (fig 1-12).

A different type of scarring reaction is sufficient if relatively large sheets of mesh are used for repair of rectocele or cystocele. The pressures (forces per unit area) acting on fascia are far smaller than those acting on the suspensory ligaments, so only minimal fibrous tissue reaction is required.

The Significance of the Size of the Interfibril Space

Without providing experimental evidence, Amid (1997) stated that a space between fibres greater than 10 microns is required for macrophages to penetrate mesh spaces, and that a space of 75 microns is required for a fibrovascular bundle. However, Papadimitriou et al (2005) have demonstrated experimentally that multifilament fibrils were surrounded by macrophages two weeks after implantation (fig 4-18) and fibrovascular bundles were penetrating between spaces often <5 microns (figs 4-13, 4-15). It is known from electron microscopic studies that macrophages can traverse interendothelial spaces which may have a diameter of less than 1 micron (fig 4-11) (Papadimitriou et al 1989). This capacity is achieved by shape distortion and development of thin 'lamellopodia'.

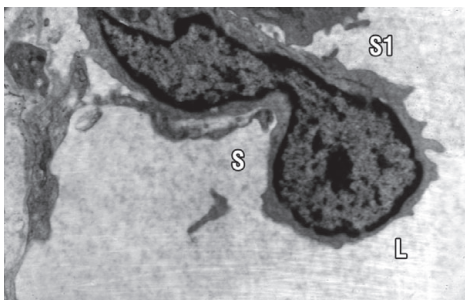


Fig 4-11c Electron microscopic image showing that macrophages can traverse interendothelial spaces, S-S1, which may have a diameter of less than 1 micron by development of thin 'lamellopodia' (L) (Papadimitriou et al 1989).

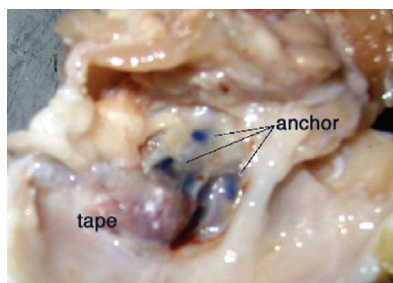


Fig. 4-12 Fibrous tissue at 2 weeks. This shows how tissue encapsulates the polypropylene anchors of the TFS system

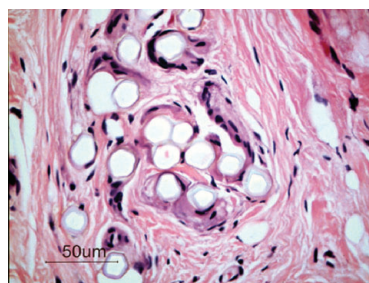


Fig. 4-13 Fibrous tissue at 2 weeks. Shows how macrophages and fibrovascular tissue have infiltrated the microfibrils of a multifilament polypropylene mesh at 2 weeks

Histological Patterns

Experimental work on animals with the Tissue Fixation System (TFS) (figs 4-12 & 4-13) and, previously, Petros & Ulmsten 1990) confirmed Harrison's descriptions. This work showed that fibrous tissue encapsulates the polypropylene anchors of the TFS system at 2 weeks.

The Nature and Behaviour of Foreign Body Reactions

A foreign body inflammation is benign, irrespective of the amount of tissue reaction. A mature foreign body reaction is characterized by the presence of macrophages and multinucleate giant cells (figs 4-14 & 4-15). It was found that the intensity of tissue reaction varies according to the volume of the implant. It also varies markedly from patient to patient, from minimal to copious sterile pus (Petros PE, Doctor of Surgery thesis, 1999). A sterile tape abscess is rare and is an extreme foreign body inflammation, not dissimilar to a splinter abscess. The pain caused by tissue distension disappears on removal of the foreign body.

Figures 4-14 to 4-17 are derived from histological study of mono and multifilament meshes in the human by Papadimitriou at the University of Western Australia (Papadimitriou et al. 2005). The slides were stained for collagens 1 and 3 and proteoglycans. The collagen 1 fibres were found to be somewhat thicker and more tightly compacted forming a cylinder around the multifilamentous mesh. This indicates that the quantum of collagen formation is directly proportional to the density of the mesh (ie more mesh = more collagen). The collagen cylinder greatly facilitates the tape removal. In contrast, the dense collagen around the 150 micron fibres of a multifilament tape may embed into the organ and may be difficult to remove.

Proteoglycans, (fig 4-17), and even some argyrophillic fibres (collagen 3 fibrils) were found between the multifilaments, proof that connective tissue is deposited between the multifilaments and macrophages (fig 4-18). It is known that Type 3 collagen is the collagen that is secreted by fibroblast early in the process of repair and is generally degraded by macrophages and fibroblasts as the wound ages. Its presence in a 2 year old implant may indicate a certain plasticity in the implant.

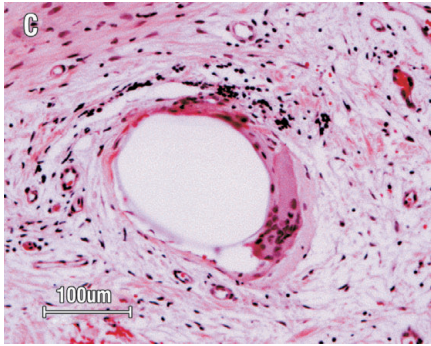


Fig. 4-14 Connective tissue in the vicinity of the monofilamentous mesh. Note the relatively small, poorly compacted collagen bundles, the large multinucleate giant cells apposed to the monofilamentous mesh and the presence of inflammatory cells in the adjacent connective tissue.

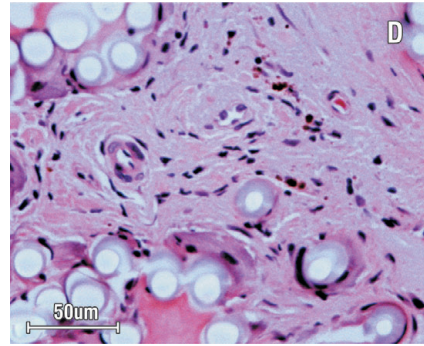


Fig. 4-15 Connective tissue in the vicinity of the multifilamentous mesh. Note the relatively thicker, more compacted collagen bundles. Small multinucleated cells are apposed to the components of the multifilamentous mesh. Amorphous pink coagulum (proteoglycan) can be seen in interstices. Only a few inflammatory cells are present in the adjacent connective tissue.

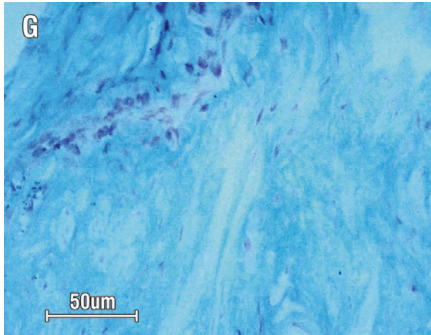


Fig. 4-16 Alcian blue stain showing the presence of proteoglycans in the connective tissue adjacent to the monofilamentous mesh.

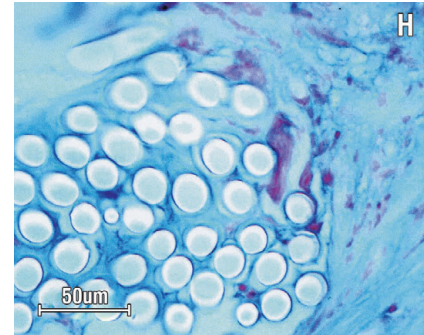


Fig. 4-17 Alcian blue stain showing the presence of proteoglycans between the interstices of the multifilamentous mesh as well as in the adjacent connective tissue.

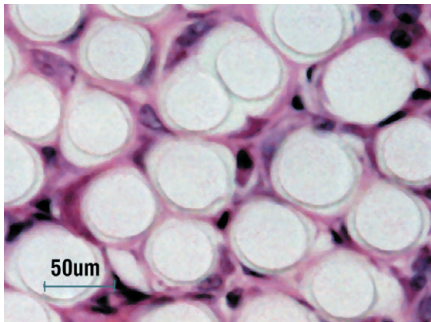


Fig. 4-18 (left) Macrophages surrounding multifilament fibrils. Rat specimen, 2 weeks after implantation. The microfibrils are surrounded by macrophages, proteoglycans and collagen III. (Papadimitriou J. and Petros, PE, (2005)).

Repair of Damaged Fascia

There are two types of fascial damage, discrete tears in the rectovaginal and pubocervical fascial sheets, and homogenous overstretching thereof. It is not always possible to distinguish between the two types of damage. Whereas it is possible to directly repair a break in the fascia, direct repair to an overstretched sheet of fascia is not likely to be as successful.

The Critical Role of Optimally Tensioned Fascia to Restoration of Organ Function

4

A striated muscle contracts only over a fixed distance. Any laxity 'L' (fig 4-19) means that the vaginal membrane cannot be fully stretched, so that the function determined by those muscles will be suboptimal. So any of the symptoms detailed in the Pictorial Algorithm may persist, even though the implanted mesh may act as an effective barrier to further prolapse. For example, inability to stretch the vagina sufficiently to support 'N' (fig 4-19) may result in persistence of urge and frequency symptoms.

Because the vaginal fascia transmits the striated muscle forces which activate organ opening and closure, it is important to restore the original tension of the fascia, if organ function is to be restored. Figure 4-20 illustrates the prolapsed state of the fascia 'F'. In such a case, any mesh applied as a passive barrier will not restore function *unless* the natural tension of the fascia is also restored. This means that the laterally displaced fascia should be approximated towards the midline prior to placement and attachment of the mesh. If the the fascial or mesh sutures do not tear out within 10 to 14 days the fibrogenesis induced by the mesh will strengthen the fascia, which will then 'set' in the restored tensioned position.

However, it is risky to rely on sutures to apply tension to mesh. It is extremely difficult technically and inaccurate (in terms of achieving the optimum tension).

More recent whole-mesh replacement techniques use a mesh that has four 'arms' attached to address the problem of anterior vaginal wall prolapse. The four 'arms' are threaded through the supero and infero-medial borders of the obturator fossa, and then pulled to apply tension to the mesh. This method has potential limitations because it is not a natural anatomical restoration.

A mesh attached to a posterior sling is used to address posterior vaginal wall prolapse. This method has limitations because of the inability to tension laterally displaced recto vaginal fascia.

The TFS system uses a soft-tissue anchor with a built in mechanism that allows the tension of the tape to be adjusted. This method can accurately restore fascial tension in any part of the anterior or posterior vaginal wall (fig 4-21).

Direct repair of fascia

Preservation of spaces between the organs is important to allow their independent movement. Excision of excess tissue (red circles, fig 4-22) may only intensify mesh scarring, and cause organ adhesion. It is safer to excise no tissue at all, and to simply reposition any excess tissue.

Even with surgeons who favour mesh implantation, the first question which must be asked is, 'does this patient really need mesh reinforcement of the vaginal repair?' In

the author's experience, in patients who have not had previous surgery, it is possible to repair most types of fascial damage without any mesh implantation and still achieve an acceptable success rate.

Reinforcement of fascial tissue using homologous tissue, mesh sheets or heterologous tissue

Use of Homologous Tissue to Reinforce Fascia ('Bridge repair')

In a 'bridge repair' the excess tissue from a rectocele is used to create a double layer of tissue over the central part of the herniation, its weakest part (fig 4-23a to fig 4-23c). This also brings together the laterally displaced fascia (F) (figs 4-24a & b). Allis forceps are placed on the right and left sides of the vaginal wall and brought to the centre so as to determine the width of the bridge incision. This is an important step because an overly wide bridge may lead to excessive tension, tearing, and post-operative herniation. Once the length and width has been assessed, a full thickness, leaf-shaped 'bridge repair' is cut into the vaginal wall (fig 4-23a). The 'bridge repair' surface is cauterized to destroy the surface epithelium. The superior part of the 'bridge repair' is attached to the fascia around the uterosacral ligaments, or anchored with a posterior sling tape. Inferiorly it is attached to the perineal body, and laterally it is attached to the underlying fascia with interrupted absorbable sutures (fig 4-23b). If required, a transvaginal 'holding suture' can be used to help retain the tissues in position while the scar tissue strengthens (fig 4-24b).

The 'bridge repair' is especially useful for the posterior vaginal wall, but it should only be used where there is excess vaginal tissue which would normally be excised. A 'bridge repair' can also be used in the anterior vaginal wall. However, if there is a paravaginal defect as well as a central defect, a post-operative recurrence involving the whole anterior wall may emerge weeks or months after surgery. Although there are few glands in the vagina, retention cysts may occur many months later in up to 5% of patients. This is treated by aspiration or excision of the cyst and repair of the vaginal wall.

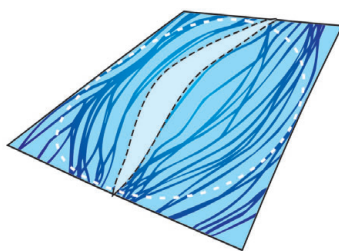


Fig. 4-23a 'Bridge' repair. A 'bridge' between 1 and 2cm wide is created by full thickness vaginal incisions.

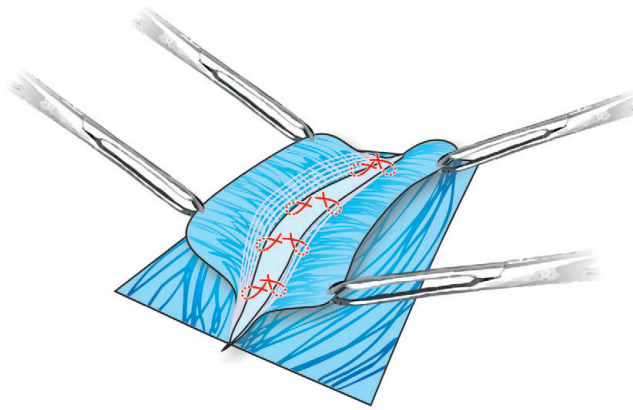


Fig. 4-23b 'Bridge' repair. A full thickness leaf-shaped ellipse is cut into the posterior vaginal wall. The lateral vaginal walls (V) are then sutured over the 'bridge'. The ellipse is sutured laterally to healthy fascia with interrupted sutures.

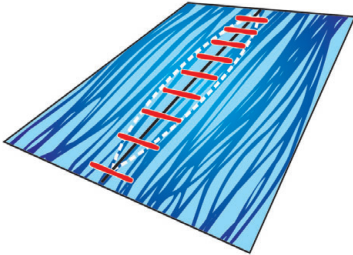


Fig. 4-23c The 'bridge' is covered by approximation of the vaginal edges.

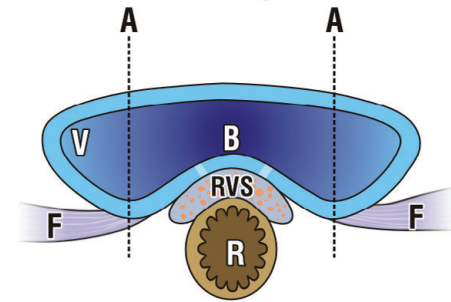


Fig 4-24a (left) Incisions for 'bridge repair' - transverse section. Incisions are made to create the bridge (B). F = laterally displaced rectovaginal fascia, position demarcated by 'A'. RVS = rectovaginal space; R = rectum; V = vagina.

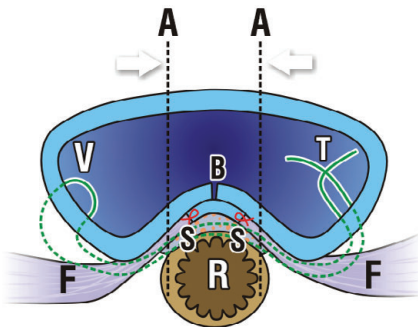


Fig 4-24b (left) 'Bridge repair' completed. The bridge (B) is attached laterally to fascia (F) by sutures (S). Note approximation of 'A' to 'A'. T = transvaginal holding suture.

Use of Mesh Sheets to Reinforce Fascia

Where the fascial layer has been weakened by age or previous surgery, there may be little option but for the surgeon to use mesh sheets or porcine dermis to reinforce the thinned out fascia.

It is probably best to use mesh sheet only where previous surgery has failed to repair the condition. In such cases, especially when the whole membrane is thinned out, there is often little musculofascial tissue available to create underlying support.

One technique is to cut the required size of mesh with two elongations placed below the pubic bone into the Space of Retzius, or to use various configurations which pass through the obturator membrane. The bottom end may be rounded to minimize erosion or viscus perforation. Many surgeons prefer to leave the mesh 'tension-free', and they advise a wide dissection to free the bladder or rectum from vaginal tissue laterally so that the mesh is held in place by tissue pressure. Others prefer to suture the mesh laterally and to the cervical ring posteriorly. In this case, the mesh must be sufficiently large to extend laterally towards the ATFP without stretching. The anterior border of the mesh should be 1cm behind the bladder neck so as to not interfere with the bladder neck closure mechanism (c.f. 'tethered vagina syndrome', this chapter).

The use of mesh is still controversial in some quarters. For instance, Milani et al (2004) advised against mesh implantation during vaginal surgery. They reported up to 13% vaginal erosion rates, a 63% increase in dyspareunia, and a 20% decrease in sexual activity following mesh implantation during vaginal repairs.

The histology of mesh implants is identical to that for tapes, as described earlier.

Use of Heterologous Tissue to Reinforce Fascia

Only acellular porcine tissue is addressed here: cadaveric fascial tissue cannot avoid the criticism of transmissible viral diseases, an issue which must impose an attitude of zero tolerance to its use.

When used to reinforce fascia, porcine skin or intestinal mucosa is treated so that all cellular tissue is removed. It is then manufactured into thin sheets which can be used as an alternative to polypropylene mesh. Porcine tissue is said to avoid many of the complications encountered with mesh, for example, surfacing, inflammation, infection, dyspareunia. Short and medium-term success rates from use of porcine tissue have been reported. However, there are complexities, as the efficacy of a heterologous tissue implant for a particular patient is species, donor, site and age dependent. Animal collagen may only be 85% homologous with human collagen (Peacock 1984). These are fundamental immunological issues and raise some concerns about the long-term viability of this material.

*Repairing Damaged Fascia: Ongoing and post operative considerations**Possible Effects of Long-term Change in the Properties of Collagen*

Collagen stiffens and contracts with age (Peacock 1984). The collagen of a 70 year old is 4 times stiffer than that of a 25 year old. A suburethral sling may contract with time and present many years later as urethral obstruction. The scar tissue around large mesh in the vagina may also contract years later to restrict the free movement between rectum and vagina. Therefore care needs to be taken with the selection and placement of mesh so as to avoid future long-term complications.

Fistula

The pelvic organs are constantly moving. So mesh may move or tear out even if sutured, resulting in surfacing, erosion, or fistula. If the mesh is too narrow, it is more likely to fold and penetrate a viscus, bladder or rectum. The fibrosis from such a perforation is intense, and repair requires a wide dissection so as to restore mobility to the bladder and vagina, a pre-requisite for operative success of the fistula.

Adherence of One Viscus to Another.

The organs are densely bound only at their distal 3 cm. Beyond that distance, they need to be able to slide on each other. Large sheets of mesh may cause dense fibrous adherence between rectum and vagina, or vagina and bladder base. This may lead to dyspareunia, or even abnormal function in the longer term given that collagen scarring stiffens and contracts with age.

Mesh Rejection

Mesh 'rejection' may be due to surfacing, foreign body reaction or sometimes, infection. Its incidence varies between 3% and 28% (Von Theobald P, and Salvatore, S., Pers. Comm.).

All implanted materials cause a foreign body reaction, which may vary widely in its intensity. A foreign body reaction and infection are both defined as inflammatory reactions. Historically, John Hunter differentiated between a foreign body reaction and infection. He defined the former as "adhesive inflammation", and the latter as "suppurative inflammation". Whereas a foreign body reaction is relatively benign, a tissue infection may not be. Before the diagnosis of infection can be made, a significant bacterial culture (>1,000,000 organisms/mg) is required, (Van Winkle and Salthouse, 1976). Tapes and mesh entirely rejected by a foreign body reaction or infection are surrounded by fluid, and usually pull out easily if totally rejected. Total rejection is more common with nylon or polyester (Mersiline) tapes. It is less common with polypropylene tapes.

Surfacing

In the first 48 hours after an operation, there is an efflux of fluid around the tape, similar to a wound reaction. In some patients, this may lead to 'slippage', usually minimal at this early stage. If the tape is close to the vaginal scar, the foreign body reaction to the tape may cause dissolution of the scar. This may lead to surfacing of the tape some weeks or months after surgery, especially in patients with weak or thin vaginal tissue. Sometimes there is no granuloma formation or vaginal discharge. Such 'surfacing' may become re-epithelialized spontaneously in time.

Tightening the overlying fascia of the hammock anteriorly and the uterosacral ligaments (USL) posteriorly will hold the tape in position and create a barrier between the tape and the vaginal scar. Restoring hammock tightness will also give an improved cure rate for SI and Intrinsic Sphincter defect (ISD) because of their contribution to the urethral closure mechanism. Uterosacral ligament tightening is likely to give a higher cure rate for 'posterior fornix syndrome' symptoms.

Granulomatous Erosion into the Vagina

Tape or mesh erosion in the vagina, where accompanied by granulation tissue, is almost always a foreign body reaction. It is usually a minor problem which can be dealt with as an office procedure in most cases by trimming the extruded segment. Individual patient's immunological systems reacted very differently to an implanted Mersilene tape with its ends left free in the vagina (figs 4-25, 4-26) (Petros Doctor of Surgery Thesis 1999). In that study, it was found that, at six weeks, some patients had very little granulation tissue. Others had moderate amounts and a few had a sterile purulent reaction. Yet no patient had a raised temperature or white cell count. Swab and bacteriological culture of vaginally extruded tapes during anterior and posterior sling surgery rarely grew bacteria (Petros 1990, 1996, 1997, 2001), even when bacteria were detected on the tapes by gram staining, a not unexpected finding, given the abundance of bacteria in the vagina.

Van Winkle and Salthouse defined bacterial contamination in their 1976 monograph (Ethicon):

"It is important to distinguish between contamination and infection. Contamination exists when bacteria are present, but their numbers are not so great that the body defences cannot dispose of them locally. Infection exists when the level of contamination reaches a point where local tissue defences cannot cope with the invading bacteria. It has been shown that the level at which contamination becomes infection for most organisms is about 1,000,000 bacteria per gram of tissue. Contaminated wounds can be converted to infected wounds when necrotic tissue, devascularised tissue, blood clots, etc., are present. Bacteria can multiply in such circumstances, safe from the cells that provide the local tissue defences."

It follows (from Van Winkle 1976) that the presence of a few bacteria on a tape implanted in healthy tissue are unlikely to be a factor in its rejection, whatever the configuration of the tape, as any bacteria will be 'mopped up' by macrophages on an ongoing basis. Findings of proteoglycans and macrophages between the fibrils of multifilament tapes (figs 4-17, 4-18) provide further evidence that macrophages and fibroblasts have penetrated between the fibrils and laid down connective tissue. This makes the 'concealment' of bacteria between fibrils (as asserted by Amid (1997), unlikely.

The erosion rate for polypropylene tape in patients undergoing stress incontinence surgery is approximately 1-3%. This complication very rarely causes major problems, such as abscess. Tape slippage and mechanical factors may be important factors in tape erosion. Thin vaginal tissue will more easily allow the tape to surface.

When a tape erodes or surfaces into the vagina, the first sign is usually a thick yellow painless discharge. The site of erosion can usually be identified by an area of granulation tissue which forms around the tape (figs 4-25, 4-26), although sometimes the tape surfaces without any erosion at all. The patient is almost invariably afebrile, with normal white cell count. It is rare to culture bacteria from the tape. Histology demonstrates granulation tissue around the tape. This consists mainly of macrophages, multi-nucleated giant cells, lymphocytes and neutrophils. The granulation tissue is

surrounded by a layer of collagen (figs 4-25, 4-26). To remove the extruded tape segment, the tape is grasped with a haemostat and stretched. A totally rejected tape pulls out easily. Once resistance is encountered, cease pulling, trim the extruded segment by placing scissors around the tape, pressing down on the vaginal surface and cutting. Pulling forcibly against a firmly implanted tape may cause trauma and a small haematoma, a perfect culture medium for abscess formation. Extreme care needs to be taken if the mesh is monofilamentous and suburethral, as it is very easy to perforate the urethra during the removal process. Removing a multifilament tape is safer and easier as it is usually surrounded by a fibrous capsule and so can usually be removed from within the capsule.

Infection

In cases of significant clinical infection, the clinician would expect to find erythema, pyrexia, raised white cell count and microabscesses on histological examination, and bacterial growth of $>1,000,000$ organisms/mg.

A low grade infection may co-exist with the foreign body reaction. Even here the clinical course is usually benign. If there is any concern about infection (a rare occurrence in my experience), bacteriological investigation of the extruded segment is appropriate, and where relevant, appropriate antibiotics administered prior to removal. An abdominal skin sinus usually originates from a vaginal granulation. In this case, the tape should be removed vaginally only, by pulling on it, but only after investigation and treatment for pathogenic bacteria. Under appropriate antibiotic cover, an incision is made exactly at midurethra and the tape is removed simply grasping and pulling on it, as it will be surrounded by fluid all the way along its track. A perineal sinus consequent on a posterior sling is removed with a vertical incision in the posterior vaginal fornix. Any sinus usually seals within 48 hours of tape removal. At all times, excision of the sinus should be avoided, as this may spread any bacterial infection contained by the collagen cylinder into the surrounding tissues. Whether, or how much, infection

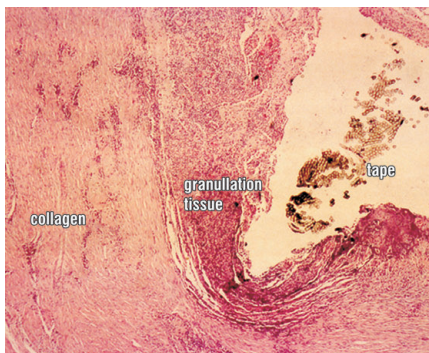


Fig. 4-25 Tape erosion in the vagina. The granulation tissue has surrounded the tape and the collagenous layer surrounds the granulation tissue.

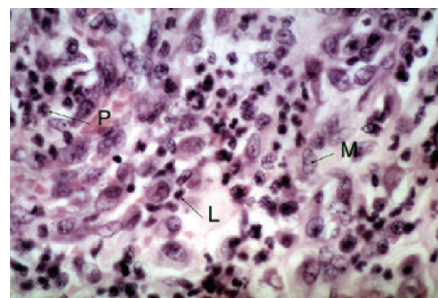


Fig. 4-26 Tape erosion in the vagina - high powered microscopic view of the granulation tissue surrounding the tape in Fig 4-10a. Note the paucity of polymorphonuclear leucocytes 'P' and the preponderance of lymphocytes, 'L' and especially macrophages, 'M'.

contributes to tape erosion is a controversial issue. It is unlikely that infection occurs in implanted tapes or meshes to any great extent in vaginal surgery because erosion rates with polypropylene tapes are generally less than 3% and abscesses are extremely rare. Research studies in animals and with humans have demonstrated that there was no clinical infection even when a tape was left with one end free in the vagina (Petros et al. 1990). This absence of infection occurs because the collagenous sheath around the tape (fig 4-07) prevents the transmigration of bacteria into the tissues.

Nevertheless, the potential for any infection from surgery may be reduced by:

- routine pre-operative vaginal swabs to identify and treat streptococci and staphylococci
- the use of intra-operative prophylactic antibiotics
- sterile surgical technique
- ensuring that the tape is inserted flat (i.e. avoiding folding or stretching)
- good haemostasis to avoid haematomas.

4.3 Application of the Integral Theory Surgical System according to Zone of Damage

In this section, the surgical approach described previously in this chapter is applied towards repair of specific connective tissue defects in the three zones of the vagina.

4.3.1 Surgery of the Anterior Zone

The Structures of the Anterior Zone

The Anterior Zone extends between the external urethral meatus and bladder neck. The urethral tube lies entirely within the anterior zone. Inability to close off the tube will result in involuntary urine loss. This may take the form of stress incontinence, unconscious seepage, etc.

The pubourethral ligament (fig 4-28) is the most important structure for control of stress incontinence, followed by the vaginal hammock and external urethral ligaments (figs 4-27 to 4-29). These structures work synergistically to close the urethral tube. As damage in each structure needs to be identified and repaired, this section begins with a description of the surgical anatomy. Figures 4-30 to 4-32 illustrate the role of the hammock and external urethral ligament (EUL) in urethral closure.

The Indications for Surgery in the Anterior Zone

Structural

In the patient with stress incontinence, significant laxity in the external urethral meatus, especially with eversion of the urethral mucosa is an indication for repair of EULs. Similarly a 'urethrocoele' (hammock laxity) should also be tightened as urethral closure 'at rest' is effected by slow twitch fibres stretching an adequately tight hammock along its length. A flat sulcus indicates the connective tissue between the vaginal hammock and adjacent pubococcygeus muscle may need repair via two paraurethral incisions.

Functional

Stress incontinence controlled by the midurethral anchor test is a prime indication for a suburethral sling; a symptom of intermittent ‘unconscious leakage’ is a symptom of intrinsic sphincter defect (ISD). Laxity in some, or all, of the three connective tissue structures (fig 4-28) may be major contributory causes of ISD. ‘Motor urgency’ may occur especially in older patients when the PUL atrophies to a point where the outflow tract is forcibly pulled open by the backward/forward directional forces (LP and LMA), for example, when a patient is getting up from a chair, as illustrated in figure 4-30.

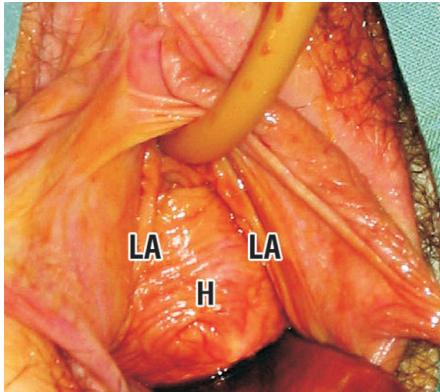


Fig. 4-27 A lax suburethral vaginal hammock (H). View into the vagina in a live patient. ‘LA’ indicates the position of the anterior portion of pubococcygeus muscle (PCM).

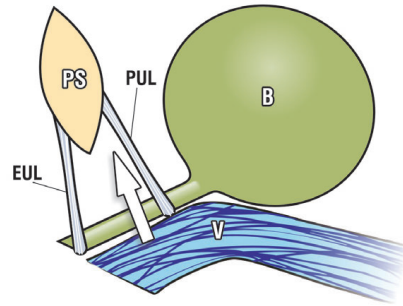


Fig. 4-28 The urethral closure mechanism. The vagina ‘V’ is pulled forwards towards the bone by the anterior portion of pubococcygeus muscle (arrow) pulling against the external urethral ligament (EUL) and the pubourethral ligament (PUL). Laxity in EUL, PUL or V may invalidate the closure force by the muscle.

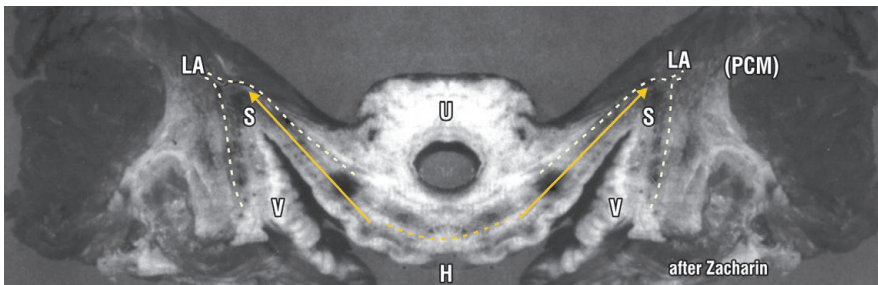


Fig. 4-29 Coronal section of vagina. Note how the vagina (V) is attached at the sulcus (S) to the anterior portion of pubococcygeus muscle (LA). The arrows indicate the directional movement of the hammock ‘H’ to close off the urethra from behind. S = paraurethral sulcus. Cadaver, after Zacharin (1961), by permission. The hammock closure mechanism was demonstrated with ultrasound (figs 4-31 & 4-32) in 1990, and it was confirmed by DeLancey in 1994.

The Methods: Strengthening a Weakened Pubourethral Ligament with a Tape

If the pubourethral ligament is weak, LP and LMA may stretch open the outflow tract from 'C' (closed) to 'O' (open during effort) (fig 4-30). The tape is used to reinforce the pubourethral ligament (figs 4-30). The levator plate muscle (LP) stretches the urethra backwards against the tape. This action tensions the trigone. The trigone extends to the external urethral meatus and acts as a 'splint' for the hammock during closure by PCM. Therefore the vaginal hammock needs to be adequately tight for adequate closure to take place.

If either the hammock or tape is excessively loose, the operation may fail, allowing the urethral diameter to be stretched open from 'C' (closed) to 'O' (open during effort) (fig 4-30). Conversely, excessive tightness of the sling may cause urethral constriction. Rotation of the trigonal plane around the tape is activated by LMA, which relies on an adequate uterosacral ligament for the downward force to work properly. This mechanism explains the improvement frequently seen in stress incontinence symptoms after the posterior sling operation.

The aims of anterior zone defect repair are to reinforce PUL by implanting a tape *without constricting* the midpart of urethra, to tighten the vaginal hammock (H) if loose, and to anchor the external meatus by shortening its anchoring ligaments (EUL) if they are also loose. A firm EUL is needed for bulbo and ischiocavernosus muscles to anchor the meatus, and for proper functioning of the hammock closure mechanism (fig 4-32).

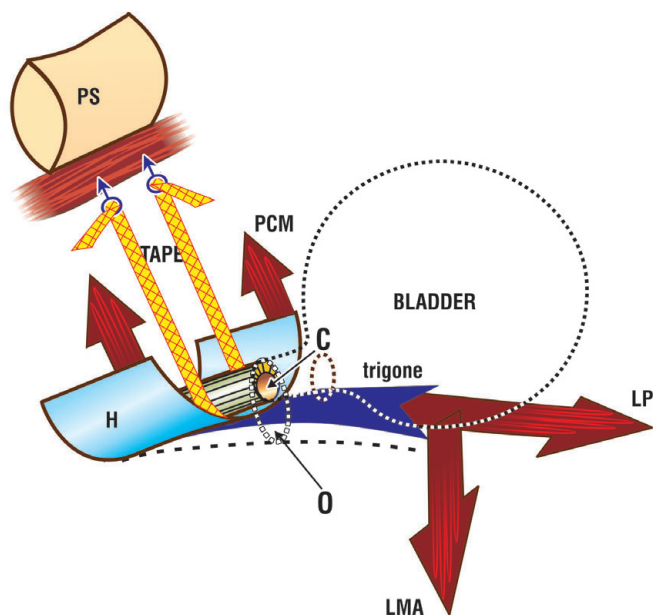


Fig. 4-30 Subpubic TFS – A polypropylene mesh tape sited at midurethra reinforces the pubourethral ligament (PUL) by providing a firm anchoring point for all muscle forces (arrows). If PUL is weak, the posterior muscle forces (arrows) may forcibly open the urethra from the closed position 'C' to the open position 'O'. H = vaginal hammock.

Rationale for Repairing External Urethral Ligament (EUL) and Hammock

Urethral closure occurs distally (fig 4-32). Usually one, but at most two extra sutures are required to tighten the hammock and EUL. If there is intrinsic sphincter defect (ISD) (maximal urethral pressure less than 20 cm H₂O), then also repairing both the hammock and the external urethral ligament (EUL) may be critical as success will undoubtedly be higher if a full restoration of anatomy is made. In a subgroup of 11 patients, a cure rate of more than 90% was obtained for patients with ISD, higher than the main group (cure rate 88%) (Petros 1997).

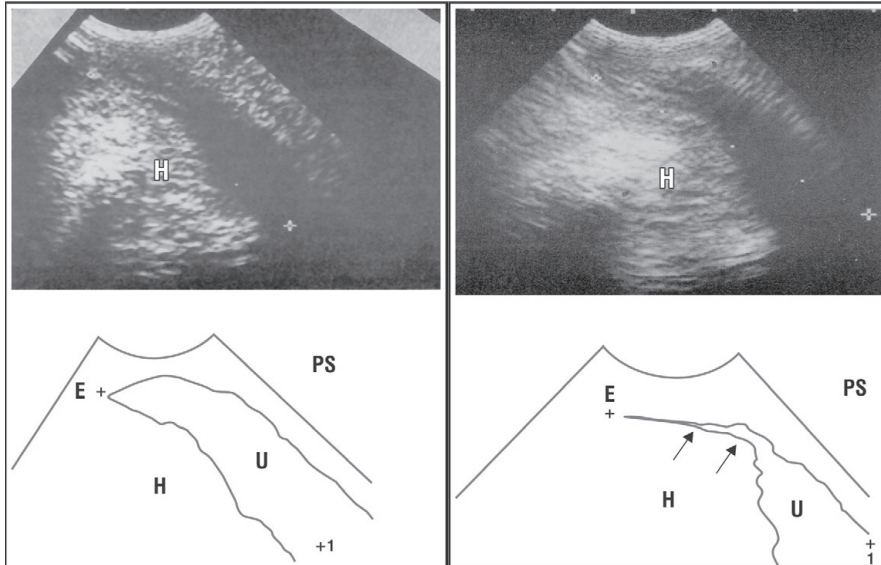


Fig. 4-31 At rest – This is an abdominal ultrasound in a continent woman. E= insertion of external urethral meatus, (external urethral ligament). U = urethra; PS = pubic symphysis; H = hammock. (From Petros & Ulmsten, 1990))

Fig. 4-32 Straining – The arrows demonstrate how the urethral cavity (U) is closed by muscle forces acting on the attached vaginal wall from behind (arrows). ‘E’ denotes the attachment of the external urethral meatus to pubic symphysis (PS). Clearly, if ‘E’ is loose, then distal closure may be compromised.

*Surgical Technique for Repair of the Anterior Zone Anatomy**‘Tension-Free’ Suburethral Sling*

The main indication is for cure of stress incontinence. A polypropylene sling is inserted in a ‘U’ shape, below the mid-point of the urethra, to the level of the rectus sheath (fig 4-33) (Petros & Ulmsten 1993, Petros 1996, 1997, Ulmsten et al. 1996). The tape can be inserted via an abdominal or a vaginal approach using a number of commercially available delivery instruments. The hammock should be adequately tensioned. The difference between continence and incontinence may only be 2 mm. Accuracy is critical.

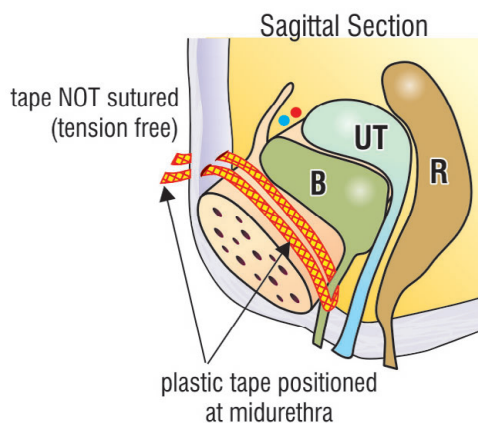


Fig. 4-01 'Tension-free' midurethral sling reinforces the pubourethral ligament (Petros and Ulmsten 1993).

Slippage of tape to the bladder neck is a cause of post-operative retention. If slippage is likely in a particular patient, suture the tape into the paraurethral tissues on one side with a 2-0 Dexon suture.

Four approaches to the 'tension-free' suburethral sling are presented below: the midline vaginal approach, the suprapubic approach, the paraurethral approach and the trans-obturator approach.

Midline Vaginal Approach

A catheter in the urethra is used as a splint to lessen the possibility of urethral perforation. Place the vaginal epithelium under stretch. Make a full thickness incision in the midline from meatus to midurethra (figs 4-34, 4-34a). Dissect between vagina and urethra laterally with scissors. Proceed with perforation of the diaphragm with scissors between the periosteum and subpubic ligaments, creating a space approximately 6mm in diameter, sufficient for entry of the delivery instrument. The description below applies to all vaginal delivery systems.

Making a hole in the perineal membrane is the most critical step, no matter which delivery instrument is used, because it confers built-in safety to what is, essentially, a blind procedure. The hole prevents excessive thrust and allows perfect control of the instrument at all times, helping avoid the major complications of this procedure, bladder and major vessel damage. Furthermore, if the subpubic venous sinuses are breached, this can be identified because the bleeding flows out through the hole. The bleeding can be controlled by applying digital pressure for three minutes against the pubic bone from below.

Once the tip of the delivery instrument has entered the diaphragm, move the delta wing handle so it is horizontal. This is another critical step, as the external iliac vessels may be only 1.5-2 cm lateral to the exit point of the delivery instrument. The instrument can only move upwards if the delta wing is horizontal. No pressure is applied against the posterior part of symphysis pubis.

Use fingertip pressure only to gently roll the tip of the instrument over the posterior surface of the pubic bone. This vastly reduces the incidence of bladder perforations. A resistance is met at the level of the rectus sheath. At this point sufficient pressure is applied to 'pop through' the tip. The insert is left *in-situ*, and the procedure is repeated on the contralateral side.

With both inserts now *in situ*, the bladder is filled with 500 ml of saline and a cystoscopy is performed. A volume of 500 ml is required to distend the bladder sufficiently to ensure there are no folds obscuring any perforation. Care is taken to search especially around the air bubble at the 11 and 1 o'clock positions, the most common perforation sites.

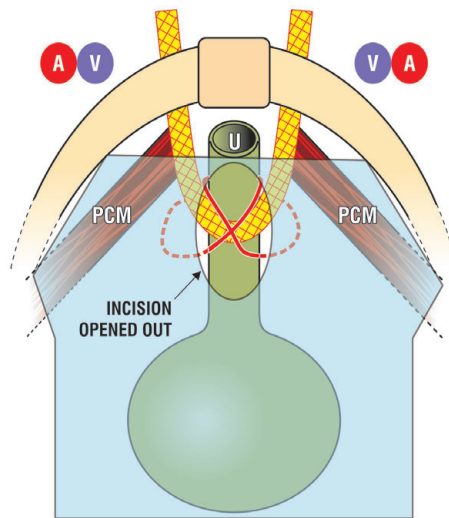


Fig. 4-34 Midline incision. Hammock tightening supports the tape from below. Perspective: Looking into anterior vaginal wall

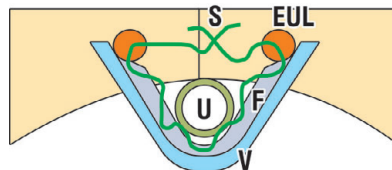


Fig. 4-34a Hammock suture (S). The vaginal fascia 'f' is tightened so the vagina functions as a buttress just below the urethra. Lax EUL is tightened by approximating hammock fascia 'f', and both EULs below the external urethral meatus. Note how the urethra is displaced upwards towards the pubic symphysis (P). Perspective: Coronal section level of external urethral meatus.

Childhood urge incontinence caused by a lax PUL- cure with a midurethral sling Miss 'X', a 21year old nullipara presented with severe urge incontinence since childhood, requiring 3-4 pads per day. Though the patient admitted to occasional slight stress incontinence, there was no demonstrable urine loss even with 10 coughs in the upright position with a full bladder. 24 hour pad loss was 90.4 gm. Transperineal U/S demonstrated rotation and a bladder base descent of 17.7 mm, but no funnelling. Overactive bladder was diagnosed on urodynamic testing. Residual urine (catheter) was 2ml. Unilateral digital pressure at midurethra ("simulated operation"), totally relieved the sensation of urgency. A midurethral "tension-free" polypropylene tape was inserted. Immediately after surgery, the patient reported 100% disappearance of her urge incontinence symptoms, and also, her stress incontinence symptoms. On post-operative ultrasound, bladder base descent was 9.2cm, with no rotation. The patient remained cured at last review 4 years later.

Interpretation

This case is of interest on several counts. Miss 'X' had a congenital defect, confirmation of a lax pubourethral ligament with a 'simulated operation' disappearance of urgency with digital midurethral anchoring), surgical cure in the presence of "overactive bladder", and decision to operate in a patient who intended to become pregnant sometime in the future. Total cure of urgency and stress symptoms appear to validate lax PUL as the cause of symptoms.

One significant concern for the patient, her mother (and indeed the surgeon), was to assess whether the proposed surgery would interfere with any future childbearing. Based on the anatomical knowledge of where the tape was placed, what happens to bladder base during labour (it rotates suprapubically), and previous experience (Petros, 1990, Tsia Shu Lo et al 2001, Vella et al 2007), I was able to reassure the patient and her mother that problems during pregnancy or labour were unlikely. Surgical cure in the presence of urodynamic "overactive bladder" (OAB) presents a singular validation of the recent Cochrane report (Glazener et al, 2006), that the urodynamics OAB has no predictive value in incontinence surgery.

If a non-stretch tape is used, a No. 7 Hegar dilator is inserted to splint the urethra, and the tapes are pulled up one by one. Sufficient tension is exerted to ensure the tape has no folds. At all times during this step, the dilator is pushed downwards to minimize urethral constriction. At this point, the tape is directly inspected for excessive tightness. The tape should be touching the urethra without indenting it (fig 4-35). If there is indentation, loosen the tape. The tape is left 'tension-free', and is *not* sutured in any way to the abdominal muscles.

If an elastic monofilament tape is used, a 0.5mm space should be left between the tape and the urethra to allow for subsequent retraction of the tape.

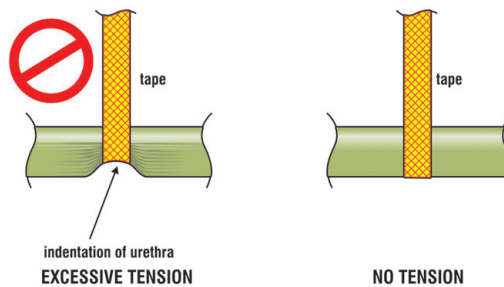


Fig. 4-35 Lateral view, non-elastic tape. The tape should touch the urethra. Touching increases the adhesive frictional force of the tape, making it less likely to surface. With an elastic tape, the surgeon has to “guess” the space which is needed to allow for elastic contraction post-operatively. Indentation is contraindicated with any type of tape, as it is likely to create obstruction. The closure mechanism works by providing an anchoring point for the 3 directional muscle forces, not by obstruction.

The Suprapubic Approach

Anatomically, the suprapubic approach is similar to the midline vaginal approach, except that entry of the application instrument is from above, downwards.

The Paraurethral Approach

The paraurethral approach was first used in the Goebell-Frangenheim-Stoeckel sling in the early 1900's. It allows a more anatomically accurate restoration in that the hammock can be re-attached to the closure muscles. It is especially indicated if the sulcus is shallow. Repair of EUL is more anatomical, as it cannot constrict the external urethral meatus. Its disadvantages are that it requires two incisions. Also a tunnel has to be made in the tissue between vaginal epithelium and urethra, something which is difficult to accomplish in patients with a deep paraurethral sulcus.

Two full-thickness longitudinal incisions are made in the lateral urethral sulcus, extending from just below the level of the external urethral meatus to the level of midurethra (fig 4-36). A Foley catheter identifies the bladder neck.

A suburethral tunnel (Tu) is created between vagina and urethra at the level of midurethra. The tape is inserted into the tunnel and brought through the anterior

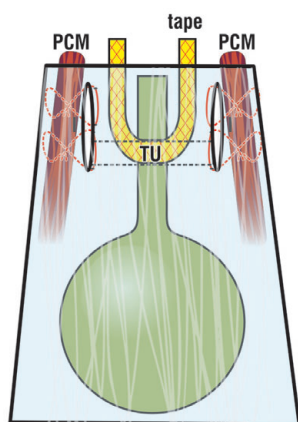


Fig. 4-36 Paraurethral vaginal skin incisions The tape passes through a tunnel 'TU' between the incisions. Perspective: Looking directly into vagina

abdominal wall with the delivery instrument. Cystoscopy is performed. The tapes are pulled up one side at a time and adjusted for tension over a No. 7 Hegar dilator.

Potential Intra-Operative Complications of Retropubic 'Tension-Free' Tape Slings

It is emphasized that inserting a suburethral sling with a delivery instrument is a blind procedure. The small bowel in the prevesical pouch (fig.4-36a), the bladder, the external iliac vessels and the obturator nerves and vessels all lie within 2 to 4cm of the track taken by the instrument. Creating a hole in the pelvic diaphragm directly below the bone and orienting the delivery instrument so it can only move upwards vastly reduces the possibility of major complications.

Bleeding

If there is bleeding from the venous sinuses (fig.4-36b) during insertion, apply digital pressure for 2 to 3 minutes. If bleeding persists, a haemostatic gel may be placed along the tape from below and digital pressure re-applied until the bleeding ceases.

Fig. 4-36a Cadaver supine position shows how an instrument inserted blindly may damage bladder, small bowel (SB) and, if too lateral, the external iliac vessels. SR = Space of Retzius; PS = pubic symphysis; I = instrument.

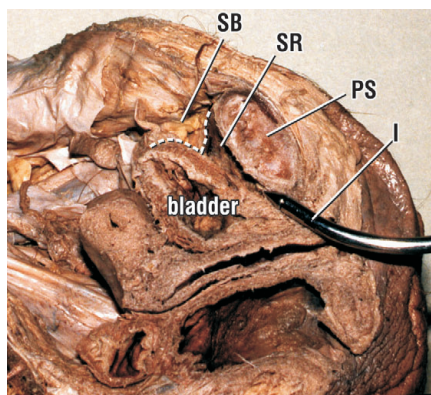
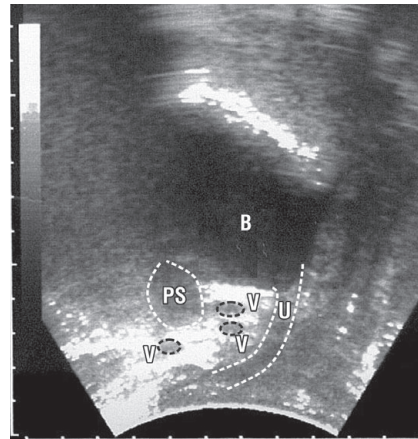


Fig. 4-36b Venous sinuses. Ultrasound sagittal position, The venous sinuses 'V' are in the direct line of approach of a blindly inserted delivery instrument. PS = pubic symphysis; U = urethra; B = bladder.



Difficulty with Passage of the Delivery Instrument with retropubic slings

It is important to open out again the retropubic channel with scissors and avoid excessive pressure on the delta wing handle as this may make the point 'dig into' the soft cartilage of the symphysis and obstruct upward movement. Always ensure the delta wing is horizontal on re-entry.

Retropubic Fibrosis from Previous Incontinence Surgery

Where there is excessive retropubic fibrosis from previous surgery, dissecting scissors may be used to create a plane of dissection between periosteum and scar tissue. Once the plane is created, continue the dissection for 2.5 to 3cm upwards. This creates a space between bone and scar tissue for insertion of the delivery instrument. If resistance continues, re-insert scissors and continue further dissection upwards, always angling the scissors towards the bone. Re-insert the delivery instrument. On rare occasions, it may only possible to insert one side of the sling. In such circumstances, attach the other side deep into the pubococcygeus muscles.

Scarring in the Rectus Sheath

If scarring from a previous abdominal operation is preventing abdominal surfacing of the delivery instrument, the surgeon may occasionally need to cut down on to the rectus sheath with a scalpel.

Urethral Constriction by the Tape

Tape constriction of the urethra can be avoided by inserting a No. 7 Hegar dilator into the urethral cavity when tightening the second limb of a non-stretch tape. If an elastic tape is used, a space must be left between the tape and the urethra. Failure to pass any urine at all within 48 hours generally indicates a tape obstruction which

needs to be surgically relieved. In the few cases that have been experienced by the author, microscopic loops were used to identify the shiny fibrils of the tape which is always under tension. The tape retracts immediately when incised gently with a sharp blade.

Bladder Perforation

4

Bladder perforation may occur in the superolateral surface usually between 11 and 1 o'clock. If this occurs, remove the tape and re-insert. Use a cystoscope with sheath and fill bladder with 500 ml fluid. Sometimes, there is no bleeding with perforation. The only sign of perforation may be the finding of a low bladder volume at the end of the operation due to extraperitoneal loss. If bladder perforation is suspected, and can't be identified, inject an ampoule of methylene blue into 500ml of saline, fill the bladder, and look for suprapubic staining at exit of tape.

Testing for Continence at the End of Midurethral Tape Operations

Adjusting tape tension during coughing was previously considered to be an important part of the operation (Petros and Ulmsten 1993). However, because of the anatomical accuracy of a three point repair (PUL, EUL and hammock), such testing for continence is less critical, and it allows the operation to be done more confidently under general anaesthetic (Petros 1999).

Trans-Obturator Approach (TOT), Delorme 2001.

In this method, special instruments are used to insert a tension-free midurethral tape, fig. 4-37. The entry point is from the medial border of the obturator fossa at the level of the clitoris. The tape is horizontally disposed, and so it is not strictly anatomical, as the pubourethral ligaments descend vertically. This horizontal placement may explain the lower cure rate achieved for ISD (Intrinsic Sphincter Defect). Advantages include avoidance of bladder perforation and small bowel injury. Potential disadvantages include damage to the obturator nerve or vessels, especially from the 'inside out' approach and to the urethra from the 'outside in' approach. There have been recent reports of major haemorrhages (De Sala et al 2007, Altman et al 2007) from the transobturator approach for suspended anterior mesh repairs, and this can be attributed to the presence of the abnormal obturator vessels, which lie directly in the path of the insertion instruments, fig. 4-37a. One complication not yet reported is paradoxical opening of the outflow tract during straining. The symptoms are identical with those of the 'tethered vagina syndrome', and are addressed in that section later in Chapter 4.

"Tension-free" minislings.

Following an incision at midurethra and a short dissection, a short length of tape, with a Vicryl pad or small anchor at each end, is forcibly inserted alongside the urethra

Fig. 4-37 Transobturator tape ‘outside in’, CT scan. From Prof Palma, by permission.

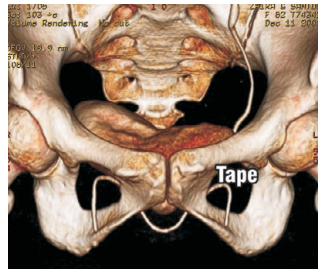
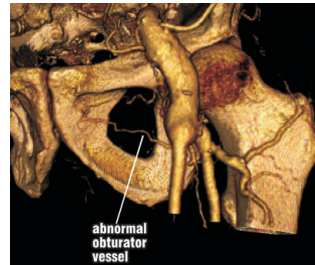


Fig. 4-37a Abnormal obturator vessels, directly in the path of the TOT insertion instruments. CT scan, from. JP Spinosa, by permission.



in a vertical or horizontal direction. There is no tightening mechanism, so the tape stays where it is placed. Preliminary results indicate that “tension-free” minislings are not as effective as the retropubic or TOT techniques. The explanation for this may lie in the short length of the tape. It does not give the same ‘grip’ as the retropubic or transobturator (TOT) approaches, predisposing to slippage and longer-term failure.

Complications

Though the experience with this type of minisling is short, already reports of post-operative urinary retention, bleeding and bladder perforation have been reported.

“Tensioned”mini sling

The midurethral TFS ‘Tissue Fixation System’, (fig 4-37b) (Petros & Richardson 2005, 2008), is identical to the 1st part of the “tension-free” midurethral sling. An 18gauge Foley catheter is inserted to measure the urethral length and act as a barrier to over-tightening. Failure to diagnose a short urethra may inadvertently lead to bladder perforation. The vagina is dissected off the urethra. A channel is made towards the lower border of pubic symphysis, and carried 1cm beyond the perineal membrane, just sufficiently for the passage of the applicator, which is triggered to release the TFS anchor. The procedure is repeated on the contralateral side. The tape is tensioned over a urethra distended by an 18G Foley catheter, and the free end cut. The vaginal hammock fascia and the external ligaments are tightened with 2–0 Vicryl sutures, fig.4-34a. No cystoscopy is required. Mean operating time was approximately 5 minutes, with all

patients discharged within 24 hours, with no urinary retention, and only paracetamol analgesia (1st report: Petros & Richardson 2005). The cure rate seems equivalent to “tension-free” slings, with little deterioration at 3 year review, (Petros & Richardson 2008). Post-operative urethral constriction is possible, but almost unknown if the tape is tightened over a non-distensible 18G Foley catheter. No significant bleeding has been reported to date.

4

Outpatient Local Anaesthetic Technique

Dr Sekiguchi from Yokohama, Japan (*J. Urol.* 2009), has used a local anaesthetic TFS technique in a free standing outpatient clinic. She achieved a 91% cure rate at 12 months in 39 patients, 40% of whom had ISD (intrinsic sphincter defect). With an LA technique, the tape can be intra-operatively tightened precisely to the point where leakage stops on coughing.

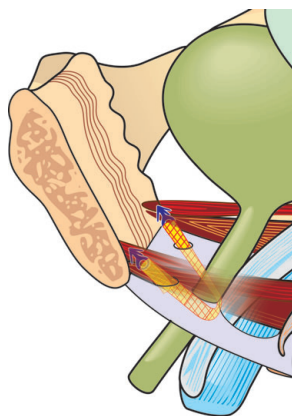


Fig. 4-37b Anatomical position of the TFS anchor. The midurethral tape is anchored into the inferior surface of the pelvic floor muscles immediately behind the perineal membrane.

EUL and Hammock Tightening

With a No. 18 Foley catheter in situ, and using the tip of a short needle, the fascial tissue is firmly penetrated on both sides from the inside with a horizontal mattress suture so that the fascial tissue is brought towards the midline (figs 4-34a & b). It is essential to avoid contact with the tape during suturing. By taking the needle into the lower end of EUL it is possible to tighten EUL and hammock using only one suture.

EUL Reinforcement with a Small Segment of Polypropylene Tape

This simple minor operation can strengthen the EUL quite effectively in patients with very loose external urethral ligaments. A vertical incision is made through the distal part of the anterior vaginal wall into the ligaments, almost to the pubic bone.

A rectangle of polypropylene tape, dimensions approximately 0.5cm x 0.8 cm is then inserted into the incision and sutured to close it off. Extrusion of the tape may occur in some cases.

EUL reinforcement with a prepubic TFS sling, fig 4-37c, box, fig 4- 37d.

With a No. 18 Foley catheter in situ, the dissection channel is carried forward between the anterior surface of the pubic bone, and its muscle covering. The anchors are inserted, and the tape tightened lightly over the catheter. There has been only one report of somatic pain from a prepubic TFS sling. Some 2 weeks after a clinically successful operation, the patient complained of a sharp pain suprapubically when sitting in a particular position. On examination, it was clear that the anchor had moved through the covering tissues to touch the inner part of the prepubic skin. Because her leakage was 100% cured, the patient decided to wait for 3 months when it was explained that there was a strong possibility that the collagen covering the anchor would change from the soft collagen III to collagen I, which is much tougher. At about 3 months post surgery, over a period of a few days, the pain disappeared completely.

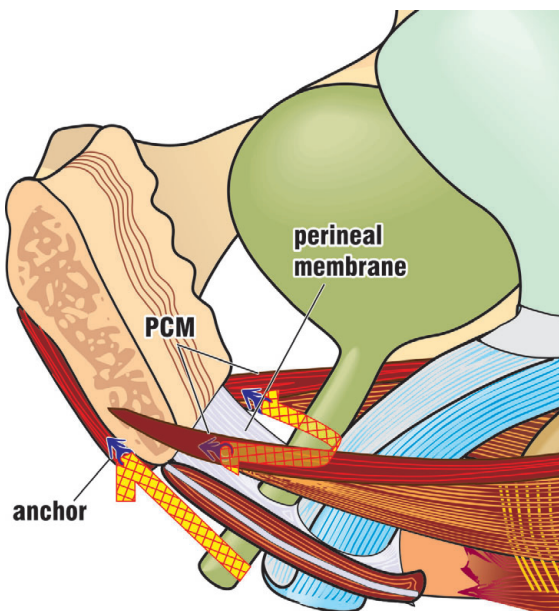


Fig. 4-37c The prepubic (external ligament) TFS tape is positioned between the muscle layer and tissue covering the anterior surface of the pubic bone. The urethral part of the tape is positioned behind the external urethral ligaments.

Case history –EUL defect.

Non-stress incontinence cured by prepubic TFS sling. A 46 year old woman who was entirely cured of stress incontinence with a midurethral ‘tension-free’ tape sling presented with symptoms of insensible urine loss, worse in the afternoon, on sudden movement or bending. She felt a “bubble” during urine loss. There was no SI with 10 coughs in the upright position with a bladder volume of 430ml. Mean 24 hour urine loss was 227 gm (range 190-265 gm). With a vaginal tampon in situ, the loss/24 hrs was mean 44gm (range 36-55 gm). A TFS pre-pubic sling was performed, to reinforce the external urethral ligament (EUL), fig. 4-37. 24 hour urine loss at 5 weeks was 18gm. At 12 months the loss had decreased to 4gm/24 hours.

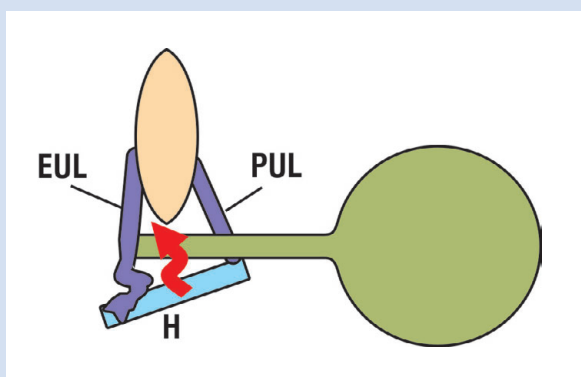


Fig. 4-37d Effect of a lax EUL

Interpretations

1. A lax EUL will not allow the closure muscles (crooked arrow) to stretch the hammock (H) forwards to seal the urethra. Once the mucosal seal is broken, the hammock “droops” under the force of gravity, and urine seeps out.
2. Decreased urine loss at 12 months is explained by scar tissue contracture providing a “tighter seal”.
3. The ‘tampon test’ appears to be a specific test for EUL laxity. Further work is required to validate this hypothesis.

4.3.2 Surgery of the Middle Zone

The Structures of the Middle Zone

The pubocervical fascia extends as a broad membrane between bladder neck and the cervical ring or hysterectomy scar (fig 4-38). The bladder base sits on this membrane. Collagen and smooth muscle within the vaginal wall provide its main structural components. Herniations caused by lax connective tissue in the midline (cystocele), laterally ('paravaginal defect'), or at the attachment to the cervical ring ('transverse defect') are not easy to repair using traditional techniques, as up to one third may recur.

A fourth (iatrogenic) defect, excessive tightness from scarring or excessive elevation at the bladder neck, needs plastic surgery techniques to restore tissue elasticity in that area, the 'zone of critical elasticity'.

As there are no transverse ligaments in the middle zone, the pubocervical fascia is the main supporting structure. This is generally considered as the most difficult part of the vagina to repair because it has an inherent tendency to prolapse due to intra-abdominal pressure above and gravity below.

The vagina is suspended between arcus tendineus fascia pelvis (ATFP) laterally and the cervical ring posteriorly. Correct diagnosis of which structures are damaged, central membrane, collagenous 'glue' to ATFP or the ATFP itself, or attachment to cervical ring, is an essential precondition for repair (figs 4-38, 4-39).

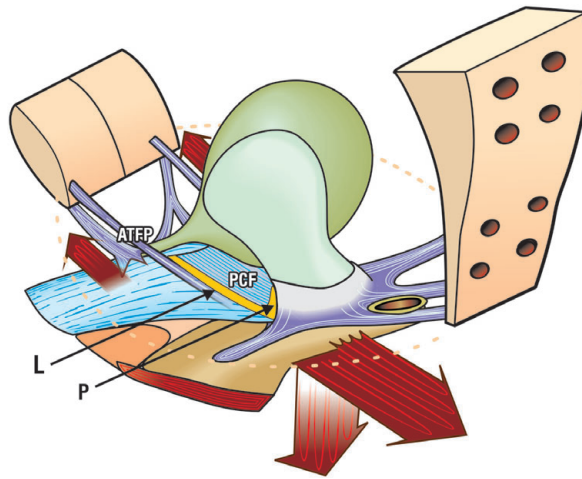


Fig. 4-38 The pubocervical fascia (PCF). The fibromuscular layer of the vaginal wall (PCF) is attached laterally (L) to arcus tendineus fascia pelvis (ATFP) and posteriorly (P) to the cervical ring by collagenous tissue (yellow). Dislocation of 'L' may cause a paravaginal defect and of 'P', a high cystocele. Muscle contractions (arrows) stretch the pubocervical fascia (PCF) to support the bladder base (as illustrated in the 'trampoline analogy').

It is helpful to conceptualize the ATFP as two suspended lines extending between symphysis and ischial spine. Dislocation of ATFP from the ischial spine causes a 'dip' in the lines. Excessive stretching of the collagenous 'glue' between vagina and the adjoining muscles appears as a flattening of the paravaginal sulcus. If the central fascial layer is intact, rugae are seen. The surgical technique used needs to address all three components if it is to be successful.

Sites of damaged fascia

The circles in figure 4-41 are simple representations of the foetal head stretching the fibromuscular layer of the vagina ('pubocervical fascia' (PCF)), its principal supporting structure. When dislocated from the cervical ring, a high cystocele is created. Damage further down creates a mid cystocele and laterally, a paravaginal defect (figs 4-39, 4-40).

A central cystocele (fig 4-42) is caused by rupture or thinning of the pubocervical fascia (PCF) causing prolapse of the bladder base, giving it a shiny appearance on examination.

With a central cystocele, the supporting fascia is broken (or thinned out) so that the vaginal epithelium appears shiny. With a pure paravaginal defect, transverse rugae are seen. Ring-type sponge-holding forceps applied in the lateral sulci restore the prolapse with a paravaginal defect. A cystocele continues to bulge when the patient strains. Often both defects coexist (fig 4-43).

Fig 4-43 demonstrates the inferolateral bulging of a central herniation (arrows). Given the wide distribution of the foetal head pressure (broken lines) it is highly likely that the tissues may also be damaged more laterally (arrows) in the paravaginal areas.

It is important to exclude dislocation of PCF from the cervical ring (fig 4-44) as a cause of urgency symptoms. This can be done using a 'simulated operation' technique by gently compressing its lateral edges with Littlewood's forceps and observing the effect on the urge symptoms.

A high cystocele (cervical ring/cardinal ligament defect), fig 4-40a, can be differentiated from other causes of cystocele using a 'simulated' operation in the OR. The vaginal tissue is grasped laterally in the position of the cardinal ligaments and approximated medially, fig. 4-40b.

The Relationship between the Middle and Posterior Zones

Figure 4-45 demonstrates the structural relationships between the middle and posterior zones. Repair of vault prolapse may temporarily appear to 'cure' the cystocele. However, if the fascia is damaged, the condition is likely to recur (fig 4-46). In a functional sense, the apparent 'cure' may provide sufficient structural support to 'N' (fig 4-45) to relieve co-existing urge symptoms for a few weeks, but they are likely to return after recurrence of the cystocele.

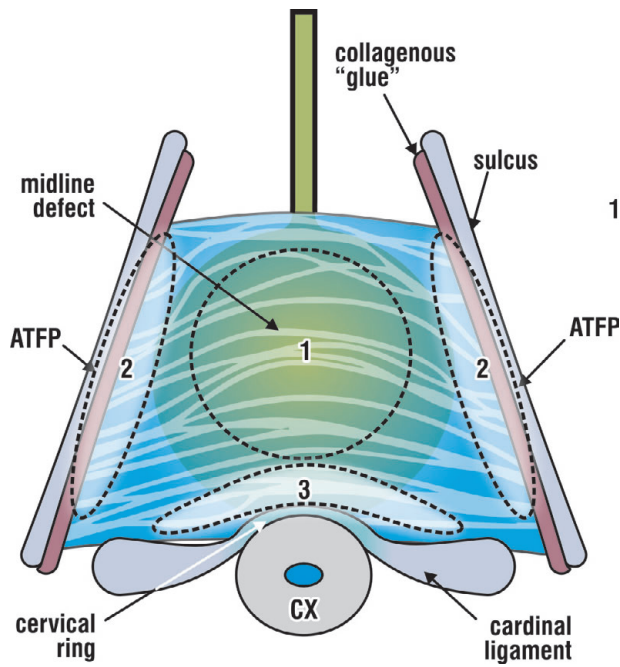


Fig. 4-39 Potential sites of damage: 1. Midline defect (central part of PCF); 2. Paravaginal defect (collagenous 'glue' and ATFP); 3. High cystocele (attachment of PCF to cervical ring, 'transverse defect'. Schematic 2D view from below. Perspective: looking into the anterior wall of the vagina.

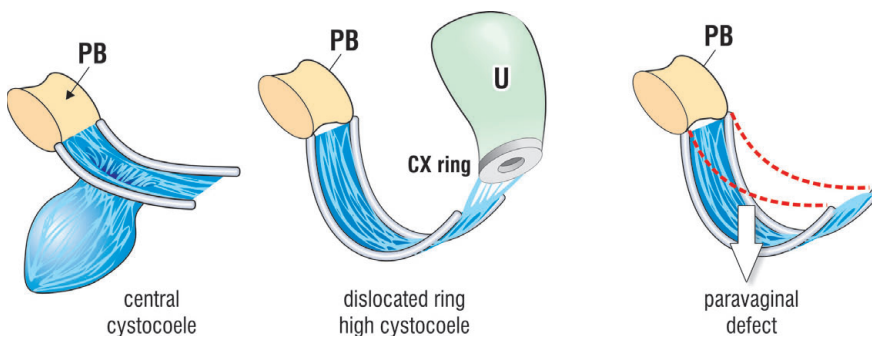


Fig. 4-40 The structural differences between midline (cystocele), lateral (paravaginal) and cervical ring (high cystocele) defects. All appear as 'lumps' in the vagina. Sagittal view.

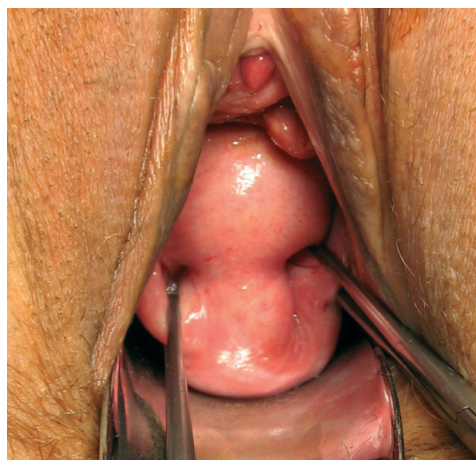


Fig. 4-40a Diagnosing a cardinal ligament/cervical ring defect. The vaginal tissue is grasped in the position of the cardinal ligaments, and approximated medially.

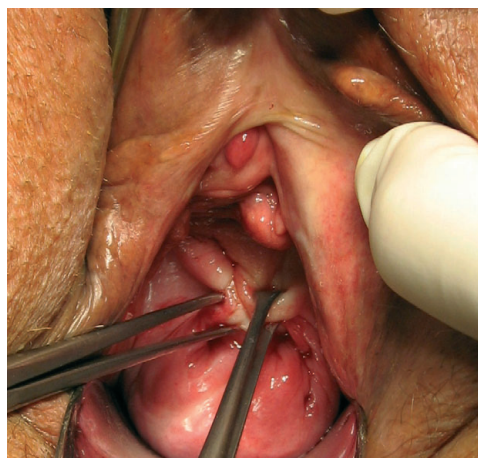


Fig. 4-40b Disappearance of the cystocele confirms cardinal ligament/cervical ring defect as the cause of the cystocele. Persistence of a bulge indicates the cystocele is central/paravaginal.

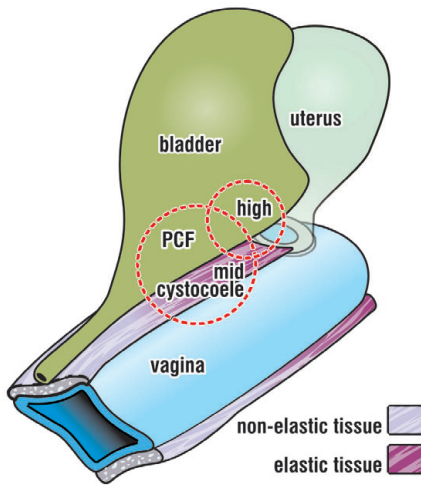


Fig. 4-41 Damage to fascia may cause a central or cervical ring defect. 3D sagittal view.

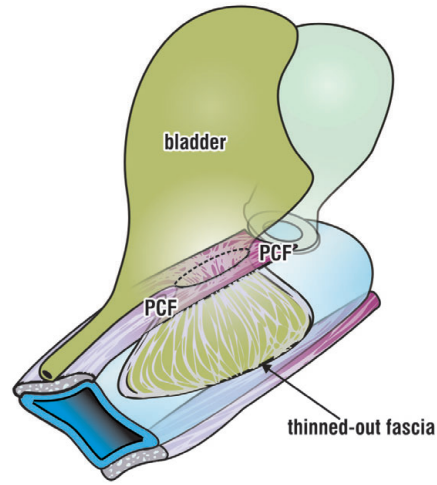


Fig. 4-42 Thinning of the pubocervical fascia (PCF) causes prolapse of the bladder base. 3D sagittal view.

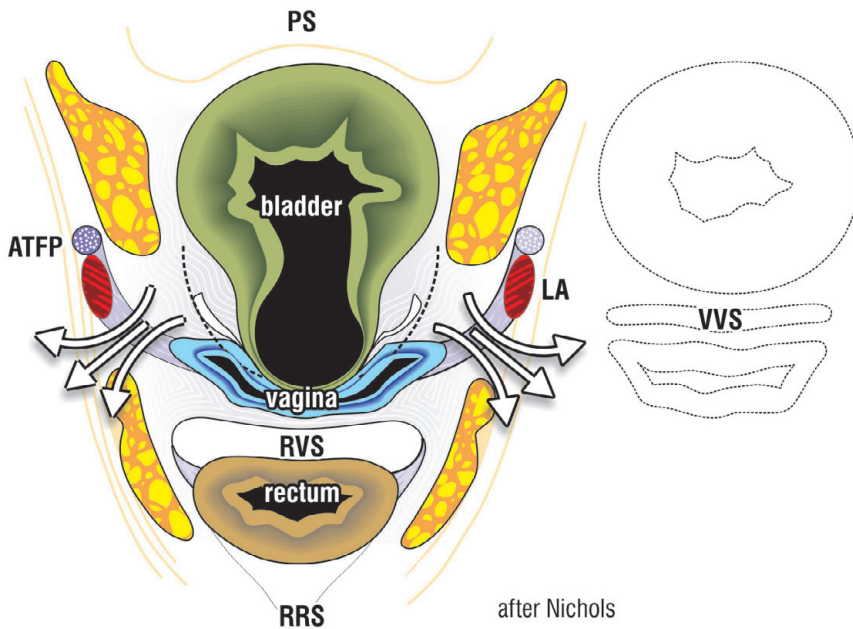


Fig. 4-43 Co-existence of central and lateral defects. The ghost areas to the right indicate the shape of undamaged vagina and bladder (B). VVS = vesicovaginal space; ATFP = arcus tendineus fascia pelvis; LA = levator ani muscle; R = rectum. Broken lines represent pressure exerted by the foetal head.

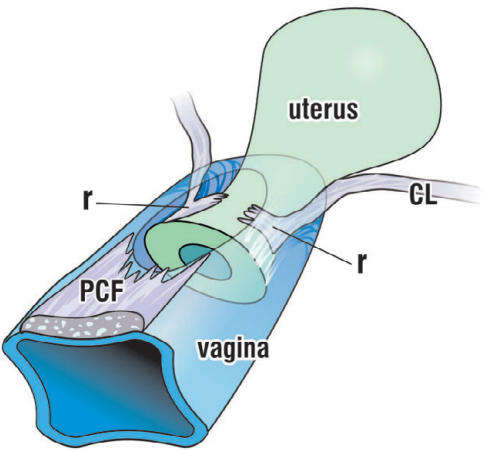


Fig. 4-44 Cervical ring extension. The cervical ring (r) extends laterally to the cardinal ligament (CL). A break in the cervical ring may cause prolapse of the puboservical fascia (PCF) or uterine prolapse due to lateral displacement of CL.

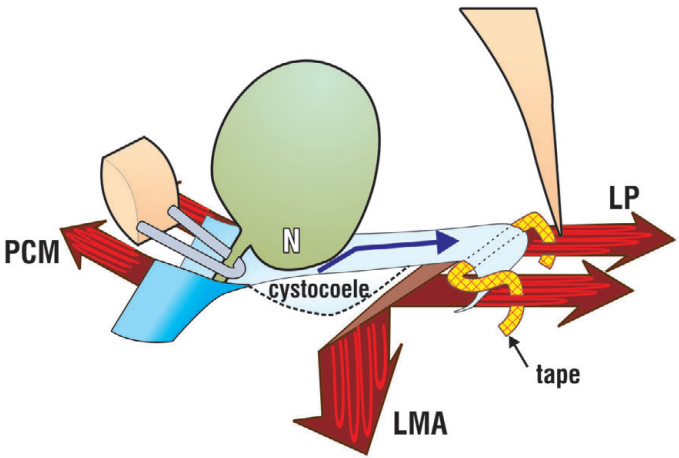


Fig. 4-45 The relationship between middle and posterior prolapse. Backward stretching of the anterior vaginal wall with a Posterior IVS may 'cure' the cystocele. If PCF is damaged, however, the cystocele may recur.

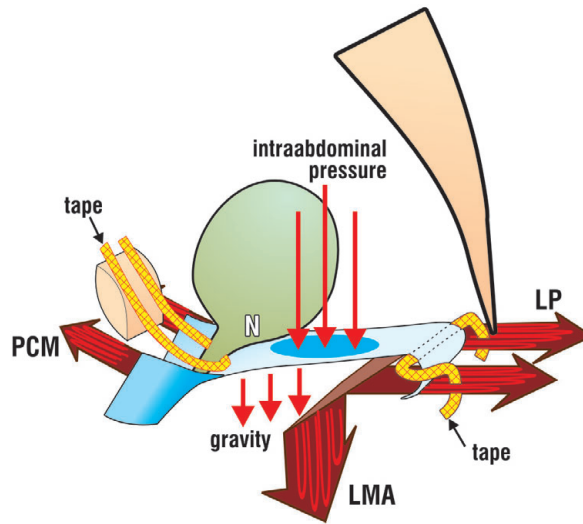


Fig. 4-46 A middle zone prolapse has an inherent tendency to recur if the fascia is damaged. This is because of the dual impact of intraabdominal and muscle forces on a membrane which has no structural support from below.

The Indications for Surgery in the Middle Zone

Structural

Everting anterior wall due to paravaginal, central defects or cervical ring dislocation, may cause dragging pain, discomfort or even ulceration if the eversion is chronic.

Functional

Abnormal emptying is the main symptom associated with middle zone defects. Symptoms of urgency may occur if the patient has sensitive nerve endings.

The Methods - Surgical Repair of the Middle Zone

Surgical Options

The options available are:

1. Direct repair - with maximal conservation of vaginal tissue
2. Recycling excess autologous tissue into a 'double-breast' or 'bridge' repair
3. Reinforcement with mesh sheet or porcine dermis
4. A mesh with 2 transobturator arms attached to large mesh sheets.
5. Using a tensioned tape such as the TFS system to apply the "suspension bridge" principle.

Direct Repair

Direct repair cannot always adequately restore stretched damaged tissue. Moreover, the site of the surgical operation requires at least 6 weeks to achieve wound strength, rendering the wound vulnerable to dislocation by the intraabdominal and muscle

forces acting on it. Even if the wound does not dehisce, already damaged tissue is being attached to damaged tissue.

Direct Repair: Central Defect (Cystocele)

Commencing 1cm below bladder neck, a vertical full thickness vaginal incision is made, extending to the cervical ring or hysterectomy scar. Using minimal dissection, the surgeon frees the bladder from the vagina laterally until firm fibromuscular tissue is found. Avoid tissue excision if possible and ensure the vaginal epithelium is always supported by underlying fascia. Avoid separation of the 'fascial layer' from the vaginal epithelium during surgery. This will only weaken the repair as the 'fascial layer' is merely the fibromuscular layer of the same vaginal tissue.

Dissection between fascia and epithelium only dislocates these tissues. Often, in a total eversion, especially after previous repair, the vaginal tube is totally dislocated from healthy fascia (fig 4-48). Ensure that the vaginal epithelium is re-attached to healthy fascia (fig 4-49). Left without underlying support (fig 4-47), the vagina will simply prolapse again. Although the tissue appears 'pleated' at the end of the operation, excess epithelium generally shrinks with time.

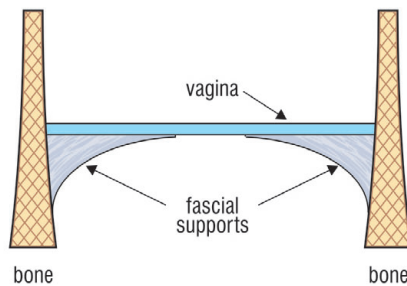


Fig. 4-47 Ensure vaginal epithelium is always supported by underlying fascia. Fascia acts as a support, much like an arch of a bridge. Cross section view.

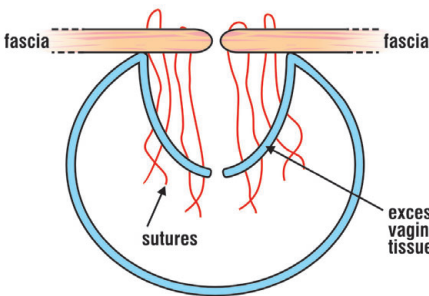


Fig. 4-49 Re-attachment of dislocated vaginal epithelium to underlying fascia.

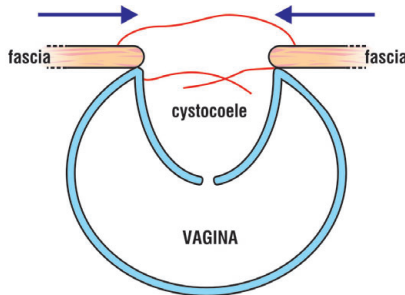


Fig. 4-48 An approximation of the fascial layer using deep interrupted sutures. Transvaginal Dexon vertical mattress sutures may be used. If this is not possible without excess tension, use a 'bridge' of vaginal tissue, mesh or transverse tape.

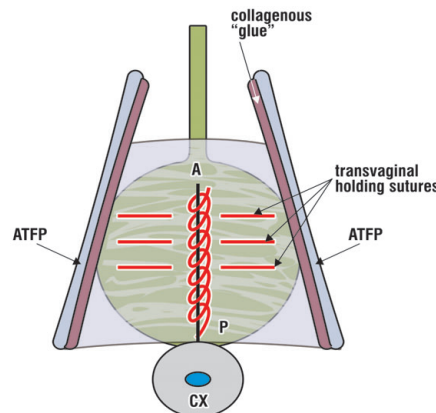


Fig. 4-50 Transverse vaginal 'holding' sutures.

Transverse vaginal sutures can be used to bring the fascial layers to the midline (fig 4-50). The transverse holding sutures are gently tightened without constricting tissue. The incision is sutured with continuous or interrupted 2-0 Dexon.

Direct Repair: Cervical Ring Dislocation ('High' Cystocele)

In many cases there is a site-specific bulge just anterior to the cervix or hysterectomy scar (cervical ring dislocation 'transverse defect'). This lesion is often accompanied by urgency and abnormal bladder emptying. An inverted 'T'-shaped full thickness incision is made in the vagina just above the junction of pubocervical fascia to the cervical ring, 2.5cm long at its base. The bladder is separated from the fascial layer of the vagina laterally on both sides under direct vision so as to avoid inadvertent bladder perforation. A No. 1 Dexon suture brings together the laterally displaced fascia and restores the attachment of PCF to the cervical ring. The epithelium is sutured together without any excision. Anatomically, the cervical ring extends across to the cardinal ligament. It is the rupture of the fascial attachment which causes the 'ballooning' so typical of this condition. In my experience, direct repair of a high cystocele has had up to 30% recurrence rate. A horizontal TFS tape extending transversely across the cervical ring along the cardinal ligament, not only reconstitutes the ring, it fuses the pubocervical fascia to the ring, and restores the axis of the cervix by pulling it backward. Functionally, restoration of fascial tension supports the stretch receptors at bladder base. Structural failure rate to date has been negligible using the TFS method.

Direct Repair: Paravaginal Defect

This operation was described by Dr G. White in the early 1900's. It can sometimes be difficult technically and has a failure rate of up to 30%.

Two full thickness incisions are made exactly in each lateral sulcus commencing at the level of bladder neck and extending almost to the ischial spine (fig 4-51). Grasp the upper and lateral cut edges of the incision with Littlewood's forceps, and open out the space between bladder and muscle with dissection and use a thin right-angled retractor to retract the medial cut edge of vagina. Identify the bladder and the lateral border of pubococcygeus muscle. Using a strong needle insert a No. 0 or 1 Dexon suture deep into the muscle, or preferably ATRP, then into the medial part of the cut vagina and approximate with minimal tension. It is a matter of judgment as to where to place the sutures. A tight suture is much more likely to tear out.

There are several possible complications. The ureters lie above the muscle floor directly below peritoneum. The site of potential injury is where they enter the bladder wall. As this operation is carried out below the peritoneal surface, the ureter is only vulnerable at its entry point into the bladder. Therefore use a right-angled tongue depressor to gently displace the bladder wall medially.

Stretching a weakened vaginal wall laterally during re-attachment could further weaken a central part of the vagina to cause a cystocele at a later date. No matter what method is being used, the surgeon is suturing damaged tissue to damaged tissue.

Techniques for Conserving and Re-using Autologous Tissue

The double-layered autologous techniques which follow provide effective barriers to further herniation, and may be an alternative to mesh sheets. These techniques

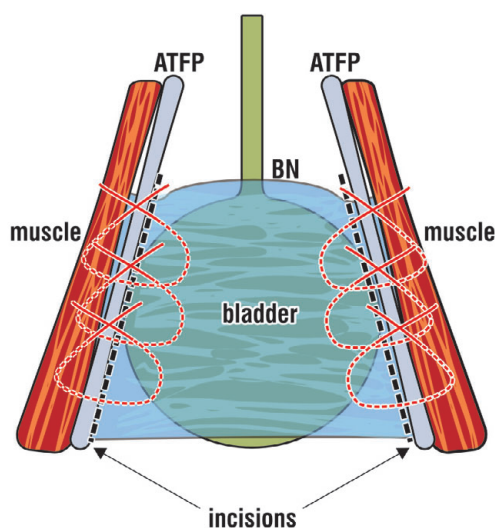


Fig. 4-51 Direct repair - paravaginal defect. Looking into the anterior wall of the vagina. BN = bladder neck

can only be performed in patients with very large herniations. It is emphasized that adequate tissue tension is not always achievable, so some symptoms may persist.

Bridge Repair of Cystocele

In patients with large herniations it is sensible to create a leaf-shaped incision ('bridge') and to anchor it deeply into the healthy fascia laterally rather than excise tissue (fig 4-53). The main complication is that stretching the vagina medially over the bridge may weaken it laterally causing a paravaginal defect. A retention cyst may occur in up to 5% of patients. The steps for anterior bridge repair are:

- Estimate the width of the bridge.
Grasp the proposed bridge with Allis forceps distally and proximally, and test by bringing the lateral vaginal walls towards the midline.
- Remember that an excessively wide bridge is more likely to break down.
- Make a full thickness leaf-shaped incision in the anterior vaginal wall, always behind the bladder neck, no more than 1.5 to 2 centimetres wide.
- Use minimal dissection to separate the edges.
- Diathermy or excise the surface epithelium.
- Dissect laterally between bladder and vagina and suture the edges of the bridge to healthy fascia laterally. Attach one end of the bridge below the vaginal skin anteriorly, and to firm tissue around cervical ring or vault scar posteriorly. Insert a series of No. 1 vertical mattress holding sutures transfixing the bridge to the rest of the vagina.
- Suture the cut vaginal skin with a continuous 2-0 Dexon suture.
- Avoid an excessively tight bridge.

Constriction Ring Formation During Vaginal Repair

In terms of shape, the vagina is essentially a tube (fig 4-52). Excision of vaginal tissue may shorten and narrow the vagina. Simultaneous repair of the anterior and posterior walls may constrict the tube at segment 'V'. To avoid such 'hourglass' constrictions it is best to *not* excise vaginal tissue.

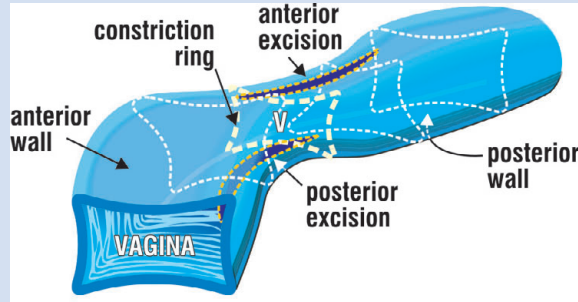


Fig. 4-52 Segmental vaginal narrowing. Perspective: patient lying supine

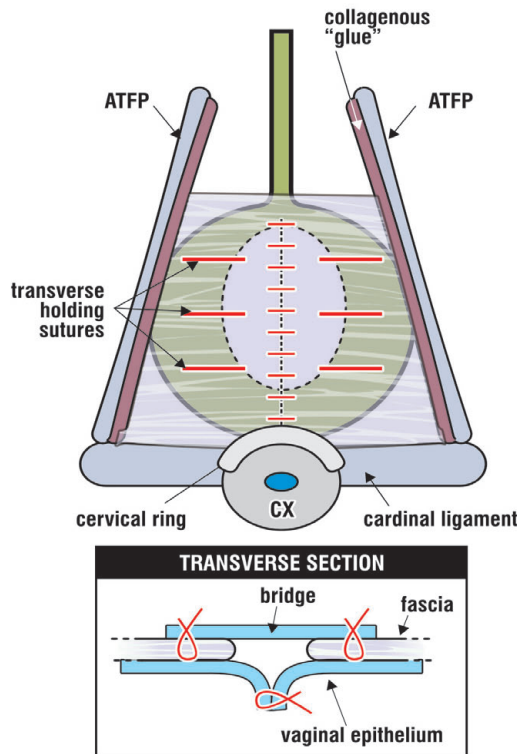


Fig. 4-53 Bridge repair of cystocele

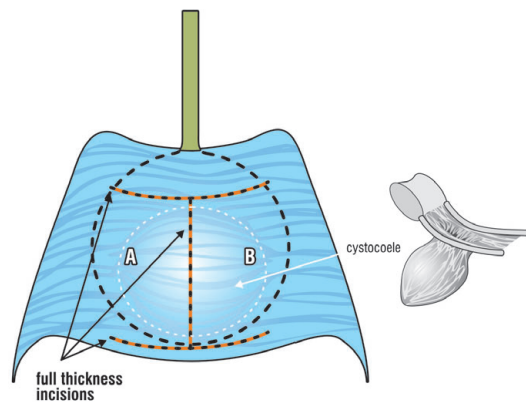


Fig. 4-54 (left) An 'H'-shaped incision is made over the cystocele to create two flaps, 'A' and 'B'.

Fig. 4-55 (Below left) Create 2 flaps 'A' and 'B' using minimal dissection

Fig. 4-56 (Below right) Secure the bottom flap 'A' by stretching it below flap 'B' by two or three No. 1 Dexon sutures. These are pulled quite laterally. They are brought out on to the outer surface of 'B' and tied.

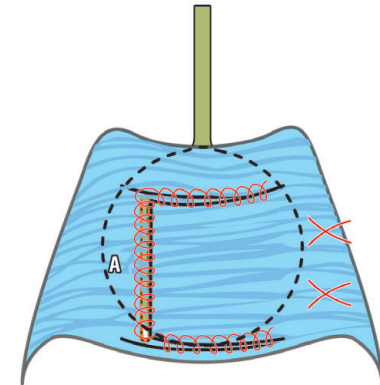
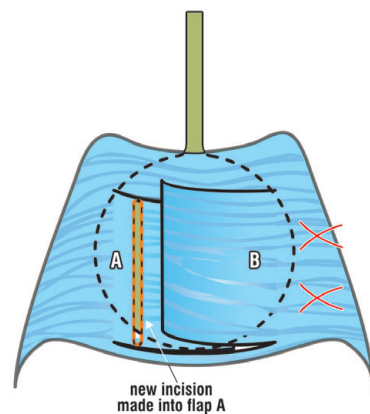
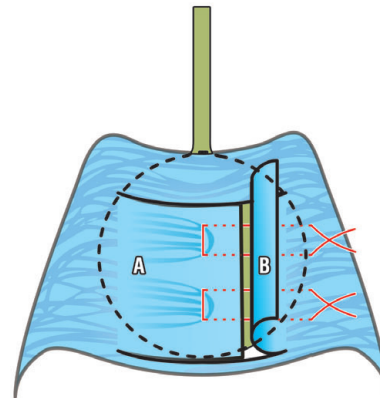
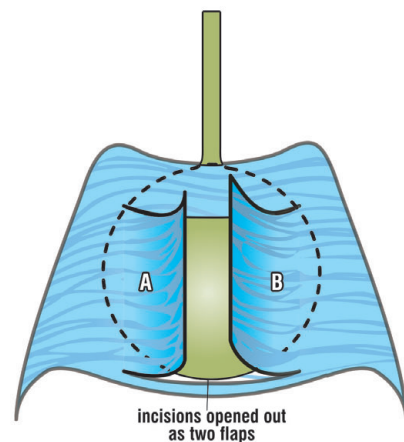


Fig. 4-57 Make a full-thickness vertical incision into flap 'A', sufficiently lateral to anchor the edge of flap 'B' into the incision without tension.

Fig. 4-58 Suture the cut edges of flap 'B' into cut edges of A. Flap 'B' is stretched minimally across like a double-breasted coat and sutured into that incision with interrupted sutures. The repair is completed by placing sutures to join the horizontal cut ends of 'A' and 'B'.

Double Breasted Repair of Cystocele

The 'double breast' technique (figs 4-54 to 4-58) is useful alternative to mesh with thin tissues, or with an everting cystocele. It is a simple operation and has great strength. The rationale for a 'double-breasted' repair is that a double layer is far stronger than the alternative, excision and stretching. The flaps are created over the central herniation. The main complication can be the tearing out of one flap if the repair is made too tight.

Reinforcement with suspended Mesh Sheets

Comment (2009) from an experienced surgeon who uses transobturator and perineal tapes attached to large mesh:

"My mesh usage has probably reduced in the past year since I am less enthusiastic than previously. The main concern at this time would be vaginal pain, dyspareunia and mesh "contraction" effects. To my mind this is the big issue currently. I think I have stopped worrying about erosions and damage to hollow viscus organs. The stuff does work but how can we reduced issues of pain and sexual dysfunction?"

Reinforcement with tensioned tapes

The above complications have not been experienced with the TFS method. The TFS does not obliterate the vesicovaginal space. Like a wire suspension bridge, structural strength is achieved by tensioning the tape. The different TFS cystocele techniques are presented in the next section, and these are followed by an anatomical analysis of the transobturator (TOT) tapes /large mesh combinations.

Paravaginal TFS Repair

This operation was designed to repair an ATRP defect. But has fallen into disuse and been superseded by the 'U-sling' procedure which also reinforces central defects.

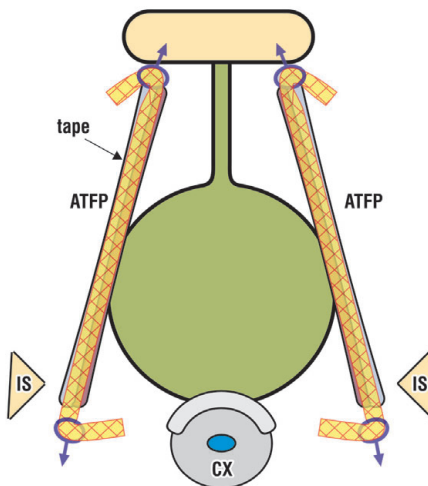
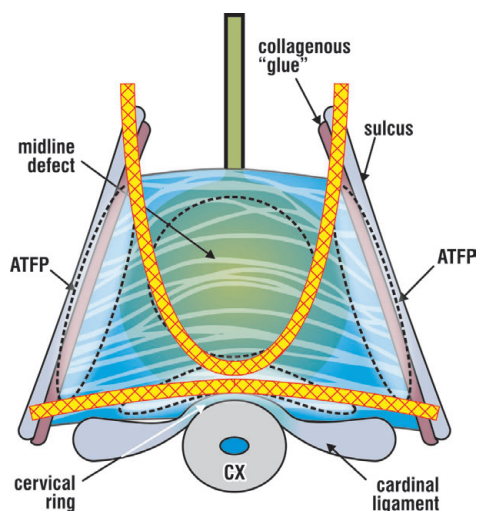


Fig. 4-59 TFS repair of ATRP. The tape reinforces ATFP and 're-glues' the vagina to ATFP by creating a collagenous reaction.

An incision is made in the lateral sulcus from the midurethra almost to the ischial spine. The bladder is displaced medially. One end of the tape is anchored to the tissues medial to the ischial spine and the other is attached subpubically much like a subpubic TFS sling. The medial part of the incised vagina is then attached deeply to the muscles or ATRP (but not tightly), much like a classical White operation. This technique is much simpler and safer than the abdominal approach for a paravaginal repair, yet takes only a fraction of the time. The main disadvantage is that it does not address the central defects which may co-exist.

Fig. 4-60 The ceiling joist principle for cystocele repair. Schematic view into the anterior wall of the vagina. The horizontal tape provides structural support to the proximal half of the anterior vaginal wall and recreates the cervical ring. The vertical U-sling joins with existing ATRP structures to provide structural support to the distal half of the vagina.



Transverse Cystocele TFS Repair for multiple cystocele defects

Initially, central and paravaginal defects were repaired by placement of 3 horizontal tapes. Although effective, this approach was wasteful of tapes and required significant dissection laterally. It has been superseded by the TFS U-Sling and cardinal ligament TFS repairs, figure 4-60.

Cardinal ligament/ Cervical ring TFS repair

A torn anterior cervical ring with lateral dislocation of the cardinal ligaments (CL), fig 4-61, is a common lesion, especially after hysterectomy, as cardinal ligament division is an essential part of this operation. In patients with no previous surgery, a transverse incision 1.5 to 2 cm is made above the cervix. The bladder is dissected lightly off the vagina, and plicated.

Using fine dissecting scissors, a 4-6 cm long channel is made along the cardinal ligament just beyond the lateral sulcus, in a direction 1-2 cm above the ischial spine. The TFS applicator is inserted into the tunnel and the anchor released. After a wait of 10 seconds, the tape is tugged to set the anchor. The procedure is repeated on the contralateral side. The tape is tightened, anteverting the uterus, fig 4-62. The laterally displaced fascia adjacent to the cervix is brought across medially to cover the tape. In patients with prior vaginal repair or hysterectomy, it is safer to perform an inverted 'T' incision, as the bladder anatomy is often greatly distorted.

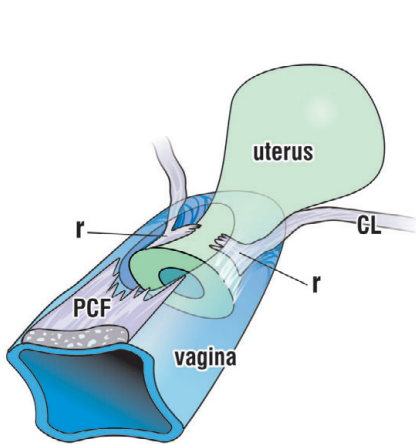


Fig. 4-61 (Left) Cervical ring defect—Sitting position. The cervical ring acts as a bridge between the two cardinal ligaments (CL). A cervical ring tear not only dislocates the attachment of the pubocervical fascia (PCF) to cause a high cystocele, it causes lateral displacement of the cardinal ligaments. This may cause uterine retroversion and downward displacement of the uterus and/or vaginal apex.

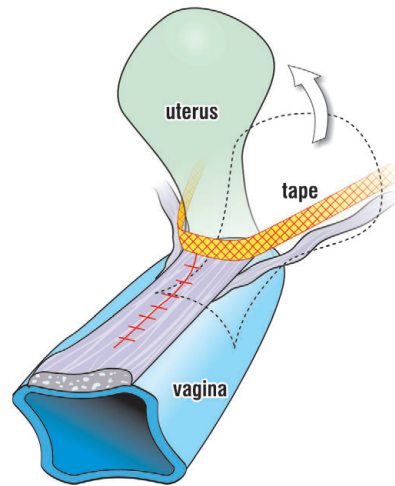


Fig. 4-62 (Right) Cervical ring/cardinal ligament repair—Sitting position. The tape is placed along the anterior lip of cervix and extends along the cardinal ligament. On tightening, the cervix is pulled back, and the uterus anteverts.

A 47 year old para 4 presented with stress and urge incontinence (24 hour urine loss was 295gm/24 hours), 2nd degree uterine prolapse, enterocoele, and classical symptoms of the “posterior fornix syndrome”, nocturia X3, frequency X12, pelvic pain, and abnormal emptying (66 second emptying time, 60 ml residual). She was successfully treated with a midurethral sling, posterior sling, and posterior vaginal wall and perineal body repair. Post-operatively she reported 100% cure of her stress incontinence, and 90% cure of urgency, frequency, nocturia and abnormal emptying. The 24hr pad loss was only 3.5 gm.

Twenty-four months post-operatively, she presented with new symptoms of urgency and return of abnormal emptying symptoms, with a 24hour pad loss varying between 7 and 97 gm. The fact that her nocturia, pelvic pain and enterocoele remained cured indicated that her uterosacral ligaments were probably intact. A 2nd degree high cystocele was diagnosed. Pre-operative “simulated operation”, digital support at bladder base almost entirely relieved the urgency symptoms. Examination in the O.R. confirmed similar anatomy to fig. 4-63. The cervical ring was dislocated. Approximation of laterally placed Allis forceps entirely eliminated the cystocele. TFS cardinal ligament repair cured the cystocele. Relief of urgency, and improved bladder emptying were reported immediately post-operatively.

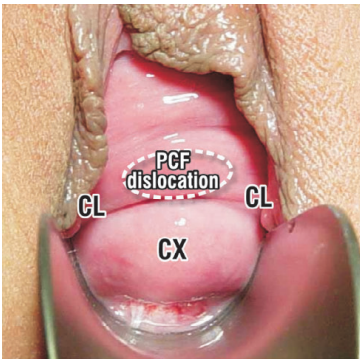


Fig. 4-63 Dislocation of pubocervical fascia (PCF) from the cervical ring loosens the cardinal ligament attachments “CL”, so that the uterus retroverts and even prolapses. Clinical photograph of fig.4-61.

TFS ‘U’ sling

The surgical principle underpinning the TFS ‘U’ sling, fig 4-64, is to mimic the ATFP and to provide a transverse neofascial ‘beam’ to reinforce the damaged pubocervical fascia. A transverse incision is made 1 cm above the cervix or hysterectomy scar. The bladder is dissected off the vaginal wall, and its fascial remnants approximated with interrupted 00 Vicryl sutures. The plane of dissection is carried behind the descending ramus, medial to the obturator fossa towards the ATFP insertion point. The TFS anchor is placed into the dissected space, displaced and tugged to fix it. This is repeated on the contralateral side and the tape tightened until a resistance is encountered. If after tightening, a significant bulge remains between the tape and the bladder neck, a 2nd ‘U’ sling can be inserted (fig 4-65). This operation is very rarely required. An inverted T incision is made in patients with previous surgery.

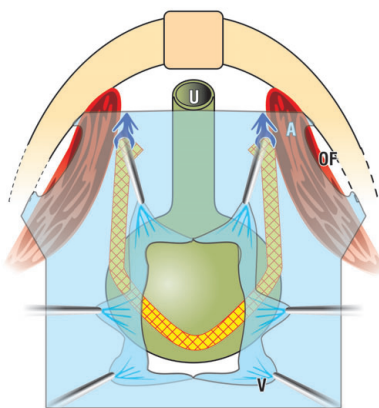


Fig. 4-64 ‘U’ sling. View into the anterior vaginal wall. Vagina (V) is dissected off the bladder wall, and stretched laterally. The TFS tape is anchored (A) just behind the obturator fossa (OF) muscles.

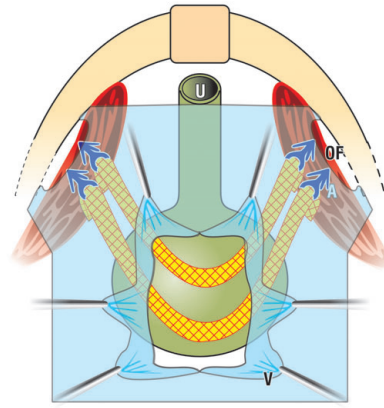


Fig. 4-65 Double ‘U’ sling. View into the anterior vaginal wall. This operation is very rarely required.

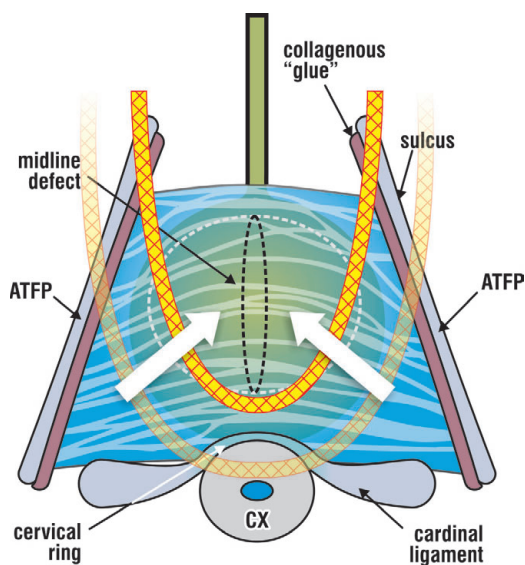


Fig. 4-66 Restoration of laterally displaced tissues by the TFS U-sling repair. The white arrows indicate the direction of movement of the laterally displaced tissues as the one-way sling is tightened, closing the weakened central area (large broken circle). The tape provides central and lateral support to the broad vaginal membrane.

TFS 'U' sling with 'bridge' repair

Originally used for very large cystoceles, this operation has generally fallen into disuse because the very deep anatomical restoration of the U-Sling absorbs the excess tissue.

TFS 'U' sling with mesh sheet

This operation was initially used in patients with large prolapses because of fears that tensioned tapes alone would not suffice. It had unacceptable complications and is no longer performed by the author. The 'U'-sling and cardinal ligament tapes have proved to provide sufficient support, even for the largest prolapses.

Transobturator (TOT) mesh for cystocoele repair

The modus operandi of such a mesh, fig.4-03b, is to create a barrier to the herniated bladder. It does not approximate the laterally displaced structures cardinal ligament or levator hiatus structures. One arm of the mesh supports is inserted high on the medial border of the obturator foramen, and one low, fig.4-03b.

De novo cystocoele herniations

The space 'S' posterior to the mesh, circle, fig. 4-66a, is the space normally occupied by the cervix. It is a major source of de novo herniations following TOT mesh repair for cystocoele. Even attaching a posterior extension of the mesh into the adjacent tissues does not address the cause of this defect, dislocation of the pubocervical fascia from the cervical ring, and lateral displacement of the cardinal ligaments.

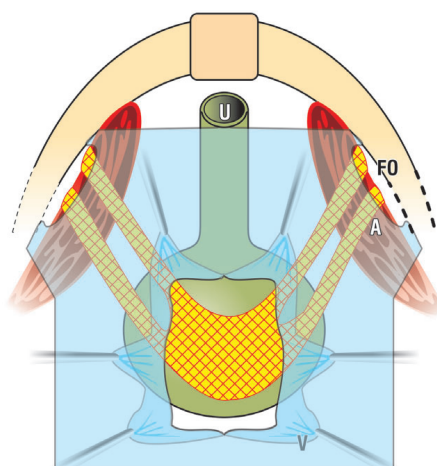


Fig. 4-03b Schematic view into the vagina of a transobturator mesh for cystocele repair. The central mesh is attached to upper and lower arms which are threaded through the medial part of the obturator fossa.

Case report

A 50 year old para 5 patient, presented with everting cystocele and uterovaginal prolapse. Other than mild pelvic pain, there were no other symptoms. She underwent a TOT anterior mesh repair, and also, an infracoccygeal sacropexy with attached large mesh extending over the posterior vaginal wall. Post-operatively, the patient reported a severe exacerbation of her lower abdominal pain, to the point where it became a dominant concern of her waking hours. Vaginal examination reproduced her pain. It also indicated that the lower suspensory arms, T2, fig. 4-66d, were very tight. At operation, the uterosacral ligaments were identified by rectal examination. They had been displaced 4 cm cranially above the ischial spines, 2cm above their normal position. Also, there was a 2nd degree apical prolapse. The arms of the TOT mesh were divided, and the apical prolapse repaired with a posterior TFS sling. The pain had almost disappeared by the time of discharge, 48 hours later. The patient remained cured at 3 month review.

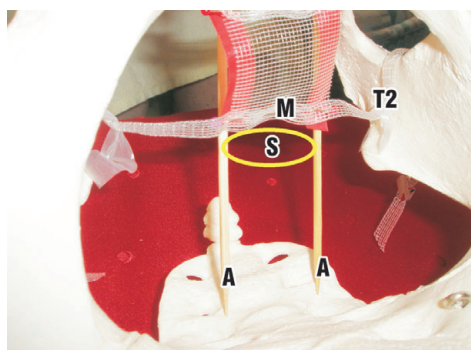


Fig. 4-66a Pelvis, view from above. The space 'S' posterior to the TOT mesh (M) is a site for potential de novo herniation. T2 is the lower arm of the mesh, and is situated in a plane 1-2cm higher than 'A', the plane of the uterosacral ligaments.

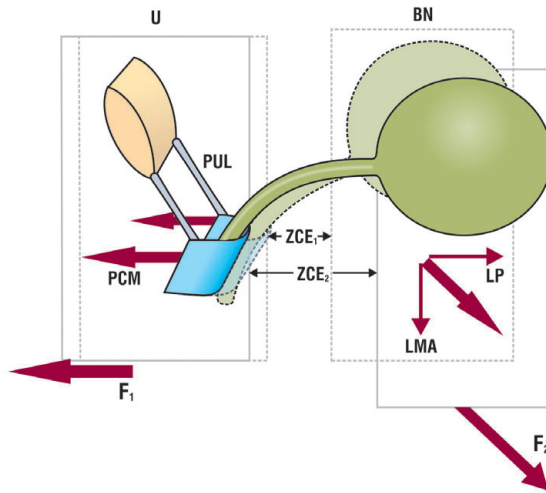


Fig. 4-67 The Zone of Critical Elasticity (ZCE) and the urethral (U) and bladder neck (BN) closure mechanisms. $ZCE_1 = \text{ZCE at rest}$; $ZCE_2 = \text{ZCE during effort or micturition}$. F_1 represents the PCM vector and F_2 represents the resultant force of the LP/LMA vectors.

Middle Zone Tightness - The Special Case of the Tethered Vagina Syndrome

The Integral Theory specifies connective tissue laxity as being the predominant cause of pelvic floor dysfunction. The 'tethered vagina syndrome' is an uncommon and entirely iatrogenic condition that is caused by scar-induced tightness in the middle zone of the vagina. As such it forms a special case. This condition needs to be considered in patients with multiple operations and severe incontinence. It is somewhat equivalent to 'motor detrusor instability' (MDI). The classical symptom is commencement of uncontrolled urine leakage as soon as the patient's foot touches the floor, indeed, often commencing as the patient rolls over to get out of bed. The patient does not complain of bed-wetting during the night. The symptoms are caused by loss of elasticity in the bladder neck area of the vagina: the 'zone of critical elasticity' (ZCE). Because scar tissue contracts with time, it may present twenty years after vaginal repair or bladder neck elevation. This condition can be cured by plastic surgery whose aim is to restore elasticity to the bladder neck area of the vagina.

Zone of Critical Elasticity (ZCE)

Figure 4-67 illustrates why elasticity at ZCE is necessary for the separate function of urethral (U) and bladder neck (BN) closure mechanisms. ZCE stretches from midurethra to bladder base. Scarring across ZCE 'tethers' muscle vectors F_1 and F_2 . Then F_2 overcomes F_1 to pull open the vaginal hammock on effort, causing uncontrolled urine loss.

Pathogeneses of the Tethered Vagina Syndrome

This condition is entirely iatrogenic and is caused by excessive tightness in the bladder neck area of vagina (ZCE) (Petros & Ulmsten 1990, 1993). It is far more common in regions where surgeons are taught to remove significant amounts of vaginal skin

during vaginal repairs. Often there is very little stress incontinence. The reason is that cough creates short sharp fast-twitch contractions, and there may be just sufficient elasticity at ZCE to prevent urine leakage on coughing.

Getting out of bed in the morning stretches ZCE far more as the pelvic floor contracts to support all the intra-abdominal organs. The classical symptom is commencement of uncontrolled urine leakage as soon as the patient's foot touches the floor. Often there is no urgency. A scar at ZCE 'tethers' the more powerful backward forces ' F_2 ' (fig 4-67) to the weaker forward forces ' F_1 ', so the bladder is pulled open as in micturition. The aim is to restore elasticity in the bladder neck area of the vagina, the 'zone of critical elasticity' (ZCE), so that ' F_1 ' and ' F_2 ' can act independently of each other.

Temporary 'Tethering'

Temporary 'tethering' may occur after bladder neck elevation, but can occur occasionally even after tension-free tape surgery where there is poor elasticity in the bladder neck area of vagina, ZCE. The patient presents with *de novo* uncontrolled bladder emptying immediately on getting out of bed in the morning. Generally this is first noticed a few days after surgery. Over the ensuing weeks to months, the patient slowly improves, by gradual natural restoration of elasticity at ZCE, most likely by an 'averaging out' of tissue tension through the walls of the vagina.

Specific Clinical Findings

Generally the tightness in the bladder neck area of vagina is obvious on speculum examination (fig 4-68). Often no urine loss is evident during coughing and even straining. On ultrasound there is generally very little descent of bladder neck, perhaps only 2 to 3mm. One provocative test which may be useful is to grasp the bladder base part of vagina gently with Littlewood's forceps and press backwards while asking the patient to cough. This removes any residual elasticity at ZCE, and very frequently a spurt of urine comes out when there was previously no urine loss on coughing. This test is specific for low elasticity at ZCE, not necessarily for the tethered vagina *per se*. Care must be taken not to clamp the forceps. This may cause severe pain, a consequence of the visceral nerve innervation of the vagina.

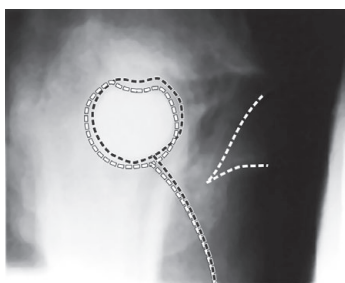


Fig. 4-67a Superimposed x-rays at rest and straining tethered vagina patient. Note minimal descent on straining. (Petros & Ulmsten, 1993).

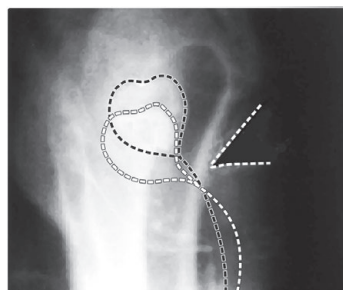


Fig. 4-67b Superimposed x-rays at rest and straining tethered vagina patient following successful skin graft to bladder neck area of vagina. Normal descent on straining. (Petros & Ulmsten, 1993).



Fig. 4-68 Scar at bladder neck. The scar 'tethers' the anterior and posterior muscle forces, so that the urethra is forcibly pulled open on getting out of bed in the morning.

By permission Goeschen, K.

The Surgical Restoration of Elasticity to the Bladder Neck Area of the Vagina

Preliminaries

No matter what technique is used, it is essential to dissect the vagina from the bladder neck and urethra, and then to free all scar tissue from urethra' bladder neck ('urethrolysis') and pubic bones.

Restoration of Elasticity to the Zone of Critical Elasticity (ZCE)

The surgical principle applied is that fresh vaginal tissue must be brought to the bladder neck area of vagina. If there is a severe shortage of tissue, the only solution is a skin graft. This can be a free graft, a Martius labium majus skin graft, or a split labium minus flap graft. A free graft can be problematical as up to one third may not 'take' or shrink excessively. Labium minus or Martius grafts are technically challenging, but bring their own blood supply.

I-plasty

This is the simplest technique and is especially indicated if there is a co-existing cystocele. I-plasty aims to increase the volume of tissue in the bladder neck area of the vagina, thereby restoring elasticity (fig 4-69). It will not work long term if there is a net deficit of vaginal tissue.

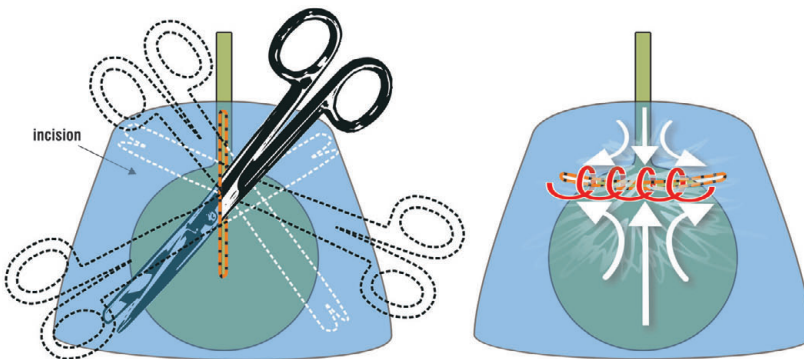


Fig. 4-69 I-plasty. The vagina is widely separated from the underlying tissue (above left). The freed vagina is sutured transversely without tension (above right).

A vertical incision is made from midurethra to at least 3-4 cm beyond bladder neck. The vaginal skin is dissected off the scar tissue and is extensively mobilized, forwards to the edges of the vaginal hammock, backwards as far possible right down to the cervix or hysterectomy scar, and as laterally as possible. The freed tissue is brought into the ZCE and is sutured transversely with interrupted sutures. This increases the quantum of vaginal tissue in this area.

Skin Graft to Bladder Neck

This procedure can be performed either with a transverse or vertical incision at bladder neck, depending on the prevailing geometry. Following the incision, the vagina, urethra and bladder neck are dissected free of scar tissue and widely mobilized, as in the I-plasty operation. Once this is done, the vagina retracts laterally and the tissue deficit becomes evident.

A full thickness skin graft, 5 x 3-4 cm, is removed from an elastic area of the body, lower abdomen or buttocks. The former is far less painful post-operatively. It is difficult to gauge the exact size of the graft. Generally a graft which takes well will shrink 50% over the ensuing 6 months. An excessively large skin graft may sometimes cause incontinence within 6-9 months by creating excess laxity in the hammock and adjoining tissues. Ensure a dry bed for the graft. Remove all fat from the skin graft. The graft is then applied to the bladder neck area of the vagina (ZCE) with a series of quilting sutures to the bladder neck and base. The aim is to prevent the possibility of a haematoma dislodging the graft. Finally, the graft is sutured to the surrounding vaginal tissue with interrupted 00 or 000 dexton. The advice and assistance of a plastic surgeon is advisable for the first few cases.

The quilting sutures (fig 4-70) are followed by suturing the graft to the cut edges of vagina, taking care not to devascularize the tissues with excessively tight sutures. Once the skin graft takes it permits the forward and backward closure forces to operate independently of each other.

Complications

The graft may be rejected in one third of the cases. If this happens, more fibrosis may be created at ZCE and this may worsen symptoms. An excessively large graft may loosen the hammock, thereby causing SI.

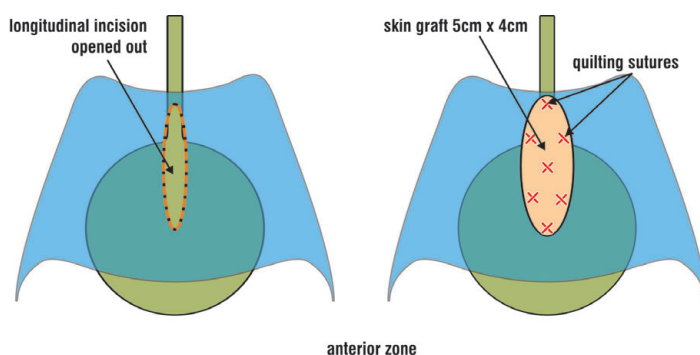


Fig. 4-70 Skin graft to bladder neck area of vagina is attached by quilting sutures.

Labium Majus Martius Skin Graft with Vascular Fat Pedicle

This operation (figs 4-71 to 4-75) was devised by Professor Klaus Goeschen, Hanover, Germany. A 4 x 2.5 cm ellipse of vulval skin is created over the labium majus and is transferred as a Martius fat graft into the dissected area. It is attached to the adjacent vaginal skin taking care to avoid constriction of its vascular pedicle.

Figures 4-71 to 4-75 were kindly supplied by Professor Klaus Goeschen.

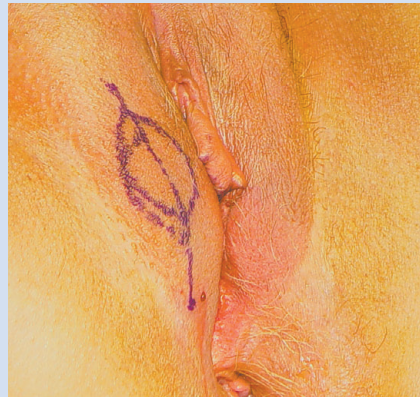


Fig 4-71 Marking of labium majus



Fig 4-72 Graft freed from underlying tissues

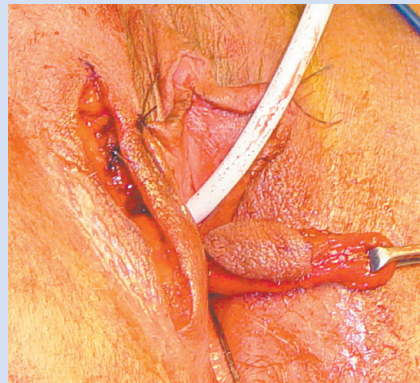


Fig 4-73 Graft brought through to the vagina

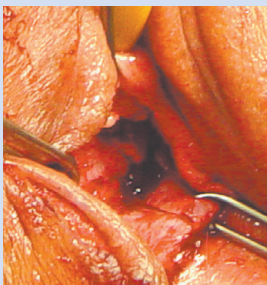


Fig 4-74 Transverse incision at bladder neck. The vagina, urethra and bladder neck are freed from the scar tissue

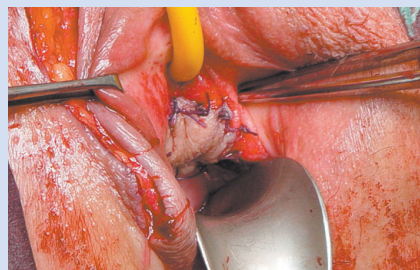


Fig 4-75 Martius skin graft sutured to the edges of the vagina. The wound from the site of the graft is to the left. This is sutured with subcuticular 00 Dexon sutures.

Labium Majus Martius Skin Graft with Vascular Fat Pedicle

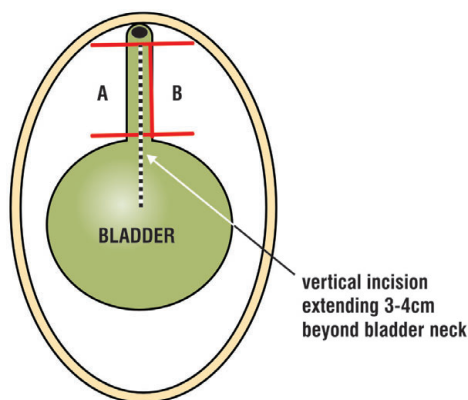
Professor Klaus Goeschen reports significantly better results with this technique than with I-plasty or free skin graft (see figs 4-71 to 4-75). He compared three methods for cure of the 'tethered vagina syndrome' (n=57): I-plasty (n=13); free skin graft (n=21); bulbocavernosus-muscle-fat-skin-flap from the labium majus.(n=23). At 6 month follow-up, cure rates were 23%, 52% and 78% (urine loss of <10gm/24 hours). The mean operating time was 73 minutes (range 41 – 98 min) for the scar dissection and the flap-repair. No serious bleeding was observed. No patient required a blood transfusion. A major problem with this operation is the constriction of the space created to transfer the graft. This may strangle the blood supply to cause failure.

Labium Minus Flap Graft

The labium minus flap graft operation (figs 4-76 to 4-81) works well in patients with normal or large labia minora (LM). In essence it consists of separating the inner mucosal surface of LM from its outer surface, opening it out and swinging it across to provide new tissue to the urethra area of the vagina. One graft is usually sufficient for the tethered vagina syndrome. It is anticipated that these grafts could be useful for fistula surgery where there is tissue damage around the urethra and bladder neck.

The operation has two stages. Firstly, two flaps 'A' and 'B' (fig 4-76) are created separate from the urethra and swung down towards the bladder neck. Secondly, the labium minus graft is stretched across to cover the bare area left by 'A' and 'B'. Three full-thickness incisions (as indicated in fig 4-76) are made, beginning with a vertical incision extending from external meatus 3-4 cm beyond bladder neck exactly as per an I-plasty incision. Flaps 'A' and 'B' are created with two horizontal incisions: one just below the external urethral meatus, the other at the level of the bladder neck and opened out. Dissect vagina clear of urethra, bladder and where relevant pubic bone from below.

The dissection aims to free vagina from scar tissue, mobilizing it as far as possible inferiorly, laterally and superiorly.



Post-operatively, there is very little pain. The labium minus becomes vestigial and is displaced medially. (The vestigial labium minus is situated just above the label 'flap' in figure 4-81.) There have been no complications recorded thus far with this procedure. Failure rate has been 25% at 12 months due to re-scarring at the operation site.

The limitation of this operation is that it cannot be performed in patients with small labia minora.

Fig. 4-76 Labium minus flap graft. An 'H'-shaped vaginal incision is made to create vaginal flaps 'A' and 'B'.

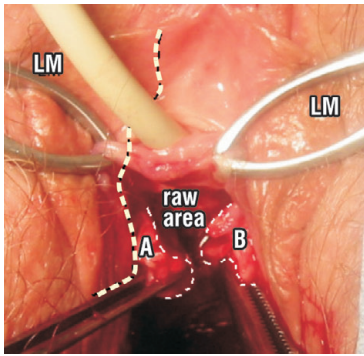


Fig. 4-77 Preparation of flap. 'A' & 'B' are mobilized and swung downwards into the ZCE. Using a sharp scalpel, a transverse incision is made across the base of the inner surface of LM extending up towards the clitoris (broken lines).

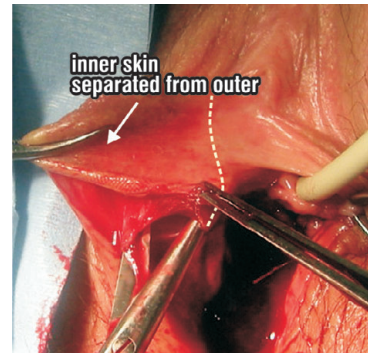


Fig. 4-78 Separation of outer and inner surfaces of LM. Dissecting scissors are used to separate inner and outer surfaces of the LM flap, taking care not to 'buttonhole' the outer surface, as the labium minus tissue is often very thin. Two parallel vertical cuts are made along the sides of the labium minus to the central ridge to open the flap.

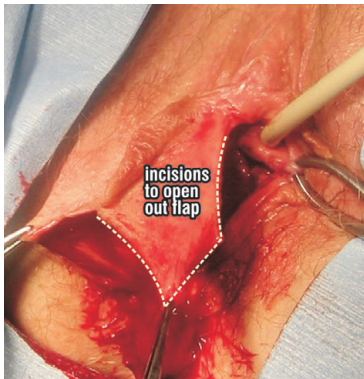


Fig. 4-79 LM flap completed and opened out. The inner (mucosal) surface of LM has been separated from its outer (skin) surface.

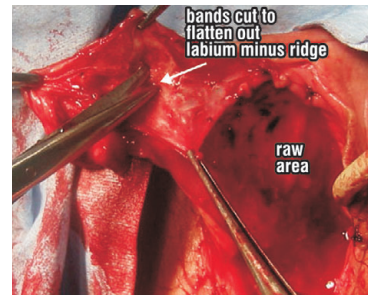


Fig. 4-80 Release of ridge bands to open out ridge. The flap is turned over and the collagenous bands which form the ridge are divided, 'flattening out' the ridge. This greatly increases the available surface area of the graft.

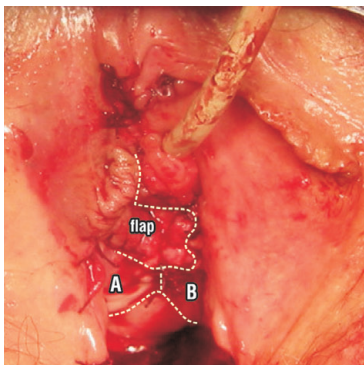


Fig. 4-81 (left) Completion. The LM flap is now attached to the laterally sited pubococcygeus muscles, urethra and the two parts of the hammock, A and B which have now been mobilized and rotated downwards. 'A' & 'B' are sutured to the new tissue brought into the bladder neck area of the vagina. It may be necessary in some patients to insert a midurethral sling if in the opinion of the surgeon, there is a possibility of stress incontinence post-operatively.

Cure of “tethered vagina” with bladder neck skin graft

A 68 year old patient gave a history of a previous abdominal colposuspension, hysterectomy and cystocoele repair with a wedge excision of vaginal tissue 16 and 24 years previously. She presented with classic symptoms of the “tethered vagina syndrome”, uncontrolled bladder emptying immediately her foot touched the floor on getting out of bed in the morning, in her case, without any urgency whatsoever. There was no SI on objective testing. Her 24 hour urine loss was 201 gm, experienced mainly on getting up off a chair, out of bed, squatting etc, but not with coughing or sneezing. Bladder neck descent was only 1.4mm on straining. There was no evidence of detrusor overactivity on urodynamic testing. The bladder neck was scarred and immobile. On grasping and stretching the vagina just behind bladder neck backwards with a Littlewood’s forceps, stress incontinence was provoked during coughing. The patient became completely dry immediately after a labium minus flap graft to the bladder neck area of vagina. She remained dry at 6 month review, but she lost 1.0 ml of urine on SI testing with 10 coughs performed with a full bladder.

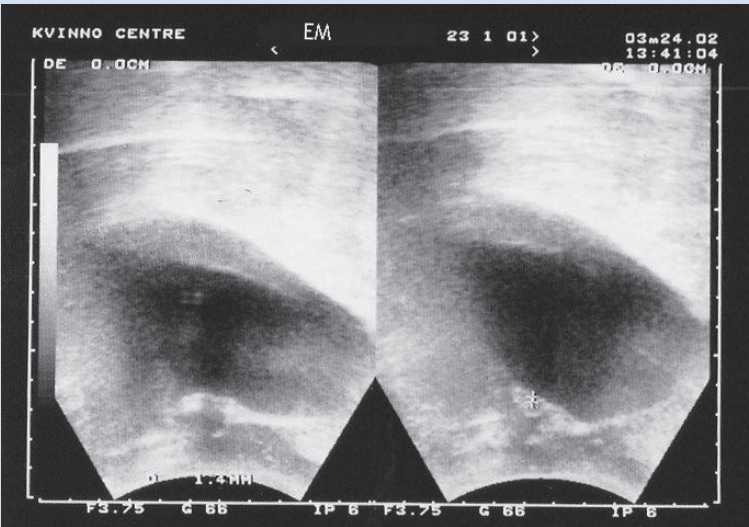


Fig. 4-81a Minimal descent of bladder neck on straining. The bladder neck and distal urethra are closed during straining.

Interpretation: The zone of critical elasticity, ZCE, was compromised by multiple operations in the area of bladder neck. Scar tissue contraction over a 16 year period produced symptoms of “tethered vagina”. The restoration of elasticity with the graft restored the closure mechanisms, but appeared to have induced some minor vaginal laxity, evidenced by recurrence of mild SI.

'Tethered vagina' after transobturator tape for cure of urinary stress incontinence.

The author has personally seen 4 such cases following transobturator tape for cure of urinary stress incontinence. This suggests that this complication may be reasonably common, and is not being diagnosed. The patient presented in all cases with large urine loss, for example, on getting off a chair or immediately on getting out of bed in the morning. The diagnosis was made definitively in each case with transperineal ultrasound. When asking the patient to strain, the tape moved backwards and the patient leaked urine. Surgical cure consisted of making a midline incision, dissecting the tape off the urethra and vaginal wall, and re-inserting a 'tension-free' retropubic tape, or a vertical minisling.

Interpretation: A TOT inserted at the level of the clitoris is very close to the ATFP and the lateral part of pubococcygeus muscles, which proceed backwards to form the levator plate which contracts backwards on straining. Any attachment of the tape to these muscles would stretch open the posterior wall of the urethra, causing classical symptoms of 'tethered vagina syndrome'.

4.3.3 Surgery of the Posterior Zone

The Structures of the Posterior Zone

The posterior zone extends between the cervical ring and perineal body (fig 4-82). It includes the uterosacral ligaments, the apical segment of the vagina, rectovaginal fascia, perineal body and external anal sphincter. These structures work synergistically as a subsystem, so that repair of all three is often required. The role of the uterus as a 'keystone' of the pelvic floor, and its conservation where possible is emphasized, as is conservation of the vagina. The vagina is no less an organ than the uterus. Therefore, with rectocele repair, excision of tissue should be avoided where possible.

The Fibromuscular Supports of the Vagina

Interconnectedness of the Posterior Zone Fascia

In figure 4-82, the cervix is a key anchoring point for the posterior part of the vaginal membrane. Contraction of the smooth muscle components of uterosacral (USL) and cardinal ligaments (CL) help to tension the vagina and to counteract 'F', the force of gravity (fig 4-83).

The inherent strength of the rectovaginal fascia (RVF), together with its backward stretching by the levator plate (LP), are major factors in preventing prolapse - which is really a form of intussusception. Note the importance of the descending branch of the uterine artery as a major blood supply to the apical fascia and uterosacral ligaments (USL). This explains why it is often difficult to locate USLs in patients who have undergone hysterectomy due to atrophy.

In terms of structure, the uterus functions in a similar way to the keystone of an arch (fig 4-84).

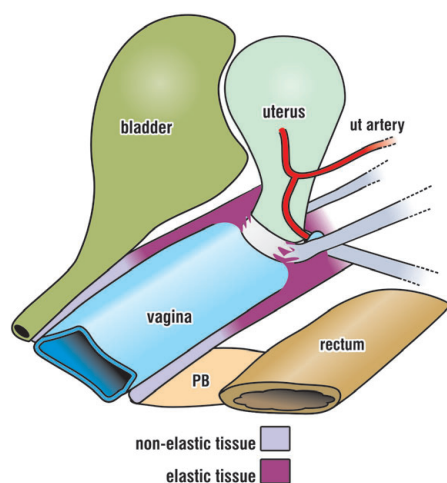


Fig. 4-82 The fibromuscular supports of the vagina. Note the dense fibrous tissue at the distal 2-3 cm of the vagina, urethra and anus. Superior to this area there is less collagen, and more smooth muscle and elastin.

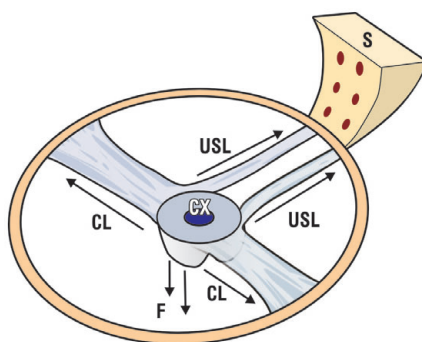


Fig. 4-83 Ligamentous support of the cervix. The arrows indicate the line of tension created by the ligaments. F = force of gravity; CL = cardinal ligament; USL = uterosacral ligament. Perspective: View from above.

Hysterectomy may weaken the fascial side-wall support, and weaken the uterosacral ligaments by removing a major part of its blood supply. Conservation of the uterus is important in the long-term prevention of vaginal prolapse and incontinence (Brown 2000, Petros 2000).

The fascial sheets (fig 4-85) are all interconnected, extending anteriorly (pubocervical fascia) and superolaterally to the arcus tendineus fasciae pelvis, posteriorly (apical fascia) and infero-laterally (rectovaginal fascia (RVF)), between vagina and rectum. Thus BOTH the anterior and posterior fascial supports may need repairing in a patient with uterine or vault prolapse.

The ring around the cervix (fig 4-86) is composed of pure collagen. Therefore it provides a strong anchoring point for the fibromuscular tissue (fascia) which extends forwards below the bladder as the pubocervical fascia, and backwards above the rectum as recto-vaginal (Denonvillier's) fascia to the perineal body. Tearing of the attachment points may present as a high cystocele, high rectocele, or enterocele.

The rectovaginal fascia (or Fascia of Denonvilliers) attaches the posterior vaginal wall to the perineal body (PB) inferiorly and to the levator plate muscle group (LP) superiorly (fig 4-87) (Nichols 1989). Contraction of LP (arrow) stretches the posterior vaginal wall backwards against the perineal body into the horizontal position shown in figure 4-86. The intra-abdominal and gravitational forces act to maintain this position.

Because the levator plate (LP) stretches the vagina via the rectovaginal fascia (RVF) any fascial repair must be adequately tight to enable the muscle forces to give strength to the system by their tensioning effect. This is evident in the radiograph figures 6-37 to 6-40 (inclusive, see Chapter 6). It follows that a loosely applied mesh sheet cannot enable this system *per se*. The displaced fascia still needs to be restored before the organ can be tensioned sufficiently by the muscle forces to restore function (cf Chapter 2).

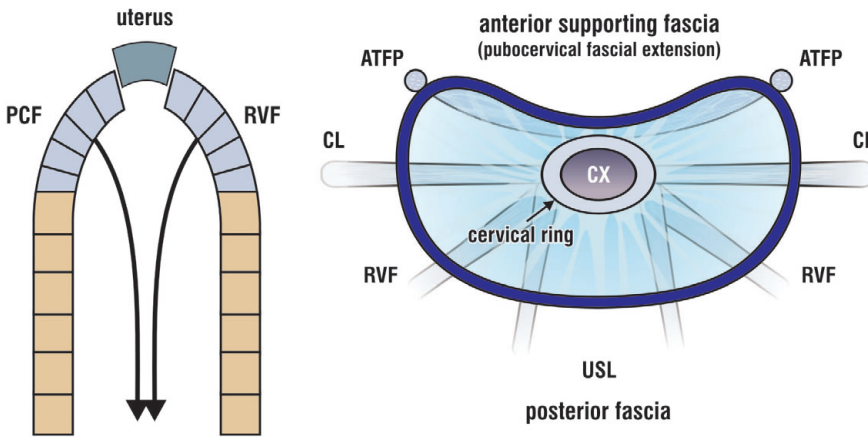


Fig. 4-84 (left) The uterus acts like a keystone of an arch. Adequately tight fascia (PCF, RVF) supports the uterus from below. Therefore PCF and RVF may also need to be repaired.

Fig. 4-85 (right) Interconnectedness of pelvic fascia. Perspective: 3D view, looking into the posterior fornix of the vagina. All fascial and ligamentous structures insert directly or indirectly into the cervical ring.

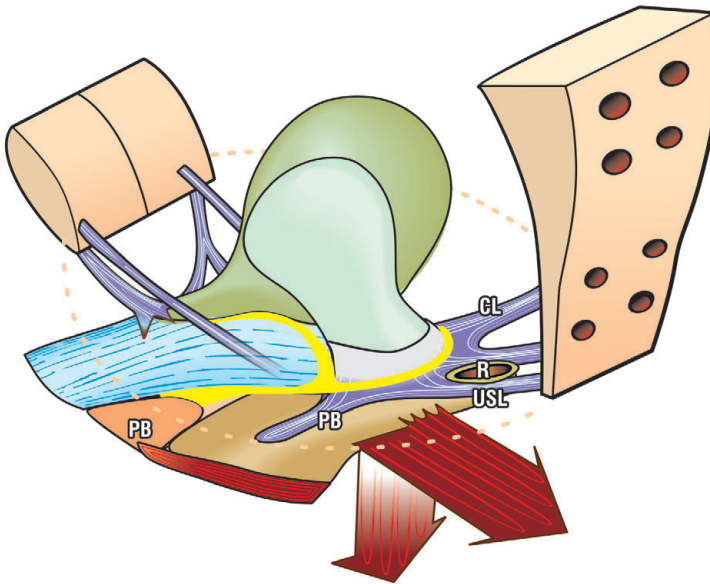


Fig. 4-86 The cervical ring (yellow) is an important attachment point for pubocervical, rectovaginal and apical fascia

Prolapsed Vagina

In the normal patient, the vagina is anchored by the cardinal (CL) and uterosacral ligaments (USL), supported laterally and inferiorly by the rectovaginal fascia (RVF), and superiorly by the pubocervical fascia (PCF). It is tensioned by the levator plate muscles (fig 4-87, arrow). Note how the uterus acts as a central anchoring point.

A prolapsed vagina is essentially an intussusception (fig 4-88). Herniations (prolapses) are caused by breaks and lateral displacement of this fascia, and/or stretching of the suspensory ligaments. Frequent accompaniments to the vault prolapse are traction enterocele and high cystocele and rectocele (fig 4-88). Congenital laxity can occur in nulliparous women. For permanent reduction, the side walls may need to be strengthened to a critical mass beyond which the apex cannot progress to eversion, much like repair of an intussusception. This may require repair of anterior (PCF) and posterior (RVF) fascia.

Uterine Prolapse

Uterine prolapse (fig 4-90) is caused by weakened cardinal (CL) or uterosacral (USL) ligaments and is often accompanied by weakening and displacement of the fascial sidewall support, which causes the uterus to descend into the vaginal cavity.

It is clear that as well as a posterior sling, approximation of the sidewall fascial supports (fig 4-91, arrows) is also needed to support the apical repair as well as lengthen the vagina. A significant superior defect (cervical ring/cardinal ligament) should also be repaired as required.

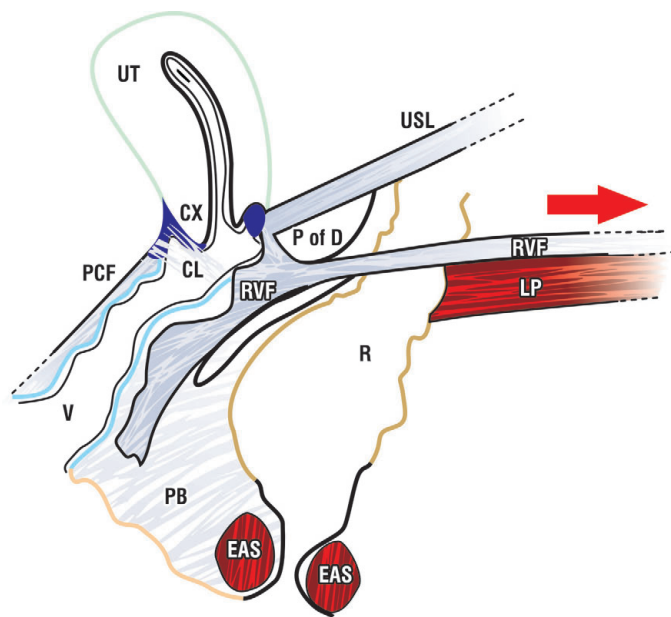


Fig. 4-87 Rectovaginal fascia (RVF) extension (fascia of Denonvilliers) to levator plate (LP). PB = perineal body; CX = cervix; P of D = Pouch of Douglas; UT = uterus; V = vagina; R = rectum; EAS = external anal sphincter. (After Nichols)

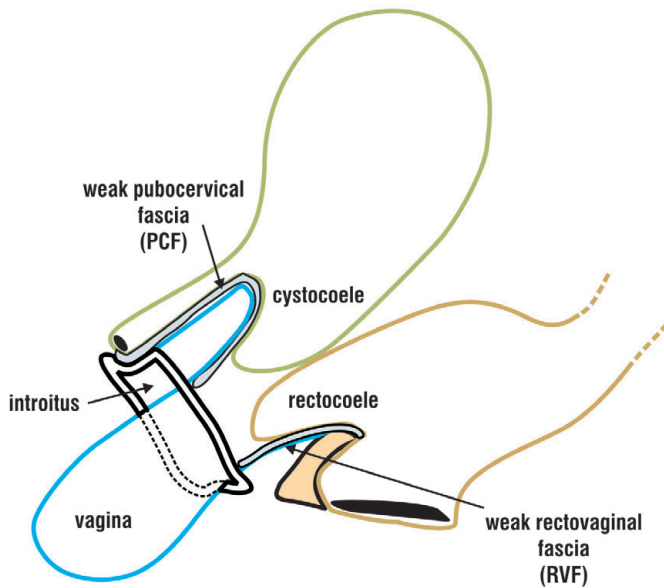


Fig. 4-88 Prolapsed Vagina - 'intussusception'. Diagram shows the 'traction' prolapse of adjoining fascia.

Damaged Rectovaginal Fascia (Rectocele)

When damaged, rectovaginal fascia (RVF) and attached ligaments (CL, USL) may be displaced laterally (fig 4-92, arrows). The anterior wall of rectum may balloon anteriorly or even superiorly to obliterate the rectovaginal space (RVS), and become adherent to adjacent tissues (fig 4-93). Damage to apical fascia may cause enterocele. Rupture of the RVF attachment to levator plate (LP) and perineal body (PB) (fig 4-94) may invalidate backward stretching of the vagina, as may lateral displacement of perineal body (PB), or detachment of PB from external anal sphincter (EAS). As stretching the anterior wall of the rectum into a semi-rigid membrane is a prerequisite for bowel evacuation, laxity in these structures may lead to evacuation difficulties. The surgical significance of organ adhesion (as in fig 4-93) is that the anatomical integrity of the organ needs to be restored and the fascial remnants plicated, whatever the type of surgery performed. Excising centrally herniated vagina, with suturing of the edges, further weakens an already weak structure.

A high rectocele may be mistaken for an enterocele (fig 4-94). The peritoneum is a weak structure, so there is little to be gained by opening an enterocele electively during repair, as the surgeon may mistakenly open into the rectum. It is sufficient to approximate and strengthen the apical fascia and damaged uterosacral ligaments to cover the herniation, preferably over a mesh tape reinforcement.

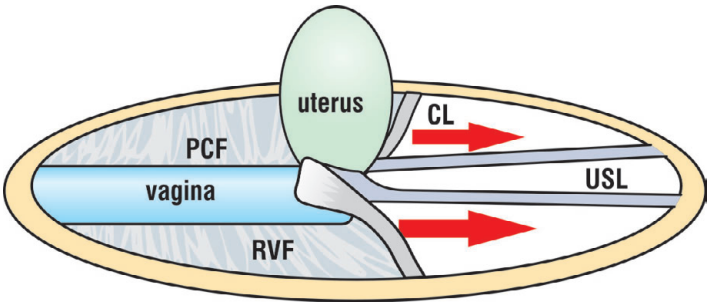


Fig. 4-89 Schematic representation of fascial support for the vaginal vault in a normal patient. Arrows = LP contraction.

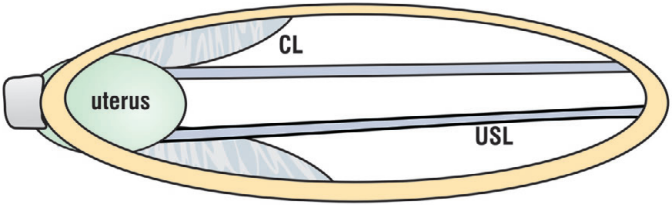


Fig. 4-90 Uterine prolapse may be caused by laxity of CL, USL and adjoining fascia.

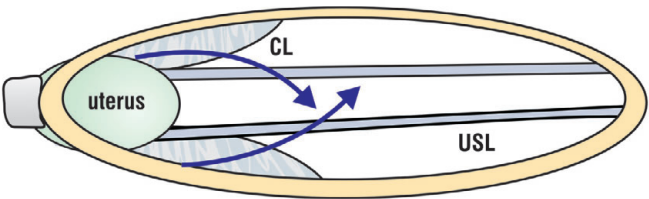


Fig. 4-91 The importance of fascial repair in vault prolapse, illustrating the need for reinforcement of the side wall anterior (PCF) and posterior (RVF) fascia.

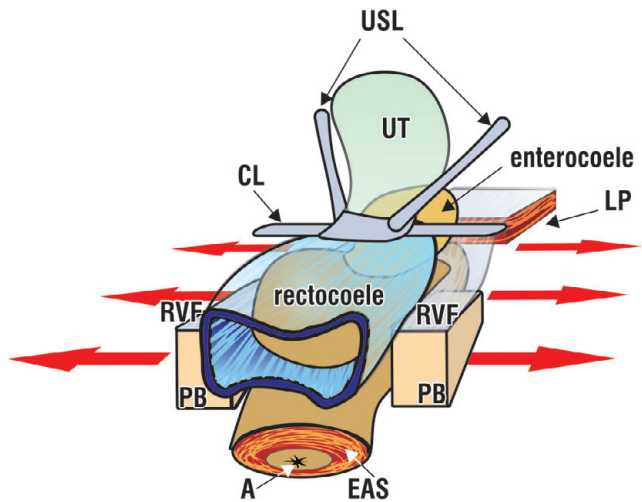


Fig. 4-92 The lateral displacement of rectovaginal fascia (RVF) and perineal body (PB) allows protrusion of a rectocoele into the vaginal cavity. Damage to apical fascia may cause enterocoele. A = anus.

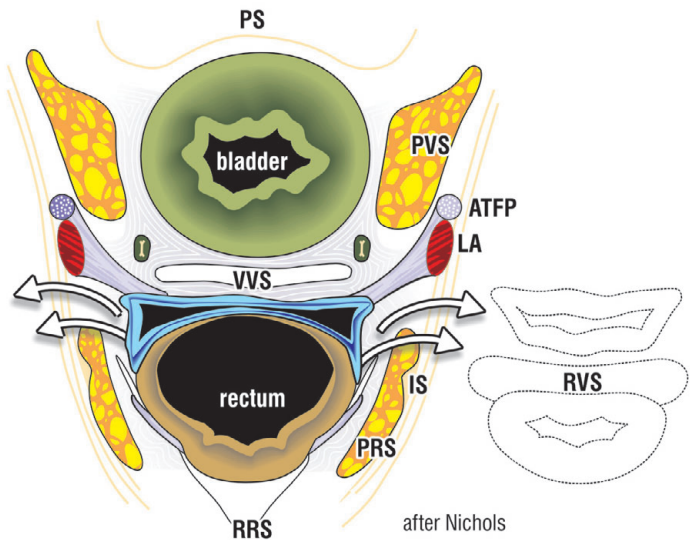


Fig. 4-93 Superolateral displacement of rectocoele. Rectocoele may eliminate the rectovaginal space (RVS) and displace laterally causing adhesions between vagina and rectum.

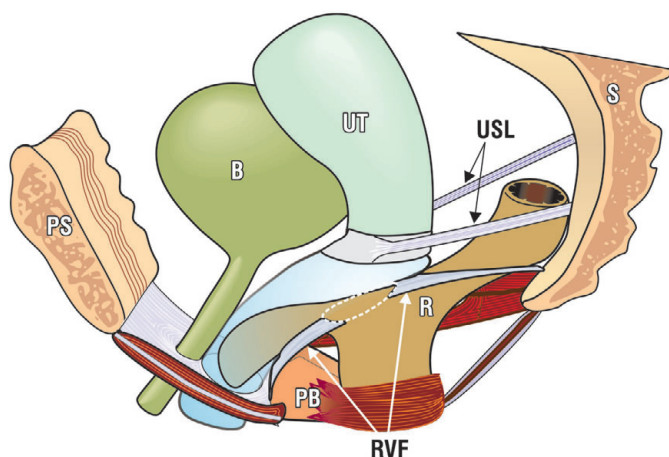


Fig. 4-94 A high rectocele (RVF fascial defect) may be confused with an enterocele (apical defect).

Indications for Posterior Zone Surgery: Damage to the Uterosacral Ligaments and Perineal Body

Manifestations of damage may be structural or functional.

Structural

Prolapsed uterus or vaginal apex, or posterior vaginal wall defects causing discomfort.

Functional

Symptoms of 'posterior fornix' syndrome: urgency, frequency, nocturia, abnormal emptying and pelvic pain, are the main symptoms associated with posterior zone defects (fig 1-11, chapter 3). Insensible urine loss and mild stress incontinence may also occur with USL defects in some patients. The amount of prolapse may be minimal in patients with the 'posterior fornix syndrome'.

The uterosacral ligaments are usually atrophic (following hysterectomy), or attenuated (in prolapse). With reference to figure 4-87, contraction of levator plate (LP) stretches the vagina (V) backwards and downward in the axial plane so it becomes compressed by the intra-abdominal pressure. Adequately strong rectovaginal fascia is needed for this to occur.

The Methods: Surgical Repair of the Posterior Zone

The posterior zone functions as a subsystem. Therefore it is advisable to repair all damaged parts of the system if there is evidence of damage. That is, uterosacral ligaments, apical fascia, rectovaginal fascia and perineal body should be repaired.

In principle, the same operation is performed for uterine prolapse and vaginal vault prolapse. Generally, uterosacral ligaments and their regional fascia are much thinner in patients with vault prolapse who have undergone hysterectomy.

In the posterior zone, it is primarily damage to the distal part of the uterosacral ligament (USL) which causes dysfunction. However, cervical ring rupture and lateral displacement of the cardinal ligaments (fig 4-61) can, on its own account, cause apical or uterine prolapse. In the author's experience, this damage usually extends to the adjoining upper rectovaginal fascia.

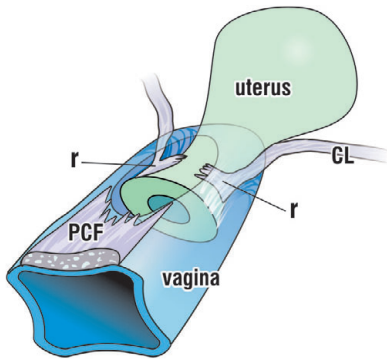


Fig. 4-61 Ruptured cervical ring (r) may induce laxity of the cardinal ligament (CL) causing retroversion or prolapse of the uterus

Simple level 1 repair of the posterior zone

This operation is especially indicated for patients with minimal prolapse and major posterior zone symptoms. It gives good results in the shorter term (6-12 months). It can easily be performed as an outpatient procedure under local anesthesia. Using a 10ml syringe with a long 19 gauge needle, the posterior vaginal fornix is infiltrated with 1% lignocaine. Gently grasping the two lateral sides of the apex with Littlewood's forceps, a full thickness transverse incision 2.5 cm long is made between the forceps. A single No1 Vicryl suture attached to a large needle is inserted behind and lateral to the forceps on both sides so as to grasp the laterally displaced uterosacral ligaments, and tied, fig 4-94a. The significant longer term failure rate of this operation can be attributed to approximating poor tissue to poor tissue, and this was instrumental in the creation of the infracoccygeal sacropexy operation, 'Posterior IVS'.

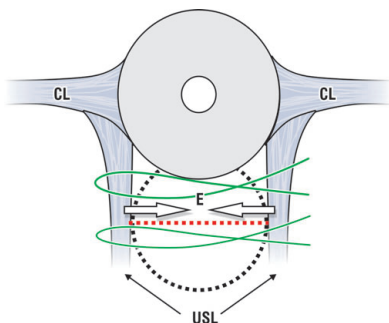


Fig. 4-94a Simple posterior fornix repair. A transverse incision is made in the posterior fornix, and the uterosacral ligaments (USL) approximated. CX= cervix; CL=cardinal ligament.

The Posterior Fornix Syndrome addressed with simple posterior fornix repair Petros PE & Ulmsten U. The posterior fornix syndrome: a multiple symptom complex of pelvic pain and abnormal urinary symptoms deriving from laxity in the posterior fornix. Scand J Urol Nephrol (1993). The initial improvement rates were recorded as a percentage. The true % incidence of the symptoms in that group of patients is denoted with brackets.

Stress incontinence 45%, (32%); urge incontinence, 55% (39%); abnormal emptying, 60%(35%); pelvic pain, 75% (32%); deep dyspareunia, 68% (39%); residual urine >50ml, 50% (53%).

The stress incontinence was incidental, minor, and was not a presenting symptom. Improvement in SI symptoms can be explained by restoration of the downward rotating force, LMA, fig.4-30, following reinforcement of its anchoring point, the uterosacral ligament.

Posterior Sling Operation for Vaginal Vault or Uterine Prolapse ('Infracoccygeal Sacropexy') - Level 1 Repair

Essentially the same operation is performed for both uterine or vault prolapse (figs 4-95 to 4-99). The posterior sling or 'infracoccygeal sacropexy' works differently to the TFS in that it only reinforces the distal part of the uterosacral ligaments and it anchors the vaginal apex to the posterior muscles of the pelvic floor with a polypropylene tape (Petros 2001). A high cystocele indicates the cervical ring/cardinal ligament complex has been disrupted (fig 4-61) and needs to be repaired. If the apex is wide (fig 4-95), a transverse full-thickness incision approximately 2.5 to 3 cm wide is made in the posterior vaginal wall 1cm below the hysterectomy scar line. If the apex is narrow, or if the surgeon prefers it, a longitudinal incision is made starting from the level of the scar. Using dissecting scissors with the tip pressed against the vaginal skin, a channel is made in the direction of the ischial spine sufficient to insert the index finger. The ischial spine is located, and the point of entry through the pelvic muscles for the insertion instrument determined (fig 4-98). If an enterocoele is opened it is ligated with a high purse string suture.

With the patient in the lithotomy position (fig 4-96), bilateral skin incisions 0.5 cm long are made in the perianal skin at the 4 and 8 o'clock positions halfway between the coccyx and external anal sphincter (EAS) in a line 2cm lateral to the external border of EAS. The tunneller is pushed 3 to 4 cm into the ischiorectal fossa (IRF) keeping the plastic tip parallel to the floor. The index finger is placed into the tunnel created in the vagina to locate the tip of the tunneller which is then brought to the point of penetration of the pelvic muscle 1 cm medial and caudal to the ischial spine (figs 4-97 and 4-98). At this point, the tunneller is safely sited well away from rectum and peritoneum.

With the index finger continually applied to the plastic tip (fig 4-98), the tunneller is gently inclined medially, towards the vaginal vault, and pushed through the incision. With uterine prolapse, it is helpful if the tape exits through the uterosacral ligament. A rectal examination is made to ensure there has been no perforation. The insert is

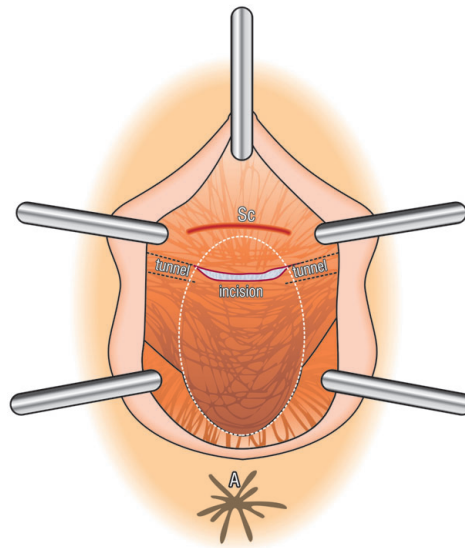


Fig. 4-95 Posterior IVS operation ('infracoccygeal sacropexy') Sc = hysterectomy scar.

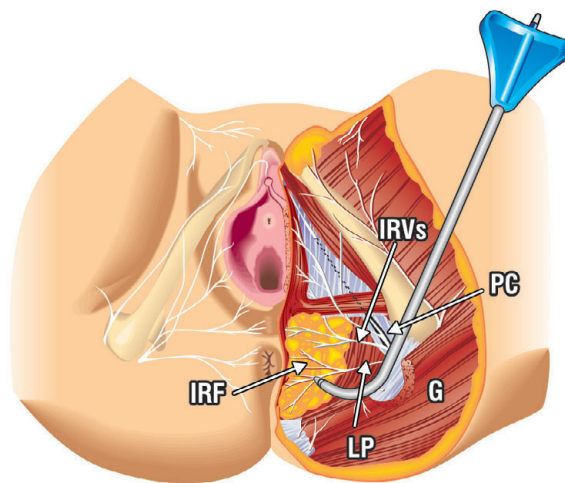


Fig. 4-96 Insertion of the tunneller. IRV = inferior rectal veins; PC = pudendal canal; IRF = ischioanal fossa; LP = levator plate; G = gluteus muscle.

reversed. An 8mm polypropylene tape is threaded into the eye of the plastic insert, bringing the tape into the perineal area. The procedure is repeated on the contralateral side, leaving the tape as a 'U' entirely unfixed at the perineal end.

Ensure the tape is kept flat, then suture it securely with interrupted No. 00 Dexon sutures behind the hysterectomy scar or, preferably, uterosacral ligaments. Ensure the tape is positioned well away from the incision, so as to minimize erosion. The remnants of the uterosacral ligaments and attached fascia are brought across to cover the tape. Generally this converts the transverse incision to a longitudinal one, narrowing the apex and lengthening the vagina. If there is excessive tension, suture the vagina as a 'Y' or transversely. Excessive tension may lead to wound breakdown and exteriorization of the tape. According to surgeon preference, one or two loosely applied No. 1 Dexon transvaginal mattress sutures help to keep the tissues in place while wound healing occurs. The perineal ends of the tape are pulled to full extension and then cut and left free, without suturing. The skin incision may be sutured without tension or apposed with 'steri strips'. If sutures are used, ensure that they are removed in 24 hours as this is usually the most painful part of the operation.

4

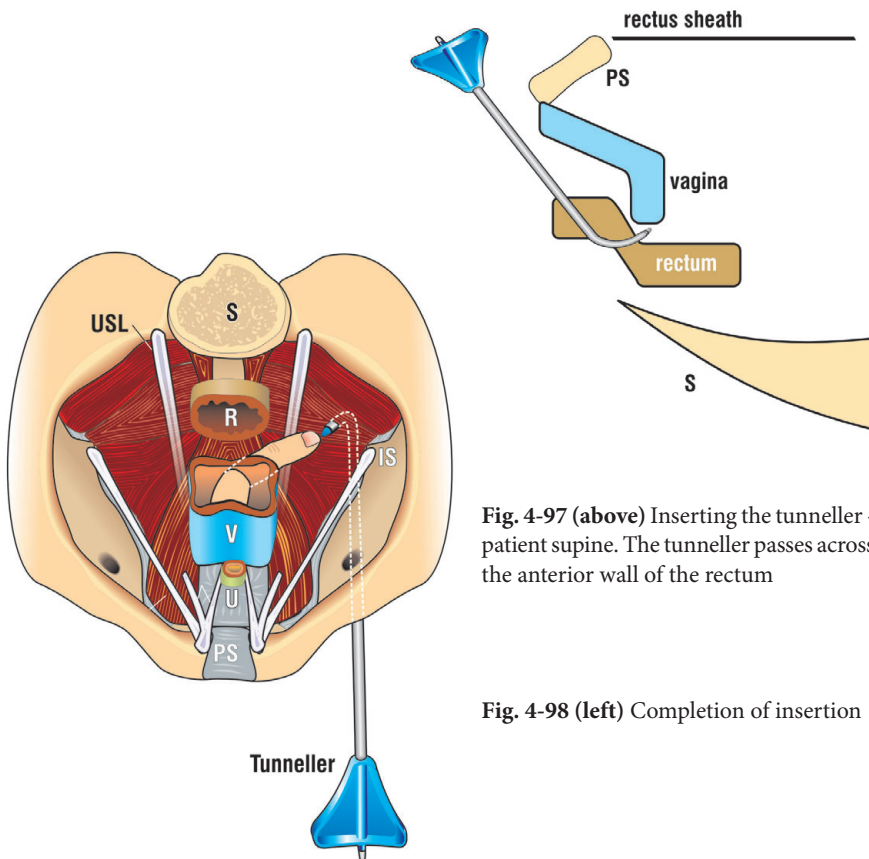


Fig. 4-97 (above) Inserting the tunneller - patient supine. The tunneller passes across the anterior wall of the rectum

Fig. 4-98 (left) Completion of insertion

Choosing Between a Transverse or Vertical Incision

Some surgeons use a longitudinal incision routinely, others only if the vaginal apex is narrow. The laterally displaced fascia at the level of the uterosacral ligaments (USL) should be brought across to cover the tape. This displaces the apex further posteriorly.

Overlying Fascial Repair

A fascial layer not only protects the tape from erosion, it helps reduce the prolapse. The fascia will begin to adhere to the tape by the tenth day. A No. 1 Dexon transvaginal holding suture helps to maintain the tissues in position while healing takes place. A TFS tape better restores the laterally displaced fascia (fig 4-101), and so better restores function.

Posterior Sling Repair of Uterine Prolapse

In this case, similar principles to the Manchester Repair are followed and these are combined with a posterior sling. An elongated cervix is amputated.

A transverse incision is made 1.5 to 2 cm below the junction of vaginal skin to cervix and opened out. This brings the uterosacral ligaments (USL) into view.

In patients with a normal cervix, a longitudinal incision in the posterior vaginal wall, starting at the cervix may be preferred.

Once the amputated cervix is reconstituted, the posterior sling is inserted as described previously. If possible, exit of the tunneller is directed between uterosacral ligaments (USL) and cervix. The tape is sutured into the USLs near their insertion to cervix. A temporary 0 Maxon suture is first inserted to approximate the laterally displaced rectovaginal fascia. Taking care not to include the tape, internal approximating sutures are placed as laterally as possible into the vaginal tissue. The purpose is to bring together the USL remnants and the laterally displaced vaginal fascia. Then a series of transvaginal No. 1 Dexon mattress sutures is inserted during repair of the rectovaginal fascia to ensure the fascia stays in a medial position, beginning at the level of USL and ending at the perineal body. The Maxon suture is removed at the end of the operation.

Equally important to the posterior sling in restoring the position of the uterus is adequate approximation of USLs and rectovaginal fascia (Petros 2001). If the prolapse is not adequately restored, it is possible that the transvaginal fascial suture is not lateral enough. It may also be necessary to re-attach the laterally displaced parts of the pubocervical fascia to the cervical ring if there is a high cystocele. This further reduces the prolapse.

Simultaneous repair of anterior and posterior walls may cause a ring constriction at that point (fig 4-52). Longitudinal vaginal incisions and avoidance of tissue excision help avoid these constrictions.

If the cervix is very wide, a wedge can be resected from 4 to 8 o'clock (fig 100). This simplifies approximation of the uterosacral ligaments and rectovaginal fascia without tension. However, care must be taken to electively ligate the descending branch of the uterine artery as primary post-operative bleeding may occur if the cervical sutures loosen post-operatively. This is always a possibility given the difficulties usually encountered in suturing the cervix.

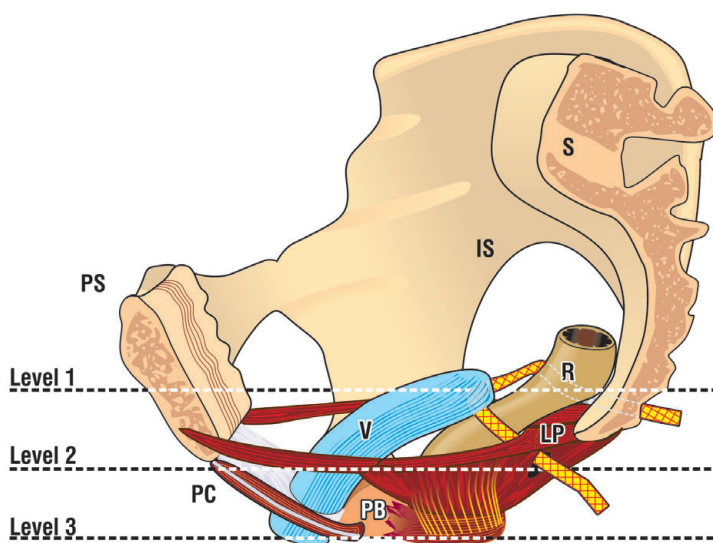


Fig. 4-99 The role of the posterior sling tape in anchoring the apex of the vagina. The posterior IVS operation does not reinforce the uterosacral ligament along its course. It anchors the apex of the vagina to the posterior pelvic floor muscles, which then contract to retain it in position.

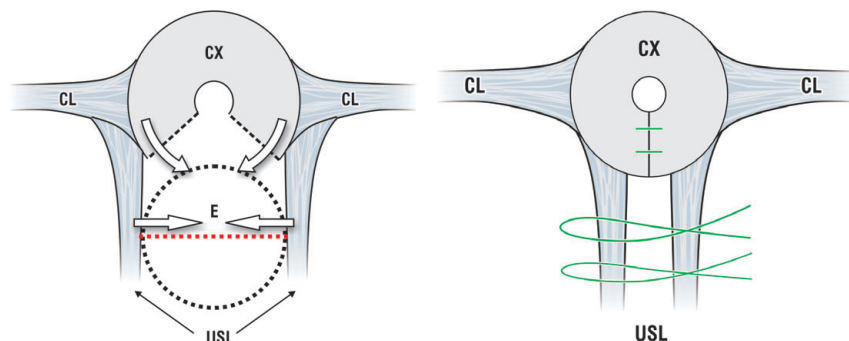


Fig. 4-100 Wedge resection of large cervix. E = enterocoele; CX = cervix; USL = uterosacral ligaments

Posterior Sling with Apical Defect Repair (enterocoele) (Level 1 Repair)

The apical defect follows the same surgical principles as vault prolapse repair. A longitudinal or transverse incision is made at the apex of the enterocoele, usually between 1.5 to 2 cm posterior to the cervix or hysterectomy scar. Care is taken to free the enterocoele sufficiently so as to locate the cardinal and uterosacral ligaments. The enterocoele is not routinely opened. With a large prolapse, the enterocoele is dissected clear. If entered, closure is effected with a purse string suture. A Posterior sling operation is performed, and the tape is anchored to the uterosacral ligaments or behind

the hysterectomy scar. The uterosacral ligaments and attached fascia are approximated to close the enterocele and to cover the tape using internal and transvaginal sutures as described previously. Excess vaginal tissue is not excised, rather it is sutured into the fascia. Excision of the vagina will only narrow or shorten it.

The Posterior TFS sling

The posterior TFS sling restores the apex and closes the enterocele (fig 4-101). A full thickness, 2.5cm transverse incision is made in the vaginal apex, 2 cm below the cervix, or just below the hysterectomy scar. The uterosacral ligaments or their remnants are identified and grasped with Allis forceps. If an enterocele is present it is reduced. Under tension, fine dissecting scissors create a 4-5 cm channel through the USLs, fig.101, just sufficient to accommodate the TFS delivery instrument. At the required depth, the instrument is triggered, and the anchor ejected. The instrument is removed, and 10 seconds allowed to elapse so as to allow for restoration of the tissues. The anchor is 'set' by pulling on the tape. The insertion is repeated on the contralateral side. Maintaining the instrument to support the anchor base, the tape is tightened along the instrument axis, and inspected for adequate tightening. The free end of the tape is cut 1cm from the anchor. The lax uterosacral ligaments and adjoining fascia above the tape are approximated as an extra layer of support for the TFS. Total operating time for this operation in a patient with no prior hysterectomy can be as little as 5-10 minutes.

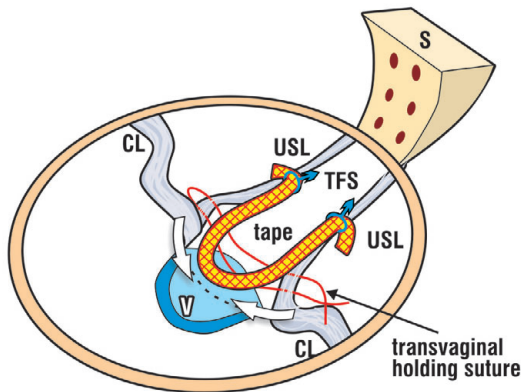


Fig. 4-101 Posterior TFS. Perspective: View from above. The tape is placed along the exact position of the uterosacral ligament (USL). The arrows indicate that the remnants of USL and also the cardinal ligaments (CL) need to be approximated if the apex is wide, so as to prevent enterocele formation.

How the posterior TFS differs anatomically from other vault suspension procedures.

On comparing figure 4-99 with fig. 4-101, it is evident that the plane of TFS sling is higher than that of the infracoccygeal sacropexy (Posterior IVS) sling, and it is angulated upwards, not downwards. As regards sacrospinous fixation, the vaginal axis is distorted laterally, the plane is 2cm lower than the uterosacral ligament (USL), and the potential restoration length significantly shorter, as the USL proceeds far behind the SSL towards the sacrum.

The Posterior Fornix Syndrome addressed with TFS posterior sling

Petros & Richardson (2008), 67 patients, mean 9 month review. Improvement rate expressed as a percentage: prolapse cure (n=67) 97%; urinary frequency >10/day (n=27) 63%; nocturia >2/night 83% (n=47); urge incontinence >2/day 78% (n=36); abnormal emptying 73% (n=53); pelvic pain 86% (n=46) faecal incontinence 87% (n=23). Significant improvement was noted in 10/17 patients with severe urge incontinence with no stress incontinence symptoms (mean change 215gm-6gm), and 6/8 patients with symptomatic detrusor instability (mean change 288gm-17gm).

Posterior TFS Sling at the Time of Vaginal Hysterectomy

Vaginal vault prolapse is a major long-term complication of hysterectomy. Posterior TFS sling during vaginal hysterectomy is simple, takes only a few minutes to perform, yet provides strong vaginal vault support at 12 month review (Petros and Richardson, unpublished data). A 4-5cm long channel is made directly adjacent to the uterosacral ligament pedicles. The anchor is applied to both, and the tape tightened until the vault is fully elevated and the enterocoele closed.

Repair of Rectocele

Traditional vaginal repairs approximate the laterally displaced fascia by sutures only. Damaged tissue is approximated to damaged tissue. The rectovaginal fascia is subjected to powerful stretching forces. The healing wound has little strength in the first few weeks. The high recurrence rate of this type of surgery can ultimately be attributed to not repairing the key structural supports of the posterior vaginal wall, the uterosacral ligaments, and the perineal body. The uterosacral ligaments are a vital anchoring point for the muscle forces which angulate the posterior vaginal wall (see Ch2). The perineal body acts as an anchoring point for the perineal muscles, and also, for the external anal sphincter (fig 4-94). It, too, is subjected to powerful muscle forces. A thin "stretched out" perineal body is difficult to repair using sutures only as damaged tissue is sutured to damaged tissue.

There are six main options for rectocele repair:

1. Traditional Excision of Vagina and Re-approximation of Cut Edges.

This is the worst of all options and offers no advantages to the direct repair option described below. The surgeon is guessing the position of the laterally displaced fascia. If excess tissue is excised, then the vaginal edges must be stretched, or dissected clear of the fascia so that they may be approximated. In either case the vagina is weakened further, and either shortened or narrowed. fig. 101a.

2. Direct Repair without Excision of Vagina

This technique works well if the displaced tissues appear strong. If the fascia is reasonably good, it can be brought to the midline. A midline incision is made. Adherent rectum is freed from vagina. Laterally displaced fascia is approximated.

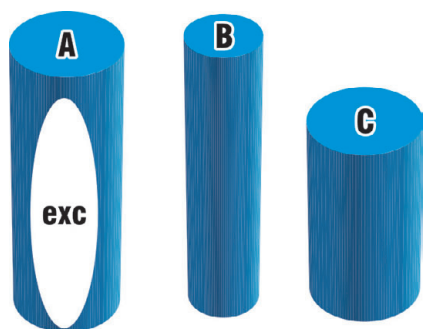


Fig 4101a Excision of vaginal tissue “A”, will narrow the vagina ‘B’ or shorten it “C”.

Excess vagina is attached to the deeper fascia rather than excising it (fig 4-49). Apparent excess of tissue usually shrinks by the post-operative visit. A temporary transvaginal Maxon suture placed as laterally as possible is helpful in bringing healthy fascial tissue more medially, where it is accessible to repair.

3. ‘Bridge Repair’

A ‘bridge repair’ (figs 4-102 & 4-103) uses autologous fascia (‘bridge’) to reinforce the middle part of the herniation. This creates a strong central bridge over the centre, the weakest part of the herniation. It should only be used with very large herniations which would usually require excision of vaginal tissue.

‘Creation of the Bridge’

Full thickness parallel longitudinal incisions are made along the posterior vaginal wall. These are carried down to within 1 cm of the introital skin to create a ‘bridge’ of tissue generally between 1.0 and 1.5 cm wide (fig 4-102). The borders of the incisions are separated with minimal dissection. Adhesions between vagina and rectum are separated. The surface epithelium of the bridge is destroyed by diathermy, and the edges of the bridge attached with interrupted sutures into the fascia below the adjoining vagina tissue.

The bridge is anchored distally to the perineal body (fig 4-103), and also proximally to the uterosacral ligaments or posterior sling. Interrupted mattress sutures bring the laterally displaced fascia towards the midline. The bridge is anchored into this fascia.

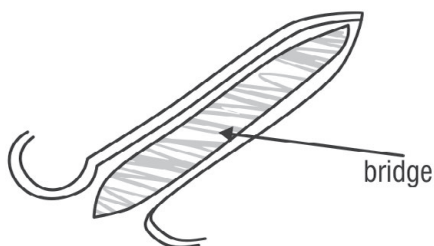


Fig. 4-102 Creation of the bridge

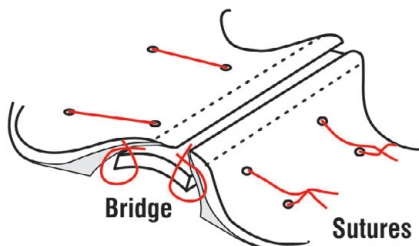


Fig. 4-103 Suturing the ‘bridge’ ‘B’

Potential Complications of 'Bridge' Repair

- a. Excessive width of the bridge may narrow the vagina or break down post-operatively.
- b. A retention cyst may form in 5% of patients. This is filled with sterile yellow fluid and it can be located with transperineal ultrasound. It is easily treated by excision.

4. Use of Sheet of Mesh to Cover the Whole Posterior Wall

4

In patients with previous vaginal repairs and especially if the lateral fascia is weak, there may be little option but to reinforce the weakened epithelium with polypropylene mesh. Erosion rates from 3% to 28% have been reported. The erosion rate may be related to technique. A general rule is to approximate the laterally displaced rectal smooth muscle with interrupted sutures and use a mesh large enough to extend towards the lateral attachments of the vagina. Some surgeons prefer to suture the mesh laterally, others not.

A greater problem than erosion is the elimination of the rectovaginal space, fig.4-22, and adhesion of the vagina to rectum. This would prevent the backward stretching of vagina which occurs during straining and micturition (figs 2-17 and 2-19), and importantly, intercourse. This may explain the reports of pelvic pain and dyspareunia reported with mesh procedures (Milani et al 2005). Biological mesh mostly avoids such complications, but it has a much higher failure rate.

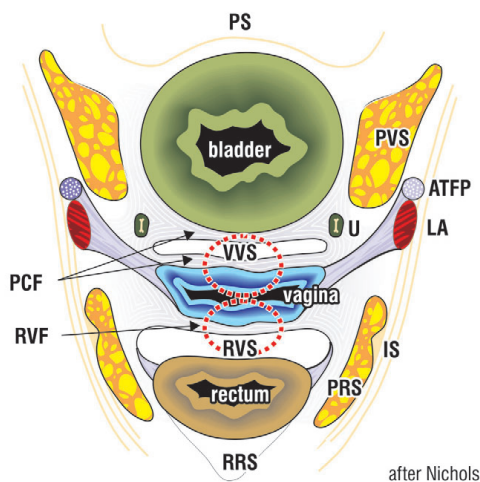


Fig 4-22 The importance of preserving the spaces between the organs. The red circles indicate how the spaces between the organs may be obliterated when mesh is inserted between the rectovaginal (RVS) or vesicovaginal (VVS) space. U = ureter; RVF = rectovaginal fascia; RRS = rectorectal space; IS = ischial spine; ATFP = arcus tendineus fascia pelvis; LA = intermediate pubococcygeus muscle

5. Mesh Sheet or 'bridge' plus Posterior Sling ('Prolift, Apogee etc.')

From a structural perspective, this technique is superior to unattached mesh as the sheet is anchored into the posterior muscles by the sling. The same reservations as all mesh sheet implants (shrinkage, erosion, fistula) remain. Anchoring the mesh or sling through the sacrospinous ligament (SSL) is potentially hazardous, as there is a significant danger of damaging sacral nerves issuing directly above the SSL, and the

plexus of vessels often found below (Barksdale et al 1998). Bleeding from such vessels is extremely difficult to control.

6. Posterior sling plus Perineal Body Repair

Only the types of perineal body repair will be described in this section. There is some confusion as to what constitutes the “Perineal Body”. The area of the perineal body (circle, fig 4-103a) is also known as the central tendon of the perineum, circle, fig. 4-103a, a fibromuscular structure densely adherent to the anus and distal part of the vagina. It is the insertion point of the bulbocavernosus muscle (BS), and deep and superficial transverse perinei muscles (TP), fig. 4-103a. Anatomically, there are two perineal bodies linked inextricably by a firm central tendon. In a normal woman, the Perineal Body complex structurally supports >50% of the posterior vaginal wall (See fig. 2-43, Ch2). It is evident from examining fig. 4-103a, that if the central tendon is sufficiently stretched, the supporting muscles, in particular, the deep transverse perinei, may be displaced laterally and inferiorly, fig 4-103b, causing protrusion of the rectum (low rectocele), and prolapse of the anal canal and associated structures. This is sometimes described as the ‘descending perineal syndrome’.

Simple Perineal Body Repair (Level 3 Repair)

The perineal body is 3-4 cm long and is often found stretched very thinly on the anterior surface of the anus, especially in patients who have to manually support the perineum so as to empty their bowels. A transverse incision just inside the muco-cutaneous junction facilitates access to the laterally-placed parts of the perineal body. The rectum is often adherent to PB, and requires careful dissection to reveal the PB situated below.

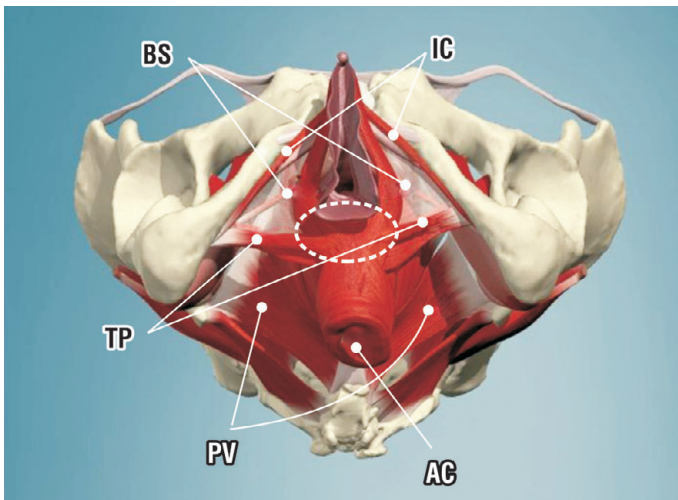


Fig 4-103a The broken circle represents the central tendon of the perineal body. It is the insertion point of the bulbocavernosus muscle (BS), and deep and superficial transverse perinei muscles (TP). PV=pubovaginalis; AC=anal canal; IC=ischio-cavernosus ; AC=anal canal. From Santoro G, by permission.

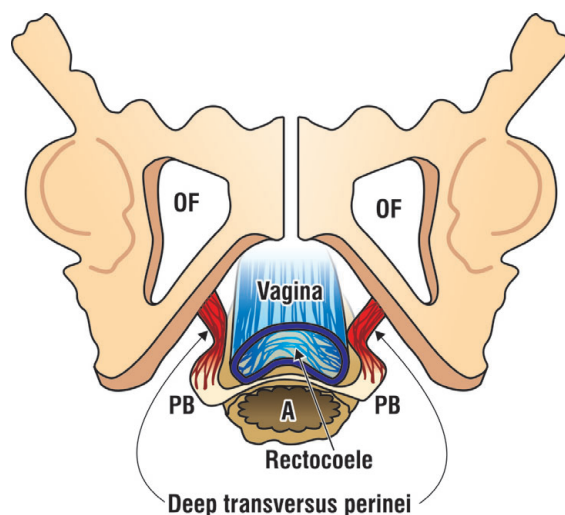


Fig 4-103b Stretched and damaged peineal body. The muscle bellies in particular the transverse perinea muscles (TP) have separated laterally and prolapsed. The anus (A) and rectum protrude into the vagina (V). OF=obturator fossa.

The PB is firm and whitish in appearance. If the PB is deep and lateral, a No1 Vicryl suture on a large needle is helpful in locating it. Tight approximation of the laterally displaced perineal bodies may lead to pain, disruption, and recurrence. The use of Maxon or PDS sutures may cause a 'pinhole' fistula if the anal tissue is very thin and the sutures are tight.

TFS Perineal Body Repair (figures 4-103c to 4-105)

The perineal body is dissected from adherent rectum as above. The perineal body is located and brought medially with a No1 Vicryl suture on a large needle, and then grasped with an Allis forceps for security. Thus held, a longitudinal channel approximately 4 cm long is made into the substance and along the length of the deep transverses perinei, fig. 4-103c, to just behind the posterior border of the inferior pubic ramus. An index finger in the rectum guides the dissection. Following insertion of the anchors, the laterally displaced perineal bodies are gently approximated by tightening the TFS tape until a resistance is felt, fig.103c. At this stage, a 'bridge' of tape 1.5 cm long can usually be seen between the bodies, fig.103c. The 'bridge' becomes infiltrated with scar tissue in time, and cannot be felt by the patient or her partner during intercourse.

Plication of Rectal Serosa as an Adjunct to Vaginal Repair

The serosal layer of the rectum may 'balloon out' much as the vagina does with a rectocele. Plication buttresses the herniated sero-muscular layer of the rectum. With the cut ends of the vagina separated, and with one finger in the rectum, the rectal serosa

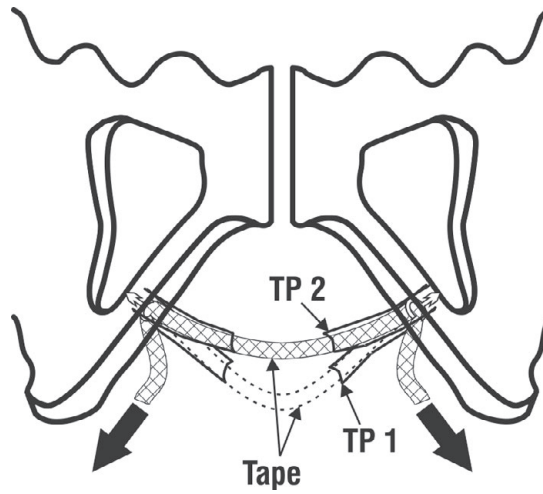


Fig 4-103c TFS repair of the perineal body. A channel is made longitudinally on both sides through the deep transverses perineal muscle (TP) just beyond the posterior surface of the descending pubic ramus. The anchors are inserted and tightened (arrows). This elevates the prolapsed tissues and brings them towards the midline, leaving a 1.5cm 'bridge' of tape between the bodies. TP1=position of a lax deep transversus perinei muscle, and TP2 after it has been tensioned.

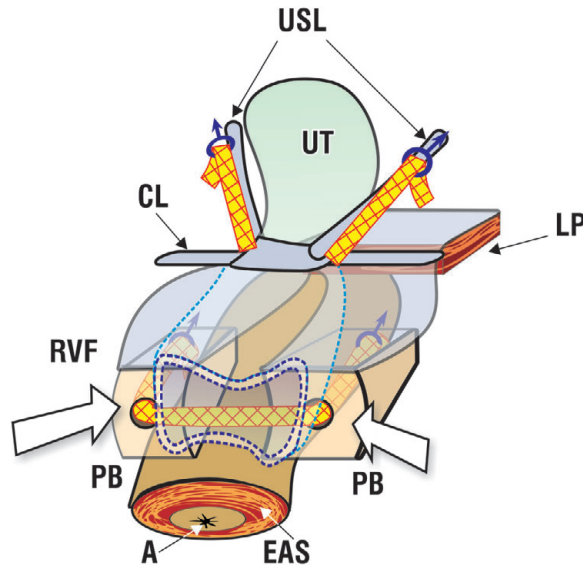


Fig 4-104 Large rectocele repair. Approximation of the perineal body (PB) and uterosacral ligaments (USL) by tightening the TFS, effectively blocks entry of the rectocele into the vagina. A=anus; RVF=rectovaginal fascia; CL=cardinal ligament.

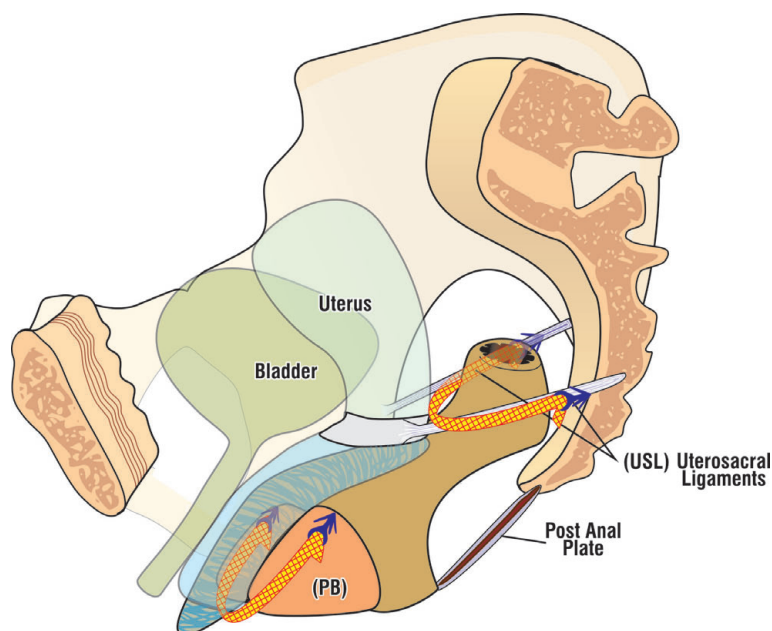


Fig. 4-105 Repair of everting rectocele and anterior rectal wall intussusception. Lateral perspective view. The USL tape supports the fascia of the anterior rectal wall and “re-glues” it to the utero-sacral ligaments. The inferior perineal body (PB) tape brings together the laterally displaced PB and fascia narrowing the herniated space, and supporting the lower half of the posterior vaginal wall.

TFS perineal body repair of rectocele recurrence

A 46 year old patient presented with a rectocele, faecal incontinence and difficulty with bowel evacuation requiring digitation. A 3 level posterior repair was performed: posterior sling, level 2 repair without vaginal excision, and dissection and approximation of laterally displaced perineal bodies. The rectocele and bowel evacuation difficulty, cured initially, recurred within 6 months, as did requirement for digitation. The faecal incontinence remained cured. The rectocele and lax perineal body were addressed with an inverted T incision in the posterior vaginal wall, with TFS perineal body repair, fig 4-104. Bowel evacuation returned to normal, and the rectocele remained cured at 2 year review.

Interpretation: A simple rectocele repair approximates damaged tissue to damaged tissue, and so is prone to recur. The TFS perineal body repair creates an artificial neoligament to a depth of 4cm, extending from one deep transversus perinei to the other, and tightened to approximate the connective tissues between these structures. As the perineal bodies constitute 50% of the posterior vaginal wall support, the rectocele is also cured, fig 4-104.

is plicated using interrupted mattress-type sutures. The posterior vaginal wall is then repaired in the standard way.

Potential Complications of Posterior Zone Repair

Risk of Rectal Perforation During Vaginal Repair

In patients with a scarred perineum, it is critical to dissect only under tension so as to minimize the risk of rectal perforation. Finger dissection in these circumstances is especially dangerous. It is suggested that haemostats be placed on the edge of the vagina and also the rectal wall so as to create sufficient tension for the dissection to be performed with dissecting scissors. A good assistant creating counter tension and one finger in the rectum are helpful. If the rectum is perforated, then the rectal wall must be mobilized sufficiently from the adjacent scar tissue so as to facilitate a 'tension-free' repair in at least two layers.

Haematoma

Anatomically, the tunneller is inserted into the ischio-rectal fossa, well away from the perirectal veins or the pudendal nerve. The blunt tip of the tunneller reduces (but does not eliminate) the risk of haematoma in the fossa. Infection is rare. A haematoma from the vaginal repair is more likely.

Rectal Perforation by the Tunneller

Any perforation is extraperitoneal, punctate, and is closed by smooth muscle contraction. If perforation occurs, simply remove the tunneller and redo. Any small injury is sutured with two sutures applied from the vaginal end. Fistula formation is highly unlikely.

Tape Erosion with Polypropylene Tapes

Tape erosion is uncommon with polypropylene mesh tape. Erosions generally occur centrally into the vagina. The tape is grasped, the vaginal mucosa is pushed down around it. Under tension, the eroded segment is trimmed with scissors pushed down below the vaginal mucosa. Often this can be done as an office procedure. Deeply burying the tape behind the hysterectomy scar helps reduce the erosion site to 1% – 2%. Although clinical infection is rare, it is advisable to perform bacteriological swabs so as to identify pathogenic bacteria and to treat the patient with appropriate antibiotics prior to any surgical intervention. In rare cases, an ischio-rectal sinus may occur. The track usually extends to a granulation site at the vaginal apex, from where the tape can be removed. The site of the tape fixation (uterosacral ligaments) is distant from the rectum, making rectal erosion highly unlikely.

Complete Rejection with Polypropylene Tapes

Complete rejection occurs only rarely with polypropylene tapes. The tapes are easily removed in toto by grasping the vaginal end and pulling gently. The prolapse may recur after removal of the tapes.

Surgical cure of Idiopathic Faecal Incontinence by suspensory ligament repair

This section summarizes a series of 5 surgical studies, comprising part of a larger work, published online as “A Musculoelastic Theory of Anorectal Function and Dysfunction in the Female” Petros & Swash, J. Pelviperineology 2008; 27, 3: 107-121 (www.pelviperineology.com). These 5 works (Studies 8-12) directly challenged the Theory by implanting tapes in the suspensory ligaments in patients with faecal/urinary incontinence and/or “obstructed defaecation”.

Study No.8 Stress urinary incontinence results from muscle weakness and ligamentous laxity in the pelvic floor. (Petros, Swash & Kakulas J. Pelviperineology 2008; 27, 3: 107-9). A blinded clinical/muscle biopsy study demonstrated a minor role for myopathy in SI causation. Though myopathy was found in the majority of biopsies, a majority of patients with anterior zone (pubourethral ligament) damage were cured of SI following creation of an artificial pubourethral neoligament,

Study No.9 - Double incontinence, stress urinary and faecal, cured by surgical reinforcement of the pubourethral ligaments. (Hocking I, J. Pelviperineology 2008; 27, 3: 110). Cure of >90% of patients who had both stress urinary and faecal incontinence (anterior zone damage only) with a midurethral sling operation demonstrated that pubourethral ligament damage may cause both conditions.

Study No.10: -Faecal incontinence cured by surgical reinforcement of anterior and posterior pelvic ligaments (Petros & Richardson J. Pelviperineology 2008; 27, 3: 111-3). Cure of faecal incontinence (FI) and multiple posterior zone symptoms (such as urgency, nocturia, and pelvic pain) indicated that laxity in uterosacral ligaments may also cause FI. Abnormal anal manometry, slow pudendal nerve conduction times, and damaged internal anal sphincters were not predictors of surgical failure.

Study No 11: Ligamentous repair using the Tissue Fixation System (TFS) confirmed a causal link between damaged suspensory ligaments and urinary and faecal incontinence (Abendstein et al J. Pelviperineology 2008; 27, 3: 114-7). Patients had surgical repair of damage in all 3 zones, including cystocele (middle zone repair). The cure rate for faecal incontinence (FI) was 89%. The cure rate of other symptoms (such as urgency, nocturia, and pelvic pain) was similar to that of Study No 10, indicating that middle zone defect (cystocele), did not appear to be a significant aetiological factor in faecal incontinence causation.

Study No 12. Role of the uterosacral ligaments in the causation of rectal intussusception, abnormal bowel emptying, and faecal incontinence. (Abendstein et al.J. Pelviperineology 2008; 27, 3: 118-21). This radiologically controlled study demonstrated that symptoms of obstructed defaecation, faecal incontinence anterior rectal wall intussusception, pelvic pain, and urinary symptoms can be improved following creation of artificial uterosacral neoligaments, repair of rectovaginal fascia, and perineal body.

Retention Cyst following Bridge Repair

This is uncommon (<5%) but it may present as an egg-shaped painless cystic lump. Treatment involves excision of the cyst and vaginal repair.

4.4 Post operative Monitoring: Strategies for Managing Recurrent or New Symptoms

In the application of the Integral Theory surgical system, the surgeon needs to address post-operative symptoms from the perspective of 'ongoing management and cure' rather than 'single fix' surgery.

In some cases, more than one operation may be required before sufficient improvement is achieved because of weak tissues, multiple sites of damage, or because the structure of the pelvic floor readjusts after surgery to expose new weaknesses. Because the Integral Theory surgical system emphasizes conservation of tissue, minimal invasiveness and relative absence of pain, repeat operations can be performed in patients with recurrent or new symptoms without harming the patient. It is important to explain all this to the patient before surgery is performed especially as it is difficult for a patient to distinguish between new or persisting symptoms. Rarely do patients volunteer improvement in some symptoms but not others. They mostly state: 'I am not cured'.

The best way to reassure such patients and give renewed hope is to demonstrate improvement in urgency or stress symptoms by use of 'simulated operations' (Chapters 3 and 6).

Unravelling the anatomical basis for 'failure to cure' may be a complex issue. From the surgeon's perspective, 'failure to cure' may be due to wrong diagnosis, decompensation of other connective tissue structures caused by the intervention itself, or surgical failure.

The author's approach is outlined below. This approach is based on the surgeon having a good knowledge of the connective tissue structures (fig 1-10) and the Integral Theory Diagnostic system, particularly how to diagnose minor degrees of connective tissue damage (because these may be the cause of major symptoms). These understandings are critical in any assessment of recurring or emerging symptoms and are described in detail in Chapters 3 and 6 (section 6.2.4).

The pre-operative protocol set out in Chapter 3 (questionnaire, 24 hour urinary diary, cough and 24 hour pad tests (Appendix)) are particularly useful as a benchmark for patients with ongoing problems.

The Origins of Subclinical Damage - How One Zone May Decompensate After Repair of Another Zone

In the normal pelvis, the pelvic forces are absorbed by the elastic component of the ligaments, muscles, and fascia, all of which act as 'shock absorbers'. Figure 1-09 shows how it is likely that multiple zones may be damaged - each to a different extent - if

the foetal head cannot pass easily through the canal. Because the structures of the pelvic floor are interdependent, the three zones may 'balance' the structural defects so that the full extent of the damage is not necessarily reflected by the full expression of symptoms.

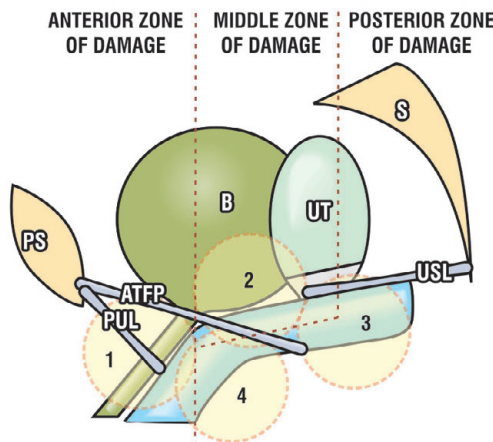


Fig 1-09 The foetal head (circles) may rupture or weaken (subclinically damage) ligaments or fascia in one or more zones of the vagina.

Thus, repairing one part of the vagina may cause the pelvic and abdominal forces from the zone that was repaired to be diverted to the other two zones. The weakest zone may give way, either as a total herniation (prolapse) or as a minimal but symptomatic herniation. The author has observed such decompensation ('blowouts') in 16% of patients after the posterior sling operation.

The Dynamics of Symptom Formation

The anatomical cause of new symptom formation is not always clear. Symptom formation is a dynamic process. It is secondary to the interaction of muscles, connective tissue and sensory nerves. The diagnosis of zone damage may not be clear in up to 20% of cases. However, a sound knowledge of dynamic anatomy (Chapter 2), the techniques of 'simulated operations' (Chapters 3 and 6), and the awareness that some neurologically based symptoms such as nocturia, urgency and pelvic pain may be caused by minor anatomical defects, is very helpful in working out the anatomical basis of symptoms.

Persistence of symptoms, in particular urgency, may 'camouflage' a connective tissue decompensation in another zone that causes similar symptoms to emerge. In such cases, the physician needs to compare the post-operative symptoms with the pre-operative symptoms, using the Pictorial Diagnostic Algorithm (fig 1-11) as a guide.

The appearance of new, different symptoms gives a strong indication as to the site of damage. A standard semi-quantitative questionnaire (Appendix) used pre- and post-operatively, and in collaboration with the Pictorial Diagnostic Algorithm (fig

1-11), can provide comprehensive insights. However, use of the Pictorial Diagnostic Algorithm does not help diagnose the ‘tethered vagina syndrome’ which should always be suspected in patients with multiple vaginal repairs who report large losses of urine. In the ‘tethered vagina syndrome’, the scar tissue ‘tethers’ the directional muscle forces so that the posterior urethral wall is pulled open by the posterior muscle forces during prolonged slow-twitch effort (see Chapter 4).

Example 1: Persistence of Symptoms

Persisting urgency after surgical repair of one zone may not always be caused by surgical failure: it may be caused by connective tissue decompensation (‘blowout’) in another zone. The physician needs to always be aware that symptoms merely reflect the changing dynamics of structure caused by surgical intervention. In this situation, the first step is to meticulously compare the post-operative symptoms against the pre-operative symptoms, preferably by using a standard semi-quantitative questionnaire (Appendix).

Example 2: New Symptoms

The occurrence of neourgency and difficulty in bladder emptying are the best known ‘new’ symptoms. These symptoms occur in up to 20% of patients after a Burch Colposuspension and may be reasonably attributed to a tight elevation activating the stretch receptors from below, and prevention of active opening out of the outflow tract (fig 2-19). Subsequent improvement in both symptoms can be explained by restoration of normal vaginal tension by viscoelastic creep. Patients with post-Burch urgency and abnormal bladder emptying who also develop an enterocoele are more likely to have suffered connective tissue ‘blowout’ to the posterior zone. Often such patients have other posterior zone symptoms such as pelvic pain and nocturia (fig 1-11).

Example 3: Stress Incontinence Cure After a Posterior Sling

Many patients report improvement in their stress incontinence symptoms after a posterior sling. This can be attributed to improved function of the downward rotational muscle force (LMA) which acts against the uterosacral ligaments.

Example 4: Post-cystocoele Cure of Stress Incontinence

Many patients report improvement of their stress incontinence symptoms after they develop a cystocoele. This can be explained by backward stretching of the vaginal hammock by cystocoele distension; the pubococcygeus closure muscles grip better and close the urethra from behind. Digitally supporting the cystocoele prevents this distension; the patient loses urine during coughing.

Managing Persisting Symptoms - An Anatomical Approach

Step1. Diagnose Zone of Damage.

The diagnostic protocol as described in Chapter 3 is used to identify the zone of damage: questionnaire, examination, and where relevant, ‘simulated operations’ and perineal ultrasound examination.

In some cases, especially with posterior zone symptoms, (fig 1-11) there may be no evident prolapse on clinical examination. However, if there are two or more posterior zone symptoms, some degree of posterior zone prolapse is almost invariably found when in the operating theatre.

Step2. Distinguish Between New and Old Symptoms - A Question of Timing.

Pre- and post-operative symptoms need to be compared. The scenarios are:

a) Appearance of New Symptoms

It is likely that the connective tissues in another zone have decompensated. Generally any new symptoms will appear weeks or months after surgery, but they may even appear within days.

b) The Same Symptoms Persist Immediately After Surgery

Persistence of symptoms immediately after surgery may be due to wrong diagnosis of zone of damage, or surgical failure due to wound disruption. In patients with

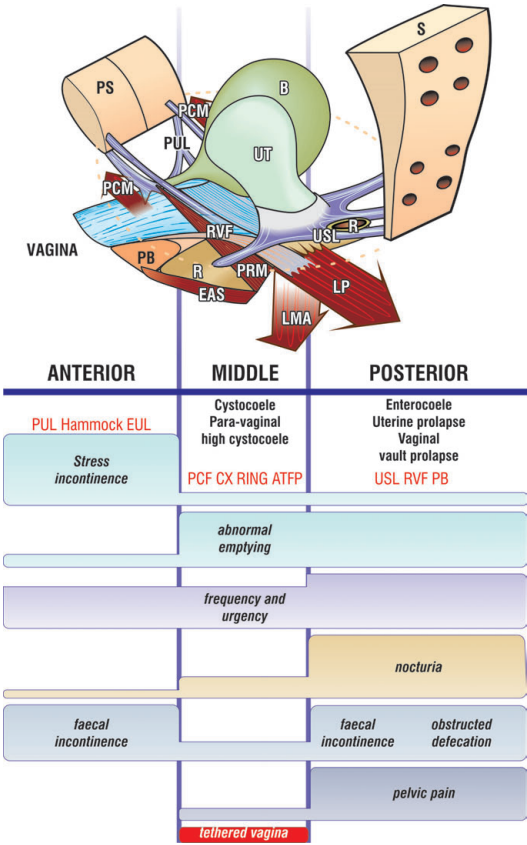


Fig. 3-03a Referring to the Pictorial Diagnostic Algorithm helps guide the physician as to the site of damage.

symptoms of urgency, causes such as fibroid, vesical cancer, post-operative infection, etc, need to be excluded.

c) Same Symptoms Reappear After a Period of Improvement

If the same symptoms reappear, the cause may be longer-term surgical failure due to poor tissue condition. Symptoms such as urgency which are shared between all three zones may be presented by the patient as 'persisting symptoms'. Detailed questioning of the patient is especially important here.

There are only two possible diagnostic possibilities if a patient reports recurrence of a symptom after a period of weeks or months: recurrence of the original defect, or decompensation ('blowout') in another zone. Because even minor anatomical defects may cause major symptoms, a careful examination of each zone is required using the diagnostic algorithm.

'Simulated operations' (Ch3) are especially useful in patients with minor degrees of damage. The physician needs to ensure that a patient's bladder should be sufficiently full to elicit urge symptoms in the supine position. This may require a period of waiting in the consulting rooms until the patient reports that she has urge symptoms. Some surgeons insert a catheter to fill the bladder until the patient reports urgency. The 'simulated operations' procedure is then undertaken, as outlined in chapter 3 and chapter 6 (section 6.2.4).

Step 3. A Zone By Zone Approach

Post-operative Anterior Zone Symptoms - Persisting Stress Incontinence

One of the main causes of failure of a midurethral sling is excessive laxity of the sling. However, the individual contribution of other structures to stress incontinence control needs to be assessed by performing simulated operations: the external ligament, pubourethral ligament, vaginal hammock, and posterior ligaments (see Chapters 3 and 6).

In patients who have had a midurethral sling and who leak unpredictably on sudden movement, but not during coughing, lax external ligaments (EUL) should

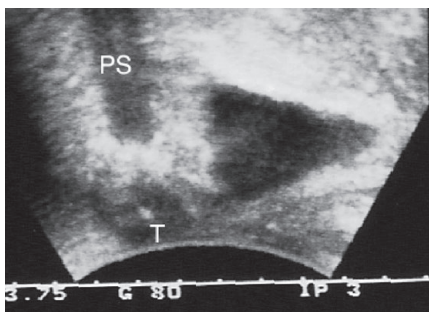


Fig 4-106 Failed sling, sagittal view, straining. Note rotation, funnelling and distal position of the sling 'T'. PS = pubic symphysis.

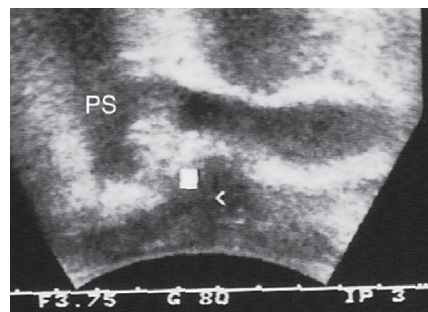


Fig 4-107 Same patient as 4-106, straining, midurethral anchoring with haemostat (<) restores urethrovesical geometry and continence. The distal urethra remains in the 'open' position.

be suspected, especially if the patient complains of a 'bubble' being released from her urethra. A gaping external meatus or urethral mucosal prolapse, is suggestive of EUL laxity. Transperineal ultrasound can identify the rotation and descent of the bladder base in the post-operative ultrasound (fig 4-106). This signifies an excessively loose pubourethral anchoring mechanism. By applying a haemostat unilaterally to the midurethra, as shown in figure 4-107, the urethrovesical geometry and continence is restored, indicating that this patient requires another midurethral sling.

In the case illustrated in figure 4-107, closer examination reveals that the bladder neck has closed but the distal urethra remains open. In this case, this patient would almost certainly require tightening of the suburethral vaginal hammock fascia, and possibly external urethral ligaments as well, for optimal cure.

As demonstrated previously, (Petros, Neuro. Urol. 2003), in patients with previous bladder neck elevation surgery, urine can leak without rotation and descent; these patients exhibited significant changes in their urethral closure pressure with a midurethral simulated operation (figs 6-08 and 6-12). A high percentage of these patients were cured with a midurethral sling and hammock repair. In rare occurrences, post-operative tape slippage may result in the tape holding the urethra open, analogous to the historical description of a fibrotic 'pipestem' urethra. This can be diagnosed by using a transversely applied ultrasound probe. In this case, the urethra does not close, or may even be pulled open during straining by a fibrous attachment to the posterior urethral wall, much as happens during micturition (fig 2-21).

Stress incontinence is mainly an anterior zone symptom. However, in patients with failed anterior sling surgery, who have had hysterectomy, and who continue to leak with coughing even during a midurethral 'simulated operation', lax uterosacral ligaments may be a contributory cause to their stress incontinence. This possibility can be verified by supporting the posterior fornix during a cough stress test (Chapter 6, section 6.2.4).

Multiple Operations, and a Failed Midurethral Sling Operation

In cases with multiple unsuccessful stress incontinence operations an exploratory/curative operation may be performed. The first step is to perform a careful full thickness midline incision to examine the urethral anatomy. If the tape is attached to the urethra, distending it into the open position, the urethra needs to be freed from the scar tissue, and as much tape as possible needs to be excised. If the urethral wall is thin, stretched and dilated, the cylindrical shape of the urethra may need to be restored by suturing the external surface with 3-0 dexton sutures.

If possible, these operations should be performed under local anaesthetic/sedation. Each of the structures contributing to continence control can be repaired and checked, one by one. This is done by installing 300ml saline in the bladder. The patient is asked to cough before and after each stage of the operation:

- reinsertion of a new tape,
- tightening the tape,
- then the hammock, and
- repair of the external ligaments.

If the patient is still leaking urine after this sequence, it may be necessary to test the contribution of the posterior ligaments. The posterior fornix is infiltrated with 1% Xylocaine, the right and left parts of the apex are grasped by Allis forceps and gently approximated to the midline, and the patient asked to cough. If this manoeuvre controls urine loss with stress, the posterior ligaments may need to be tightened, preferably with the aid of a posterior sling.

Especially after multiple vaginal repairs and/or Burch colposuspensions, ‘tethered vagina syndrome’ (Chapter 4) should always be excluded in patients reporting large losses of urine. In this case, it is the operation itself which has caused the problem. The cardinal symptom is large loss of urine every morning as soon as the patient’s foot touches the floor on getting out of bed in the morning. The cardinal sign is scarring and immobility in the bladder neck area of the vagina. Stress incontinence is not a major feature of this condition.

Post-operative Middle Zone Symptoms

Post-operative cystocele may occur in up to 16-18% of patients after posterior zone surgeries (Shull 1992, Petros 2001). Consulting the Pictorial Diagnostic Algorithm, (fig 1-11) and undertaking a speculum examination helps diagnose the exact site of middle zone damage - central, paravaginal, or cervical ring attachment. ‘Simulated operations’ performed for urgency (see Chapters 3 and 6) help to confirm how much the middle zone defect is contributing to causation. Given that the middle and posterior zones are related anatomically, the posterior zone should always be examined in patients with post-operative urge symptoms.

In patients who report large losses of urine on getting out of bed in the morning, and who have a tight scar across bladder neck, ‘tethered vagina syndrome’ should be suspected.

Post-operative Posterior Zone Symptoms

If neourgency occurs after a stress incontinence operation, the physician should consult the Pictorial Diagnostic Algorithm (fig 1-11) to check for *de novo* occurrence of pelvic pain, abnormal emptying, and nocturia. The presence of any of these symptoms strongly suggests posterior zone ‘blowout’. Sometimes there may be minimal uterine or vault prolapse on vaginal examination. To confirm the characteristic posterior fornix bulge often seen with such patients, the surgeon may need to apply upward pressure on the anterior vaginal wall with ring forceps, while asking the patient to strain downwards. Pelvic pain can be reproduced digitally by pressing into the posterior fornix. This needs to be done with great care, and once only, as it can cause significant pain to the patient. Slow emptying time (>60 seconds) and raised residual urine may help confirm the diagnosis of posterior zone laxity. Slow urine flow rate (<20ml/sec) is an unreliable parameter in the individual patient. See chapters 3 and 6 (section 6.2.4) for further details.

Future Directions for the Objective Diagnosis of Zone of Connective Tissue Damage

Using higher resolution ultrasound machines, and by developing more advanced diagnostic techniques, it may be possible in the future to diagnose breaks or weakness in the fascia, and, therefore, earlier stages of organ prolapse. At this stage, ultrasound is preferable to MRI because of access, cost, and the dynamic nature of the image. Emerging technology such as elastometers or piezo-electric instruments able to measure tissue stiffness may all contribute to the objective diagnosis of abnormally lax or damaged tissue.

4.5 Summary Chapter 4

This chapter discusses the concepts, principles and practice of the Integral Theory system of pelvic floor surgery. The most important concepts are that: restoration of form will also restore function; that the repair of connective tissue damage in the nine structures, three in each zone, will restore prolapse as well as function; and that major symptoms may occur with only minor structural defects. Certain surgical principles need to be followed: conservation of the uterus and vaginal tissue where possible (because of long-term effects); and the use polypropylene mesh tapes to reinforce damaged ligaments (as they cannot be otherwise repaired).

Basic rules which need to be observed so as to achieve day surgery are:

1. Avoid tension when suturing the vagina
2. Avoid vaginal excision
3. Avoid surgery to the perineal skin
4. Avoid tightness in the bladder neck area of the vagina

Surgical practice has two major elements:

1. Use of special instruments to minimize the surgery.
2. Site specific insertion of tapes to repair five main structures: pubourethral ligament, cardinal ligament, ATFP/pubocervical fascia, uterosacral ligaments and perineal body.

Various systems for reconstruction of vaginal herniations are analysed: traditional repairs, autologous 'bridge' repairs, heterologous grafts, 'tension-free' tapes, with or without large mesh attachments, and the newer, safer, 'tensioned minislings' which apply a different bioengineering principle to large mesh. The final section presents a framework for addressing recurrent or new symptoms following surgery. This framework is based on the three zone diagnostic approach, but includes strategies for assessing some possibly confounding anatomical issues arising from the intervention itself.

Pelvic Floor Rehabilitation

according to the Integral Theory

Towards a more time efficient method for pelvic floor rehabilitation and with a wider symptom scope

5.1 Introduction

The scope of traditional pelvic floor rehabilitation methods is mainly confined to Kegel exercises for improvement in stress incontinence, and 'bladder drill' to improve urgency symptoms. 'Bladder drill' can be explained as a 'training' of the neural inhibitory circuits from the cortex to all the inhibitory centres to maximal efficiency.

The Integral Theory System for pelvic floor rehabilitation (PFR) differs from traditional methods in four major ways:

1. It addresses symptoms of urgency, nocturia, frequency, abnormal emptying and pelvic pain in addition to stress incontinence
2. It introduces special techniques to strengthen the 3 directional muscle forces, and their ligamentous insertions.
3. It combines electrotherapy, hormones, fast and slow twitch exercises.
4. It is designed to seamlessly fit into a patient's daily routine.

The anatomy of traditional Kegel Exercises

'Squeezing', upward pulling of the pelvic diaphragm as described by Kegel (1948) is the core element of all traditional PFR methods. It involves a trained voluntary upward stretching of the organs, figs. 6-18 and 5-01

All organs and even levator plate (LP) are actively pulled upwards and forwards with 'squeezing' (figs 5-01,6-18). Only voluntary contraction of puborectalis can explain these movements. This movement does not pull directly against any of the pelvic ligaments, although it is likely that PCM reflexly contracts to pull the hammock forwards against the pubourethral ligament.

Although urge symptoms are not addressed with conventional pelvic floor exercises, anecdotal reports of patients controlling urge symptoms by 'crossing their legs and squeezing' are consistent with the pelvic muscles having a role in control of urgency symptoms. This can be explained by the pelvic muscles stretching the vaginal membrane upwards to support the stretch receptors (cf trampoline analogy).

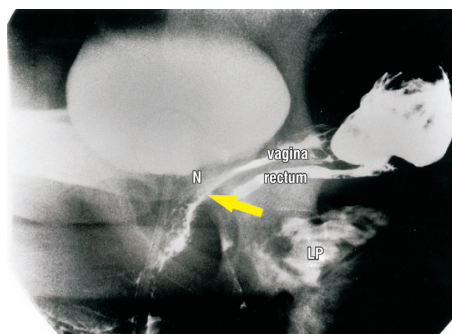


Fig. 6-18 Kegel exercise -voluntary pelvic floor contraction of m. puborectalis (arrow). The levator plate (LP), vagina, rectum and bladder are pulled upwards and forwards to lift and close the urethra from behind..

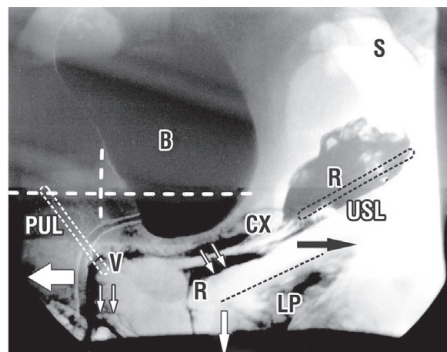


Fig. 2-21 Urethral closure during effort (coughing or straining),-same patient as fig. 6-18. The forward muscle force (arrow) stretches the distal vagina (V) forwards against the pubourethral ligament (PUL) to close the distal urethra, 'urethral closure mechanism'; the backwards and downwards muscle forces (arrows), stretch and angulate the upper vagina and urethra around PUL to 'kink' the proximal urethra, 'bladder neck closure mechanism'

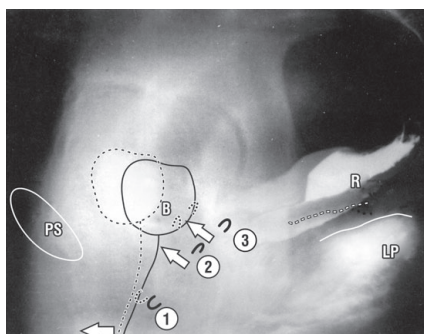


Fig. 5-01 The muscle movements during 'squeezing' are upwards and forwards. LP = levator plate; B = Foley balloon; R = rectum. Note the difference with the movements in figure 5-02. Because 'squeezing' is not the natural mechanism, it must be learned (fig 5-02). (Kegel 1948)

Rest = unbroken lines

Squeeze = broken lines

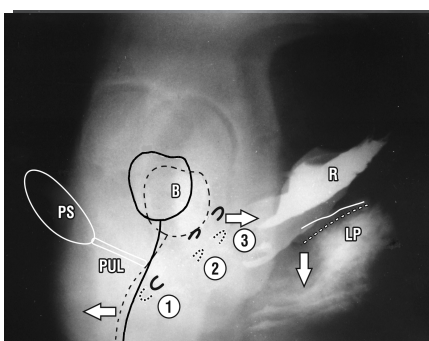


Fig. 5-02 Reflex muscle movements during coughing and straining. Same patient and labelling as figure 5-01. Note how the 3 different directional movements and downward angulation of levator plate pull against the pubourethral and uterosacral ligaments.

Rest = unbroken lines

Strain = broken lines

The anatomical basis for the Integral Theory System for pelvic floor rehabilitation (PFR)

It is emphasized that the urethral closure induced by Kegel-type muscle contractions (figs 5-01&6-17) differs radically from natural urethral closure, which is fully explained in Chapter 2, and summarized in figs 2-21 & 5-02.

Why the Integral Theory System for pelvic floor rehabilitation was developed

It was evident from radiological studies (Petros & Ulmsten 1993), that the organ and muscle movements observed during Kegel exercises, were radically different from those observed during coughing and straining, in that widely different muscles and ligaments were involved. It was evident that the pubourethral (PUL), and uterosacral ligaments (USL), were major insertions for the 3 directional muscle forces. It was already known that simultaneous surgical reinforcement of the PUL by a midurethral sling, and USL by a posterior sling (Petros 1997), gave high cure rates for symptoms of stress incontinence (SI), urgency, frequency, abnormal emptying, and pelvic pain. It was reasoned that using exercises such as squatting and straining would strengthen the natural closure muscles, and their ligamentous insertions, PUL and USL. It was also reasoned that if the Theory was valid, not only SI, but a much wider range of symptoms such as urgency, frequency, abnormal emptying, and pelvic pain should also be curable simply by including squatting type exercises. This proved to be so. The methods and results of the 1st and 2nd applications of the Integral Theory System PFR (Skilling & Petros, 2001, 2004) are detailed below in Tables I&II.

Towards a more time efficient method for pelvic floor rehabilitation – use of a “fit ball”

Despite conscientious application and follow-up, the dropout rate for the PFR methods used in the 1st and 2nd studies was 50%. On analysis, it appeared that a principal reason many of the patients discontinued was lack of time. It was reasoned that sitting on a rubber “fitball” would strengthen the same slow twitch pelvic muscles and ligaments as the squatting exercise. Therefore patients were advised to use a rubber “fitball”, fig.5-03, instead of a chair at work or at home, and to develop a habit of squatting instead of bending. It was also reasoned that the Kegel exercises could be dispensed with, as they did not address the natural closure muscles (figs. 2-21 & 5-02). The initial results in a pilot study of 12 working women with families was encouraging. All agreed to use the rubber fitball at work. The dropout rate at 6 weeks was zero, and the initial improvement rates appeared equivalent to the more involved techniques used in the studies 1&2.

This is a promising method which needs to be more fully evaluated with larger numbers of patients, and preferably, an RCT, with or without intravaginal electrotherapy.

*Methodology for the 1st and 2nd studies, Tables I&II.**Summary*

The main innovation was the addition of squatting-type exercises. It was proven that a significant improvement could be obtained with symptoms of urgency, nocturia, bladder emptying, pelvic pain, and stress incontinence.

The 1st study (Petros & Skilling, 2001) directly challenged the Integral Theory. It is known that strengthening a muscle also strengthens its tendinous insertions. It was



Fig. 5-03 The patient sits on a rubber ball instead of a chair. The act of balancing enforces correct posture, and slowtwitch contracture of the abdominal, pelvic, and thigh muscles.

reasoned that as the pubourethral and uterosacral ligaments are major insertions for the 3 directional muscle forces (fig 2-21), then using exercises such as squatting and straining would not only strengthen the natural closure muscles, they would also strengthen their ligamentous insertions. If this hypothesis, and indeed the Theory itself were valid, improvement could be expected in not only stress incontinence, as per the Kegel method, but also symptoms said to derive from uterosacral ligament laxity, urgency, nocturia, frequency, pelvic pain and abnormal bladder emptying

The 2nd study, Table 2, which was more rigorously conducted, confirmed the results of the 1st study.

Results of the First study (Petros & Skilling, 2001)

Sixty patients completed the study. Improvement was defined as >50% improvement in their symptoms (see Table 1).

Table 1	
Fate of Individual Symptoms (n=60)	
condition	>50% improvement
stress (n=42)	78%
urge (n=39)	61%
frequency (n=53)	62%
nocturia (n=24)	75%
pelvic pain (n=20)	65%
leakage (n=50)	68%
bowel problems (n=28)	78%

Results of the Second Study (Skilling, PM and Petros PE (2004), Table 2.

Of 147 patients (mean age 52.5years), 53% completed the programme. Median QOL improvement reported was 66%, mean cough stress test urine loss reduced from 2.2 gm (range 0-20.3 gm) to 0.2 gm (range 0-1.4 gm), $p < 0.005$ and 24 hour pad urine loss from a mean of 3.7 mg (range 0-21.8 mg) to a mean of 0.76 mg (range 0-9.3 gm), $p < 0.005$. Frequency, nocturia were significantly improved ($p < 0.005$). Residual urine reduced from mean 202 ml to mean 71 ml ($p < 0.005$) (See Table 2 for improvement in individual symptoms).

Table 2	
Fate of Individual Symptoms (n=78)	
condition	>50% improvement
stress incontinence (n=69)	57 (82%)
urge incontinence (n=44)	33 (68%)
frequency only (n=12)	10 (83%)
nocturia (n=32)	29 (90%)
pelvic pain (n=17)	13 (76%)

5.2.1 Indications

There were no exclusion criteria in the descriptions below. Any patient, regardless of the seriousness of her condition, was accepted for PFR. Patients who lost less than 2 gm urine with the cough stress test, or less than 10 gm in a 24 hour period, were particularly encouraged to do PFR.

Design

The regime consists of four visits in three months. The Pictorial Diagnostic Algorithm (fig 1-11) guides diagnosis of anatomical defects in the anterior, middle and posterior zones of the vagina. Hormone replacement therapy (HRT) is administered to thicken epithelium and prevent collagen loss. Electrotherapy is given for 20 minutes a day for the first four weeks to improve neuromuscular transmission. The patients do slow twitch muscle exercises – squatting or sitting on a rubber ‘fit’ball – for a total of 20 minutes per day.

First Visit

The patient is instructed in a Kegel exercise routine, two lots of twelve, three times per day. The exercises are performed in bed, face downwards, morning and night with legs apart, according to the methods of Bo (1990). The remaining 24 squeezes are performed at lunchtime or during visits to the toilet. It is helpful for the patient to

visualise squeezing the sides of a lemon inwards, or to pretend she is cutting off her urine stream. Endocavity electrical stimulation of 20 minutes per day is prescribed for four weeks. With any anterior zone defect, the probe is placed just inside the introitus on alternate days and in the posterior fornix every other day. The aim is to strengthen both PCM and LP. With pure posterior zone defects, the probe is placed in the posterior fornix only. Squatting or sitting on a 'fit ball' for a total of 20 minutes per day if possible is encouraged as a universal slow-twitch exercise. The aim is to integrate this activity into the patient's daily routine. For instance, the patient is encouraged to substitute squatting for bending at all times. If a patient has arthritis, she may sit on the end of a chair with legs apart or on a fitball. Compliance is vastly improved by explaining the principles behind the exercises, and encouraging patients to plan and record their daily routine.

Second Visit

In patients without a cystocele, a reverse downward thrust is taught on the second visit. The patient presses upwards with the probe or a finger placed approximately 2 cm inwards from the introitus, and strains downwards. The downward thrust is now alternated with the Kegel squeezes, each three times per day. The downward-acting exercises strengthen the fast twitch fibres of all three directional muscle forces.

Third Visit

The attendant checks the patient compliance (diary), discusses how she has incorporated the programme into her daily routine, and reinforces the aims and principles of the programme.

At the three month review (fourth visit), in consultation with the patient, a decision is made whether to proceed to surgery, or continue with Maintenance PFR

Maintenance PFR

By the end of three months, it is assumed that the patients have incorporated the exercises into their normal routine. Squeezing is alternated with the downward thrust, a total of six sets of 12 exercises per day. Squatting is by now an acquired habit. Electrotherapy is performed five days per month. The patient is advised to continue this routine for the rest of her life.

Comments

Those patients improved of their stress incontinence symptoms reported that they did not leak even when caught "off guard", in contrast to improvement with Kegel exercises. Kegel patients almost invariably leak when caught "off guard".

Almost 70% of patients who completed the treatment seemed unwilling to perform the reverse pushdown exercises. Squatting, Kegel and electrotherapy were well received.

Electrotherapy was found very useful (Skilling & Petros 2004), in that a marked improvement was noted within 2 weeks of commencing, a positive factor for patients to continue the programme.

Conclusions

The Integral Theory System for pelvic floor rehabilitation closely mimics the natural muscle movements, and provides improvement for a much wider spectrum of symptoms than traditional Kegel exercises. One disadvantage is that the squatting exercises may worsen stress incontinence in a small group of patients. A natural evolution of this system is the use of the rubber “fitball” instead of a chair. This is a very simple method, and extremely time efficient. Though the initial results are promising, it requires rigorous scientific testing, preferably with an RCT with or without electrotherapy, before it can be routinely recommended.

Acknowledgement:

The routine presented is that practised by Dr Patricia M. Skilling, Kvinno Centre, Perth, Australia.

Mapping the Dynamics of Connective Tissue Dysfunction

6.1 Mapping Function and Dysfunction of the Pelvic Floor

In 1976, the International Continence Society (ICS) introduced the first definitions for urodynamic testing. This was a seminal step in the history of pelvic floor science, as it established the principle of objective assessment of the lower urinary tract. Moreover, by creating standard definitions, a common language for investigators was created. Subsequent advances in ultrasound, radiology, MRI and biomechanics have provided additional tools for the clinician to identify damaged structures, and to proceed some way towards quantification of the damage. This section shows how such tools may be used to more accurately identify damaged structures. Accurate mapping of function and dysfunction (as opposed to diagnosing specific structural defects) is a far more difficult problem, as not all apparently damaged structures necessarily cause dysfunction. For example, not all patients with ‘funnelling’ during straining (anterior zone defect) necessarily have stress incontinence: Some patients with major degrees of prolapse (posterior zone defect) have no symptoms associated with lax posterior ligaments, yet others with minor degrees of prolapse may ‘complain bitterly’ of their symptoms (Jeffcoate 1962). ‘Detrusor instability’ may be found in up to 70% of normal patients (Van Doorn 1992), yet it is absent in up to 50% of patients with bladder instability symptoms. In order to overcome such problems, the concept of ‘simulated operations’ is introduced. This technique helps the clinician to more accurately assess function by observing the change following anchoring of a specific connective tissue structure.

Although all urodynamic tests are objective, they only provide a ‘snapshot’ of the system at that particular point in time. Even with the same test, the result may be different just half an hour later. The reason for this is that the control mechanisms of the pelvic floor behave in a non-linear (chaotic) manner, i.e., even a small change in a minor component of the system may have a major outcome as a result. Non-linear control helps to explain why symptoms (and even objective test results) may vary widely from day to day. It is essential that the basis for variability in test results be understood if objective tests are to make a meaningful contribution to ‘mapping’ of function and dysfunction of the pelvic floor (Petros & Bush 1998, Petros 2001).

6.1.1 Urodynamics - An Anatomical Perspective

The dysfunctions of the pelvic floor described in this book are all potentially curable by using the simple day-care techniques (as described in Chapter 4) to repair the nine causative defects identified in figure 1-10. The primary aim of 'mapping' techniques is to objectively assess which of these nine defects are the causal agents for the dysfunction that is occurring in the patient. The preceding pages have emphasized the physical properties of the urethra and anus. In simple terms, these are smooth muscle tubes linked by connective tissue to the pelvic muscles which activate opening or closure. The resistance generated within these tubes is perhaps the most critical factor in determining normal function and dysfunction of the bladder or rectum to which they are connected. Very important insights can be obtained by measuring the physical expressions of this resistance, that is, pressure and flow. Urodynamics is a means of measuring pressure within the bladder and urethra and also urine flow parameters. The Integral Theory approach to urodynamics can only be applied to the female at this stage.

The main emphasis of the ICS system in the female is on the cystometric diagnosis of 'detrusor instability' (DI), the presence of DI being a contraindication for surgery. However, this approach overlooks anatomical defects as causal phenomena. In the Integral Theory system, the presence of DI is not a contraindication for surgery: non-neurological patients with DI are potentially curable by repairing the anatomical defects which may be causing the DI. In particular, patients with no SI, but with urge frequency, nocturia, and perhaps other symptoms of posterior zone defect, are curable in 80% of cases following reconstruction of the posterior ligaments (Petros 1997, Farnsworth 2001).

There is no set technique for urodynamic measurement. Controversies exist for almost every aspect of measurement, especially as the act of measurement itself may significantly alter any result obtained. The aim of this section is to give the anatomical and biomechanical basis for urodynamic measurement, and to explain how these measurements relate to symptoms. This involves developing an understanding of the neurological feedback mechanisms. By observing real-time changes in urodynamic and ultrasound parameters following the anchoring of key ligaments, the Integral Theory concept of 'simulated' operations emerges. In this context, the patient's cortex functions as the urodynamic 'machine' which sensitively discriminates the impact on, say, urgency sensations, after each anchoring action of the 'simulated operation'.

Detrusor Instability is now known as "Overactive Bladder" (OAB).

The Basis of Urodynamics: Urethral Resistance

In its most basic form, the urethra is a tube which links the storage organ, the bladder, to the outside. The bladder contracts and pushes the urine out against the intra-urethral resistance. (As the x-ray studies show, the urethral tube is *narrowed* along its length by three directional muscle forces during *closure*, but *opened* along its length by two directional muscle forces during *micturition*. The intra-urethral resistance is inversely proportional to the 4th power of the radius (r^4) (fig 6-02) and directly proportional to the length. Therefore, the inability to actively close or open out the urethra because of lax connective tissue may have a disproportional effect on continence or emptying (i.e. bladder emptying times, peak flow and residual urine).

The Anatomical Basis of Urodynamic Measurement

Pressure transducers are used to measure pressure in the bladder, urethra and rectum. The rectal pressure is equated with the abdominal pressure and is subtracted from the bladder pressure to give the 'detrusor pressure'.

However, this methodology is inherently flawed. Like the bladder, the rectum is a receptacle surrounded by smooth muscle, and this may confound measurement. If the transducers are sited below the level of the pelvic diaphragm, pressure readings will be affected by the external anal sphincter (EAS) and puborectalis muscle (PRM) contraction. Only an intraperitoneal transducer can accurately reflect intra-abdominal pressure. Clearly this is not an acceptable methodology. A more valid approach to pressure increase for diagnosing DI is to seek a phasic pattern in the bladder channel because this will accurately reflect an activated micturition reflex.

6

In the normal patient during filling cystometry, the three directional muscle forces reflexly stretch the vagina to support the hydrostatic pressure of the urine. This relieves pressure on the stretch receptors (N). At the same time, the urethral tube is stretched and narrowed, so that the urethral pressure rises, a common observation during filling.

In the patient with lax ligaments, the vagina cannot be easily stretched (see the 'trampoline analogy'). Inability of the lax vagina to support 'N' may prematurely activate the micturition reflex. PCM relaxes, the urethral pressure falls, the detrusor contracts and this is recorded as 'detrusor instability'. Inflammation or pressure on N (e.g. cancer, uterine fibroids, excess bladder neck elevation) may create the same sequence of events by stimulating the stretch receptors directly.

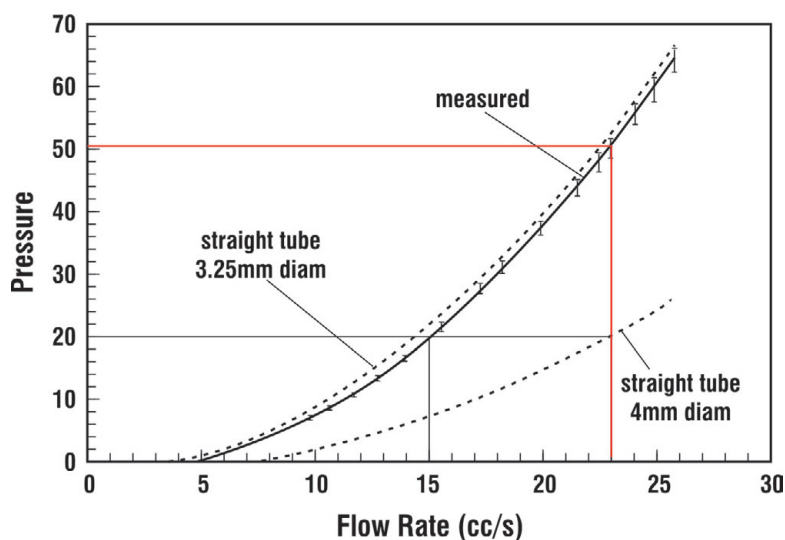
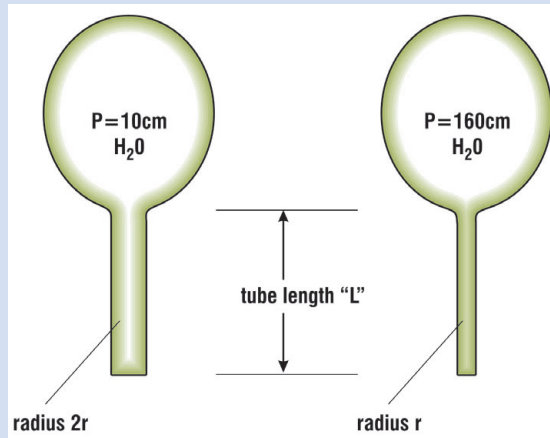


Fig. 6-01 The pressure/ flow relationship as measured during bench experiments (unbroken lines) and by computer simulation (broken lines). Note that a 0.75mm decrease in tube diameter from 4mm to 3.25mm (a 19% decrease) increases the expulsion pressure by 250% (red lines), consistent with the 4th Power Law of Poiseuille. After Bush et al. (1997).

Urethral Resistance and the Pressure-Flow Relationship

Urethral resistance is the key variable influencing bladder function and urodynamic measurements. The urethral resistance is governed by the musculoelastic mechanism which opens and closes the urethral tube. The diameter of the urethra determines pressure and flow during micturition and also effects closure. In simple terms, the bladder contracts and expels the urine through the tube (fig 6-02).

Fig. 6-02 The effect of urethral radius on expulsion pressure. Three directional muscle forces alter the urethral resistance by the 4th power during closure, and two muscle forces alter it during micturition.



Hagen-Poiseuille's Law - the Pressure/Flow Relationship

Hagen-Poiseuille's Law is fundamental to understanding the anatomical basis of urodynamics. It explains what happens during closure (continence) and opening of the urethral tube (micturition). It states that "the pressure 'P' required to expel a liquid through a tube varies according to the resistance within that tube". It can be simplified to: 'the resistance to flow within a tube varies directly with the length of the tube and inversely with its radius (to the 4th power)'. Thus, in figure 6-02, if the urethral tube can be opened out from radius r to $2r$ then the micturition pressure required *reduces* by a factor of 16 (i.e. 2^4). Failure of the two muscle forces to open out the urethra (i.e. increase r) means that the bladder has to expel the urine against a higher resistance. This may be experienced by the patient as 'obstructed micturition'. Conversely, if during coughing, the urethra can be closed from $2r$ to r by a Kegel contraction, then leakage will only occur with a pressure greater than 160cm H_2O .

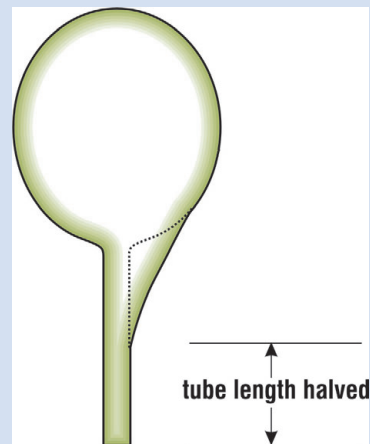


Fig. 6-03 Effect of length on expulsion pressure. During micturition 'funneling' effectively shortens the urethral tube, further reducing resistance and, therefore, expulsion pressure.

The Origin of Intra-Abdominal Pressure

As the pelvic and abdominal muscles share a common embryological origin (Power 1948), pelvic muscle contraction reflexly activates an abdominal muscle contraction. This proportionately increases the intra-abdominal pressure. This explains observations by Enhorning (1961) and Constantinou (1985) that during coughing, rise in urethral pressure frequently precedes the rise in bladder pressure. The former is activated by pelvic floor contraction, and the latter by abdominal contraction.

The Dynamics of Urethral Pressure Changes

The pressure measured at every point along the urethra by a pressure transducer is determined by the forces acting at that point and the intra-urethral area. (Pressure is force per unit area.)

'Closure Pressure'

'Closure pressure' (CP) is bladder pressure subtracted from urethral pressure. At 0 cm CP there is no resistance to urine leakage. However, many patients with 0cm CP do not leak during testing. Even at 0 cm, CP dynamic and frictional resistance factors may impede urine loss.

The 'Cough Transmission Ratio'

The 'cough transmission ratio' (CTR) is the ratio of the rise in urethral pressure divided by the rise in bladder pressure during coughing. The CTR is expressed in percentage terms.

An adequately tight hammock and pubourethral ligament (PUL) are required to close both 'd' and 'p' parts of the urethra during effort (coughing) (fig 6-04). The downward vector LMA also acts around PUL. Observations from surgeons of SI improvement after the Posterior IVS operation indicate there is also a role for the uterosacral ligament (USL) during urethral closure, USL being the insertion point of the LMA vector.

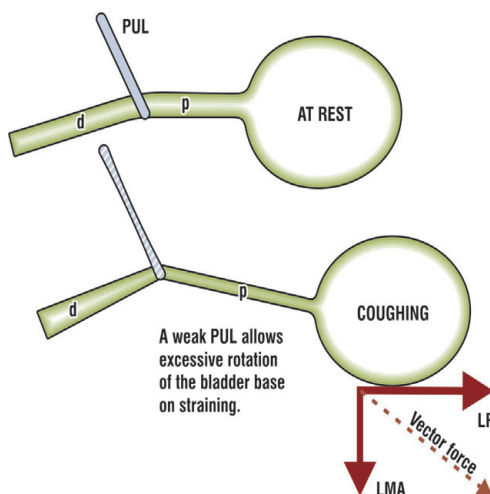


Fig. 6-04 Pubourethral ligament length affects urethral pressure. A weak pubourethral ligament may be stretched excessively by the LP/LMA vector. This may stretch and narrow the proximal urethra 'p'. A weak PUL cannot anchor the PCM force required to close the distal urethra 'd'.

If, during coughing, the distal closure mechanism is defective and 'd' remains the same size, then the pressure recorded at 'd' may be low, as the area within 'd' is greater relatively than in 'p'. (This is illustrated in the lower part of figure 6-04). The 'cough transmission ratio' (CTR) is low (figs 6-08 to 6-12.) In some cases where the pubourethral ligament (PUL) is weak, stretching of the bladder base by LP and LMA vectors may lengthen and narrow 'p' (fig 6-04) so that a high CTR may be recorded at 'p' during coughing, even though the patient may have stress incontinence. However, if LMA vector forces are inactivated, for example by a lax USL, 'p' may not be stretched so that the pressure at 'p' may remain low. The patient may have a low CTR and yet be continent if the distal closure mechanism is sufficient.

Valsalva Closure Pressure

Valsalva closure pressure measured at midurethra is usually less than 100%. In patients with stress incontinence, 'p' usually opens out, ('funnels'), so if LMA is weak because of lax uterosacral ligaments (USL), 'p' (fig 6-04) may remain relatively narrowed and so a positive valsalva closure pressure may be recorded. Thus, a positive valsalva CP in a patient with SI may indicate lax USLs (Petros and Ulmsten 1993).

Clinical Implications

CTR and even closure pressure measurements are not directly involved in the decision tree for surgery. Urine loss on coughing, controlled by a unilateral anchor and/or 'pinch test', ('simulated operations') is far more helpful.

Urethral Pressure

The horseshoe shaped striated muscle, 'rhabdosphincter' (SM) is concentrated in the middle third of the urethra (fig 6-05). A urethral pressure profile is obtained by pulling T2 through the urethra. Pubourethral ligaments (PUL) insert into midurethra. The curve seen with urethral pressure profiles can be attributed to the concentration of the horseshoe striated muscle (SM) at midurethra, but the action of muscle forces acting at PUL may also be a factor.

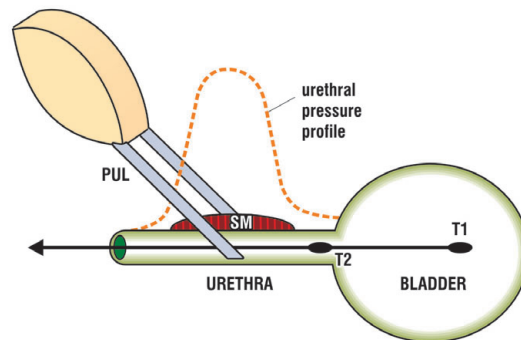
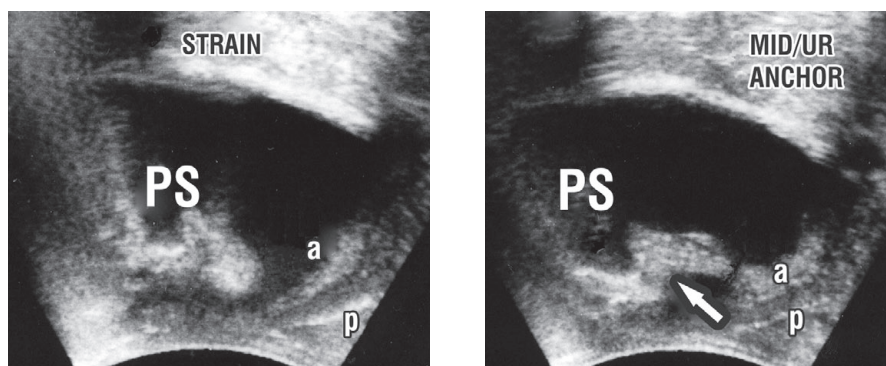


Fig. 6-05 Urethral pressure measurement – Schematic longitudinal section of urethra. T1 and T2 are pressure transducers 6 cm apart. SM = rhabdosphincter.



Figs 6-06 (left) and 6-07 (right) – Restoration of continence by midurethral anchoring (arrow). Midurethral anchoring enables urethral closure. Perineal ultrasound patient with stress incontinence. a = anterior vaginal wall; p = posterior vaginal wall; PS = symphysis pubis.

6

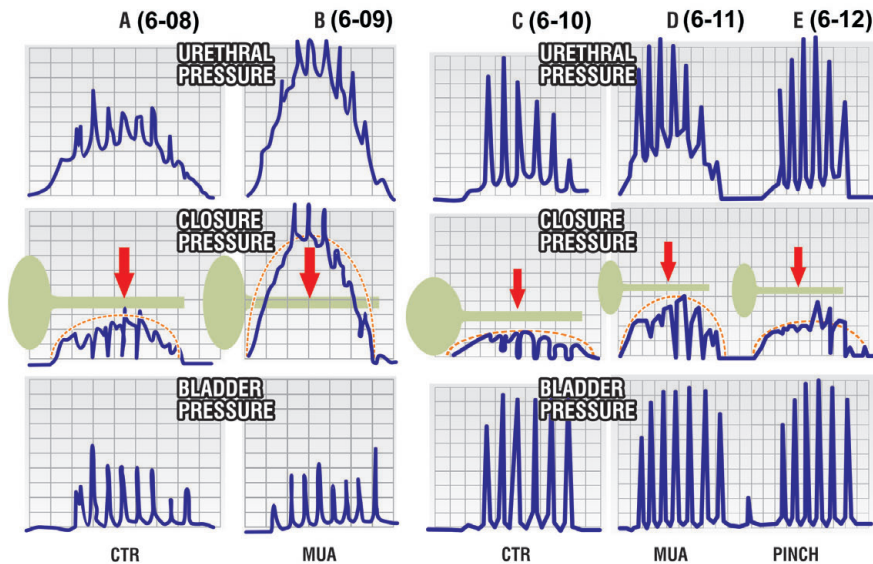
Figures 6-06 and 6-07 are ultrasonic demonstrations of the situation portrayed in figure 6-08 and 6-09. Ultrasound allows a real-time assessment before and after midurethral anchoring. Figures 6-06 and 6-07 are perineal ultrasounds of a patient with stress incontinence. They show the opening out of the bladder neck and distal urethra during straining. With unilateral midurethral anchoring, there is restoration of geometry (fig 6-07) and closure pressure (fig 6-09) (Petros and Von Konyk 1999).

The series of figures 6-08 to 6-12 (inclusive) shows a series of urethral pressure measurements which illustrate the anatomical basis for urethral pressure measurements. The green outline represents bladder and urethra. The red arrow marks the midurethral point. The red broken lines outline the resting urethral pressure profile.

The forces generated in the bladder (abdomen) and urethra are proportional. Thus the dynamic urethral pressure changes on effort to give an instantaneous index of change in the intra-urethral area.

In a patient with stress incontinence (figs 6-08 and 6-09, graphs 'A' & 'B'), application of a haemostat at midurethra mimics the effect of a competent pubourethral ligament. The haemostat restores the capacity of the backward force (LP) to stretch the trigone and for the hammock to close off the urethra along its length from behind. A low distal pressure after midurethral anchoring may reflect a lax hammock and/ or EUL. An example of this may be seen in figure 6-11, graph 'D' where midurethral anchoring (MUA) made little impact on the closure pressure. In this situation, a unilateral fold was taken in the suburethral vaginal hammock, ('pinch test', fig 6-12, graph 'E') to restore the muscle force (PCM), enabling it to narrow the distal urethra, and improve the closure pressure.

In figure 6-08, the 'cough transmission ratio' (CTR) of the second spike is $40/60 = 66\%$. Note the CTR rise in figure 6-09 after midurethral anchoring. The simultaneous rise in pressure may be explained as a result of the reciprocal reflex contraction of the abdominal and pelvic floor muscles, as both arise from the same embryological myotome: abdominal contraction causes the rise in bladder pressure, and pelvic floor contraction causes the rise in urethral pressure.



Figs 6-08 to 6-12 (Graphs A-E) The anatomical basis for urethral pressure measurements. 'A' - Note the decrease in closure pressure with each cough. 'B' - Mid urethral anchor (MUA), same patient as 'A'. Note the rise in resting profile and the much higher closure pressure with each cough. 'C' (different patient) - Note the low resting urethral pressure, and the zero closure pressure on coughing. 'D' (same patient as 'C') - Mid urethral anchor (MUA). There is some rise in the resting urethral pressure, but the closure pressure remains at zero. 'E' - Unilateral fold of vagina, taken at the distal urethra ('pinch test'). Same patient as 'C'. Note the rise in closure pressure. (For detailed biomechanical analysis of these events see Petros PE *Neurourol. and Urodynamics* (2003).)

The Urodynamics of Micturition

The bladder has two stable modes, closed and open ('micturition'). In figures 6-13 and 6-14, the closed mode (continence) circuits are shown as red, and the open mode circuits ('micturition') are shown in green. Both modes have central (neurological) and peripheral (musculoelastic) components.

The open mode requires activation of the micturition reflex. As the bladder fills, the hydrostatic pressure activates the stretch receptors (N) to produce afferent impulses. These impulses are shut off by the inhibitory centre (which acts much like a trapdoor to shut out the afferent impulses), and by the contraction of the three directional muscle forces (PCM, LMA and LP) which stretch the vaginal membrane to support the hydrostatic pressure of the urine. This process stops 'N' firing off. The red lines in figure 6-13 represent the closed mode (C), and the green lines the open mode 'O'.

Beyond a critical mass, the afferent impulses saturate the inhibitory centres and pass information directly to the cortex to be perceived as 'urgency'. Valuable information on the unstable bladder may be obtained from a provocative handwashing test. This test works by interrupting the cortical inhibition of the micturition reflex.

In the open ('micturition') mode ('O' in fig 6-14), central inhibition ceases and the 'trapdoor' opens allowing the afferent impulses to pass through the pons. The forward muscle PCM relaxes, allowing LP and LMA to stretch the vagina backwards to open out the urethra. The detrusor contracts. Several seconds must elapse before this process can be reversed. This explains the wave forms seen in detrusor instability graphs.

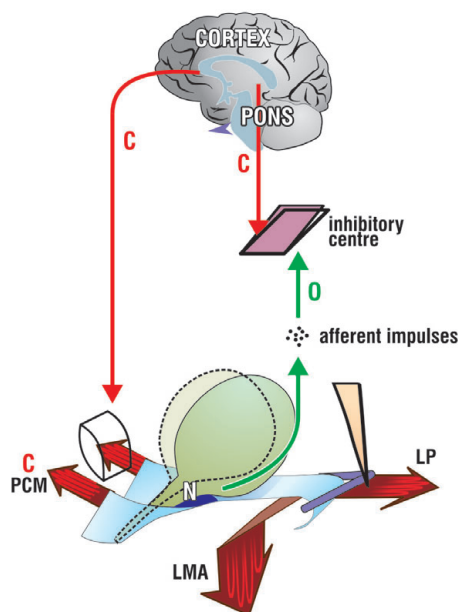


Fig. 6-13 Closed mode: the anatomical system for control of unscheduled emptying (premature activation of the micturition reflex.) The muscles contract the vaginal membrane to support 'N', diminishing afferent impulses (broken lines).

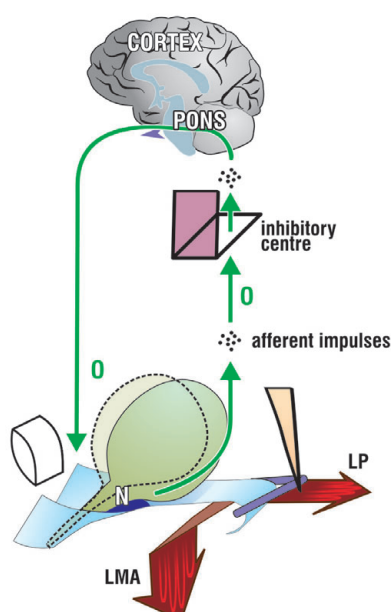


Fig. 6-14 Open (micturition) mode: the anatomical system for acceleration of emptying. Urine entering the proximal urethra accelerates production of afferent impulses (Barrington 1921).

Urodynamic Bladder Instability – Premature Activation of the Micturition Reflex

The peaks (small arrows, fig 6-16) denote the closed phase and the troughs the open phase of the micturition reflex. Closed and open phases alternate and produce a sinusoidal curve because of the time taken to switch from one mode to the other. Figure 6-15 represents these events according to Chaos Theory as two competing 'attractors'. An 'attractor' is a phase state which occurs as a result of certain conditions. Normal elasticity in the tissues is one essential condition contributing to the 'closed' attractor. Without elasticity, the urethra is like an open tube and forms the 'open' attractor. Loss of elasticity may initiate a cascade of events which combined with sensitive stretch receptors may cause the bladder to swing between 'open' and 'closed' phases (fig 6-15). With reference to figure 6-16, the open phase overcomes the closed phase only in the centre where 16.6 gm urine loss is recorded.

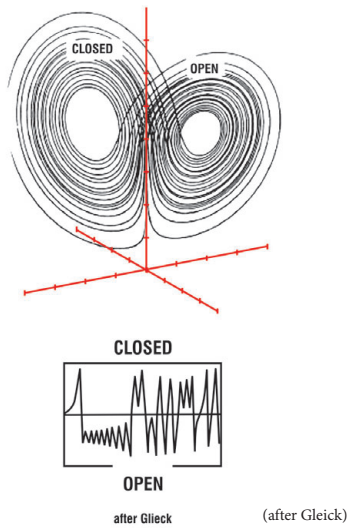


Fig. 6-15 (above) Detrusor instability explained as two attractors, open and closed. Inability of tissue elasticity to maintain the closed position causes the unstable bladder to oscillate between closed (continence) and open (micturition) phases. Because of the time delay in switching between these two phases, the pressure curves are sinusoidal. This is clearly illustrated in both 'U' and 'B' in figures 6-16 and 6-17. The process is similar to the feedback systems described in Chaos Theory (Gleick).

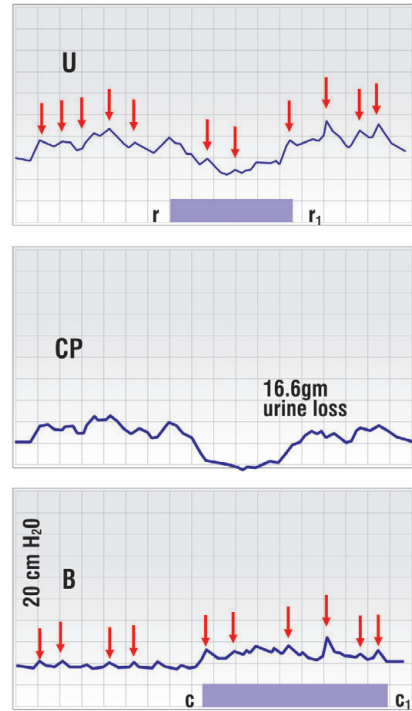


Fig. 6-16 Urodynamic bladder instability - premature activation of the micturition reflex. Microtransducers in bladder (B) and midurethra (U). CP=closure pressure (U-B). Note how urethral relaxation (r-r1) precedes detrusor contraction (c-c1).

Voluntary Control of the Micturition Reflex

A common history is of the patient who is shopping, stops, crosses her legs and controls her urgency by 'squeezing' (fig 6-18). 'Squeezing' stretches the vaginal membrane to support the stretch receptors and it is this which controls the afferent flow of impulses from the bladder base stretch receptors - which are perceived by the patient as urgency symptoms.

Figure 6-17 is a urodynamic graph of a patient with a full bladder who is subjected to a handwashing test. At 'X' sensory urgency is experienced and the urethral pressure begins to fall. However, urine loss is controlled by voluntary pelvic floor contraction 'squeezing' ('holding on'). On 'letting go' the urethral pressure falls dramatically, the detrusor contracts (Y, 'd') and urine is lost (red arrow).

Figure 6-18 is the anatomical representation for the situation illustrated in figure 6-17. 'Squeezing' (yellow arrow) has lifted the levator plate (LP) and stretched the vaginal membrane forwards. This provides support for the stretch receptors (N). The 'resting' radiograph of the same patient is figure 2-15.

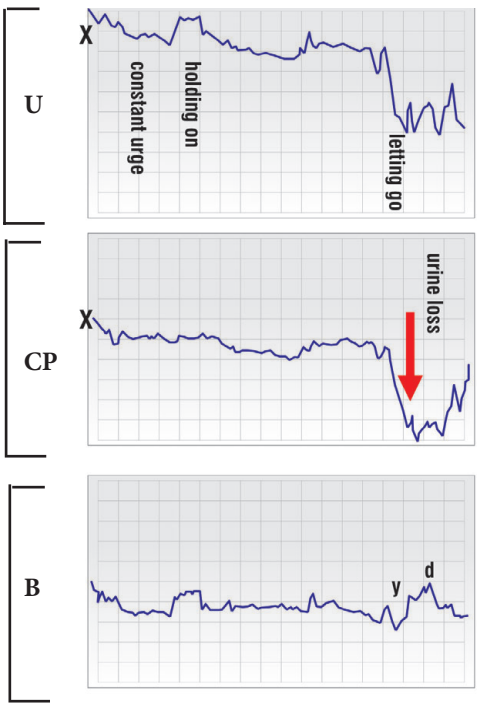


Fig. 6-17 Control of detrusor instability by pelvic floor contraction. X = start of urethral relaxation; Y = start of detrusor contraction 'd'.

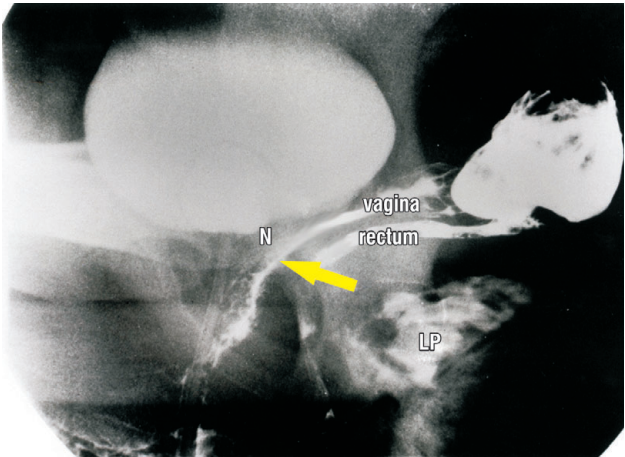


Fig. 6-18 Control of detrusor instability by voluntary pelvic floor contraction (arrow). The levator plate (LP), vagina, rectum and bladder are pulled upwards and forwards - probably by contraction of m. puborectalis.

Normal Micturition and 'After Contraction' – A Sign of Normal Tissue Elasticity

Figure 6-20 shows a normal micturition curve conforming to the outlet geometry as shown in figure 6-19. During peak flow, the vesical cavity has opened out almost to the midurethra, vastly decreasing urethral resistance. There is a rise in detrusor pressure ('after contraction') which occurs after the end of micturition. This is evident on comparing the cessation of urine flow in the third graph 'FLOW' with the second graph 'DETRUSOR' pressure, figure 6-20. An 'after contraction' can be explained as occurring when a relaxation of the backward vectors at the end of micturition (diagonal arrows, figure 6-19) causes the vagina to recoil and close the urethra (broken yellow lines, fig 6-19). Ongoing contraction of the detrusor against the closed urethra leads to a rise in detrusor pressure 'after contraction'.

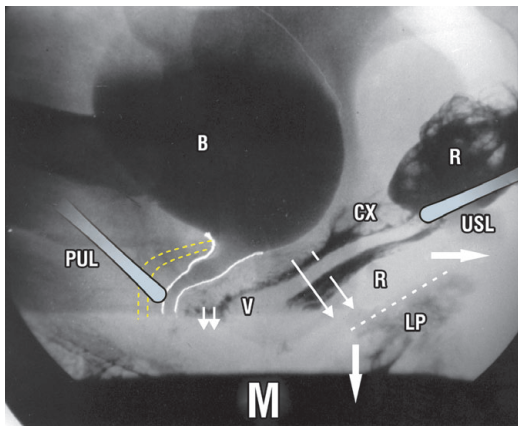


Fig. 6-19 Micturition x-ray showing external opening of the posterior urethral wall. The broken yellow lines indicate the position of the closed urethra at rest.

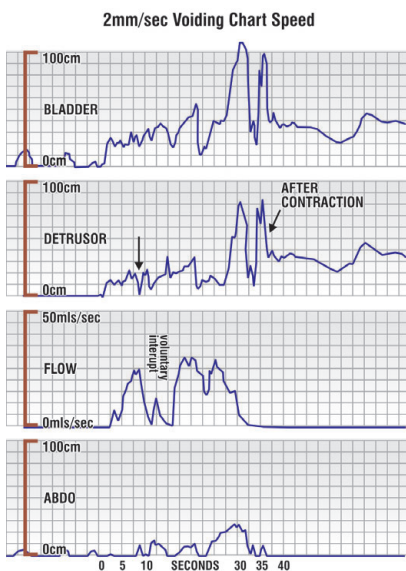


Fig. 6-20 Normal micturition and 'after contraction'. The detrusor pressure momentarily reaches zero (arrow) during peak flow. "After contraction": the detrusor continues to contract against a urethra closed by elastic recoil.

'Outflow Obstruction'

If the urethra is 'collapsed' because lax connective tissue does not allow its expansion during micturition, the patient may be diagnosed as having an 'obstructed urethra'. However, obstruction is rarely found on urethral dilatation. The 'obstruction' is functional, caused by the bladder's attempts to expel urine through a narrower tube with high resistance.

Figure 6-21 is a flow chart in a patient with an EMG electrode in the posterior fornix of vagina, recording contraction of the levator plate muscles (LP). The EMG is activated before urine flow commences, indicating that LP contraction precedes urine flow. It can be seen that there is constant activation of the pelvic floor muscles together with a slow prolonged urine flow because of fast-twitch muscle tiring. The geometry of the outflow tract is closer to the closed position (yellow broken lines) (fig. 6-19).

6



Fig. 6-21 'Outflow obstruction' in the female - Connective tissue laxity requiring constant activation of the LP/LMA vectors.

Limitations of Existing Tests: The Need for a Finite Element Model for Urodynamics

Existing tests rely on a single group of measurements taken at a point in time. However, this is only a 'snapshot' of a highly complex and variable system. Even a minor variation in the diameter of the urethral tube may cause major changes in micturition pressure and flow rates (fig. 6-01).

Conceptually the flow graphs in figures 6-20 and 6-21 can be explained in terms of tissue elasticity. Thus measurement of tissue quality with some type of elastometer is an important future development. Lose has developed a system for testing urethral elasticity by distending the urethra with a balloon (Lose 1990, 1992). This is an important contribution, but it is elasticity in the *whole system* which needs to be measured. Using parameters of tissue strength and elasticity, pressure and flow measurements, and measurements of muscle bulk, it may be possible, (in conjunction with a large data base), to develop a finite element model to apply to each patient (Petros 2001). This may provide a model of the continuum of forces and events contributing to the dysfunction, rather than reliance on a mere 'snapshot', as at present.

6.1.2 The Chaos Theory Framework – Its Impact on the Understanding of Bladder Control and Urodynamic Charting

One of the most exciting scientific advances in the 20th century has been the clear exposition of ‘Chaos Theory’ (Gleick 1987). Chaos Theory states that every biological organism consists of a series of interrelated systems. Each system has several components working synergistically (such that the whole is greater than the sum of the parts). A change in any component of the system, no matter how minor, may have profound consequences for the system and the organism itself.

The pelvic floor is such a system. With regard to bladder and rectum, the pelvic floor has just two functions, opening (micturition, defaecation) and closure (continence). Its components are the pelvic bones, striated muscles, smooth muscles, ligaments, fascia, organs, and the sympathetic and parasympathetic nerves which link all parts of this system to the central nervous system. As every person is different, each component will have a different significance, and so it will contribute differently to normal function within that system. The significance of each component and therefore each contribution will follow a probability curve.

Within the Chaos Theory framework large scale symptoms (such as urge incontinence) may be the result of a small dysfunction (disequilibrium) in the connective tissue structures. Hence the emphasis in the Integral Theory framework on obtaining a clear and precise understanding of how each component structure contributes to the dynamic structural anatomy of the pelvic floor. This is a vital stage in finding the origins of the dysfunction. Only with a more precise diagnosis can a surgeon obtain the best clinical results from the minimalist surgical techniques described in Chapter 4.

In particular, there are two aspects of Chaos Theory which have had profound ramifications for the Integral Theory: fractals and the ‘butterfly effect’.

Fractals

Fractals explain the relationship between macro and micro domains, and the self-similarity in the components. Good examples are the lung and arterial systems. Each microdomain (alveolus) reflects the major domain (the lung). In the pelvic floor, one macrodomain is laxity in one or more of the three zones; with component fascia and ligaments, collagen and proteoglycans forming even smaller microdomains. This relationship is exploited therapeutically. Hormone treatment aims to decrease collagen loss with age. Pelvic floor exercises strengthen the muscles, the ligamentous insertion points of these muscles, the periosteal attachment of these ligaments, and may even change the muscle metabolism. Another example of fractals is the sinusoidal shape of a detrusor instability curve, and its fractal-like subsections.

Extreme Sensitivity to Initial Conditions (The ‘Butterfly Effect’)

The ‘butterfly effect’ is used in Chaos Theory to illustrate the phenomenon of extreme sensitivity to initial conditions. It explains how a minute disturbance or change (such

as the flapping of butterfly wings) can disrupt a system (such as the weather) in dynamic equilibrium and manifest as huge changes elsewhere in that system (such as a hurricane). In the pelvic floor several systems exhibit this behaviour. Minor degrees of posterior zone laxity may cause pelvic pain and multiple symptoms in the bowel and bladder. Detrusor expulsion pressure and urine flow vary according to the intra-urethral resistance, which varies (in simple terms) inversely with the 4th power of the radius. Thus a urethra which can be actively opened out ('funnelled') so that it doubles its width lowers the urethral resistance by a factor of 16 (i.e. 2^4) (fig. 6-02). Micturition then requires only 1/16th the expulsion pressure than one where lax tissues entirely prevent this action. This is an example of 'non-linearity', and it explains why it is very difficult to replicate results from 'objective' tests such as flow rate (fig. 6-01). Slight variance in any of the components contributing to active opening of the outflow tract will affect exponentially the intra-urethral resistance encountered during a particular test and, therefore, the flow rate. In analysis using a linear system framework, halving the resistance would halve the expulsion pressure required, not decrease it 16 times as one finds when a 'non-linear' system framework is used. The dynamics within a non-linear system vastly shorten the opening and closure intervals and the threshold for incontinence is raised exponentially for a normal patient. In a linear system, the dynamics would be such that, as the urine entered the bladder, it would stimulate the stretch receptors and the patient would leak at low volumes.

Detrusor instability is another example where Chaos Theory provides a useful framework to help us unravel the complex interactions between bladder function and the cortex. With Chaos Theory, for the first time, there is a theoretical framework that can describe how a small structural defect can lead to a neurological response that creates further instability in the overall system. Micturition has both 'mechanical' and neurological dimensions, but the relation between the two is not simple. Bladder function is not a 'hard wired' network linked to the cortex. Incontinence, by definition, involves some type of malfunction, or 'false' urge. And even in a normally functioning system, the handwashing test can 'bring on' micturition urge.

In a patient with very sensitive nerve endings, only minor alterations in the tension of the vaginal membrane may cause the stretch receptors to 'fire off' (cf. the 'trampoline analogy') and activate the micturition reflex. There is a cascade of events which may culminate in uncontrollable urine loss or urge incontinence. This phenomenon explains how minor degrees of 'prolapse' may cause major symptoms, and supports the idea that surgical reinforcement using polypropylene tapes be used to improve symptoms as described in the Pictorial Diagnostic Algorithm (fig 1-11) even in patients with minimal prolapse.

Using Chaos Theory as a basic framework, the author was able to interpret the apparently contradictory data which followed a handwashing test to link low compliance to 'detrusor instability' (Petros 1999).

By using a basic feedback equation $X_{\text{next}} = cX(1-X)$, where X represents the number of afferent impulses, with 1 being the maximum possible number of impulses and ' c ' represents the inverse of cortical and peripheral suppression mechanisms, it was possible to mimic all states of the bladder, acontractility, normal response to a full bladder, 'low compliance' (a micturition reflex activated but controlled) and instability (fig 6-25).

6.1.2 A Non-Linear Perspective of the Neurological Control of the Micturition Reflex

Normal Function

The control of the micturition reflex is essentially by a feedback system. The squares containing dots (fig 6-22) represent neurological impulses, afferent (O_a) or efferent (O_e). As the bladder fills, the stretch receptors (N) 'fire off' and afferent impulses ' O_a ' are transmitted via the spinal cord. This is the initiating part of the micturition reflex. If inconvenient, the cortex activates the closure reflex (C). This has two stages. Firstly, the inhibitory centres all along the brain and spinal cord are activated. These function like trapdoors to shut off afferent and efferent impulses. Secondly, the pelvic floor muscles contract (C_m) to close off the urethra and stretch the vaginal membrane to support 'N'.

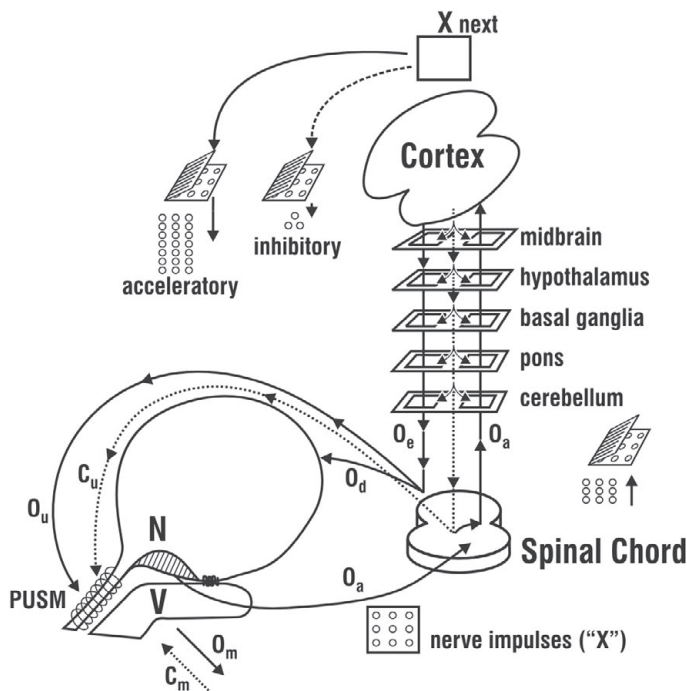


Fig. 6-22 The neurological control mechanisms for micturition. 'O' (unbroken lines) represents the 'open' (micturition) phase and 'C' (broken lines) the closed (continence) phase. N = stretch receptors; V = vagina; PUSM = periurethral striated muscle (a thin muscle sited mainly on the superior wall of the middle third of the urethra); C_m = anterior part of pubococcygeus muscle (reflex contraction) or puborectalis muscle (voluntary contraction); O_m = LP/LMA vector. The dots 'X' (small circles) represent nerve impulses. The paired oblong squares along the brain and spinal cord represent the acceleratory and inhibitory centres. These work like 'trapdoors'. O_u = urethral relaxation; C_u = urethral closure; O_d = detrusor contraction.

Conversely, if it is convenient to micturate, the acceleratory nuclei are stimulated. The inhibitory centre is suppressed, so its 'trapdoors' open. The anterior part of 'Cm' relaxes and 'Om' contracts to open the urethra. 'Om' contraction further stimulates 'N' to produce more afferent impulses.

Dysfunction

If the vaginal membrane 'V' is lax, 'N' may 'fire off' at a lower bladder volume. 'C' may not be able to control the micturition reflex 'O' and the patient may wet. Similarly, any neurological lesion along the path of 'C' (e.g. in multiple sclerosis) may prevent the closure reflex so that the afferents pass directly through the pons to cause incontinence. Transection of the cord will not allow 'Oe' to pass through, so the patient may have retention of urine (fig 6-22).

Note: The 'trapdoor' system has only two phases, open ('O') and closed ('C') (cf. the binary system of a computer).

Bladder Instability - A Struggle Between the Opening (O) and Closure (C) Reflexes

Figure 6-23 is a urodynamic graph which reflects the events illustrated in figure 6-22. The interpretation given below correlates the urodynamic traces in figure 6-23 with the dynamic events described in figure 6-22. With reference to figures 6-22 and 6-23:

Fig. 6-23 Detrusor instability - a premature activation of a normal micturition reflex. This is a urodynamic graph of a patient with a full bladder undergoing a handwashing test.

The sequence of events is:

- (1) a feeling of urgency,
- (2) a fall in urethral pressure at X (graph 'U'),
- (3) a rise in bladder pressure at Y (graph 'B') then
- (4) urine loss arrow, (graph 'CP').

U = urethral pressure graph;

B = bladder pressure graph;

CP = closure pressure graph (U minus B)

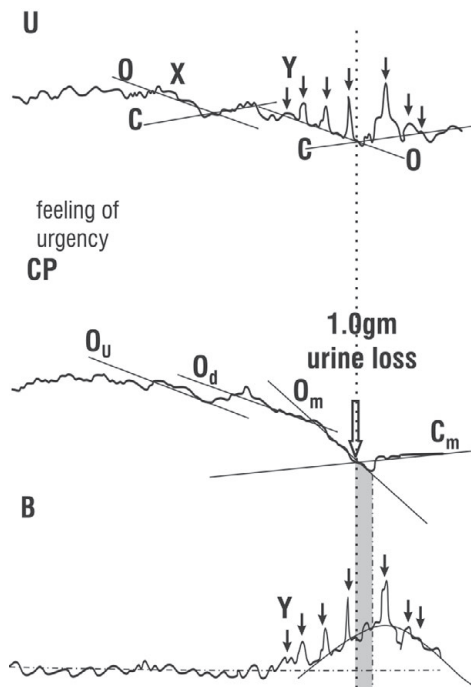
C = closure (continence) reflex

O = opening (micturition) reflex, with its components being:

O_u = urethral relaxation;

O_d = detrusor contraction;

O_m = opening out of the outflow tract.



- The afferent impulses from the stretch receptors reach cortical consciousness as feelings of urgency. These pass through the pons to cause a fall in urethral pressure (X, graph U), by causing relaxation of Cm and the PUSM (fig 6-22).
- However, this is soon counteracted by assertion of the closure reflex ('C' on graph U) and so urethral pressure rises.
- This correlates with contraction of the forward arrow, Cm and PUSM, in figure 6-22. The micturition reflex 'O' is too strong, however, and it dominates.
- Thus the closure pressure falls dramatically (graph CP) and detrusor pressure rises (Y graph B) with urine loss (white arrow, graph CP).
- Note the precipitous fall in CP (Om, graph CP). This correlates with opening out of the urethra by the posterior muscle forces Om, in figure 6-22.
- As bladder smooth muscle contracts by muscle-to-muscle transmission (Creed 1979), it effectively 'spasms'. This 'spasm' is denoted by a curve starting at 'Y' in figure 6-23. The small downward arrows (graph U) are consistent with efforts of fast-twitch striated PCM muscles ('Om' fig 6-22) contracting ineffectively against this 'spasm'.

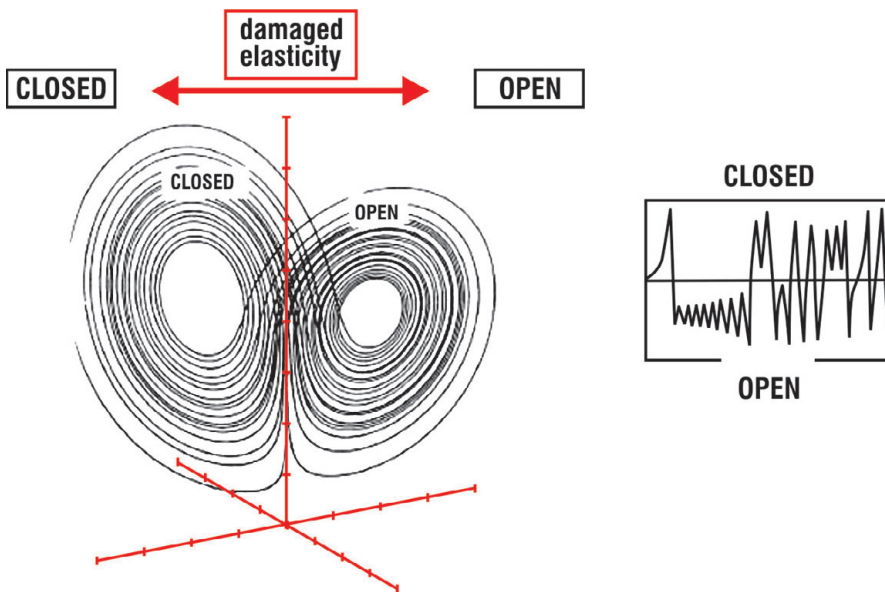


Fig. 6-24 (after Gleick 1987). Unstable opening and closure of the bladder - two competing 'attractors'. With damaged tissues, passive elastic closure is diminished and so the bladder may not be able to either close or open properly. In a continent patient, the 'open' phase (micturition) is a temporary state created by a normal micturition reflex. Damaged connective tissue may prevent passive elastic closure such that the patient now has two competing 'attractors', 'open' and 'closed'. With urgency, the loose vaginal tissue cannot support the hydrostatic pressure of urine and the stretch receptors may fire off at a lower bladder volume: 'detrusor instability'.

Mathematical Testing of Feedback Control of the Micturition Reflex

The graph (fig 6-25) represents iteration of the classical feedback equation, $X_{\text{next}} = Xc(1-X)$, where 'X' represents the afferent impulses and 'c' represents the central and peripheral control mechanisms. The maximum number of impulses which can be carried by the system is 1, and $X < 1$. As the bladder fills, afferent impulses 'X' travel to the cortex, and these are controlled by 'c'.

When 'c' is small, iteration of the equation shows the impulses are extinguished. This can be correlated with the state of urinary retention.

When 'c' is between 2 and 3, the system is stable and it remains closed. As 'c' becomes larger than 3, the system splits into 2 phases. As 'c' increases further, the phases become a geometric progression, 4, 8, 16, etc., and reach the chaotic zone (Gleick 1987).

In this urodynamic context, low compliance is explained by bladder contraction which is controlled by 'c'. The upper part of the graph (fig 6-25) explains the often seen conversion of low compliance into detrusor instability, a phasic pressure variation in the bladder.

To illustrate the above mathematical testing procedure, the iterations of a simple feed back equation, viz $X_{\text{next}} = Xc(1-X)$, are presented below. These are taken from an actual experiment, in which a group of patients were subjected to a handwashing test during fast-fill cystometry. A full account of the experiment and a more detailed analysis on which the above is based is available in Petros (1999).

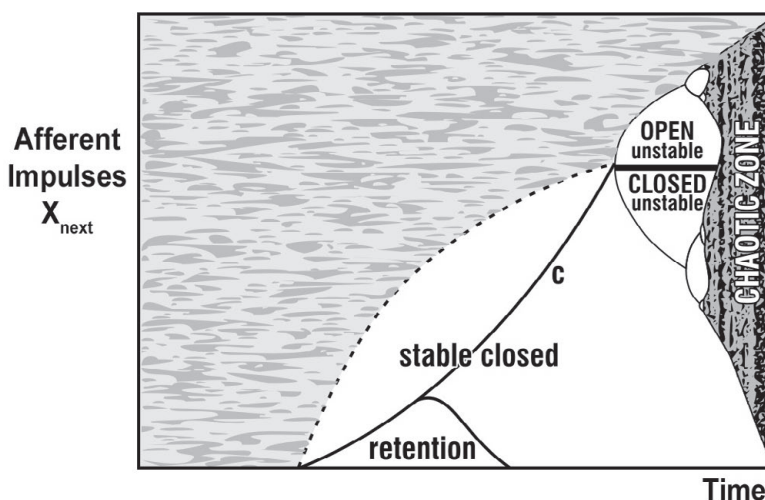


Fig. 6-25 (after Gleick 1987). Feedback control -bladder instability as a manifestation of Chaos Theory. The line 'c' represents the sum of cortical and peripheral inhibition by the musculo-elastic system (two variables). The broken line represents the course plotted when there is only one variable. X_{next} can be equated to the number of afferent impulses and also the detrusor pressure. x axis = time; y axis = X_{next} .

Example of Iterations of a Simple Feedback Equation (as per figure 6-25)

Taking a nominal bladder volume of say, 300ml, and the maximum number of impulses originating from the stretch receptors to be 0.5 (i.e. 50% of the possible maximum), then, based on observed results, (no urgency in a normal patient, a low compliance pattern in some patients, and detrusor instability (DI) and urine loss in others), one can postulate that inhibition of the micturition reflex is working:

- successfully in the normal patient,
- partially in the low compliance group, and
- unsuccessfully in the detrusor instability group.

By equating degrees of inhibition of the micturition reflex with the central and peripheral control mechanisms (c), it is possible to calculate what happens in each system when it is subjected to the feedback process. This is done by using the formula $X_{\text{next}} = Xc(1-X)$.

Normal Patient

In figure 6-22, all control systems are assumed to be functioning perfectly, stimulation of 'N' is controlled, and the equation is iterated with a low 'c' value of 0.2.

$$\text{1st iteration: } X_{\text{next}} = 0.5 \times 0.2 (1 - 0.5) = 0.05$$

$$\text{2nd iteration: } X_{\text{next}} = 0.05 \times 0.2 (1 - 0.05) = 0.019$$

$$\text{3rd iteration: } X_{\text{next}} = 0.019 \times 0.2 (1 - 0.019) = 0.0037$$

'X' is almost extinct by the 3rd iteration. This is the 'retention' area in fig. 6-25.

Low Compliance Group

As bladder contraction is an accepted cause of low compliance, and no urine was lost during filling, 'c' needed a value that reflected an activated, but 'stable closed' state, as shown in figure 6-25. The equation was iterated with a 'c' value of 2.0 to reflect a constant 'X' value.

$$\text{1st iteration: } X_{\text{next}} = 0.5 \times 2 (1 - 0.5) = 0.5$$

$$\text{2nd iteration: } X_{\text{next}} = 0.5 \times 2 (1 - 0.5) = 0.5$$

$$\text{3rd iteration: } X_{\text{next}} = 0.5 \times 2 (1 - 0.5) = 0.5$$

'X' remains at 0.5, a steady state at the 3rd iteration. (The 'stable closed' area in fig. 6-25.)

Bladder Instability Group

The patterns of urethral and bladder pressure shown in figure 6-22 are clearly much less controlled, indicating more numerous afferent impulses from the bladder stretch receptors. As 'c' needed to be in the region of >3.0 to reflect fluctuation between the 'unstable open' and 'unstable closed' states, the equation was iterated with a 'c' value of 3.6.

$$\text{1st iteration: } X_{\text{next}} = 0.5 \times 3.6 (1 - 0.5) = 0.9.$$

$$\text{2nd iteration: } X_{\text{next}} = 0.9 \times 3.6 (1 - 0.9) = 0.324.$$

$$\text{3rd iteration: } X_{\text{next}} = 0.324 \times 3.6 (1 - 0.324) = 0.788.$$

$$\text{4th iteration: } X_{\text{next}} = 0.788 \times 3.6 (1 - 0.788) = 0.601$$

$$\text{5th iteration: } X_{\text{next}} = 0.601 \times 3.6 (1 - 0.399) = 0.864.$$

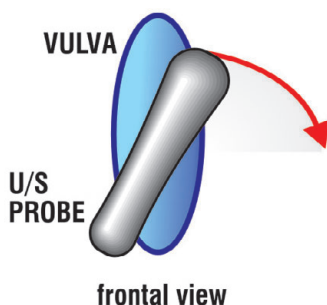
$$\text{6th iteration: } X_{\text{next}} = 0.864 \times 3.6 (1 - 0.136) = 0.423.$$

'X' is oscillating between two states, 'unstable open' and 'unstable closed', as shown in figure 6-25.

6.1.3 Transperineal Ultrasound

Ultrasound uses reflected sound waves to detect soft tissue structures. It is a relatively inexpensive office tool which allows the clinician to determine the dynamic geometry of the pelvic organs, urethra, bladder, vagina, anus and rectum, at rest, during effort and during anchoring of specific connective tissue structures. It can also identify the pelvic muscles, their movements relative to rest, and the location of implanted tapes and meshes. This section explains how the physician can use ultrasound to assess funnelling and rotation of the bladder neck (anterior zone), then proceed to assessment of the other zones. Using the 'simulated operations' of anchoring specific ligaments and observing the changes in urethrovesical geometry, it is possible, over time, for the clinician to gain a greater understanding of the importance of adequately tight ligaments for pelvic floor function. These techniques are also a means of directly testing predictions of the Integral Theory.

The image must be oriented in the sagittal position to obtain accurate data. A 3.5 or 3.75 MHz curvilinear abdominal probe is applied to gently touch the perineum, pointing upwards into the vagina. A split image is used to allow comparison of the geometry of the resting and straining positions. The bladder and urethra are located



Using the ultrasound probe (above):

Apply probe at an angle of 5 - 10 degrees until the urethra and bladder are outlined. Rotate slowly so as to keep the urethra in focus. To visualise the levator plate, turn the probe at a greater angle until the rectum and posterior muscles come into view. Then follow the movements by angulating the probe. X-ray (above right) shows the anatomical relationships of the organs in resting position.

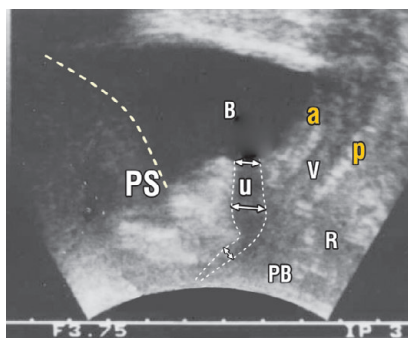


Fig. 6-26 Ultrasound at rest - sagittal view. Patient semi-recumbent. The arrows at bladder neck, mid and distal urethra show the positions used for measuring diameter change from the resting to the straining position. PS = symphysis pubis; a = anterior vaginal wall; p = posterior vaginal wall; U = urethra; V = vagina; R = rectum; PB = perineal body.

at rest. Then, the probe is rotated slightly during straining so as to retain a picture of the urethra as the bladder base descends from the bladder during straining. The three directional forces are easily identified during coughing and straining. Upward movement of all the organs and levator plate are seen when the patient 'squeezes'. The technique is easily learned.

Ultrasound Assessment of the Anterior Zone

Changes in urethral diameter during straining (fig 6-27 right) may be used to assess the integrity of the urethral and bladder neck closure mechanisms. Bladder base descent greater than 10 mm and funnelling during straining might suggest a pubourethral (PUL) defect. Gross rotation and funnelling during straining is evidence of gross laxity in the PUL. Repeating this manoeuvre after unilateral anchoring at midurethra restores geometry and continence (Petros & Von Konyky 1999).

Ultrasound Assessment of the Middle Zone

Knowledge of the middle zone and its relationship to the anterior and posterior zones can be obtained by observing changes in morphology during straining, coughing and after anchoring various connective structures, such as the pubourethral ligament (PUL), arcus tendineus fascia pelvis (ATFP) or uterosacral ligaments (USL). Stretching (and therefore) tightening of the suburethral hammock can sometimes be observed as the cystocele moves downwards (Petros 1998).

A cystocele is easily recognized just behind bladder neck. On straining it balloons downwards. Often it is irregular in shape (fig 6-30). A paravaginal defect is not so easily recognized. To detect it, the transducer must be directed more laterally. It is more curved. If there is also some degree of vault prolapse, anchoring the posterior fornix during straining may often result in a marked diminution of the size of the cystocele. This demonstrates the interconnectedness of the middle zone with the posterior zone.

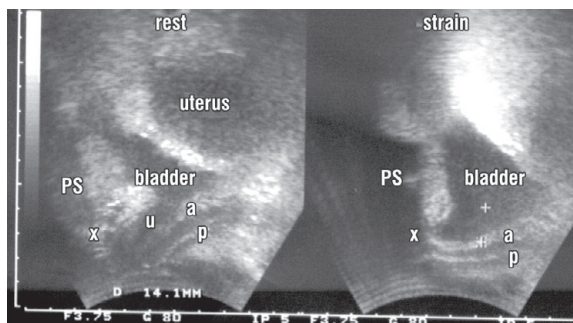


Fig. 6-27 Patient with SI. Left = resting; Right = Straining; The anterior and posterior vaginal walls are stretched backwards to open out the bladder neck. U = urethra; a & p = anterior and posterior vaginal walls; X = lower border of pubic symphysis (PS). The same directional movements occur during coughing as when straining.

Lateral Attachment of Mesh (M)

After cystocele repair lateral attachment of mesh can be accurately identified by turning the transducer horizontally and pointing it posteriorly (fig. 6-31). If there is a discrepancy in the level of attachment between the two sides if the attachment, one will be sited lower than the other.

Identification of mesh is very useful. Any detachment from its lateral inserts is readily identified.

6

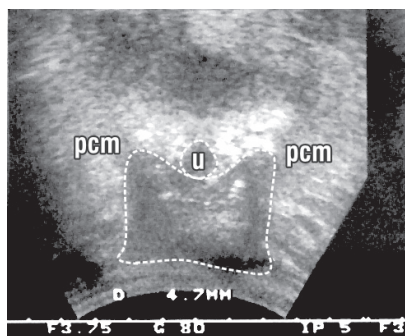


Fig. 6-28 Anterior zone - transverse position of 3.5 MHz probe - focus on midurethra. Note the 'H-shaped' vagina and urethra (U) sited above the anterior vaginal wall. On straining or coughing the angles move sharply upwards as does the distal urethra. When focused more posteriorly, the bladder neck and proximal urethra are pulled downwards.

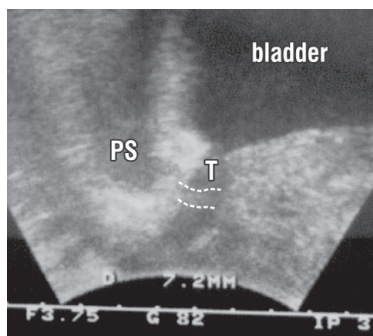


Fig. 6-29 The tape sited at midurethra appears as an opaque strip which passes behind PS. As polypropylene is opaque to ultrasound, it is quite easy to locate. This technique is especially useful for locating the tape in patients with post-operative urethral obstruction after an anterior sling procedure who may require incision of the tape.

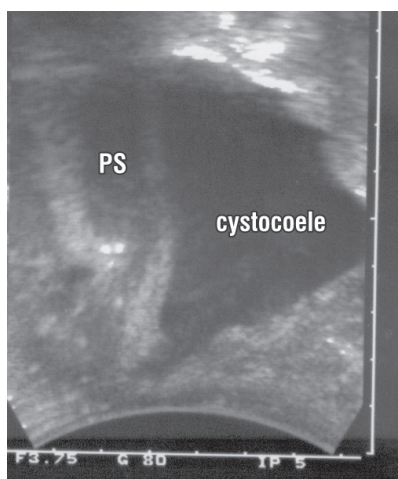


Fig. 6-30 Middle zone cystocele, 3.75 MHz probe axial

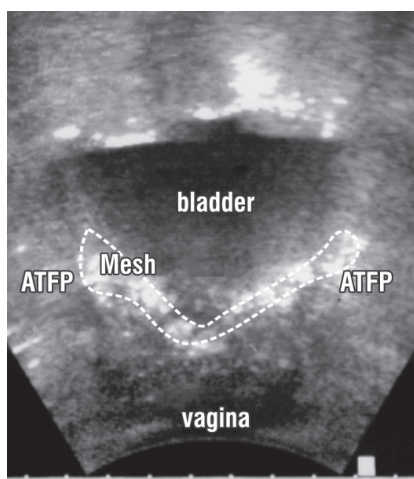


Fig. 6-31 Middle zone ultrasound - identifying mesh. 3.75 MHz probe transverse.

Ultrasound Assessment of the Posterior Zone

With ultrasound it is possible to visualize almost all the structures seen with more invasive or costly techniques, such as video x-ray and MRI, and in a dynamic way. Anchoring vital structures such as perineal body, PUL or USL while testing can give profound insights as to how these structures contribute to pelvic floor geometry and function. Pointing the probe more posteriorly, one can visualize the anus and rectum. Behind the rectum, a thickened vertical muscle mass is sometimes seen. This corresponds to the longitudinal muscle of the anus (LMA). The LMA is separated from the rectum (R) by a space. LMA connects LP to the external anal sphincter. More posteriorly, horizontal collagenous fibres indicate the position of levator plate (LP) and its attachment to the posterior wall of the rectum (fig 6-33). In the normal patient, during straining or coughing, LP moves backwards and upwards, with downward angulation of its anterior border. With a lax perineal body (PB), there may be a momentary downward flicker followed by an upward pull. Digitally anchoring PB restores downward angulation of the anterior border of LP. This sequence of events

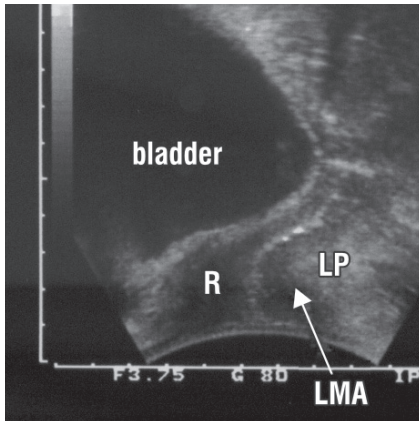


Fig. 6-32 Posterior zone - probe axial

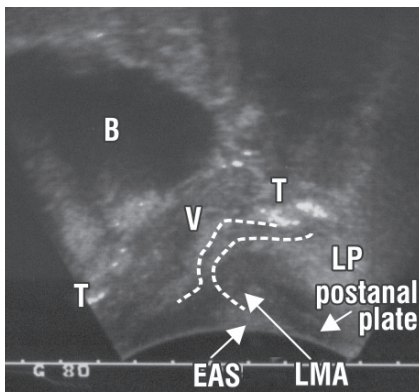


Fig. 6-33 Posterior zone - probe axial

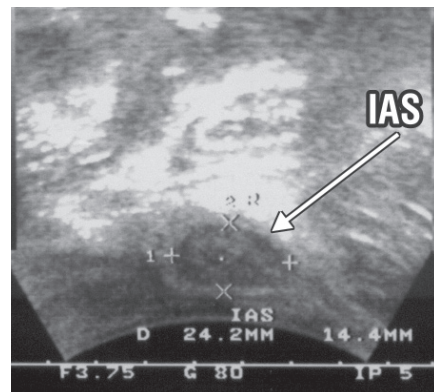


Fig. 6-34 Internal anal sphincter location - probe transverse

convincingly demonstrates that the role of the perineal body is to help anchor the external anal sphincter, the insertion of the downward muscle force (LMA).

The two limbs of the posterior tape 'T' (fig 6-33) attached behind the apex of the posterior vaginal wall 'V' are visible as two thick short opaque lines sitting just above the horizontal part of the rectum (broken lines) and pointing towards the superior surface of levator plate (LP). A midurethral tape 'T' can be seen just above the distal part of the vagina. There is a first degree enterocoele just above 'V' (fig 6-33).

The internal anal sphincter is easily assessed from the perineum, preferably with a 5.5 MHz probe.

The probe is placed on the perineal body and turned backwards (fig 6-34). This is a far less painful method than using the endoanal probe. The thickness of the anterior and posterior parts of the internal anal sphincter muscle can be measured.

6

6.1.4 The Role of X-rays in the Diagnosis of Ligamentous and Connective Tissue Defects

Although x-rays have been largely supplanted by transperineal ultrasound, insertion of radio-opaque dye into the organs and the levator plate gives valuable information about function and dysfunction.

Anterior Zone X-rays

An intact pubourethral ligament (PUL) is a prerequisite for directional stretching of the vagina by the pelvic muscles. The following x-rays demonstrate organ prolapse occurring due to the inability of PUL to anchor the muscle forces.

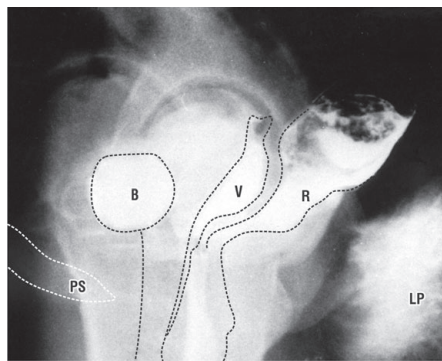


Fig. 6-35 At Rest

PS = pubic symphysis; B = Foley balloon in the bladder; V = vagina; R = rectum; LP = levator plate.

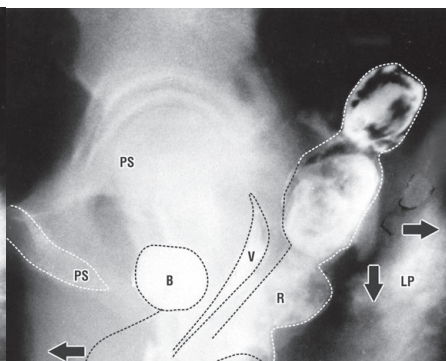


Fig. 6-36 Straining - Pubourethral ligament defect. Note the apparent collapse downwards and backwards of vagina, bladder base and rectum. However, the three directional forces (arrows) appear to be functioning normally. Note the downward angulation of the levator plate (LP).

Middle and Posterior Zone X-rays

The following sequence of x-rays is presented to demonstrate the role of adequately tensioned connective tissue in maintaining normal geometry as well as how an inadequately angulated vagina may predispose to prolapse of the middle and posterior zones.

The Normal Patient

In the normal patient, the proximal vagina (V) is nearly horizontal (fig 6-37). It is compressed on to the rectum (R) during straining (fig 6-38).

Figure 6-37 is a standing lateral x-ray in a normal nulliparous woman at rest. The anatomical relationships are essentially normal. '1', '2' and '3' delineate the three levels of the pelvis (cf. anatomy section). The angle 'a' is the angle of the proximal vagina (V) to the horizontal.

Figure 6-38 shows a downward angulation of the vagina around perineal body (PB) and midurethra. Note the obvious stretching backwards of vagina and rectum, and the downward angulation of the levator plate (LP). The angle 'a' becomes almost zero as the vagina is stretched virtually to a horizontal position. Note the compression of level 2.

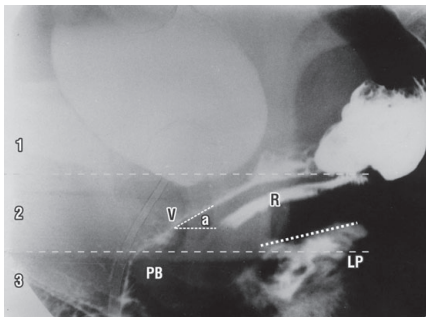


Fig. 6-37 (above) The role of the posterior zone - at rest. R = rectum; LP = levator plate.

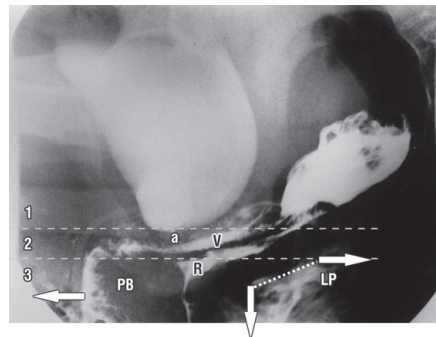


Fig. 6-38 (above) Role of the posterior zone - Straining.

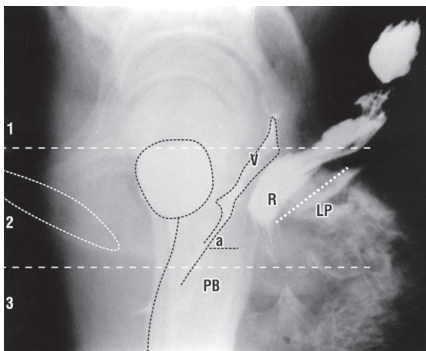


Fig. 6-39 At rest

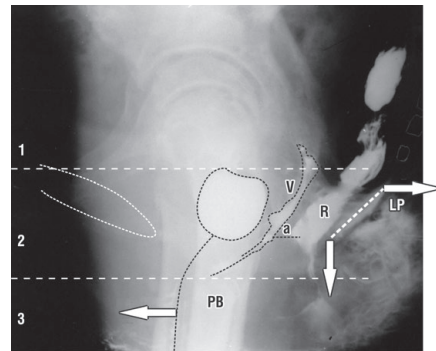


Fig. 6-40 Straining

Abnormal Middle and Posterior Zone Anatomy X-rays

There is failure to convert the abnormal vertical position of the vagina at rest (fig 6-39) to a horizontal position during straining (fig 6-40). The intra-abdominal and pelvic floor forces distend an already weakened vagina.

In figure 6-40 there is normal movement downwards and backwards of the Foley balloon, and the three directional forces (arrows) appear to be working adequately. However, there is little change in the angle 'a', and there is obvious distortion downwards of the central wall of vagina 'V', indicating also a middle zone defect.

There is no compression of level 2. Given the apparent normal functioning of the three muscle forces, the anatomical defect appears to be in the connective tissue insertions of the system, between muscle (LP) and vagina and perhaps perineal body also.

Clearly, weakness in the uterosacral ligaments (USL), rectovaginal fascia (RVF) and perineal body (PB) may all contribute to such dysfunction.

6

6.2.4 Dynamic Mapping with 'Simulated Operations': A Clinical Example

In the Integral Theory framework, diagnosis seeks to test the predictions of damage derived from the Clinical Assessment or Structured Assessment pathways. Diagnosis testing by means of 'simulated operations' is especially useful in patients with urgency symptoms as these are not 'zone specific'. As the 'trampoline analogy' demonstrates, any ligament, if loose, may cause urgency symptoms. With 'simulated operations' methodology, the patient herself is used as the 'urodynamic machine'; that is, the reference point to determine by how much urgency symptoms are diminished while a particular structure is being mechanically supported.

The following case report is presented as an example of the extent to which this method can assist the diagnostic process. It is emphasized that only the *changes* in stress or urge (table in fig 6-41) are used in clinical decision making. The changes in ultrasound and urodynamics simply reinforce the fact that restoration of anatomy also restores function.

Background to the Clinical Example

The patient, a 32 year old, stated that she had suffered from both stress and urge incontinence all her life, but these symptoms had worsened since childbirth. Symptomatically, she had stress incontinence, urge incontinence, frequency 13-20 times per day, nocturia 4-5 times per night, difficulty in emptying her bladder, and low abdominal and sacral backache. On examination, there was obvious laxity in her external urethral ligaments, and suburethral vagina (hammock). She had second degree uterovaginal prolapse, second degree enterocele, and second degree paravaginal defect. Referring to the Pictorial Diagnostic Algorithm, it was clear she had anatomical defects in all three zones of the vagina. On urodynamic testing, there was sensory urgency but no detrusor instability. Her bladder capacity was 356 ml, emptying time

26 seconds, her maximum flow rate was 50 ml/sec and residual 170 ml. On cough stress testing (10 coughs), she lost a total of 5.1gm and she lost 26 gm of urine on 24 hour pad testing.

The algorithm indicated there was connective tissue laxity in all three zones of vagina. The patient was assessed with a full bladder and described strong feelings of urgency in the supine position.

The Intervention - 'Simulated Operation'

The structures 1-6, (6-41) in three zones of vagina were anchored serially. All results recorded were as agreed by two observers. A haemostat was unilaterally applied to the external urethral ligaments '1' and pubourethral ligaments '2'. The sub urethral vaginal hammock '3' was tightened unilaterally by taking up a fold of the vagina. Ring forceps were applied paravaginally '5', in both sulci, just behind the bladder neck, and also to anchor the cervix (the uterosacral ligaments '6') and to support the bladder base '4'. Care was taken not to obstruct the urethra during the anchoring process. The pressure applied was firm, but not sufficient to elicit pain. The reference points for the objective tests were the funnelling observed during straining on perineal ultrasound, and the zero closure pressure observed during coughing. The same 6 interventions were applied:

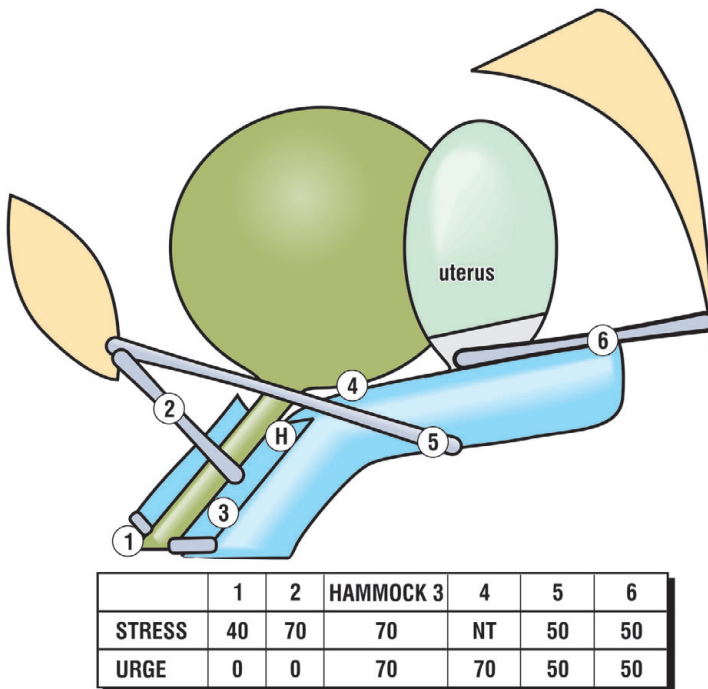


Fig. 6-41 Changes in stress and urge incontinence. The figures represent the percentage diminution in observed urine loss on coughing ('stress') and percentage diminution in urge symptoms ('urge') following the anchoring, in turn, of each structure 1-6.

- a) in the supine resting position. Percentage subjective diminution of urge symptoms with interventions 1 through 6 was recorded (fig 6-41);
- b) in the supine position during repeated vigorous coughing (minimum 8 times). The percentage diminution in urine loss with interventions 1-6 was agreed upon by two observers (fig 6-41);
- c) in the supine position during a single straining episode with simultaneous perineal ultrasound monitoring, the changes in urethrovesical geometry with interventions 1-6 were observed and recorded on film;
- d) in the supine position during repeated vigorous coughing (minimum 8 times) simultaneous bladder and urethral pressures were recorded with interventions 1-6 using dual Gaeltec microtip transducers spaced 6 cm apart drawn through the urethra with an electric puller.

Note: the clinical, urodynamic and ultrasound tests were not performed simultaneously, but within a few minutes of each other.

The Post-Intervention Results – Anchoring One Structure at a Time

The post-intervention results are summarized collectively in figure 6-41 (clinical), the ultrasound results in figures 6-43 to 6-48 inclusive, and the closure pressure results in figures 6-49 to 6-55 inclusive.

Figure 6-41 is a schematic sagittal representation of the supporting structures of the vagina, bladder base and urethra. '1' is the external urethral ligament (EUL), '2' the pubourethral ligament (PUL), 'H' or '3' is the hammock, '4' the bladder base, '5' is the arcus tendineus fasciae pelvis (ATFP) and '6' is the uterosacral (USL). These were anchored seriatim, and the percentage diminution of symptoms of stress and urgency on supporting each structure is indicated.

Post intervention Results – Two Structures Anchored Simultaneously

This patient presented an ideal opportunity to directly challenge one aspect of the Integral Theory, that all structural components of the pelvic floor may play a synergistic role in maintaining continence for urge and stress. With reference to figure 6-41, tightening the hammock '3' plus midurethral anchoring '2' simultaneously gave 100% control of urine loss during coughing. Anchoring the cervix '6' plus both ATFP's '5' simultaneously diminished urgency symptoms to zero.

Figures 6-42 to 6-48 (inclusive) show the impact of support during ultrasound observations. These examples are presented to emphasize the potential of 'simulated operations' when applied to verifying tests such as ultrasound and urodynamics. The same techniques have also been applied during filling cystometry ('detrusor instability') and to determine the effect on tissue stiffness using a piezo-electric probe.

Comment

The morphological changes in the urethrovesical angle, bladder base descent, and the anterior and posterior shelf of the bladder (figs 6-43 to 6-48 inclusive) are of special interest. The 'shelf' is formed by the bladder trigone. The urethral pressure results are presented in terms of closure pressure change in the proximal and distal parts of the urethra. The functional urethral length is obviously lengthened during anchoring of

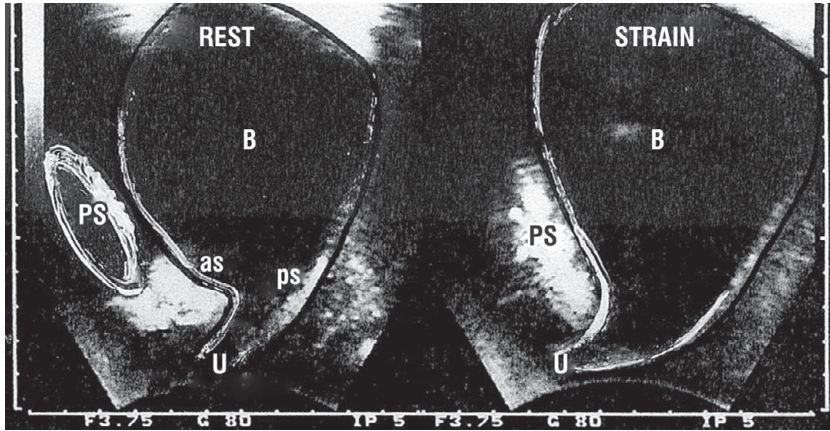


Fig. 6-42 (above) Ultrasound at rest
B = bladder; PS=pubic symphysis;
U = urethra; as = anterior bladder shelf;
ps = posterior bladder shelf.
Same labelling for all figures.

Fig. 6-43 (above) Ultrasound during straining
– This figure is the reference point for all interventions. Note descent of bladder base and funnelling of proximal urethra and associated urine leakage on straining. Note absence of ps.

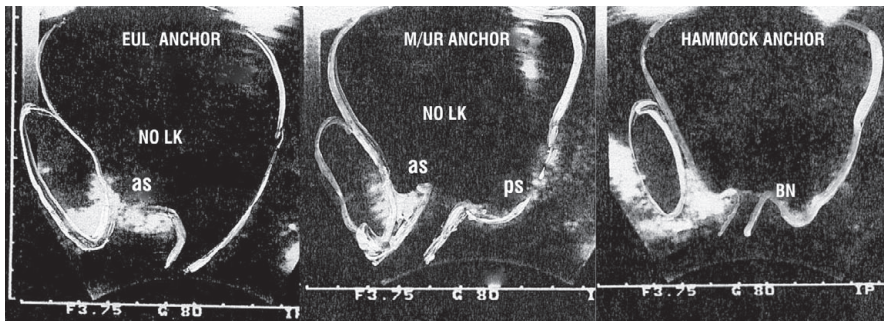


Fig. 6-44 EUL – During straining with EUL anchor. Note bladder base still descends and funnels, but there has been a restitution of the anterior bladder shelf, and no leakage on straining.

Fig. 6-45 PUL – During straining with PUL anchor. There is no bladder base descent or funnelling. Note restitution of anterior and posterior bladder shelf, with no leakage on straining.

Fig. 6-46 Hammock – During straining with hammock tightening. There is no bladder base descent or funnelling. Note restitution of anterior and posterior bladder shelf, with no leakage on straining.

the hammock, ATPF and cervix. With repeated vigorous coughing, control of urine loss with single anchoring was incomplete, 70% with either PUL ('2') or hammock ('3') anchoring (fig 6-41). Complete control of urine loss was achieved by combining two or more anchorings. For stress incontinence, combined tightening of the hammock plus PUL gave complete control of urine loss even with strong repetitive coughing. When both ATPF and cervical anchoring were combined, control of urge was total. *Combining two such 'simulated operations' directly demonstrates the synergistic action of structures in maintaining urinary continence.*

The change in closure pressure can be explained with reference to the formula $\text{Pressure} = \text{Force}/\text{Area}$ (of the urethral tube). Improved closure as evidenced by

6

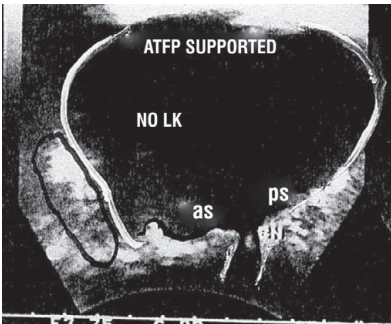


Fig. 6-47 (above) ATPF During straining with ATPF support. There is no bladder base descent or funnelling. Note restitution of anterior and posterior bladder shelf, with no leakage on straining.

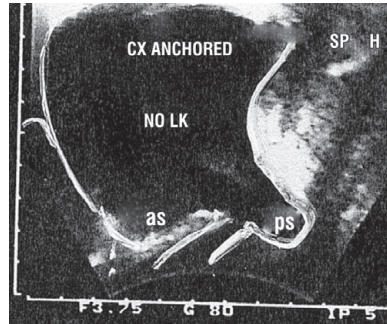


Fig. 6-48 (above) USL – During straining with anchoring of cervix. There is no bladder base descent or funnelling. Note restitution of anterior and posterior bladder shelf, with no leakage on straining.

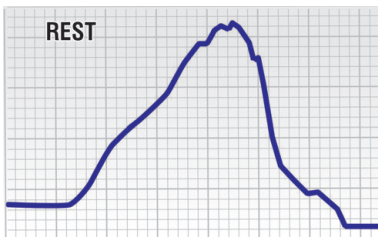


Fig. 6-49 (above) Urethral pressure at rest.

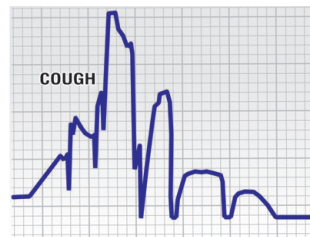


Fig. 6-50 (above) Urethral closure pressure (UCP) during coughing – The closure pressure is diminished in the proximal urethra, falling to zero in the distal urethra. This is the reference point for all subsequent interventions.



Fig. 6-51 (left) UCP during coughing with EUL anchor – The closure pressure is significantly increased in all parts of the urethra.

decreased urine loss with stress indicates the intra-urethral area was narrowed, also causing the intra-urethral pressure to rise.

Anchoring the insertion points of the muscles may work much like a trampoline: even one loose spring may prevent the membrane being tensioned. Restoring damaged ligaments (springs) allows the three muscle forces to stretch the vaginal membrane (trampoline). This supports the bladder base, preventing premature activation of the stretch receptors and consequently, the micturition reflex (sensation of urgency).

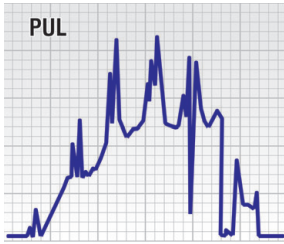


Fig. 6-52 (above) UCP during coughing with PUL anchor – The closure pressure is significantly increased in all parts of the urethra.

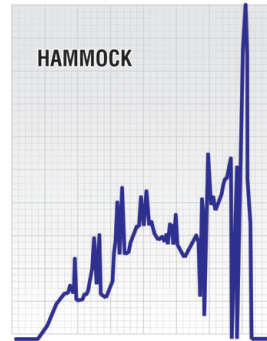


Fig. 6-53 (above) UCP during coughing with hammock tightening. The closure pressure is significantly increased in all parts of the urethra, as is functional urethral length (FUL).

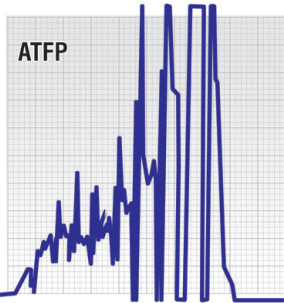


Fig. 6-54 (left) UCP during coughing with ATFP anchor. There is no significant improvement in closure pressure in any part of the urethra. This is an increase in PUL.

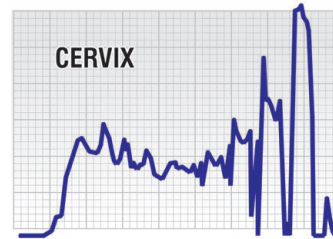


Fig. 6-55 (right) UCP during coughing with cervical anchoring. The closure pressure is significantly increased in the proximal urethra, but not distal urethra.

Acknowledgement: The author is grateful to Pr. Dr. Med B. Abendstein from Hall, Austria for his assistance with the test procedures.

Conclusion

These are coarse tests, but they do give an insight into the synergistic action of different structures. It is highly likely that pressure applied at one site (hammock) may have also partly anchored an adjacent site (PUL). As both belong to the anterior zone, and as both should be repaired during surgery, precise differentiation is not a practical concern.

Even with this limitation, the results emphasize the collective contributions of individual structures to the whole system thereby supporting the Integral Theory. Each of the six interventions created a symptomatic or objective change, while two simultaneous anchoring points were required to achieve total control of stress and urge.

This study gives a brief insight into the synergism of multiple structures in continence control. 'Simulated operations' appear to be a useful technique in determining more precisely which ligamentous/connective tissue defects may be contributing to stress and urge symptoms.

6

6.3 Summary Chapter 6

Urethral resistance, and especially how it changes exponentially (to the 4th power) with the changes in diameter enacted by the opening and closure mechanisms, is presented as the very basis for urodynamics, both as concerns intra-urethral pressure measurement and, flow. A prematurely activated micturition reflex explains both detrusor instability (DI) and the 'low compliance' bladder.

The concept of non-linear control of the opening and closure mechanisms, and the role of Chaos Theory in explaining symptom variability and inconsistency is introduced. The anatomical basis for DI is explained with reference to an actual urodynamic graph.

'Dynamic mapping' of the three zones of the vagina using ultrasound, urethral pressure and the patient's own perception of her symptoms as the reference point' in an individual patient demonstrate the synergistic nature of the three zones of the vagina in control of urgency symptoms and urine loss during coughing.

Current and Emerging Research Issues

7.1 Introduction

The muscles, nerves and ligaments of the pelvic floor work synergistically to maintain the *structure* of the pelvic floor and the proper *functioning* (opening and closure) of the pelvic organs. In terms of structure and function, connective tissue is the most vulnerable component of the pelvic floor. Two key precepts of the Integral Theory are:

1. Even a minor degree of ligamentous laxity has the potential to cause major pelvic floor symptoms;
2. These symptoms are potentially curable by reinforcing the pelvic ligaments using polypropylene tapes.

The validity of this simple surgical concept has been substantiated already by more than 1,500,000 anterior sling operations for cure of stress incontinence. There is also a rapidly growing validation of posterior zone symptom cure following the posterior sling. Therefore, it can no longer be stated that these conditions are surgically incurable. The minimalist surgical approach postulated by the theory and the excellent results, have facilitated a rapid evolution in surgical technique, as well as a plethora of delivery instruments and tapes. All this activity in surgical methods is a healthy sign of growth and it is to be encouraged.

Surgical techniques developed within the Integral Theory framework have been significantly refined and minimized, but some important questions remain, especially concerning the long term effects of interventions and materials. Individual clinicians must decide which technique, which tape, which material, (homologous, heterologous or synthetic) to use, according to their training and experience. All options have their risks and benefits. The solutions will only come from well-planned statistically relevant clinical trials, not from anecdotal descriptions. Any scientific comparisons must examine all risks and benefits, not focus on a single particular issue. The most significant challenges facing the proponents of the theory are:

1. To develop a reliable and accurate diagnostic system to find which structures have been damaged;
2. To accurately define the relationship of each structural component to a particular dysfunction.

The sections which follow are devoted to current and emerging research issues. They are presented under separate headings. Some, such as the cure of idiopathic faecal incontinence, have been significantly documented. Others, such as interstitial cystitis and vulvar vestibulitis, having only a few case reports and associations with other symptoms specific to a particular zone of the pelvis, are merely postulated.

A third, more fundamental issue, is the development of an understanding at the micro level. This involves issues about changes in the biochemistry of the tissue, the collagen cross links, etc. At present, it is not possible to assess a particular structure in this way. There is clinical and experimental evidence of genetically defective connective tissue in certain families. This helps to explain the occurrence of abnormal symptoms in nulliparous women.

Although oestrogen has little therapeutic impact on symptoms, there is evidence that oestrogen may prevent collagen degradation after the menopause.

Surgically, being able to assess subclinical damage in an apparently normal structure, is of considerable importance. Shull (1992) reported greater than 30% 'blowout' in other parts of the vagina following a site-specific repair. Up to 20% such herniations, in particular cystocele, may occur after posterior IVS surgery. The reinforcing of one subsystem is likely to concentrate (or shift) the pelvic floor forces onto another weak part of the system and thereby cause another 'blowout' of the vaginal membrane. For example, the author has seen several cases of stress incontinence developing *de novo*, months after vault prolapse repair by Posterior IVS. Much work is needed at the micro level to determine hormonal and the other factors that influence connective tissue, genetics, effects of childbirth and ageing.

Currently, there are no reliable objective methods for gauging strength and elasticity of connective tissue. Improvements to diagnosis and management will come from a better assessment of connective tissue strength, and a better understanding of the interaction of structures within the pelvic floor.

A major obstacle in this endeavour is the non-linearity of the interactions between pelvic floor structures. In particular, how even minor variations in the degree of damage may result in quite different symptom expression in individual patients. The variation may be as extreme as from no symptoms with major damage, to major symptoms with minor damage. The symptomatic manifestations depend entirely on the balance of all the elements (nerves, muscle forces, and connective tissues) within the pelvic floor system. (see Chapter 3).

Constructing an elastometer which can 'map' the physical characteristics, strength and elasticity of the organs of the pelvic floor and their suspensory ligaments will be an important step towards assessing the biomechanical characteristics of connective tissue. A prototype elastometer has already been constructed and tested at the UWA School of Materials Science Engineering (Harrison et al 2008), but it awaits clinical application. Muscle size can be assessed using MRI and ultra sound techniques. From these it is possible to infer muscle forces. The biomechanical characteristics of the tissue, and the forces which act on them, are key components in the quest to develop a mathematical model of bladder neck opening and closure. It is hoped that successful mathematical modelling - a 'finite element model' - will allow analysis of pelvic floor functions in the same way that structural engineers use mathematical models to analyse potential stresses on structures.

An example of this methodology is the non-linear mathematical model of micturition created at the University of Western Australia by Professor Bush and his team using ABAQUS software. This model examined (and confirmed) some of the Integral Theory's predictions as regards micturition. The approach used in this model

has potential application for unravelling the anatomical causation of specific symptoms in the individual patient. It may also help predict how surgical reinforcement of one part of the system may cause decompensation in other subclinically damaged structures¹. Such sophisticated analysis will be based on improved applications of urodynamics and ultrasound, and will also require instruments which can accurately assess various structural aspects of the pelvic floor, such as tissue structure (strength and elasticity), strength of muscle force contraction, and effectiveness of the ligamentous anchoring points. The analysis will be enhanced by the development of an extensive and relevant data base to correlate specific symptoms with clinical outcomes following surgical repair of specific structures. This will allow more accurate probability factors to be calculated for each condition (figs 1-11, 3-09). The computational power required even for the micturition model is very large and time consuming. However, improved methodology, and improved computer software and hardware will make ‘Finite Element Modelling’ a reality in future clinical management.

7.2 Improvements in the Diagnostic Decision Path

The Integral Theory divides diagnosis into three zones of potential damage. This is a simple and efficient starting point, but it requires continuous refinement and adaptation in practice. How variations and error in the diagnostic process can be reduced or eliminated is of particular interest.

Diagnosing the ‘zone of damage’ involves a decision path based on a probability distribution of the occurrence of a symptom or test result. Refinement of the probability analysis is an ideal application for computer-assisted diagnosis. A significant decrease in pre-operative diagnostic error was demonstrated by the author in application of the Integral Theory Diagnostic Support (ITDS) system. The ITDS system has been planned as a dynamic tool which will improve in diagnostic accuracy as the data base increases over time. As the data base grows, feedback diagnosis will allow the clinician to more accurately define the weighting to be applied to each existing parameter,

¹ ‘Mechanical Model For the Opening of the Female Urethra’, by Messner-Pellenc L. and Moron from the Departement de Mecanique, Ecole Polytechnique France and Professor Mark Bush from The University of Western Australia, School of Mechanical Engineering. The urethra was initially modelled using only the inflation from bladder contraction. Using material data of urethral properties from other studies, the characteristic funnelling observed during micturition could not be obtained. Furthermore, a force much greater than 60cm H₂O was required to inflate the urethra, suggesting that the internal pressure generated from the bladder may not have been sufficient to inflate the urethra. The funnelled shape was obtained by fixing the distal urethra, and applying external downward and backward forces to the proximal urethra. Even here, stiffening to the anterior and posterior urethral wall nodes was needed to obtain the funnelling: anteriorly, consistent with the ligament of Gilvernet, and, posteriorly, with the trigonal extension along the posterior wall of the urethra. The complete dissertation is available on the internet at: www.integraltheory.org.

as well as providing the ability to add new parameters. For this to occur, data from many thousands of cases will be needed. The strategy is to develop a system whereby hundreds of clinicians can post anonymous data via the internet.

7.3 The Integral Theory Diagnosis Support System (ITDS)

The Integral Theory Diagnosis Support System (ITDS) is a computerized version of the Structured Diagnostic system. It also has a data base function. With data from the questionnaire put into the computer, it pictorially presents anatomical defects in the three zones of vagina. The diagnosis is modified after input from the vaginal examination, and again after the ultrasound and urodynamics examinations.

The necessary resources for ITDS are contained on a compact disc which can be ordered from the website developed to accompany this book (www.integraltheory.org). The questionnaire, examination and urodynamics sheets are bar-coded for ease of use. It is emphasized that the diagnostic part of the ITDS is only a support tool. The ultimate responsibility for diagnosis and management rests, as always, with the attending surgeon.

7

7.4 Possible Clinical Associations

Many discoveries from the Integral Theory were made by a process of listing possible associations of symptoms and then following them up with a more deductive approach. The association of symptoms and anatomical defects presented in the Pictorial Diagnostic Algorithm are sufficiently documented to be used in diagnosis. There are other conditions based on associations that are not so well documented and these are potentially important research targets.

7.4.1 Vulvar Vestibulitis (Vulvodynia)

Vulvar vestibulitis is a symptom of the posterior zone. It is a disabling condition which occurs in up to 15% of women aged between 18 and 64. It is characterized by extreme entry dyspareunia. It is diagnosed by using a cotton bud applicator to gently touch the vestibule around the hymenal ring and the external urethral meatus. This gentle touching causes extreme discomfort for the patient.

Women with vestibulitis experience an intolerable pain sensation. Currently, the most efficacious treatment involves vestibulectomy or pelvic floor muscles exercises. Such treatment leads to cure rates of 85% and 50%, respectively (Marinoff 1991). The aetiology of vulvar vestibulitis has not yet been elucidated. In association with Professor Jacob Bornstein, of Haifa, Israel, the author has observed three consecutive patients who experienced complete cure of their vulvar vestibulitis by inserting a posterior sling to reinforce the posterior zone.

Other symptoms of the posterior fornix syndrome, urgency, frequency, nocturia and abnormal bladder emptying were also improved in these patients. This has given rise to a hypothesis that vulvar vestibulitis could be a referred pain caused by insufficient ligament support for the afferent unmyelinated nerve fibres carried in the uterosacral ligaments. Cure in five women have already been reported (Petros & Bornstein 2004) and there have been other anecdotal reports of cure, notably from Japan (Yoshimura 2007, personal communication). These data are not sufficient in themselves to draw any definitive therapeutic conclusions, but they do open up a promising new direction for research.

This hypothesis has been tested further (Bornstein et al 2005).. Two cc of 2% Xylocaine was injected into each of the uterosacral ligaments at the posterior fornix of the vagina of 10 consecutive patients who had been diagnosed with vulvodynia. The 10 patients were retested after five minutes. Eight patients reported complete disappearance of introital sensitivity, to two separate examiners. In the other two patients, direct testing confirmed that the allodynia (exaggerated sensitivity) had disappeared on one side, but remained on the other side. Retesting the patients showed that the blocking effects disappeared after 30 minutes.

The short-term disappearance of introital pain especially on one side is an important step in further substantiating the hypothesis that vulvodynia may be a referred pain originating from failure of lax uterosacral ligaments to support the afferent pain fibres within them.

7.4.2 Interstitial Cystitis

Three patients with Interstitial Cystitis (IC) have been observed with more than an 80% improvement of symptoms following posterior ligament reconstruction with polypropylene tapes. Although the results from these three cases were not in themselves sufficient to draw conclusions, they were instrumental in initiating a survey of known IC cases. With the assistance of Sandy McNicol, secretary of the Canadian Interstitial Cystitis Society, the structured Integral Theory Questionnaire (Appendix 1) was distributed to members. Of 136 questionnaires completed in the year 2000, 130 had two or more parameters consistent with posterior ligamentous laxity (Petros PE, unpublished data). It is known that vulvar vestibulitis and interstitial cystitis are related. Furthermore, urgency and pelvic pain are key symptoms in patients with posterior zone defect. Although any causal relationship is hypothetical at this stage, the association does require further investigation.

An objective office test to determine the role of the uterosacral ligaments in the causation of vulvodynia, pelvic pain and painful bladder syndrome ('Interstitial Cystitis').

Vulvodynia associated with chronic pelvic pain

The hypothesis that vulvodynia was also a referred pain was tested by injection of local anaesthetic in the position of the uterosacral ligaments (2) in 11 patients (Bornstein, Zarfati & Petros 2005). The pain was relieved for 20 minutes on both sides in 9 patients, and on one side in 2 patients. Cure of vulvodynia, chronic pelvic pain and other symptoms was reported in 5 patients following a posterior sling repair (Petros & Bornstein 2004).

Painful bladder syndrome, vulvodynia and chronic pelvic pain

More recently, 3 patients with painful bladder syndrome, and a diagnosis of interstitial cystitis from a major Italian centre specializing in this condition were given the local anaesthetic test described for vulvodynia (Bornstein et al. 2005). All patients had classical glomerular formations noted on cystoscopy. There was disappearance of urethral, cervical, abdominal and vaginal introital tenderness on palpation.

Patient 1 Aged 42 years, para2, had an 8yr history of painful bladder symptoms commencing after the birth of her 2nd child, and glomerular changes in bladder vasculature. Other symptoms were nocturia x2/night, urgency, but no incontinence, and symptoms of abnormal bladder emptying. On examination she was tender in the middle and lower parts of her abdomen, very tender on palpating the posterior wall of her urethra, and hypersensitive in the hymenal area on testing with a Qtip. She had an intact uterus, with only 1st degree prolapse, obvious separation of her uterosacral ligaments, and a very tender cervix to palpation. Following 5ml 0.1% Xylocaine injection in the presumed position of the uterosacral ligaments, she reported the following changes, central abdominal pain decreased from 8 to zero on a VAS (Visual Analogue Scale), and the right lower abdomen pain from 9 to 4. Vulval hypersensitivity reduced to zero, urethral tenderness to zero, and cervical excitation pain to zero. The effect lasted about 15 minutes.

Patient 2 Aged 51 years, para 2, had a history of bladder and lower abdominal pain for 10 years, worsening in the past 2 years. Her symptoms were nocturia x 3-8/night, bladder emptying difficulty, urgency but no major incontinence. She had no major prolapse. In the 4 minutes following injection, she reported total disappearance of her suburethral pain and tenderness, vulval introital tenderness, lower abdominal pain and (severe) cervical excitation pain.

Patient 3 Aged 40 years, para 2, gave a 7 year history of low left sided pelvic pain and tenderness, left-sided pain, left-sided vulval hypersensitivity, suburethral pain & tenderness, bladder emptying difficulty, nocturia x2/night, and hourly frequency and urgency. Following LA injection, her left- sided vulval hypersensitivity and suburethral tenderness reduced to zero, and her left-sided abdominal pain to 40% on a VAS scale.

Comments

1. *Perspective.* It seems simplistic to reduce all pelvic pain, vulvodynia and interstitial cystitis to a single entity, laxity of the uterosacral ligaments. Nevertheless, the results from this test are so emphatic, and the test so simple, that it is a direction of research well worth exploring.
2. *Limits of the test.* One limit of the test noted in the original description was a false negative from the local anaesthetic failing to reach one of the ligaments.
3. *A hypothesis for glomerular changes.* It is hypothesized that the pathogenesis of the glomerular changes in IC is related to the lax uterosacral ligaments (USLs). The muscle force of the posterior muscle forces effectively contract against the USLs. Muscles require a firm insertion point to function optimally. A weak muscle force prevents adequate stretching the vaginal membrane, and therefore, of the bladder veins and venous return from the bladder wall. Any rapid distension of the bladder in effect blocks off an already compromised venous return, resulting in distension and even rupture of the distended venules (“glomeruli”).

7.4.3 Unresolved Nocturnal Enuresis and Daytime Incontinence

In 1992 two young women, aged 14 and 17 years were assessed. Both were post-pubertal, both had unresolved nocturnal enuresis and daytime incontinence since they were babies. The 17 year old also had faecal incontinence. Standing x-ray assessment with dye in a Foley balloon catheter and vagina demonstrated excessive rotation and descent of the Foley balloon similar to that shown in figure 6-36 (page 167). Both patients were entirely cured of their nocturnal enuresis following an IVS operation to reconstruct the pubourethral ligament. Post-operative x-ray demonstrated the restoration of normal urethrovesical geometry at straining. It is emphasized that these patients had daytime urge and stress incontinence as well, a pattern different to that seen in most cases of nocturnal enuresis. Over the next ten years patients were asked specifically about nocturnal enuresis clearing or improving at puberty. More than 50 such patients were found. In many, the bed wetting improved at puberty, but they continued to be incontinent until cured by an anterior sling. Almost invariably there was a family history of this condition through the generations, both male and female.

The anatomical explanations given here for conditions such as nocturnal enuresis and vesico-uretic reflux intersect with those of paediatric urology. The anatomy and function in children cannot be very different to adults and it may be useful to re-examine some long-held concepts of female paediatric urology in the light of connective tissue anchoring points and muscle forces.

7.4.4 Vesico-Ureteric Reflux

A 42 year old patient presented with classical symptoms and radiological evidence of vesico-ureteric reflux. She was clinically cured of her symptoms with an anterior midurethral sling. It is possible to explain this patient's improvement by reference to the musculoelastic model for urethrovesical closure (fig 2-12). The ureters travel through the bladder wall before reaching the trigone. Because the bladder trigone relies on firm ligamentous attachments (which allow it to be stretched by the striated muscles of the pelvic floor), ligamentous laxity may loosen the trigone sufficiently to cause reflux.

Although only one case has been reported, its analysis may lead to new research and treatment directions for this condition.

Conclusion

The concepts, methods and techniques described in this book have been influenced by profound developments in scientific methodology and philosophy in recent times. In particular, the advent of digital technology and its support of non-linear thinking in biological systems has had a major impact on the diagnostic and surgical protocols described in this book.

The contribution of Chaos Theory to non-linear methodology as well as its capacity to explain the interface between micro and macro domains, is especially acknowledged. Chaos Theory provides a theoretical explanation of how a small alteration in initial conditions (microdomain) may have major consequences (macrodomain), the 'butterfly effect'. It thus provides a framework which helps explain how even minor connective tissue damage may cause severe symptoms. A direct legacy of the 'butterfly effect' has been the development of a theoretical framework for minimalist surgical techniques. Minimalist surgical techniques have meant fewer complications. This means that surgical correction is now available even to the frail and the weak.

The Integral Theory, first developed in 1990, has provided a sound starting point for this work. In particular the perspectives on anatomy and its distinction between static and dynamic has opened the way to further exploration of the nexus between muscles, ligaments and organs. The critical role of connective tissue in pelvic floor function and dysfunction cannot be overemphasised. A key concept is the interrelation of structure and form, as well as balance and imbalance in pelvic floor functioning. It follows from this that restoration of structure and form is required to restore function.

An important development presented in this book has been the distinction between the 'mechanical' and the 'neurological' dimensions of pelvic floor function, and how both of these domains can be influenced by connective tissue damage. Focusing on the dynamics of the neurological dimension can help explain how quite severe symptoms such as pelvic pain and bladder instability may be caused by minor connective tissue damage.

A key component of this book is the Pictorial Diagnostic System. It is based on the 'Zones of Damage' and uses the Structured Assessment pathways to isolate the damaged connective tissues that need corrective surgery.

Use of the Pictorial Diagnostic System allows a new suite of surgical techniques to be introduced to address both prolapse and some symptoms that were once thought to be 'incurable'. Major symptoms may in fact only require minor corrective surgery to restore normal pelvic floor function. Symptoms such as stress incontinence, frequency, urgency, nocturia, pelvic pain, abnormal bladder and bowel emptying, even idiopathic faecal incontinence, may be improved with an 80% probability of success by reconstructing damaged ligaments and fascia.

The surgical techniques described are the 'tension-free' tape techniques, and the newer and less invasive 'tissue fixation system' which can be performed under direct vision.

The main challenge for the future development of this system is refinement of the probability assessments for connective tissue structures identified in the diagnostic system as causing pelvic floor dysfunction. The Integral Theory Diagnostic Support (ITDS) provides a first step in this quest. It is hoped that this will be enhanced with an interactive internet website (www.integraltheory.org). This will be an important tool for continuing development of pelvic floor science as it allows for sharing of research results, general relevant information, new ideas and collaboration on a scale previously thought unimaginable. Such a system could incorporate an anonymous data collection system so that, potentially, each surgeon has the opportunity of becoming a contributor to the data base. Contributing information about the structure(s) repaired, and recording the change in symptoms and objective tests, may help to provide an improved probability rating for each structure and its contribution to a particular function or dysfunction. The FDA has already created the 'Maude' website for the anterior sling procedure. This is a website on which complications using the various delivery instruments are recorded. These include TVT, IVS, Sparc, and Monarc. The website URL is <http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfMAUDE/search.cfm>. The site allows the physician to type in the device name to find out any recorded 'events' associated with this device. This includes all the complications recorded on the site.

There are other roles for a confidential, password accessed internet web site:

- data on complications for particular procedures can be quickly displayed;
- requests for assistance with management of a difficult case can be discussed in a confidential 'chat room' environment;
- helpful hints which may assist diagnosis and surgical techniques can be accumulated and disseminated.

Indeed the opportunities presented by the internet for ongoing international 'interactive' research and collaboration are unprecedented in the history of medicine.

Theory is important in setting the framework for scientific advance. The Integral Theory has served us well in this respect. Further development of the Integral Theory perspective of connective tissue damage has significantly broadened the scope of curable pelvic floor conditions; in particular pelvic pain, bladder instability, anorectal dysfunction and intrinsic sphincter defect. As Dr Richardson so kindly expressed in the preface, 'the original Integral Theory has now matured into an important medical paradigm'. This theory, method and technique is now a complete working system for diagnosis and management of pelvic floor dysfunction.

Before this book, there has not been a complete theoretical and practical exposition of the Integral Theory that explained its ramifications for clinical practice. One hopes that the reader is as optimistic as the author about the prospects for future developments in female pelvic floor science and practice that this new paradigm has made possible.

Appendix 1 – Patient Questionnaires and Other Diagnostic Resource Tools

Patient Questionnaire

Self administered patient questionnaire

Part I Personal Details

Name:

Address:

Weight : kg

Number of vaginal deliveries ()

Number of caesarean sections ()

Date: _____

Date of birth :

Telephone:

Part II Symptoms

Describe in your own words your main urinary symptoms and duration:

A1

All sections: tick appropriate square . ☐ Write extra details if you wish.

A. Stress Incontinence (SI) Symptoms	No	Yes some- times	Yes 50% or more
Do you lose urine during:			
(A) Sneezing	☐	☐	☐ *
(A) Coughing	☐	☐	☐ *
(A) Exercise	☐	☐	☐ *
(1) Walking	☐	☐	☐
(A) (2) Stooping, squatting or getting up from a chair	☐	☐	☐
(P,M) Symptoms of deficient emptying			
(3) Do you feel that your bladder isn't emptying properly?	☐	☐	☐
(3) Do you ever have difficulty starting off your stream?	☐	☐	☐
(3) Is it a slow stream?	☐	☐	☐
(3) Does it stop and start involuntarily?	☐	☐	☐

* Note to physician: the filter '50% or more' (column 3) has a proven correlation for SI being caused by anterior zone defect. For all other symptoms a 'sometimes' notation is sufficient to attribute a symptom to a particular zone. 'A', 'M' and 'P' indicate the zone of causation and where the symptoms should be transcribed on the Diagnostic Summary Sheet (fig 3-03). Numbers in parentheses refer to notes at the end of the questionnaire.

		No	Yes some- times	Yes 50% or more
Urge symptoms:				
Do you ever have an uncontrollable desire to pass urine?		☐	☐	☐
If so, do you wet before arriving at toilet?		☐	☐	☐
If so, how many times a day do you wet? (Write number)				
Good day		—	—	—
Bad day		—	—	—
How much?	A few drops	No	Yes	
	A teaspoon full	No	Yes	
	A tablespoon or more	No	Yes	
(4)	Do you have pain while passing urine?	No	Yes	
(P)	How many times during the night do you get up to pass urine?	—	—	—
How many times do you pass urine during the day? (Write number)		—	—	—
(A, M)(5)	In the morning do you wet immediately on getting out of bed?	☐	☐	☐
(A) (5a)	Did you wet the bed as a child but not after puberty?	No	Yes	
(P) (5b)	Did your problems begin soon after puberty?	No	Yes	
(P) (5c)	Are your symptoms worse before a period ?	No	Yes	
Bowel symptoms:				
(A,P) (6a)	Do you have difficulty evacuating your bowels?	No	Yes	
(A,P) (6b)	Do you ever soil yourself (faeces)?	No	Yes	
	wind	No	Yes	
	liquid faeces	No	Yes	
	solid faeces	No	Yes	
Social inconvenience:				
(A,P) (7)	Are you 'moist' with urine much of the time?	No	Yes	
(8)	Do you leave puddles on the floor?	No	Yes	
	Do you lose urine in bed at night?	No	Yes	
Do you wear a pad or liner on going out? (Circle)		Never /sometimes /always		
If so, how many pads/liners per day? (Write number)		—	—	—
Previous operations: (circle the answer which matches)				
(P) (9)	Have you had a hysterectomy?	No	Yes	
If so, when? (write date) — — — —				
(10)	Have you had previous surgery for incontinence?	No	Yes	
If so, when? (write date) — — — —				
Are you <u>better</u> or <u>worse</u> since? (Circle)		Worse	Better	
(10)	Have you had previous vaginal surgery?	No	Yes	
If so, when? (write date) — — — —				

(P)(11) <i>Pelvic pain</i>	No	Yes some- times	Yes 50% or more
Do you have deep pain on intercourse?	☐	☐	☐
Do you have a pain down at the bottom of your spine?	☐	☐	☐
Do you have a pain down at the bottom of your abdomen?	☐	☐	☐
(12) Do you have pain at the entrance to your vagina?	☐	☐	☐

Quality of life grading

Please circle a grading between 1 and 5 to describe the effect that incontinence has on your normal activities. 1 is low impact, 5 is high impact.

- 1 = normal
- 2 = mild, no effect on lifestyle
- 3 = can't drink, must locate toilets on going out
- 4 = always wears pads, very restricted social life
- 5 = totally housebound.

A1

Explanatory Code for Physicians - Significance of '50% filter' (column 3)

Symptoms vary because control is a non-linear interaction of 'mechanical' and 'neurological' phenomena. Therefore when transcribing the response data to the Diagnostic Summary Sheet (figure 3-03), a 'sometimes' response is taken as a positive indication. The exception is stress incontinence (column 3). A tick in column 3 is required for a positive response because of proven correlation of the 50% filter with pad test results. The significance of the 50% filter for the other symptoms has yet to be tested statistically.

Explanatory Notes for the Numbers Preceding the Questionnaire Responses

- (1) This is usually caused by low urethral pressure (ISD) but may be from lax posterior zone.
- (2) If there is minimal SI with coughing, it is termed 'paradoxical leakage'. In age group >70 yrs generally due to PUL (pubourethral ligament) defect. Exclude tethered vagina syndrome in patients with previous vaginal surgery if a tight scar at bladder neck.
- (3) USL (uterosacral ligament) cystocele, but also after excessive bladder neck elevation, or tight suburethral sling.
- (4) Exclude UTI, chlamydia, etc.
- (5) Generally PUL defect even with previous operation, but exclude tethered vagina if tight scar at bladder neck.
- (5a) This condition runs in families. It indicates congenital PUL weakness.
- (5b) & (5c) The cervix softens to allow menstruation to pass, weakening the anchoring point of USL.
- (6a) Posterior zone defect (perineal body/ rectocele/USL) and sometimes PUL.
- (6b) Defective PUL/USL and /or anal mucosal prolapse (descending perineal syndrome).
- (7) Low urethral pressure - usually with lax suburethral vagina (80%), but can be caused by lax posterior zone (20%).
- (8) This may be defective PUL, but may be also due to USL defect.
- (9) Suspect posterior zone defect especially in age group > 60 years.
- (10) Think of tethered vagina syndrome in patients with positive answers for '5' and '2' who have scarring or tightness at bladder neck.
- (11) Posterior zone defect.
- (12) Vulvar vestibulitis which may also be caused by posterior zone defect.

Comprehensive 24 Hour Urinary Diary*

Name _____ Date _____

This chart is a 24 hour record of your fluid intake, voiding and leakage (incontinence). Please complete prior to your visit. Begin with the first toilet visit on arising. You will need a plastic measuring jug.

- 1. Record time of all intake voidings and leakage
- 2. Measure amount of fluid taken in (intake)
- 3. Measure amounts voided
- 4. Describe what you were doing at the time of leakage
- 5. Estimate amount of leakage according to the scale in column 5 (1,2,or 3)
- 6. If the urge to urinate preceded the urine leakage write YES

If you felt no urge when the leakage occurred, write NO.

Indicate good day () average day () bad day ()

1. Time	2. Intake	3. Output Amount voided (ml)	4. Activity e.g toilet, cough,..	5. Amount of Leakage 1 - damp (few drops only) 2 - wet underwear or pad 3 - soaked pad ran down leg	Urge Present? No / Yes

Note: The Urinary Diary is used to verify the consistency of the patient's questionnaire responses. It has no direct contribution to the decision tree. It should be done at the same time as the 24 hour pad test.

* Author: David Browne, Queensland, Australia. By permission.

'Objective' Tests*Pad tests*

- (A) Cough X 10 () gm
 Handwashing Test (30 Seconds) () gm
 *24 Hr Pad Test () gm
 *indicate with a tick: good day () average day () bad day ()

Perineal Ultrasound

- (A) Bladder neck descent () mm
 (A) Funnelling No / Yes
 (A) Prevention of funnelling with midurethral anchor Test: No / Yes

Urodynamics

- Bladder capacity () ml
 (M) (P) Emptying time (>60 seconds) () secs
 (M) (P) Residual urine (>30 ml) () ml
 Detrusor instability No / Yes
 (A) Maximal urethral closure pressure (MUCP) ()

A = anterior zone; M = middle zone; P = posterior zone

Pad Test Methodology Explanatory Notes

Pads are weighed on a 1000 gm digital scale.

24 Hour Pad Tests

This test measures the severity of the problem and includes urine loss from both stress and instability. Preweighed pads are worn continuously and collected over a 24 hour period.

Ask the patient to purchase a packet of menstrual pads and to set aside one dry pad. Weigh the dry pad.

Once a pad is wet it is placed in a sealed plastic bag. Because there is very little weight variation between the same type of menstrual pad when dry, the wet pads can be weighed in toto and the weight of equivalent number of dry pads subtracted to yield the weight of urine. Unless SI is very severe, a large 24 hour loss generally points to instability as the major problem.

Rapid Provocative Pad Tests

10 coughs are specific for stress incontinence (anterior zone defect). 'Cough activated instability' is easily diagnosed by asking the patient to observe if urine loss continues after cessation of coughing.

Handwashing during 30 seconds objectively tests for bladder instability by activating the micturition reflex, urine leakage associated with urgency.

Variability

With all objective tests, the loss may vary significantly from day to day. This is because the control mechanisms of the body are complex and non-linear. More reliability is obtained by asking whether day of testing is a 'good', 'average' or 'bad' day.

Post-Treatment Questionnaire

Name: _____

Date: ____ / ____ / ____

Date of Birth: ____ / ____ / ____

Instructions

Tick the box corresponding to the appropriate answer.
Select only one answer to each question, unless otherwise indicated.

Section 1 -Symptoms You Had Before Your Last Surgery

What were your main symptoms before surgery? Tick one or more in the brackets.
Important: If any of the symptoms below began *after* the surgery, write “new” inside the brackets.

- Q1 [] Urine loss during exertion or coughing
Q2 [] “Can’t hold on” - Wet before arriving at toilet
Q3 [] “Going to toilet frequently to pass urine”
Q4 [] “Getting up at night to pass urine”
Q5 [] “Can’t empty bladder properly”
Q6 [] Lower abdominal or pelvic pain
Q7 [] “Prolapse” (Lump in the vagina)
Q8 [] Bowel emptying
Q9 [] Bowel soiling

Section 2 -Symptoms After Surgery

The aim of this section is to assess if symptoms have improved since the surgery.
Only answer the questions that are relevant to your condition.

Q1: Urine loss during exertion or coughing

Has this improved since surgery?

Better	Worse	Unchanged	Estimate % improvement.
[]	[]	[]	[]

Q2 “Can’t hold on” - Wet before arriving at toilet

Has this improved since surgery?

Better	Worse	Unchanged	Estimate % improvement.
[]	[]	[]	[]

Q3 “Going to toilet frequently to pass urine”

Has this improved since surgery?

Better	Worse	Unchanged
[]	[]	[]

How many hours can you “hold on” during the day now? [] (write number)

Q4 “Getting up at night to pass urine”

Has this improved since surgery?

Better Worse Unchanged

[] [] []

How many times a night do you get out of bed to pass urine now? [] (write number)

Q5 “Can’t empty bladder properly”

Has this improved since surgery?

Better Worse Unchanged

[] [] []

Estimate % improvement.

[]

Q6 Lower abdominal or pelvic pain

Has this improved since surgery?

Better Worse Unchanged

[] [] []

Estimate % improvement.

[]

Q7 “Prolapse” (Lump in the vagina)

Has this improved since surgery?

Better Worse Unchanged

[] [] []

Estimate % improvement.

[]

Q8 Bowel emptying

Has this improved since surgery?

Better Worse Unchanged

[] [] []

Estimate % improvement.

[]

Q9 Bowel soiling

Has this improved since surgery?

Better Worse Unchanged

[] [] []

Estimate % improvement.

[]

Q10 Overall, how would you rate the results of your operation?

More than 90% improved []

More than 70% improved []

50% improved []

No change []

Worse than before []

Q11 Knowing what you know now, would you have such an operation again?

Yes []

No []

Q12 Would you recommend such an operation to a friend?

Yes []

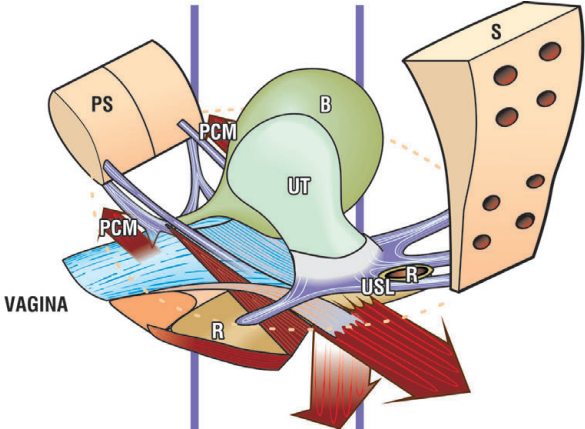
No []

Not sure []

Please feel free to add any further comments below.

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

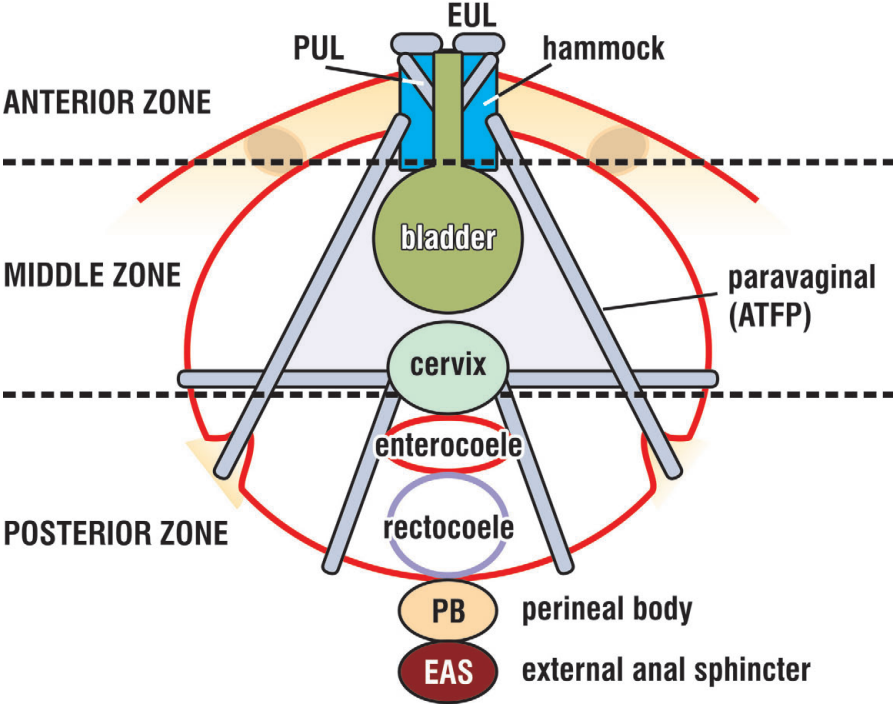
Example of a Completed Diagnostic Summary Sheet



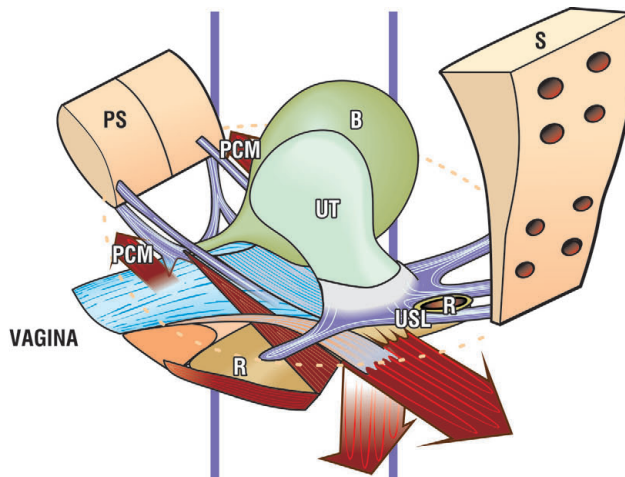
Anterior Defect (Excess Laxity)		Middle Defect (Excess Laxity)		Posterior Defect (Excess Laxity)	
Symptoms	Prob	Symptoms	Prob	Symptoms	Prob
SI (>50%) ✓ Urine loss on standing ✓ Post-stress instability ✓ "Always damp" ✓ Faecal incontinence ✓ Nocturnal enuresis cured at puberty ✓ "wet since childhood" ✓ Urgency ✓	90% 90% 70% 80% 50% 80% 80%	Emptying ✓ Urgency ✓	50%	Incontinence symptoms worse 1 week prior to period. ✓ "Always damp" ✓ Pain - low abdominal ✓ - low sacral ✓ - deep dyspareunia ✓ Faecal incontinence ✓ Emptying ✓ Nocturia ✓ Urgency ✓	80% 20% 80% 50% 50% 50% 80%
Examination		Examination		Examination	
Lax hammock ✓ Positive SI pad test ✓ Positive mid-urethral anchor test ✓ lax EUL ✓	90% 90%	Cystocele Paravaginal defect CX ring	2nd 2nd 1st	Excitation pain cervix/apex Prolapse uterus/apex Enterocoele Rectocoele high/mid/low Laxity ✓ PB/EAS	2nd 1st 1st
Urodynamics		Urodynamics		Urodynamics	
MUCP < 20cm H ₂ O Post stress DI		Raised residual urine Slow emptying time	50% 50%	Raised residual urine ✓ Slow emptying time ✓ Positive valsalva closure Pressure in patients with SI	50%
Ultrasound		Special Case - Excess Tightness			
"Funelling" on U/S ✓ UVJ Prolapse (>10mm) ✓	90%	"Tethered vagina" Uncommon (<5%), iatrogenic. May occur years after vaginal repair/BNE. Uninhibited urine loss on rising in the morning. Often no major SI. Other symptoms may coexist.			
Coughs x 10 19.7 gm 24 Hour Pad Test..... 47.6 gm					

Fig 3-03 example: An example of a completed Diagnostic Summary Sheet (See page 59)

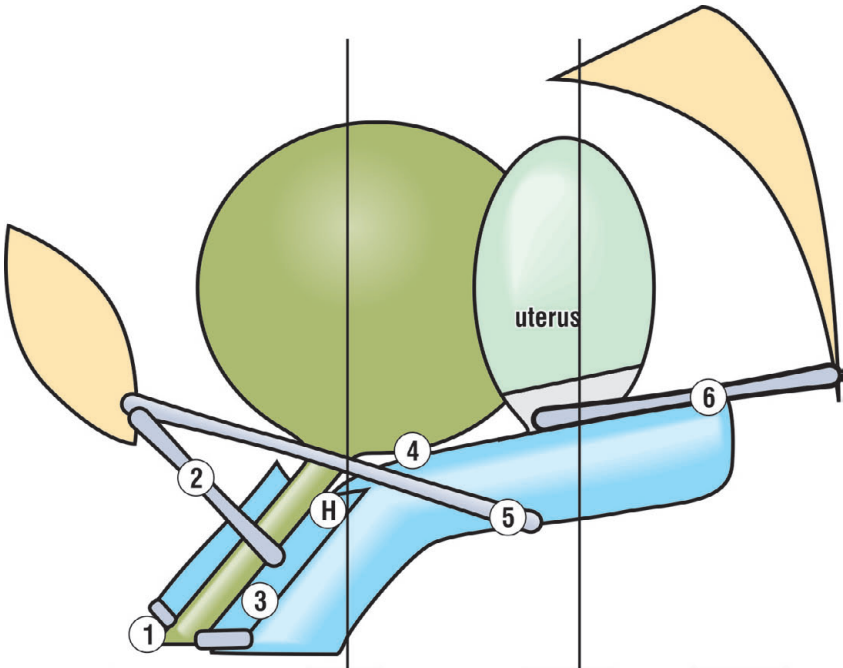
EXAMINATION SHEET
View from below



A1



Anterior Defect (Excess Laxity)		Middle Defect (Excess Laxity)		Posterior Defect (Excess Laxity)	
Symptoms	Prob	Symptoms	Prob	Symptoms	Prob
SI (>50%)	90%	Emptying	50%	Incontinence symptoms worse 1 week prior to period.	80%
Urine loss on standing	90%	Urgency		"Always damp"	20%
Post-stress instability	70%			Pain - low abdominal	80%
"Always damp"	80%			- low sacral	50%
Faecal incontinence	50%			- deep dyspareunia	50%
Nocturnal enuresis cured at puberty	80%			Faecal incontinence	50%
"wet since childhood"	80%			Emptying	50%
Urgency				Nocturia	80%
				Urgency	
Examination		Examination	degree	Examination	degree
Lax hammock		Cystocele		Excitation pain cervix/apex	
Positive SI pad test	90%	Paravaginal defect		Prolapse uterus/apex	
Positive mid-urethral anchor test	90%	CX ring		Enterocoele	
lax EUL				Rectocoele high/mid/low	
				Laxity PB/EAS	
Urodynamics		Urodynamics		Urodynamics	
MUCP < 20cm H ₂ O		Raised residual urine	50%	Raised residual urine	50%
Post stress DI		Slow emptying time	50%	Slow emptying time	
				Positive valsava closure	
Ultrasound		Special Case - Excess Tightness		Pressure in patients with SI	
"Funelling" on U/S	90%	"Tethered vagina"			
UVJ Prolapse (>10mm)		Uncommon (<5%), iatrogenic			
		May occur years after vaginal repair/BNE. Uninhibited urine loss on rising in the morning. Often no major SI. Other symptoms may coexist.			
Coughs x 10	gm				
24 Hour Pad Test.....	gm				



A1

	1	2	HAMMOCK 3	4	5	6
STRESS						
URGE						

ANTERIOR
urgency/stress
relief of urge symptoms
anterior ligaments
press, in turn, finger tip or artery forceps unilaterally at “1” then “2”, patient with full bladder and coughing
hammock
“pinch test”
If urine loss not controlled, tighten the hammock on one side by taking a fold of vaginal epithelium between the forceps

MIDDLE
urgency
relief of urge symptoms with ring forceps. Rarely does the middle zone cause SI
stress incontinence
reduction of cystocele may cause urine loss (uncovering latent SI)
tethered vagina
stretching the vagina backwards may cause urine loss with coughing in patients with no supine SI

POSTERIOR
pelvic pain
gentle palpation of cervix or posterior fornix reproduces abdominal or coccygeal pain
urgency/stress
insertion of a long-bladed Sim’s or bottom blade of a bivalve speculum may relieve urgency symptoms and sometimes stress symptoms, especially in patients where SI commenced after hysterectomy. This manoeuvre may also unmask latent SI if there is a large enterocele

Appendix 2 – References and Further Reading

Original works by the author which seek to validate the theory and its applications

A brief summary only of the most significant papers is provided in blue type to indicate the specific contribution of each work

Integral Theory

- (1) Petros P E, Ulmsten U, An Integral Theory of female urinary incontinence. *Acta Obstetricia et Gynecologica Scandinavica*, Supplement 153, Vol 69, (1990), 1-79.

The 1990 publication stated that stress and urge had a common origin, laxity in the vagina or its supporting ligaments, a result of altered collagen/elastin. Ultrasound and urethral pressure proofs of the hammock closure mechanism, effects of pregnancy, tethered vagina, and surgery were presented.

- (2) Petros P E, Ulmsten U, An Integral Theory and its Method, for the Diagnosis and Management of female urinary incontinence, *Scandinavian Journal of Urology and Nephrology* (1993) - Vol 27 Supplement No 153 – 1-93.

The 1993 publication was expanded to include abnormal emptying and pelvic pain. It presented radiological and EMG proofs of the urethral closure mechanisms, (including levator myograms), micturition, and further surgical and non-surgical proofs.

- (3) MD (Doctor of Medicine) Thesis University of Sydney 2004 “*The Integral Theory*”.

Further published surgical and non-surgical proofs of the theory were provided.

- (4a) Petros P E, Non-linearity in Clinical Practice, *J. Eval. Clin. Pract.* 2003; (2) :171-8

- (4b) Petros P E, Letter “Chaos Theory in Obstetrics and Gynaecology”, *Br. J. Obstet. Gynaecol.*, July (1995) 102 (7): 588.

All biological systems are non-linear. Most of medicine is still reductionist. These papers analyse the consequences of non-linearity with discrete clinical examples.

- (5) Petros P E, and Ulmsten U, An anatomical classification- a new paradigm for management of urinary dysfunction in the female (1999), *Int. J. Urogynecology* (1998)10: 29-35.

The anatomical basis of the 3 zone classification and the questionnaire was presented.

- (6) Petros P E, The International Continence Society and Integral Theory systems for management of the incontinent female -a comparative analysis. *Pelviperrineology* 2007; 26: 25-29

This paper compares the anatomically based Integral System with the Urodynamically based ICS system, and provides a template how the two can be integrated without conflict- designating the unstable bladder in the female as a premature activation of the micturition reflex

- (7) Petros P E, Woodman P, The Integral Theory of continence, *Int. Urogynecol. J.* (2008) 19:35–40 DOI 10.1007/s00192-007-0475-9

- (8) Petros P E, Ulmsten U, An anatomical classification- a new paradigm for management of lower female urinary dysfunction, *European Journal of Obstetrics & Gynecology and Reproductive Biology* (1998)80:87-94.

- (9) Petros P E, The sign of stress incontinence, should we believe what we see? *Aust. NZ J. Obstet. Gynaecol.* 1998; 38:32:352-353

- (10) Petros P E, Finite element models – a template for future urodynamics, *Neurourol. & Urodynamics* (2001) 20:2: 231-233

- (11) Petros P E, The Art and Science of Medicine, *Lancet* (2001) 358:1818-1819

- (12) Goeschen K, Petros P E, (2/2003) *Die Integral-Theorie: Ein neuer Weg des Verstehens* – Teil 1. gyn 8: 86-109
- (13) Goeschen K, Petros P E, (3/2003) *Die Integral-Theorie: Ein neuer Weg des Verstehens* – Teil 2 gyn 8: 162-179
- (14) Goeschen K, Petros P E, (4/2003) *Die Integral-Theorie: Ein neuer Weg des Verstehens* – Teil 3 gyn 8: 246-266
- (15) Petros P E, The need for randomised trial in urogynecology *Int. Urogynecol. J.* (2007) 18:231–232
- (16) Petros P E, Ulmsten U, Assessment of urinary symptoms in the second half of pregnancy, letter *Int. Urog. J.* (1993) 4: 250-251.

Dynamic Anatomy

- (1a) Petros P E, Ulmsten U, Role of the pelvic floor in bladder neck opening and closure: I muscle forces, *Int. J. Urogynecol. and Pelvic Floor*, (1997) vol8, 74-80
- (1b) Petros P E, Ulmsten U, Role of the pelvic floor in bladder neck opening and closure: II vagina. *Int. J. Urogynecol. and Pelvic Floor*, (1997) vol8, 69-73

These papers provide extensive radiological (including levator myograms), EMG and pressure data to validate the 3 directional muscle forces seen in urethral closure on effort, 2 muscle forces during micturition, and one during 'squeezing' (Kegel).

- (2) Petros P E, Ulmsten U, ltr. "Urethral and bladder neck closure mechanisms *American Journal of Obstetrics & Gynecology*. 173(1):346- 347, July 1995.

This letter was written in response to the 'hammock hypothesis', stating that this concept had already been presented with ultrasound proof thereof, in 1990

- (3a) Petros P E, Von Kinsky B, Anchoring the midurethra restores bladder neck anatomy and continence, *Lancet* (1999);354:9193:997-998
- (3b) Petros P E, Changes in bladder neck geometry and closure pressure following midurethral anchoring suggest a musculoelastic mechanism activates closure, *Neurourol. and Urodynamics* (2003) 22:191-197

"Simulated operations". 3a: Funnelled urethrovesical geometry was restored to normal following midurethra pressure with a haemostat, performed under video-ultrasound control. 3b: Midurethral pressure changed urethral closure pressure during coughing from negative to positive. It was concluded that this method was more sensitive than transperineal ultrasound.

- (4) Abendstein B, Petros P E P, Richardson P A, Goeschen K , Doderio D, The surgical anatomy of rectocele and anterior rectal wall intussusception, *Int. Urogynecol. J.* (2007) DOI 10.1007/s00192-007-0513-7

The important role of the perineal body and uterosacral ligaments in the causation of large rectoceles, 'obstructive defaecation', and anterior rectal wall intussusception, with cure of all 3 with posterior sling and perineal body repair was demonstrated.

- (5) Petros P, Anderson J. Role of internal anal sphincter damage in the causation of idiopathic faecal incontinence: A prospective study. *Aust N Z J Obstet Gynaecol.* 2005 Feb;45(1):77-8.

Only a minority of patients had thinning of the internal anal sphincter, indicating its role in faecal incontinence causation was likely to be minimal.

- (6) Petros P E, The pubourethral ligaments-an anatomical and histological study in the live patient, *Int. J. Urogynecology* (1998) 9: 154-157.
- (7) Petros P E, A cystocele may compensate for latent stress incontinence by stretching the vaginal hammock, (1998) *Gynecol. and Obst. Investigation* 1998; 46: 206-209.

- (8) Petros P E, Ulmsten U, Pinch test for diagnosis of stress urinary incontinence. *Acta Obstetrica et Gynecologica Scandinavica*, Supplement 153, Vol 69, (1990), 33-35.
- (9) Petros P E, Ulmsten U, Cough transmission ratio: An indicator of suburethral vaginal wall tension rather than urethral closure? *Acta Obstetrica et Gynecologica Scandinavica*, Supplement 153, Vol 69, (1990), 37-39.
- (10) Petros P E, Internal resistance may be more important for continence than anal wall tension. *Dis Colon Rectum* (2008), 51:981-2.
- (11) Petros P E, Ulmsten U, An anatomical basis for success and failure of female incontinence surgery, *Scandinavian Journal of Urology and Nephrology* (1993) - Vol 27 Supplement No 153 - PART IV: 53- 60.
- (12) Petros P E, "A physiological basis for ambulatory vaginal and incontinence surgery" *The Australian Continence Journal*, vol 1:1,14-15.
- (13) Petros P E, The anatomy of the perineal membrane: its relationship to injury in childbirth and episiotomy, *A. NZ. J. O. & G.* (2002) 42;5:577-8
- (14) Petros P E, Pubovisceral muscle avulsion, *A. NZ. J. O. & G.* (2008) DOI: 10.1111/j.1479-828X.2007.00814.x.
- (15) Petros P E, Rectocele – a gynecological perspective on anatomy, function, dysfunction, and surgical repair, *Diseases of Colon and Rectum* (2007) (in press).

Pelvic pain

- (1) Petros P E, Severe chronic pelvic pain in women may be caused by ligamentous laxity in the posterior fornix of the vagina, *Aust. NZ J. Obstet. Gynaecol.* 1996; 36:3: 351-354.

The syndrome of chronic pelvic caused by laxity in the uterosacral ligaments is described: usually onesided, varying intensity over time, often acute presentation to ED, relief on lying down, associated deep dyspareunia and low sacral backache.

- (2) Petros P E, Bornstein J, Vulvar vestibulitis may be a referred pain arising from laxity in the uterosacral ligaments- a hypothesis based on 3 prospective case reports, *A.NZ.J.O.&G.* (2004) 44: 483–486

Cure of vulval hypersensitivity and pain, along with chronic pelvic pain was reported in a small group of patients following posterior sling operation for repair of lax uterosacral ligaments.

- (3) Bornstein J, Zarfati D, Petros P E, Causation of vulvar vestibulitis *A.NZ.J.O.&G.* (2005), 45: 538–541

Local anaesthetic administered to the right and left uterosacral ligaments in 11 patients with vulvodynia caused the hyperaesthesia to disappear, for a period of 20 minutes on both sides in nine patients, and on one side only in two.

Pelvic Floor Rehabilitation

- (1a) Petros P E, Skilling P M, Pelvic floor rehabilitation according to the Integral Theory of Female Urinary Incontinence – First report, *European Journal of Obstetrics & Gynecology and Reproductive Biology* (2001) 94: 2, 264-269
- (1b) Petros P E, Skilling P M, The physiological basis of pelvic floor exercises in the treatment of stress urinary incontinence. *Br. J. Obstet. Gynaecol.* (1999) 106 :615-616
- (1c). Skilling P M, Petros P E, Synergistic non-surgical management of pelvic floor dysfunction: second report, *Int. J. Urogynae.* (2004) 15: 106-110

Squatting exercises and electrotherapy were added to Kegel exercises. A high rate of cure additional symptoms such as urgency, pelvic pain, abnormal emptying, and bowel evacuation, was demonstrated. These were validated by urodynamics and pad testing.

Urodynamics, biomechanics, and flow mechanics

PhD, “Detrusor Instability - a Critical Analysis”, University of Uppsala, 1993.

Based on a series of urodynamic papers (1a-1e below), this thesis demonstrated that ‘detrusor instability’ (OAB), was a premature activation of a normal micturition reflex, that a low compliance bladder was consistent with a partly controlled micturition reflex, that the control of micturition was non-linear and its control consistent with a simple feedback equation.

- (1a) Petros P E, Ulmsten U, Bladder instability in women: A premature activation of the micturition reflex. *Neurourology and Urodynamics* 12, 235-239 (1993).
- (1b) Petros P E “Detrusor instability and low compliance may represent different levels of disturbance in peripheral feedback control of the micturition reflex.” *Neurourol. and Urod.* (1999) 18:81-91.
- (1c) Petros P E, Ulmsten U, Tests for detrusor instability in women. These mainly measure the urethral resistance created by pelvic floor contraction acting against a premature activation of the micturition reflex. *Acta Obstetricia et Gynecologica Scandinavica*, (1993): 72: 661-667.
- (1d) Petros P E, Ulmsten U, Letter, Is detrusor instability a prematurely activated (but otherwise normal) micturition reflex? *Lancet* (1997) No 9050, vol 349, 505.
- (1e) Petros P E Letter, Is detrusor instability a premature variant of a normal micturition reflex? *Lancet* (1997) No 9060, vol 349, 1255-6.

(2) Petros P E, Ulmsten U, An analysis of rapid pad testing and the history for the diagnosis of stress incontinence. *Acta Obstetricia et Gynecologica Scandinavica*, 71, (1992), 529-536.

This work provides the scientific basis for the 10 cough pad test used to assess SI. Bladder pressures and pad tests were measured during a series of exercises such as coughing, walking, climbing stairs etc.

(3) Petros P E, Ulmsten U, Urge incontinence history is an accurate predictor of urge incontinence. *Acta Obstetricia et Gynecologica Scandinavica*, 71, (1992), 537-539.

Urge symptoms were recorded during a handwashing test confirmed to a very high degree, the patient’s testimony of urge in the pre-test questionnaire.

(4) Petros P E, Ulmsten U, “Urethral pressure increase on effort originates from within the urethra, and continence from musclovaginal closure”, *Neurourology and Urodynamics*, 14:337-350 (1995).

Measurement of pressure in exact locations inside and outside the urethra during a midurethral sling operation performed under LA indicated the pressure within the urethra was higher than the pressure outside. This experiment was the final invalidation of the Pressure Transmission Theory

(5a) Bush M B, Petros P E, Barrett-Lennard B R, On the flow through the human urethra (1997) *Biomechanics* 30:9,967-969.

(5b) Petros P E and Bush M B, A mathematical model of micturition gives new insights into pressure measurement and function, *Int. J. Urogynecology*. (1998) 9: 103-107.

The 4th power law (5th power for non-laminar flow) was calculated with computer simulation and validated by direct testing (5a). The clinical and urodynamic consequences thereof were applied to patients with regard to pressure/flow studies (5b). Flow rate was not a valid indicator of obstructed flow; micturition pressures of zero and post-micturition pressure increase were explained with reference to the external opening mechanism, according to the Theory.

(6) Petros P E, Ulmsten U, The biomechanics of vaginal tissue with special relevance to the aetiology and surgical management of female urinary incontinence, *Scandinavian Journal of Urology and Nephrology* (1993) - Vol 27 Supplement No 153 PART II: 29-45.

- (7) Ulmsten U., Petros P E, Surgery for female urinary incontinence, *Current Science* 4:456-462, (1992).
- (8) Petros P E, Ulmsten U, Natural volume handwashing urethrocystometry – a physiological technique for the objective diagnosis of the unstable detrusor. *Gynecol. Obstet. Investigation*, (1993), 36 : 42-46.
- (9) Petros P E, Change in urethral pressure during voluntary pelvic floor muscle contraction and vaginal stimulation, *Int. J. Urogynecology* (1998) 8,318.
- (10) Petros P E, Letter, The effect of urethral pressure variation in women, *Int. Urogynecol. J. and Pelvic Floor* (1996) 7: 274-5.
- (11) Petros P E, Relationship of urethral retro-resistance pressure to urodynamic measurements and incontinence severity, *Neurourology and Urodynamics* Volume 24, Issue 3, Date: May 2005, Pages: 301-302
- (12) Petros P E, The history and differential management of ‘overactive bladder’ according to the International Continence Society and Integral Theory systems. *Turkiye Klinikleri* (2007) in press.
- (13) Harrison S M, Bush M B, Petros1 PE, Towards a novel tensile elastometer for soft tissue, *International Journal of Mechanical Sciences* 50 (2008) 626–640
- (14) Petros P E (2007) On the contribution of pelvic muscles to urinary continence control, *Neurourol. & Urod.* 2007 In press
- (15) Harrison S, Bush M B and Petros P E (2007). “A pinch elastometer for soft tissue.” *Medical Engineering & Physics* 29(3): 307-315.

Histological Studies

- (1a) Petros P E, Ulmsten U, Papadimitriou J, The Autogenic Neoligament procedure: A technique for planned formation of an artificial neo-ligament. *Acta Obstetrica et Gynecologica Scandinavica, Supplement* 153, Vol 69, (1990), 43-51.
- (1b) D S (Doctor of Surgery) UWA - “Development of the Intravaginal Slingplasty and other ambulatory vaginal operations” 1999.

These works, some still unpublished (1b), provide the fundamental scientific basis for the Integral System of surgery. Comprehensive studies (xray, radioactive gallium, gross anatomy, histology, bacteriology, biochemistry) on 13 canines demonstrated how a foreign body reaction to an implanted tape may reinforce a weak suspensory ligament.

- (2) Papadimitriou J, Petros P E, Histological studies of monofilament and multifilament polypropylene mesh implants demonstrate equivalent penetration of macrophages between fibrils, *Hernia*,(2005) 9: 75-78.

Macrophages were seen in spaces of less than 5 microns. This invalidated the common belief that macrophages required 70 microns to penetrate mesh spaces.

- (3) Petros P E, Letter, “Tissue reaction to implanted foreign materials for cure of stress incontinence American Journal of Obstetrics and Gynecology letter”, 171,4, 1159 (1994)
- (4) Richardson P A, Papadimitriou J, Petros P E, Letter, A multifilament polypropylene mesh for urinary incontinence: ten cases of infections requiring removal of the sling, *B.J.O.G.* (2006) (in press).
- (5) Papadimitriou J M, Petros P E, Biocompatible properties of surgical mesh using an animal model. *A.N.Z.J.O.G.* (2006) ; 46:368
- (6) Petros P E, Monofilament and multifilament tape usage in incontinence surgery, *Am. J. Obstet. Gynecol.* (2007) Volume 196 , Issue 2 , Pages e12 - e12

Urinary Incontinence Surgical studies

D S (Doctor of Surgery) UWA, “Development of the Intravaginal Slingplasty and other ambulatory vaginal operations” (1999).

This work and the following papers provide the basis for the initial part of the Integral System of surgery, the “Tension-free tape” operations for stress incontinence, uterovaginal prolapse, and other procedures such as the “bridge” operation.

“Tension-free” midurethral sling

- (1) Petros P E, Ulmsten U, The combined intravaginal sling and tuck operation. An ambulatory procedure for stress and urge incontinence, *Acta Obstetricia et Gynecologica Scandinavica*, Supplement 153, Vol 69, (1990), 53-59.

Stress and urge symptoms were simultaneously cured with a prototype midurethral sling.

- (2) Petros P E, New ambulatory surgical methods using an anatomical classification of urinary dysfunction improve stress, urge, and abnormal emptying, *Int. J. Urogynecology* (1997) vol 8, 5: 270-278.

Uterovaginal prolapse, stress, urge, frequency, nocturia, and abnormal emptying symptoms were simultaneously cured with site-specific midurethral and posterior ‘tension-free’ slings.

- (3) Petros P E, “Medium-term follow up of the Intravaginal Slingplasty operation indicates minimal deterioration of continence with time”, *Aust. N.Z. J. Obstet. Gynaecol.* (1999) 39:3:354-356.
- (4) Merlin T, Arnold E, Petros P E, MacTaggart A, Faulkner K, Maddern G, A systematic review of tensionfree urethropexy for stress urinary incontinence: intravaginal slingplasty and the tension-free vaginal tape procedures. *British Journal of Urology International*. 2001;88(9):871- 880.
- (5) Petros P E, Ulmsten U, The development of the intravaginal slingplasty procedure: IVS II- (with bilateral “tucks”), *Scandinavian Journal of Urology and Nephrology* (1993) - Vol 27 Supplement No 153 - PART IV: 61-67
- (6) Petros P E, Ulmsten U, Further development of the intravaginal slingplasty procedure - IVS III - (with midline “tuck”), *Scandinavian Journal of Urology and Nephrology* (1993) - Vol 27 Supplement No 153 - PART IV: 69-71.
- (7) Petros P E, Ulmsten U, The further development of the intravaginal slingplasty procedure: IVS IV – (with “double-breasted” unattached vaginal flap repair), *Scandinavian Journal of Urology and Nephrology* (1993) - Vol 27 Supplement No 153 - PART IV: 73-75.
- (8) Petros P E, Ulmsten U, Further development of the intravaginal slingplasty procedure: IVS V – (with “double-breasted” unattached vaginal flap repair and permanent sling), *Scandinavian Journal of Urology and Nephrology* (1993) - Vol 27 Supplement No 153 – PART IV: 77-79.
- (9) Petros P E, Ulmsten U, The intravaginal slingplasty procedure: IVS VI – further development of the “double-breasted” vaginal flap repair – a preliminary report, *Scandinavian Journal of Urology and Nephrology* (1993) - Vol 27 Supplement No 153 - PART IV: 81-84.
- (10) Petros P E, “ Ambulatory incontinence and vaginal surgery”, *Aust. Med. J.* 161, 2,171-172, (1994).
- (37) Ulmsten U, Johnson P, and Petros P E, “Intravaginal Slingplasty”, *Zentralblatt fur Gynakologie*, 116 (1994) 398-404.
- (11) Petros P E, The Intravaginal Slingplasty Operation, a minimally invasive technique for cure of urinary incontinence in the female, *Aust. N.Z. J. Obst. & Gyn.* (1996) ; 36:4: 463-461
- (12) Petros P E, Ulmsten U, The tuck procedure: A simplified vaginal repair for treatment of female urinary incontinence, *Acta Obstetricia et Gynecologica Scandinavica*, Supplement 153, Vol 69, (1990), 41-42.

- (13) Petros P E, Ulmsten U, Cure of urge incontinence by the combined intravaginal sling and tuck operation, *Acta Obstetricia et Gynecologica Scandinavica*, Supplement 153, Vol 69, (1990), 61-62.
- (14) Petros P E, Ulmsten U, Non stress non urge incontinence, diagnosis and cure – preliminary report. *Acta Obstetricia et Gynecologica Scandinavica*, Supplement 153, Vol 69, (1990), 69-70.
- (15) Petros P E, Ulmsten U, Cure of stress incontinence by repair of external anal sphincter, *Acta Obstetricia et Gynecologica Scandinavica*, Supplement 153, Vol 69, (1990), 75.
- (16) Petros P E, Ulmsten U, Pregnancy effects on the intravaginal sling operation. *Acta Obstetricia et Gynecologica Scandinavica*, Supplement 153, Vol 69, (1990), 77-78.
- (17) Petros P E, An anatomical basis for corrective surgery in female urinary incontinence, *Proceedings of FIGO 13th World Congress of Gynecology and Obstetrics*, Singapore (1991).
- (18) Petros P E, Ulmsten U, Letter, Stress incontinence following vaginal repair, *Acta Obstetricia et Gynecologica Scandinavica*, 71, (1992), 323.
- (19) Petros P E, Ulmsten U, Surgical principles deriving from the Integral Theory, *Scandinavian Journal of Urology and Nephrology* (1993), Vol 27 Supplement No 153, PART III: 41-49.

Posterior Sling and prolapse

- (67) Petros P E, Vault prolapse II: Restoration of dynamic vaginal supports by the infracoccygeal sacropexy, an axial day-care vaginal procedure, *Int. J. Urogynecol. and Pelvic Floor* (2001) 12:296-303

4.5 year data for the posterior “tension-free” vaginal sling was presented. The operation was minimally invasive, day-care. The restoration was axial, with a high cure rate, and no report of post-operative dyspareunia.

- (69) Petros P E, Vault prolapse 1: dynamic supports of the vagina, *Int. J. Urogynecol. and Pelvic Floor* (2001) 12:292-295

X-ray vaginogram data demonstrated that the angle of inclination of the vagina (<45 degrees) was an important element in the prevention of prolapse.

- (50) Petros P E, New ambulatory surgical methods using an anatomical classification of urinary dysfunction improve stress, urge, and abnormal emptying, *Int. J. Urogynecology* (1997) vol 8, 5: 270-278.

Uterovaginal prolapse, stress, urge, frequency, nocturia, and abnormal emptying symptoms were simultaneously cured with site-specific midurethral and posterior “tension-free” slings.

- (53) Petros P E, Development of generic models for ambulatory vaginal surgery: a preliminary report, *Int. J. Urogynecology* (1998) 9:19-27.
- (66) Petros P E, Letter, Influence of hysterectomy on pelvic floor dysfunction, *Lancet* (2000), Volume 356 ,9237, 1275
- (85) Petros P E, Richardson P A, The TFS posterior sling for repair of uterine/vault prolapse – a preliminary report *A.N.Z.J.O.G.*, (2005); 45: 376 –379
- (92) Petros P E, Richardson P A, Goeschen K, Abendstein B, The Tissue Fixation System (TFS) provides a new structural method for cystocele repair – a preliminary report, *A.N.Z.J.O.G.*, (2006) 46: 474-478.
- (100) Petros P E, Posterior IVS for vault suspension: A re-evaluation, *J. Pelviperineology*, (2007), in press.
- (118) Wagenlehner F M, Bschleipfer, Liedl B, Gunnemann A, Petros P E, Weidner W, Surgical reconstruction of pelvic floor descent: Anatomic and functional aspects, *Urologia Internationalis Journal* (2009), In press.
- (8) Petros P E, Ulmsten U, The role of a lax posterior fornix in the causation of stress and urgency symptoms: A preliminary report, *Acta Obstetricia et Gynecologica Scandinavica*, Supplement 153, Vol 69, (1990), 71-73.

- (9) Petros P E, Ulmsten U, The posterior fornix syndrome: a multiple symptom complex of pelvic pain and abnormal urinary symptoms deriving from laxity in the posterior fornix. *Scandinavian Journal of Urology and Nephrology* (1993), Vol 27 Supplement No 153, PART IV: 89-93.
- (10) Petros P E, Symptoms of defective emptying and raised residual urine may arise from ligamentous laxity in the posterior vaginal fornix, *Gynecol. and Obst. Investigation* (1998), 45: 105-108.
- (11) Liedl B, Wagenlehner F, Petros P E, Prolapse Repair and Stress Urinary Incontinence, *Eur. J. Urol.* (2009) in press

Tethered vagina Syndrome

- (1a) Petros P E, Ulmsten U, The free graft procedure for cure of the tethered vagina syndrome, *Scandinavian Journal of Urology and Nephrology* (1993), Supplement No 153, PART IV: 85-87.
- (1b) Petros P E, The split labium minus flap graft technique, *Int. J. Urogynec.* (2004) 15:95-98
- (1c) Petros P E, Ulmsten U, The tethered vagina syndrome, post surgical incontinence and I-plasty operation for cure. *Acta Obstetrica et Gynecologica Scandinavica*, Supplement 153, Vol 69, (1990), 63-67.

Iatrogenic, uncontrollable “motor” type incontinence, characteristically, immediately on getting out of bed, is addressed by a graft at bladder neck (“zone of critical elasticity”) which restores vaginal elasticity

Tissue Fixation System (TFS)

The TFS minisling has been used to repair all 5 ligamentous defects, external, pubourethral, ATFP, cardinal, uterosacral ligaments, and also, the perineal body. All operations, with few exceptions were minimally invasive day-care procedures, with minimal post-operative pain.

- (1) Petros P E, Richardson P A, The midurethral TFS sling – a “micro-method” for cure of stress incontinence, preliminary report *A.N.Z.J.O.G.*, (2005); 45: 372–375
- (2) Petros P E, Richardson P A, Letter, replies to Dietz P and Goeschen K, *A.N.Z.J.O.G.* (2006) 46: 170–178
- (3) Petros P E, Richardson P A, “Midurethral Tissue Fixation System (TFS) sling for cure of stress incontinence – 3 year results”, *International J. Urogynec.* (2008) 19:869-871.
- (4) Petros P E, Richardson P A, The TFS posterior sling for repair of uterine/vault prolapse – a preliminary report *A.N.Z.J.O.G.*, (2005); 45: 376–379
- (5) Petros P E, Richardson P A, Prepubic TFS sling in curing non-stress leakage following complete cure of stress incontinence by a midurethral sling, *Pelvip erineology* (2007) 27:4
- (6) Abendstein B, Petros P E, Richardson P A Ligamentous repair using the Tissue Fixation System confirms a causal link between damaged suspensory ligaments and urinary and fecal incontinence, *J. Pelvip erineology*, (2008) 27;114-117.

Faecal incontinence and anorectal dysfunction

The following papers investigate the role of lax anterior and/or posterior suspensory ligaments in the causation of anorectal dysfunction, and the cure thereof by anterior/posterior slings.

- (1) Petros P E, Cure of urinary and fecal incontinence by pelvic ligament reconstruction suggests a connective tissue etiology for both. *International Journal of Urogynecology* (1999) 10:356-360
- (2) Petros P E, Swash M, The Musculoelastic Theory of anorectal function and dysfunction, *J. Pelvip erineology*, (2008) 27; 89-93.

- (3) Petros P E, Swash M, Directional muscle forces activate anorectal continence and defecation in the female, *J. Pelviperineology*, (2008) 27;94-97.
- (4) Petros P E, Swash M A direct test for the role of the pubourethral ligament in anorectal closure, *J. Pelviperineology*, (2008) 27;98.
- (5) Petros P E, Swash M, Reflex contraction of the levator plate increases intra-anal pressure, validating its role in continence, *J. Pelviperineology*, (2008) 27;99.
- (6) Petros P E, Swash M, Abdominal pressure increase during anorectal closure is secondary to striated pelvic muscle contraction, *J. Pelviperineology*, (2008) 27;100-101.
- (7) Petros P E, Swash M, A prospective endoanal ultrasound study suggests that internal anal sphincter damage is unlikely to be a major cause of fecal incontinence, *J. Pelviperineology*, (2008) 27;102.
- (8) Petros P E, Swash M, Correction of abnormal geometry and dysfunction by suspensory ligament reconstruction gives insights into mechanisms for anorectal angle formation, *J. Pelviperineology*, (2008) 27;103-104.
- (9) Petros P E, Swash M, Role of puborectalis muscle in anal continence – comments on original 4D pelvic ultrasound data from Chantarasorn & Dietz, *J. Pelviperineology*, (2008) 27;105.
- (10) Petros P E, Swash M, Kakulas B, Stress urinary incontinence results from muscle weakness and ligamentous laxity in the pelvic floor, *J. Pelviperineology*, (2008) 27;107-109.
- (11) Petros P E, Richardson P A, Fecal incontinence cure by surgical reinforcement of the pelvic ligaments suggests a connective tissue aetiology, *J. Pelviperineology*, (2008) 27;111-113.
- (12) Abendstein B, Petros P E, Richardson P A, Ligamentous repair using the Tissue Fixation System confirms a causal link between damaged suspensory ligaments and urinary and fecal incontinence, *J. Pelviperineology*, (2008) 27;114-117.
- (13) Abendstein B, Brugger B A, Furtschegger A, Rieger M, Petros P E, Role of the uterosacral ligaments in the causation of rectal intussusception, abnormal bowel emptying, and fecal incontinence-a prospective study, *J. Pelviperineology*, (2008) 27;118-121.

The references listed below are organised in parts corresponding to how they appear in this book. They are classified in two sections for each Chapter: 'text references' and 'further reading'. The works of authors mentioned in the text are listed under 'text references', and those relevant to aspects of the topic are listed under 'further reading'.

Chapter 2: The Anatomy and Dynamics of Pelvic Floor Function and Dysfunction

- Abendstein B., Petros P. E. P, Richardson P. A. Goeschen K , Dodero D.
The surgical anatomy of rectocele and anterior rectal wall intussusception, *Int Urogynecol J*, (2008), DOI 10.1007/s00192-007-0513-7
- Abendstein B, Petros PE, Richardson PA Ligamentous repair using the Tissue Fixation System confirms a causal link between damaged suspensory ligaments and urinary and fecal incontinence, (2008), *J. Pelviperineology*, 27;114-117.
- Bartolo, DCC, and Macdonald ADH, faecal continence and defaecation, in *The Pelvic Floor, Its functions and disorders*, Eds Pemberton J, Swash M, and Henry MM, WB Saunders London ,(2002); 77-83
- Bedwell P and Dietz HP, IUGA Taiwan 2008 Abstract Does levator trauma increase the risk of urodynamic stress incontinence?
- Berglas B & Rubin IC. Study of the supportive structures of the uterus by levator myography. *Surgery Gynecol & Obstets.*, (1953), 97:667-692.
- Brown JS, Sawaya G, Thorn DH Grady D Hysterectomy and urinary incontinence: a systematic review, *Lancet* (2000) 356:535-539
- Bush MB, Petros PEP, Barrett- Lennard BR On the flow through the human urethra *Biomechanics* (1997) 30: 967-969.
- Chantarasorn V, Dietz HP. Abstract ASUM Auckland 2008 (Australasian Society for Ultrasound in Medicine).
- Courtney H Anatomy of the pelvic diaphragm and ano-rectal musculature as related to sphincter preservation in ano-rectal surgery. *American Journal Surgery*, (1950), 79:155-173.
- Creed K. Functional diversity of smooth muscle. *British Med. Bulletin*, (1979), 3:243-247
- De Lancey J O L Structural support of the urethra as it relates to stress incontinence: the hammock hypothesis *Am J Obst Gynecol* (1994) 170: 1713-1723.
- Dietz HP, Levator trauma in labor: a challenge for obstetricians, surgeons and sonologists *Ultrasound Obstet Gynecol* (2007); 29: 368–371
- Dietz H, Simpson J. Levator trauma is associated with pelvic organ prolapse. *BJOG* (2008); DOI: 10.1111/j.1471-0528.2008.01751.x.
- Dietz HP, Shek C and Clarke B, Biometry of the pubovisceral muscle and levator hiatus by three-dimensional pelvic floor ultrasound, *Ultrasound Obstet Gynecol* (2005); 25: 580–585
- Dietz H. P, Shek., C., De Leon J. and Steensma A. B. Ballooning of the levator hiatus, Published online in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/uog.5355 *Ultrasound Obstet Gynecol* (2008); 31: 000–000
- Everaerts W, Gevaert T, Nilius B, De Ridder D, On the Origin of Bladder Sensing: Tr(i)ps in urology, *Nerourol. Urodynam.* 27:264-273,(2008).
- Florey H. General Pathology, (1971), 4th Ed, Lloyd Luke London, p457.
- Gainey HL. Post partum observation of pelvic tissue damage. *American Journal Obstets & Gynecol.* (1943), 45:457-466.

- Huisman AB. Aspects on the anatomy of the female urethra with special relation to urinary continence (1983) 10:1-31.
- Ingelman-Sundberg A The pubovesical ligament in stress incontinence. *Acta Obstet & Gynecol Scandinavica* (1949), 28:183-188.
- Jamali AA, Afshar P, Abrams RA, Lieber RL, Skeletal response to tenotomy. *Muscle Nerve* (2000); 23:851-862.
- Jeffcoate TNA *Principles of Gynaecology* (1962), (2nd Ed.) Butterworths, London.
- Lose G and Colstrup H, Mechanical properties of the urethra in healthy and stress incontinent females: dynamic measurements in the resting urethra, *J Urol.*, (1990) 144: 1258-1262.
- Macchi V, Porzionato A, Stecco C, Benettazzo F, Stecco A, Parenti A, Dodi G, De Caro R, Histotopographic study of the longitudinal anal muscle, *J. Pelviperineology* (2007); 26: 30-32
- Netter F *Atlas of Human Anatomy* (1989) CIBA-Geigy Corp Ardsley USA
- Neuman M, Lavy Y, Posterior Intra-Vaginal Slingplasty (PIVS) for the treatment of vaginal apex prolapse: medium term results of the 140 operations with a novel procedure, *Eur J Obstet Gynecol Reprod Biol.* 2006 (in press).
- Nichols DH & Randall CL *Vaginal Surgery* (1989), 3rd Ed, Williams Wilkins, Baltimore. 1-46.
- Parente M. P. L., Jorge R. M. Natal, T. Mascarenhas T. Fernandes A. A. , Martins J. A. C. Deformation of the pelvic floor muscles during a vaginal delivery *Int Urogynecol J.* (2007), DOI 10.1007/s00192-007-0388-7
- Parks AG, Swash M and Urich H Sphincter Denervation in ano-rectal incontinence and rectal prolapse. *Gut* (1977) ;18: 656-665.
- Petros PE Vault prolapse 1: dynamic supports of the vagina, *Int J Urogynecol and Pelvic Floor* (2001)12:292-295
- Petros PE Internal resistance may be more important for continence than anal wall tension. *Dis Colon Rectum* (2008);51:981-2.
- Petros P, Anderson J. Role of internal anal sphincter damage in the causation of idiopathic faecal incontinence: A prospective study. *Aust N Z J Obstet Gynaecol.* 2005 Feb;45(1):77-8
- Petros PE and Ulmsten U. Urethral pressure increase on effort originates from within the urethra, and continence from musclovaginal closure, *Neurourology and Urodynamics* (1995), 14:337-350
- Petros PE and Ulmsten U 'Urethral and bladder neck closure mechanisms' *Am J Obst Gynecol.* (1995) 173: 346-347
- Petros PE and Ulmsten U Role of the pelvic floor in bladder neck opening and closure: I muscle forces, *Int J Urogynecol and Pelvic Floor*, (1997) 8: 74-80
- Petros PE and Ulmsten U Role of the pelvic floor in bladder neck opening and closure: II vagina. *Int J Urogynecol and Pelvic Floor*, (1997) 8: 69-73
- Petros PE The pubourethral ligaments-an anatomical and histological study in the live patient, *Int J Urogynecology* (1998) 9: 154-157.
- Petros PE, Von Kinsky B Anchoring the midurethra restores bladder neck anatomy and continence, *Lancet* (1999) 354:997-998
- Petros PE Cure of urinary and fecal incontinence by pelvic ligament reconstruction suggests a connective tissue etiology for both. *International Journal of Urogynecology* (1999);10:356-360
- Petros PE Itr Influence of hysterectomy on pelvic floor dysfunction *Lancet* (2000), 356 :1275.
- Petros PE The anatomy of the perineal membrane: its relationship to injury in childbirth and episiotomy, *Aust. NZ J Obstet. Gynaecol* (2002) 42:577-8

- Petros PE, Swash M The Musculoelastic Theory of anorectal function and dysfunction (2008), *J. Pelviperineology*, 27; 89-93.
- Rechberger T, Uldbjerg N & Oxlund H. Connective tissue changes in the cervix during normal pregnancy and pregnancy complicated by a cervical incompetence *Obstets & Gynecol.* (1988), 71:563-567.
- Shafik A A new concept of the anatomy of the anal sphincter mechanism and the physiology of defecation, *Acta Anat* (1990), 138:359-363.
- Shafik A Vagino-levator refl ex: description of a reflex and its role in sexual performance, *European J Obstet & Gynecol and Reprod Biology* (1995); 60: 161-164.
- Smith ARB, Hosker GL & Warrell DW The role of partial denervation of the pelvic floor in the aetiology of genito-urinary prolapse and stress incontinence of urine: a neurophysiological study. *British Journal of Obstets & Gynaecol.* (1989a), 96:24-28.
- Smith A, Hosker G and Warrell D The role of pudendal nerve damage in the aetiology of genuine stress incontinence in women. *British Journal Obstet. and Gynaecol.* (1989b), 96: 29-32.
- Sultan AH, Kamm MA, Hudson CN, Thomas JM and Bartram CI Anal-sphincter disruption during vaginal delivery, *N Eng J Med* (1993); 329: 1905-11
- Swash M, Henry MM, Snooks SJ Unifying concept of pelvic floor disorders and incontinence. *Journal of the Royal Society of Medicine* (1985),78: 906-911.
- Yamada H. Aging rate for the strength of human organs and tissues. *Strength of Biological Materials*, Williams & Wilkins Co, Balt. (Ed) Evans FG. (1970); 272-280.
- Wyndaele J, de Wachter S, The Sensory Bladder (1): An Update on the different Sensations Described in the Lower Urinary Tract and the Physiological Mechanisms Behind Them, *Nerourol. Urodynam.* 27:274-278,2008.
- Zacharin RF A suspensory mechanism of the female urethra. *Journal of Anatomy* (1963), 97:423-427.

Chapter 2: Further Reading

- Ayoub SF Anterior fibres of the levator ani muscle in man. *Journal of Anatomy* (1979), 128:571-580.
- Berglas B & Rubin IC Study of the supportive structures of the uterus by levator myography. *Surgery Gynecol & Obstets.* (1953), 97:667-692.
- DeLancey J Correlative Study of Paraurethral Anatomy. *Obstet. Gynecol.*(1986); 68:91-97.
- Denny-Brown D & Robertson E Physiology of micturition. *Brain* (1933), 56:149-191.
- Dickinson R L The vagina as a hernial canal. *American Journal Obstets Dis Women & Child.* (1889), 22:692-697.
- Dickinson R L, Studies of the levator ani muscle. *American Journal Obstets Dis Women & Child.* (1889), 22:898-917.
- Downing S J & Sherwood OD, The physiological role of relaxin in the pregnant rat 1V The influence of relaxin on cervical collagen and glycosaminoglycans, *Endocrinology* (1986), 118:471-479
- Falconer C, Ekman-Orderberg G, Malmstrom A and Ulmsten U Clinical outcome and changes in connective tissue metabolism after Intravaginal Slingplasty in stress incontinent women, *Int Urogynecol J.* (1996) 7: 133-137.
- Fothergill W E Pathology & the operative treatment of displacements of the pelvic viscera. *Journal of Obstets & Gynaecol of the British Empire* (1907), 13:410-419.

- Gosling JA Dickson JS & Humpherson JR Gross & microscopic anatomy of the urethra II. *Functional Anatomy of the Urinary Tract* (1983), Churchill Livingstone, Edinburgh. 5.1-5.20.
- Gosling JH, Dixon JS & Critchley HOD A comparative study of the human external sphincter & periurethral ani muscles. *British Journal Urology*, (1981), 53:35-41.
- Gosling JA Structure of the lower urinary tract and pelvic floor. *Gynaecological Urology* (1985), 12: 285-294. Ed Raz S, WB Saunders & Co London.
- Kovanen V, Suominen H, Risteli J & Risteli L Type IV collagen and laminin in slow and fast skeletal muscle in rats - effects of age and life-time endurance training. *Collagen Rel Res.* (1988), 8:145-153.
- Milley PS & Nicholls DH The relationship between the pubourethral ligaments and the urogenital diaphragm in the human female. *Anat Rec.* (1971), 170:281-283.
- Nichols DH & Randall CL Massive eversion of the vagina, in *Vaginal Surgery* (1989), 3rd Ed, Eds Nichols DH & Randall CL, Williams Wilkins, Baltimore. 328-357.
- Nordin M Biomechanics of collagenous tissues, in *Basic Biomechanics of the Skeletal System* (1980), Eds, Frankel VH & Nordin M., Lee & Febiger, Philadelphia. P87-110.
- Olesen KP & Walter S Bladder base insufficiency. *Acta Obstets & Gynecol Scandinavica* (1978), 57:463-468.
- Paramore RH Some further considerations on the supports of the female pelvic viscera, in which the intra-abdominal pressure is still further defined. *Journal of Obstets & Gynaecol of the British Empire* (1908), 14:172-187.
- Paramore RH The supports in chief of the female pelvic viscera. *Journal of Obstets & Gynaecol of the British Empire* (1908), 30: 391-409.
- Peacock EE Structure, synthesis and interaction of fibrous protein and matrix. *Wound Repair* (1984), 3rd Edition, Publishers WB Saunders Co, Philadelphia. 56-101.
- Petros PE A cystocele may compensate for latent stress incontinence by stretching the vaginal hammock, *Gynecol and Obst Investigation* (1998); 46: 206-209.
- Petros PE Vault prolapse 1: dynamic supports of the vagina, *Int J Urogynecol and Pelvic Floor* (2001) 12:292-295.
- Petros PE, Swash M A direct test for the role of the pubourethral ligament in anorectal closure, 2008, *J. Pelviperineology*, 27;98.
- Petros PE, Swash M Reflex contraction of the levator plate increases intra-anal pressure, validating its role in continence, 2008, *J. Pelviperineology*, 27;99.
- Petros PE, Swash M Abdominal pressure increase during anorectal closure is secondary to striated pelvic muscle contraction, 2008, *J. Pelviperineology*, 27;100-101.
- Petros PE, Swash M A prospective endoanal ultrasound study suggests that internal anal sphincter damage is unlikely to be a major cause of fecal incontinence, 2008, *J. Pelviperineology*, 27;102.
- Petros PE, Swash M Correction of abnormal geometry and dysfunction by suspensory ligament reconstruction gives insights into mechanisms for anorectal angle formation, 2008, *J. Pelviperineology*, 27;103-104.
- Petros PE, Swash M Directional muscle forces activate anorectal continence and defecation in the female, 2008, *J. Pelviperineology*, 27;94-97.
- Petros PE, Swash M: Role of puborectalis muscle in anal continence- comments on original 4D pelvic ultrasound data from Chantarasorn & Dietz, 2008, *J. Pelviperineology*, 27;105.

- Porter NH A physiological study of the pelvic floor in rectal prolapse. *Journ R. Coll.of Surg England* (1962), 31: 379-404.
- Power RM Embryological development of the levator ani muscle. *American Journal of Obstets & Gynecol.* (1948), 55:367-381
- Rud T, Asmussen M, Andersson KE, Hunting A & Ulmsten U Factors maintaining the intra-urethral pressure in women. *Investigative Urology* (1980), 17: 4, 343-347.
- Sultan AH, Kamm MA, Hudson CN, Thomas JM and Bartram CI Anal-sphincter disruption during vaginal delivery, *N Eng J Med* (1993); 329: 1905-11
- Tanagho EA The anatomy & physiology of micturition. *Clinics in Obstets & Gynecol.* (1978), 5: 1:3-26.
- Tanagho EA & Miller ER Initiation of voiding. *British Journal of Urology* (1970), 42:175-180.
- Tanagho EA, Myers FH, Smith DR Urethral resistance: its components and implications, No 2. striated muscle component. *Investigative Urology* (1969), 7:195
- Wendell-Smith, CP & Ulsen PM The musculature of the pelvic floor. *Scientific Foundation of Obstets & Gynaecol.* (Eds) Philipp EE, Barnes J & Newton M, William Heinemann Medical Books Ltd, London, (1977), 78-84.
- Walter JB & Israel MS (Eds) Inflammatory Reaction, in *Walter & Israel Pathology*, 5th Ed., Churchill and Livingstone, Edin, (1979) 71-85.
- Wilson PD Posterior pubourethral ligaments in normal and genuine stress incontinent women. *Journal of Urology* (1982), 130:802-805.
- Woodburne RT Structure and function of the urinary bladder. *Journal of Urology* (1960), 84:79-85.
- Zacharin RF Pelvic floor anatomy and cure of pulsion enterocoele. *Springer-Verlag*, Wien, (1985).

Chapter 3: The Diagnosis of Connective Tissue Damage

- Abrams P, Blaivas J, Stanton S and Andersen J Standardisation of Terminology of Lower Urinary Tract Function. *Scand J. Urol Nephrol.* (1988), Suppl. 114.
- Abrams P, Cardozo L, Fall M, Griffiths G, Rosier P, Ulmsten U, van Kerrebroeck P, Victor A, and Wein A, The Standardization of Terminology of Lower Urinary Tract Function: Report from the Standardisation Sub-Committee of the International Continence Society. (2002), *Neurourology and Urodynamics* 21:167-178.
- Bates P, Bradley WE, Glen E, Hansjorg M, Rowan D, Sterling A and Hald T *International Continence Society First Report on the Standardisation of Terminology of Lower Urinary Tract Function* (1975)
- Bates CP The unstable bladder, *Clinics in Obstetrics and Gynaecology* (1978) 5: 1:109 - 122.
- Black N, Griffiths J, Pope C, Bowling A and Abel P Impact of surgery for stress incontinence on morbidity: cohort study. *Brit. Med J* (1997), 315: 1493-8.
- Barrington FJ. The relation of the hind- brain to micturition. *Brain*, (1921), 44:23-53. Creed K Functional diversity of smooth muscle. *British Med. Bulletin* (1979), 3:243-247.
- Bush MB, Petros PEP, Barrett- Lennard BR, On the flow through the human urethra 1997, *Biomechanics* 30:9,967-969.
- Dietz H, Simpson J. Levator trauma is associated with pelvic organ prolapse. *BJOG* (2008); DOI: 10.1111/j.1471-0528.2008.01751.x.
- Gainey HL. Post partum observation of pelvic tissue damage. *American Journal Obstets & Gynecol.* (1943), 45:457-466.

- Glazener CMA, Lapidan MC (2006) Urodynamic investigations for the management of urinary incontinence in children and adults (Cochrane Review), *The Cochrane Library*, Issue 1
- Kelly HA & Dumm WM Urinary incontinence in women without manifest injury to the bladder. *Surgery Gynecol & Obstets*, (1914), 18:444-450.
- Mayer R, Wells T, Brink C, Diokno A and Cockett A Handwashing in the cystometric evaluation of detrusor instability, *Neurourology and Urodynamics* (1991). 10: 563-569
- Palma P, Herrmann V, Urodynamics and stress urinary incontinence: the dark side of a gold standard *Int Urogynecol J*. DOI 10.1007/s00192-007-0428-3
- Petros PE and Bush MB, A mathematical model of micturition gives new insights into pressure measurement and function, (1998), *Int. J. urogynecology* 9: 103-107.
- Petros PE and Ulmsten U An Integral Theory of Female Urinary Incontinence. *Acta Obstetricia et Gynecologica Scandinavica* (1990), 69: Suppl 153 :1-79.
- Petros PE and Ulmsten U Pinch test for diagnosis of stress urinary incontinence. *Acta Obstetricia et Gynecologica Scandinavica* (1990) , 69: Suppl 153:33-35.
- Petros PE and Ulmsten U Urge incontinence history is an accurate predictor of urge incontinence. *Acta Obstetricia et Gynecologica Scandinavica* (1992) 71: 537-539.
- Petros PE and Ulmsten U An analysis of rapid pad testing and the history for the diagnosis of stress incontinence. *Acta Obstetricia et Gynecologica Scandinavica* (1992), 71: 529-536.
- Petros PE and Ulmsten U Bladder instability in women: A premature activation of the micturition reflex. *Neurourology and Urodynamics* (1993);12: 235-239
- Petros PE and Ulmsten U .An Integral Theory and its method for the diagnosis and management of female urinary incontinence. *Scand J. Urol. Nephrol.* (1993). 27: Suppl 153, 1-93
- Petros PE and Ulmsten U The posterior fornix syndrome: a multiple symptom complex of pelvic pain and abnormal urinary symptoms deriving from laxity in the posterior fornix. *Scand. J. Urol. and Nephrol.* (1993) , 27: Supp. No 153 89-93.
- Petros PE (letter) Is detrusor instability a premature variant of a normal micturition reflex? *Lancet* (1997) 349: 1255-6.
- Petros PE and Ulmsten U "Urethral pressure increase on effort originates from within the urethra, and continence from musclovaginal closure", *Neurourology and Urodynamics* (1995).14:337-350
- Petros PE and Ulmsten U An anatomical classification- a new paradigm for management of lower female urinary dysfunction, *European Journal of Obstetrics & Gynecology and Reproductive Biology* (1998) 80:87-94.
- Petros PE Symptoms of defective emptying and raised residual urine may arise from ligamentous laxity in the posterior vaginal fornix, *Gynecol. and Obst. Investigation* (1998), 45: 105-108.
- Petros PE and Ulmsten U An anatomical classification – a new paradigm for management of urinary dysfunction in the female *Int. J. Urogynecology* (1999) 10: 29-35.
- Petros PE, Von Kinsky B Anchoring the midurethra restores bladder neck anatomy and continence, *Lancet* (1999) 354:997-998
- Petros PE A cystocele may compensate for latent stress incontinence by stretching the vaginal hammock, (1998) *Gynecol. and Obst. Investigation* (1998); 46: 206-209.
- Petros PE Application of Theory to the management of pelvic floor dysfunction, *Pelvic Floor* (2001) Eds. Swash
- Petros PE Changes in bladder neck geometry and closure pressure following midurethral anchoring suggest a musculoelastic mechanism activates closure, *Neurourol. and Urodynamics* (2003) 22:191-197

- Richardson AC, Edmonds PB & Williams NL Treatment of stress urinary incontinence due to paravaginal fascial defect. *Obstets & Gynecol.* (1980), 57: 357
- Zacharin RF & Gleadell LW Abdominoperineal urethral suspension. *American Journal Obstets & Gynecol.* (1963), 86: 981.

Chapter 4: Reconstructive Pelvic Floor Surgery

- Abendstein B, Brugger BA, Furtschegger A, Rieger M, Petros PE, Role of the uterosacral ligaments in the causation of rectal intussusception, abnormal bowel emptying, and fecal incontinence-a prospective study, (2008), *J. Pelviperineology*, 27;118-121.
- Abendstein B, Petros PE, Richardson PA Ligamentous repair using the Tissue Fixation System confirms a causal link between damaged suspensory ligaments and urinary and fecal incontinence, 2008, *J. Pelviperineology*, 27;114-117.
- Altman D, Falconer C. Perioperative morbidity using transvaginal mesh in pelvic organ prolapse repair. *Obstet. Gynecol.* (2007);109:303-8.
- Amid, PK Classification of biomaterials and their related complications in abdominal wall hernia surgery, *Hernia* (1997) 1: 15-21
- Baessler K, Hewson AD, Tunn R, Schuessler B, Maher CF. Severe mesh complications following intravaginal slingplasty. *Obstet. Gynecol.* (2005);106: 713-6.
- Bailey AJ, Bazin S & De Launey A. Changes in the nature of collagen during development and restoration of granulation tissue. *Biochemica et Biophysica Acta* (1973), 328:383-390.
- Balakrishnan S, Lim YN et al. Sling distress: A subanalysis of the IVS tapes from the SUSPEND trial, *Australian and New Zealand Journal of Obstetrics and Gynaecology* (2007); 47: 496-498.
- Barksdale PA, Elkins TE, Sanders CK, Jaramillo FE, Gasser RE, An anatomic approach to pelvic hemorrhage during sacrospinous ligament fixation of the vaginal vault. *Obstetrics and Gynecology* (1998) 91(5 Pt 1) 715-8.
- Black N, Griffiths J, Pope C, Bowling A and Abel P Impact of surgery for stress incontinence on morbidity: cohort study. *Brit. Med J.* (1997), 315: 1493-8.
- Brown J, Seeley D, Grady D, Ensrud K & Cummings S Hysterectomy: The effect on prevalence of urinary incontinence. *International Urogynecology Journal* (1994), 5: 370.
- Bruce-Gregorios J, Chou SM, Core myofibres and related alterations induced in rat soleus by immobilization in shortened position. *J. Neurol. Sci.* (1984); 63:267-275.
- De Lancey J O L Structural support of the urethra as it relates to stress incontinence: the hammock hypothesis *Am. J. Obst. Gynecol.* (1994) 170: 1713-1723.
- Delorme E, La Bandelette transobturatrice: un procede mininvasif pour traiter l'incontinence urinaire d'effort de la femme. *Progres en Urologie* (2001). 11; 1306-1313
- Dimpfl Th, Jaeger Ch, Mueller-Felber, Anthuber C, Hirsch A, Brandmeier R, Schuessler B, Myogenic changes of the levator ani muscle in premenopausal women: the impact of vaginal delivery, *Neurorol. Urodynamics* (1998); 17:197-205.
- Douglas DM. The healing of aponurotic incisions, *Brit. J. of Surgery* (1952) 40:79-84.
- Falconer C, Ekman-Orderberg G, Malmstrom A and Ulmsten U, Clinical outcome and changes in connective tissue metabolism after Intravaginal Slingplasty in stress incontinent women, *Int. Urogynecol J.* (1996) 7: 133-137.
- Farnsworth BN Posterior Intravaginal Slingplasty (infracoccygeal sacropexy) for severe. posthysterectomy vaginal vault prolapse- a preliminary report, *Int. J. Urogynecol.* (2002) 13 :4-8.

- Farnsworth FB, Parodi M, Total Vaginal Reconstruction with polypropylene mesh. Objective and Functional Outcomes Assessment. *Int. Urogyn. J.* (2005), :16 Suppl 2 No 55.
- Frangenheim P. Zur Operativen Behandlung der Incontinenz der Mannlichen Harnrohre. *Verh Dtsch Ges Chir* (1914), 43:49.
- Glazener CMA, Lapidan MC, Urodynamic investigations for the management of urinary incontinence in children and adults (Cochrane Review). (2006), *The Cochrane Library*, Issue 1
- Gleick J "Inner Rhythms" in *Chaos – Making a New Science* (1987) Cardinal, Penguin, England, 275-300.
- Goebell R. Fur Operativen Beseltigung derr Angeborenen Incontinentia Vesicae. *Z. Gynaku Urol.* (1910), 2:187.
- Harrison J H, Swanson DS & Lincoln A F. A comparison of tissue reactions to plastic materials. *AMA Archives of Surgery* (1956), 139-143.
- Hunter John, as quoted by Dunphy JE. Moynihan lecture on nature and care of wounds. Royal College of Surgeons, England (1959).
- Iglesia C B, Fenner DE and Brubaker L The use of mesh in gynaecologic surgery, *Int. Urogyn. Surgery* (1997) 8:105-115
- Inoue H. Sekiguchi Y, Kohata Y, Satono Y, Hisikawa K Tominaga T, Tissue Fixation System (TFS) repairs uterovaginal prolapse with uterine preservation – a preliminary report on perioperative complications and safety.
- The Journal of Obstetrics and Gynecology Research*, (2008), in press). Jeffcoate TNA Genital Prolapse, in *Principles of Gynaecology*, Ed Jeffcoate TNA, (1962), (2nd Ed.) Butterworths, London, 282-30
- Kelly H A & Dumm W M Urinary incontinence in women without manifest injury to the bladder. *Surgery Gynecol. & Obstets.* (1914), 18:444-450.
- Johnson D, ElHaj M, O'Brien-Best E, Miller H, Fine P, Necrotizing fasciitis after tension-free vaginal tape (TVT) placement, *Int. J. Urogyn. J.* (2003) , 14:4;291-293
- Koelbl H, Stoerer S, Seliger G, Wolters M Transurethral penetration of a tension-free vaginal tape, *BJOG* (2001) 108; 7 763
- LaSala CA, Schimpf MO. Occurrence of postoperative hematomas after prolapse repair using a mesh augmentation system. *Obstet. Gynecol.* (2007);109:569–72.
- Lim YN, Rane A Suburethral vaginal erosion and pyogenic granuloma formation: an unusual complication of intravaginal slingplasty (IVS), *Int. Urogynecol. J. Pelvic Floor Dysfunct.* (2004);15(1):56-8. 242
- Lim Y N, Muller R, Corstiaans A, Dietz H P, Barry C, Rane A. Suburethral slingplasty evaluation study in North Queensland, Australia: the SUSPEND trial. *Aust. N. Z. J. Obstet. Gynaecol.* (2005); 45(1):52-9
- Lose G, Ostergard DR.:Medical technology assessment and surgery for stress incontinence. *Int. Urogynecol J. Pelvic Floor Dysfunct.* 1999;10(6):351-2.)
- Meschia M, Pifarotti P, Bernasconi F, Magatti F, Vigano R, Bertozzi R, Barbacini P, Tension free vaginal tape (TVT) and intravaginal slingplasty (IVS) for stress urinary incontinence: a multicenter randomized trial. *Am. J. Obstet. Gynecol.* (2006), 195(5):1338–1342
- Milani R, Salvatore S, Soligo S, a Pifarotti P, Meschia M, Cortese (published online 2005) M, Functional and anatomical outcome of anterior and posterior vaginal prolapse repair with prolene mesh *BJOG: An International J Journal of Obstetrics & Gynaecology* 112 (1), 107-111.
- Neuman M, Lavy Y. Posterior intra-vaginal slingplasty for the treatment of vaginal apex prolapse: Medium-term results of 140 operations with a novel procedure. *Eur. J. Obstet. Gynecol. Reprod.Biol.* (2008);140:230-3.

- Nichols DH & Randall CL Vaginal Surgery. (1989), 3rd Ed, Williams Wilkins, Baltimore.
- Osterburg D. Influence of capillary multifilament sutures on the antibacterial action of inflammatory cells in infected wounds. *Acta Chir Scandinavica* (1983), 149:751-57.
- Ostergard DR. The epochs and ethics of incontinence surgery: is the direction forward or backwards? EDITORIAL *Int.Urogynecol J.* (2002), 13:1-3
- Papadimitriou JM, Ashman RB (1989) Macrophages: current views on their differentiation, structure and function, *Ultrastruct Path* 13: 343-358
- Papadimitriou J and Petros PEP, Histological studies of monofilament and multifilament polypropylene mesh implants demonstrate equivalent penetration of macrophages between fibrils, *Hernia* (2005) 9: 75-78.
- Peacock E E Structure, synthesis and interaction of fibrous protein and matrix. *Wound Repair* (1984), 3rd Edition, Publishers WB Saunders Co, Philadelphia. 56-101.
- Petros P E The Intravaginal Slingplasty Operation, a minimally invasive technique for cure of urinary incontinence in the female, *Aust. N.Z. J. Obst. and Gyn.* (1996); 36: 463-461
- Petros P E New ambulatory surgical methods using an anatomical classification of urinary dysfunction improve stress, urge, and abnormal emptying, *Int. J. Urogynecology* (1997) 8: 270-278.
- Petros P E Development of generic models for ambulatory vaginal surgery: a preliminary report, *Int. J. Urogynecology* (1998) 9:19-27.
- Petros P E *Development of The Intravaginal Slingplasty and Other Ambulatory Vaginal Procedures* Doctor of Surgery thesis University of Western Australia (1999)
- Petros P E Medium-term follow up of the Intravaginal Slingplasty operation indicates minimal deterioration of continence with time. *Aust. N.Z J. Obstet. Gynaecol.* (1999) 39:354-356.
- Petros P E, Richardson P A, Prepubic TFS sling in curing non-stress leakage following complete cure of stress incontinence by a midurethral sling, *Pelvip erineology* 2007; 27:4
- Petros P E Cure of urinary and fecal incontinence by pelvic ligament reconstruction suggests a connective tissue etiology for both. *International Journal of Urogynecology* (1999);10: 356-360
- Petros P E Itr Influence of hysterectomy on pelvic floor dysfunction *Lancet* (2000), 356 :1275.
- Petros P E Vault prolapse II: Restoration of dynamic vaginal supports by the infracoccygeal sacropexy, an axial day-care vaginal procedure, *Int. J. Urogynecol. and Pelvic Floor* (2001) 12:296-303
- Petros PE, The split labium minus flap graft technique, *Int. J. Urogyne.* 2004,15:95-98
- Petros P E P, Richardson P A, Midurethral Tissue Fixation System sling – a ‘micromethod’ for cure of stress incontinence – preliminary report, *A.N.Z.J.O.G.* (2005); 45: 372–375
- Petros P E P, Richardson P A, Tissue Fixation System posterior sling for repair of uterine/vault prolapse – A preliminary report. *A.N.Z.J.O.G.* (2005); 45: 376–379
- Petros P E, Richardson P A, A three year follow-up review of uterine/vault prolapse repair using the TFS minisling, *R.A.N.Z.J.O.G.* (2009) in press.
- Petros P E P, Richardson P A, Goeschen K and Abendstein B, The Tissue Fixation System (TFS) provides a new structural method for cystocele repair – a preliminary report. *A.N.Z.J.O.G.* (2006) 46:474-478.
- Petros P E, Richardson P A, Midurethral Tissue Fixation System (TFS) sling for cure of stress incontinence – three year results, *International J. Urogyne.* (2008), 19:869-871.
- Petros P E, Richardson P A, Fecal incontinence cure by surgical reinforcement of the pelvic ligaments suggests a connective tissue aetiology , 2008, *J. Pelvip erineology*, 111-113.

- Petros P E, Swash M, Kakulas B, Stress urinary incontinence results from muscle weakness and ligamentous laxity in the pelvic floor, 2008, *J. Pelviperineology*, 27;107-109.
- Petros P E & Ulmsten U), Pregnancy effects on the intravaginal sling operation. *Acta Obstetricia et Gynecologica Scandinavica*, Supplement 153, , (1990, Vol 69, 77-78.
- Petros P E, Ulmsten U and Papadimitriou J, The Autogenic Neoligament procedure: A technique for planned formation of an artificial neo-ligament. *Acta Obstetricia et Gynecologica Scandinavica*, (1990), 69: Suppl.153: 43-51.
- Petros P E and Ulmsten U, Pinch test for diagnosis of stress urinary incontinence. *Acta Obstetricia et Gynecologica Scandinavica*, (1990), 69: Suppl 153:33-35.
- Petros P E & Ulmsten U, The tethered vagina syndrome, post surgical incontinence and I-plasty operation for cure. *Acta Obstetricia et Gynecologica Scandinavica*, (1990) 69: Suppl. 153, 63-67.
- Petros P E and Ulmsten U, The development of the Intravaginal Slingplasty procedure: IVS II- VI *Scandinavian Journal of Urology and Nephrology* (1993); 27: Suppl. 153 ; 61-84
- Petros P E & Ulmsten U, The free graft procedure for cure of the tethered vagina syndrome, *Scandinavian Journal of Urology and Nephrology* (1993) 27: Suppl. 153 ; 85-87
- Rechberger,T Rzezniczuk K, Skorupski P, Adamiak A, Tomaszewski J et al. A randomized comparison between monofilament and multifilament tapes for stress incontinence surgery. *Int. J. Urogynae.*(2003), 14; 432-436
- Richardson A C, Edmonds P B & Williams N L Treatment of stress urinary incontinence due to paravaginal fascial defect. *Obstet. & Gynaecol.* (1981), 57: 357-362
- Shull B L, Capen C V, Riggs M W and Kuehl T J, Preoperative and postoperative analysis of sitespecific pelvic support defects in 81 women treated with sacrospinous ligament suspension and pelvic reconstruction, *J. Obstet. Gynecol.* (1992); 166; 1764-71.
- Sivaslioglu A A, Unlubilgin E, Dölen I, The multifilament polypropylene tape erosion trouble: tape structure vs surgical technique. Which one is the cause? *Int. Urogynecol. J.* (2007), in press.
- Tsia-Shu Lo, Huei-Jean Huang, Ling-Hong Tseng, 2001, Success of Tension-Free Vaginal Tape, Procedure After Pregnancy and Vaginal Delivery, *Journal of Gynecologic Surgery*, 17(4): 129-131.
- Ulmsten U, Johnson P, and Petros P Intravaginal Slingplasty, *Zentralblatt für Gynakologie* (1994);116: 398-404.
- Ulmsten U, Henriksson L, Johnson P, and Varhos G An ambulatory surgical procedure under local anesthesia for treatment of female urinary incontinence, *Int. Urogynecol. J.* (1996); 7: 81-86.
- Van Winkle W & Salthouse T N, Biological response to sutures and principles of suture selection monograph. *Ethicon* (1976).
- Vella M, Robinson D, Brown R, Cardozo L, Pregnancy and delivery following tension-free vaginal tape. *Int. Urogynecol. J. Pelvic Floor Dysfunct.* (2007);18(3):347-8.
- White G R, An anatomical operation for cure of cystocele *J.A.M.A.* (1909), 53: 113
- Ward K, Hilton P, on behalf of the UK and Ireland TVT Trial Group. Tension-free vaginal tape versus colposuspension for primary urodynamic stress incontinence: five year follow up. *B.J.O.G.* (2008);115:226-233.
- Yamada H, Ageing rate for the strength of human organs and tissues. *Strength of Biological Materials* (1970) Williams & Wilkins Co, Balt. (Ed) Evans F. 272-280.
- Zacharin R F, A suspensory mechanism of the female urethra. *Journal of Anatomy* (1963), 97: 423-427.

Chapter 4: Further Reading

- Bailey A J, Bazin S & De Launey A, Changes in the nature of collagen during development and restoration of granulation tissue. *Biochemica et Biophysica Acta*, (1973), 328:383-390.
- Bailey A J, Sims T J, Le Lous M & Bazin S, Collagen polymorphism in experimental granulation tissue. *Biochem & Biophysical Research Communications* (1975), 66:1160-1165.
- Douglas D M, The healing of aponeurotic incisions. *British Journal of Surgery* (1952), 40:79-84.
- Farnsworth B N, A multicentre trial of the Intravaginal Slingplasty procedure with critical analysis of results, surgical methodology and complications thereof, *Int. J. Urogynecol.* (2001)12 –16.
- Goff B H, Secondary reconstruction of damaged pelvic floor, practical consideration of the damaged pelvic floor with the technique for its secondary reconstruction. *Surgery Gynecol. & Obstets.* (1928), 46:855-866.
- Harrison J H, et al., Synthetic Materials as vascular prosthesis. *American Journal of Surgery* (1958), 95:16-24.
- Leibovich S, J & Ross R, The role of the macrophage in wound repair. A study with hydrocortisone and antimacrophage serum. *American Journal of Pathology* (1975), 78:71-91.
- Madden J W & Peacock E E, Dynamic metabolism of scar collagen and re-modelling of dermal wounds. *Annals of Surgery* (1971), 174:p511.
- Muller H K, Mechanism of clearing injured tissue. *Handbook of Inflammation No 3 Tissue Regeneration and Repair*, Ed L E Glynn, Chicago Press (1981), 145-175.
- Osterburg D, Influence of capillary multifilament sutures on the antibacterial action of inflammatory cells in infected wounds. *Acta Chir Scandinavica* (1983), 149:751-57.
- Peacock E E, Structure, synthesis and interaction of fibrous protein and matrix. Wound Repair. (1984), 3rd Edition, Publishers WB Saunders Co, Philadelphia. 56-101.
- Petros P E and Ulmsten U, The combined intravaginal sling and tuck operation. An ambulatory procedure for stress and urge incontinence. *Acta Obstetricia et Gynecologica Scandinavica* (1990), 69: Suppl.153:53-59. 244 The Female Pelvic Floor
- Petros P E and Ulmsten U The tuck procedure: A simplified vaginal repair for treatment of female urinary incontinence. *Acta Obstetricia et Gynecologica Scandinavica* (1990), 69: Suppl 153: 41-42.
- Petros P E and Ulmsten U, Cure of urge incontinence by the combined intravaginal sling and tuck operation. *Acta Obstetricia et Gynecologica Scandinavica* (1990), 69: Suppl 153: 61-62.
- Petros P E and Ulmsten U, Non-stress non-urge incontinence—diagnosis and cure—preliminary report. *Acta Obstetricia et Gynecologica Scandinavica* (1990), 69: Suppl 153: 69-70.
- Petros P E and Ulmsten U, The combined intravaginal sling and tuck operation. An ambulatory procedure for stress and urge incontinence. *Acta Obstetricia et Gynecologica Scandinavica* (1990), 69: Suppl 153: 53-59.
- Petros P E and Ulmsten U, Surgical principles deriving from the Integral Theory, *Scandinavian Journal of Urology and Nephrology* (1993) – 27: Suppl. 153 - PART III: 41-49.
- Petros P E and Ulmsten U, An anatomical basis for success and failure of female incontinence surgery, *Scandinavian Journal of Urology and Nephrology* (1993) 27: Suppl. 153 - PART IV: 53-60.
- Petros P E, Tissue reaction to implanted foreign materials for cure of stress incontinence (letter) *American Journal of Obstetrics and Gynecology* (1994); 171: 1159
- Petros P E, Ambulatory incontinence and vaginal surgery. *Aust. Med. J.* (1994) 161: 171-172.

- Postlethwaite R W, Schauble J F, Dillon M L & Morgan J, Wound healing, II, An evaluation of surgical suture material. *Surgery Gynaecol. & Obstets.* (1959), 555-566.
- Postlethwaite R W, Longterm comparative study of non-absorbable sutures. *Archives of Surgery*, (1970), 101:489.
- Postlethwaite R W, Willigan D V M & Ulin A W, Human tissue reaction to sutures. *Annals of Surgery*(1975), 181:144-152.
- Richardson D A, Bent E A, Ostergard D et al., Delayed reaction to the dacron buttress suture used in urethropexy. *Journal of Reproductive Medicine*(1984), 29:689-692.
- Salthouse T M, Biological response to sutures. *Otolaryngol. Head Neck Surgery* (1980), 88: 658-664.
- Salthouse T, Some aspects of macrophage behaviour at the implant interface. *Journal of Biomed. Material Res.* (1984), 18:395-401
- Shull B L, Capen C V, Riggs M W, Kuehl T J. Preoperative and postoperative analysis of site-specific pelvic support defects in 81 women treated with sacrospinous ligament suspension and pelvic reconstruction. *J. Obstet. Gynecol.* 1992; 166: 1764-1771.
- Ulmsten U and Petros P E, Surgery for female urinary incontinence. in *Current Science* (1992).4:456-462
- Van Winkle W & Hastings J C, Considerations in the choice of suture material for various tissues, *Surgery, Gynecology and Obstetrics* (1972) 135: 113-126.

Chapter 5: Pelvic Floor Rehabilitation

- Appell R A, Bourcier A La Torre F (1998) Eds *Textbook of Pelvic Floor Dysfunction*
- Bo, K Pelvic floor muscle exercise for the treatment of female stress urinary incontinence: III.
- Effects of two different degrees of pelvic floor muscles exercises. *Neurourol Urod.*, (1990). 9: 489-502.
- Kegel A H, *Progressive resistant exercise in the functional restoration of the perineal muscles.* *Am.J. Obstets & Gynecol.*, (1948), 56:238-248.
- Petros P E and Skilling P M, The physiological basis of pelvic floor exercises in the treatment of stress urinary incontinence. *Br J Obstet Gynaecol* (1999) 106:615-616
- Petros P E and Skilling P M, Pelvic floor rehabilitation according to the Integral Theory of Female Urinary Incontinence- First report, *European Journal of Obstetric & Gynecology and Reproductive Biology* (2001) 94: 264-269.
- Petros P E, New ambulatory surgical methods using an anatomical classification of urinary dysfunction improve stress, urge, and abnormal emptying, *Int J Urogynecology* (1997) vol 8, 5: 270-278.
- Skilling P M, Petros P E, Synergistic non-surgical management of pelvic floor dysfunction: second report, *Int. J. Urogynecology*. (2004) 15: 106-110

Chapter 6: Mapping the Dynamics of Connective Tissue Dysfunction

- Abrams P, Blaivas J, Stanton S and Andersen J, Standardisation of Terminology of Lower Urinary Tract Function, *Scand. J. Urol Nephrol.* (1988), Suppl. 114.
- Bates C P, The unstable bladder, *Clinics in Obstetrics and Gynaecology* (1978) 5: 1: 109 - 122.
- Bates P, Bradley W E, Glen E, Hansjorg M, Rowan D, Sterling A and Hald T, *International*

- Continence Society First Report on the Standardisation of Terminology of Lower Urinary Tract Function* (1975)
- Barrington F J, The relation of the hind- brain to micturition. *Brain* (1921), 44:23-53.
- Bush M B, Petros P E P, Barrett-Lennard B R, On the flow through the human urethra *Biomechanics* (1997) 30: 967-969.
- Constantinou C E and Govan D E, Contribution and timing of transmitted and generated pressure components in the female urethra. *Female Incontinence* (1981), Alan R Liss, New York, 113-120.
- Constantinou C E, Resting and stress urethral pressures as a clinical guide to the mechanism of continence, in *Clinics in Obstetrics and Gynaecology*, Ed. Raz S, W B Saunders Co. London (1985), 12: 343-356.
- Creed K, Functional diversity of smooth muscle, *British Med. Bulletin* (1979), 3:243-247
- Enhörning G, Simultaneous recording of intravesical and intraurethral pressure, *Acta Chir Scandinavica* (1961), Supplement No 27:61-68
- Farnsworth B N, Posterior Intravaginal Slingplasty (infracoccygeal sacropexy) for severe posthysterectomy vaginal vault prolapse—a preliminary report, *Int. J. Urogynecol.* (2002) 13 :4-8.
- Gleick J, “Inner Rhythms” in *Chaos—Making a New Science* (1987) Cardinal, Penguin, England, 275-300.
- Griffiths D J, Assessment detrusor contraction strength or contractility, *Neurourol. Urod.* (1991);10:1-18
- Hill A V, The heat of shortening and the dynamic constance of muscle, *Proc. Royal Soc. Lond.* B 938; 126:136-195
- Jeffcoate T N A, *Principles of Gynaecology* (1962), (2nd Ed.) Butterworths, London.
- Lose G, Impact of changes in posture and bladder filling on the mechanical properties of the urethra in healthy and stress incontinent women, *Neurourology and Urodynamics* (1990). 9:459-469
- Lose G, Simultaneous recording of pressure and cross-sectional area in the female urethra. A study of urethral closure function in healthy and stress incontinent women, *Neurourology and Urodynamics* (1992);11: 55-89
- Lose G and Colstrup H, Mechanical properties of the urethra in healthy and stress incontinent females: dynamic measurements in the resting urethra, *J. Urol.* (1990) 1258-1262.
- Marinoff S C, Turner M L C, Vuvar vestibulitis syndrome: an overview. *Am. J. Obstet. Gynecol.* (1991); 165:1228-33.
- Mayer R, Wells T, Brink C, Diokno A and Cockett A, Handwashing in the cystometric evaluation of detrusor instability, *Neurourology and Urodynamics* (1991). 10: 563-569.
- Neuman M, Lavy Y (2007), Posterior intra-vaginal slingplasty for the treatment of vaginal apex prolapse: medium-term results of 140 operations with a novel procedure, *Eur. J. Obstet. Gynecol. Reprod. Biol.* (in press) DOI 10.1016/j.ejogrb.2006.07.035
- Power R M, Embryological development of the levator ani muscle. *American Journal of Obstets. & Gynecol.* (1948), 55:367-381.
- Petros P E and Ulmsten U, Bladder instability in women: A premature activation of the micturition reflex, *Neurourology and Urodynamics* (1993). 12, 235-239 246 The Female Pelvic Floor
- Petros P E and Ulmsten U, Urethral pressure increase on effort originates from within the urethra, and continence from musclovaginal closure, *Neurourology and Urodynamics* (1995), 14:337-350
- Petros P E, The effect of urethral pressure variation in women (letter) *Int. Urogynecol. J. and Pelvic Floor* (1996) 7: 274.

- Petros P E, Severe chronic pelvic pain in women may be caused by ligamentous laxity in the posterior fornix of the vagina, *Aust. N.Z. J. Obstet. Gynaecol.* (1996), 36:3: 351-354.
- Petros P E, New ambulatory surgical methods using an anatomical classification of urinary dysfunction improve stress, urge, and abnormal emptying, *Int. J. Urogynecology* (1997) 8: 270-278.
- Petros P E, A cystocele may compensate for latent stress incontinence by stretching the vaginal hammock, *Gynecol. and Obst. Investigation* (1998); 46; 206-209
- Petros P E, Change in urethral pressure during voluntary pelvic floor muscle contraction and vaginal stimulation, *Int. J. Urogynecology* (1998) 8:318.
- Petros P E and Bush M B, A mathematical model of micturition gives new insights into pressure measurement and function, *Int. J. Urogynecology* (1998) 9: 103-107.
- Petros P E, The sign of stress incontinence—should we believe what we see? *Aust. N.Z. J. Obstet. Gynaecol.* (1998);38:352-353
- Petros P E, Detrusor instability and low compliance may represent different levels of disturbance in peripheral feedback control of the micturition reflex. *Neurourol. and Urod.* (1999) 18:81-91.
- Petros P E, Von Kinsky B, Anchoring the midurethra restores bladder neck anatomy and continence, *Lancet* (1999) 354: 997-998
- Petros P E, Finite element models—a template for future urodynamics, *Neurourol & Urodynamics* (2001) 20: 231-233
- Van Doorn, Van Waalwijk E S C, Remmers A, Jaknegt R A, Conventional and extramural ambulatory urodynamic testing of the lower urinary tract in the female, *J. Urol.* (1992), 147: 1319-1325

Chapter 6: Further Reading

A2

- Kauffman SA, The Origins of Order, *Oxford Uni. Press*, NY (1993), 173-235.
- May R M, Simple mathematical models with very complicated dynamics, *Nature* (1976) 261: 459-467.
- Molloy W B M, Targeted treatment of female urinary dysfunction, *Lancet* (2002) vol 358;9308, p800
- Petros P E and Ulmsten U, Cough transmission ratio: An indicator of suburethral vaginal wall tension rather than urethral closure? *Acta Obstetrica et Gynecologica Scandinavica* (1990), 69:Suppl. 153: 37-39.
- Petros PE Doctoral thesis University of Uppsala, Sweden,(1993) 'Detrusor Instability - a Critical Analysis'
- Petros P E and Ulmsten U, Tests for detrusor instability in women. These mainly measure the urethral resistance created by pelvic floor contraction acting against a premature activation of the micturition reflex. *Acta Obstetrica et Gynecologica Scandinavica* (1993); 72: 661-667.
- Petros P E and Ulmsten U, Natural volume handwashing urethrocytometry—a physiological technique for the objective diagnosis of the unstable detrusor, *Gynecol. Obstet. Investigation* (1993), 36 : 42-46.
- Petros P E, A cystocele may compensate for latent stress incontinence by stretching the vaginal hammock, *Gynecol. and Obst. Investigation* (1998); 46; 206-209.
- Petros P E, The Art and Science of Medicine, *Lancet* (2001) 358:1818-1819
- Petros P E, Non-linearity in Clinical Practice, *Journal for Evaluation in Clinical Practice* (2002) (in press)

- Popper K R, *Theories, Falsifi ability, The Logic of Scientific Discovery* (1980), Unwin, Hyman, London, 27-146
- Schaer G N, Koechli O R, Schuessler B, Haller U, Perineal ultrasound for evaluating the bladder neck in urinary stress incontinence, *Obstet. Gynecol.* (1995);85:224-229.
- Shafi K A, A new concept of the anatomy of the anal sphincter mechanism and the physiology of defecation, *Acta. Anat.* (1990); 138:359-363.
- Swash M, Henry M M, Snooks S J, Unifying concept of pelvic floor disorders and incontinence. *Journal of the Royal Society of Medicine* (1985),78:906-911.

Chapter 7: Current and Emerging Issues

- Bornstein J, Zarfati, D, Petros P E P, Causation of vulvar vestibulitis *A.N.Z.J.O.G.* (2005), 45: 538–541
- Boukerrou M, Lambaudie E, Dubois P, Cosson M, Etude préliminaire d'un modèle mécanique de cavité vaginale, *I.T.B.M.R.B.M.* (2004) 25:3–14
- Harrison S.M., Bush M.B., Petros P.E., Towards a novel tensile elastometer for soft tissue, *International Journal of Mechanical Sciences* 50, (2008), 626–640
- Petros P E, Bornstein J, Vulvodynia may be a referred pain originating from laxity in the uterosacral ligaments, *A.N.Z.J.O.G.* (2004) 44: 483–486

Appendix 3 – Patient Information

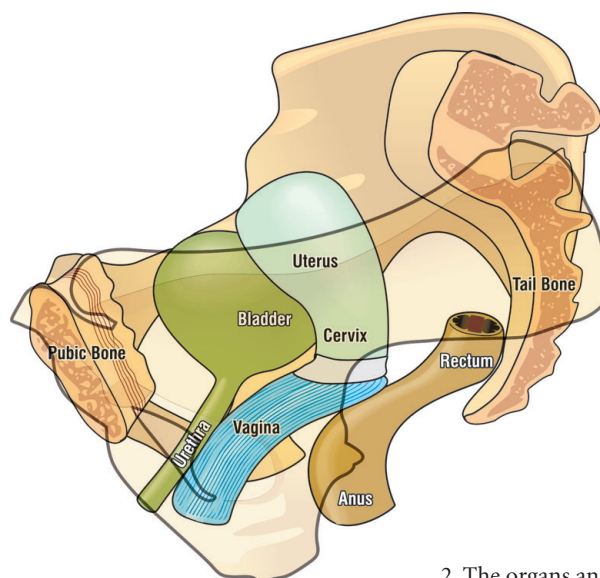
A3

Appendix 3: CHAPTER 1

UNDERSTANDING YOUR VAGINA, BLADDER, BOWEL, AND HOW THEY WORK IN A NORMAL WOMAN

Bladder, Bowel and Uterus

This is what your bladder, bowel and uterus look like when you are in the sitting position. Think of these organs as storage containers. The bladder stores your urine, the uterus your baby, and the rectum your faeces. Each organ is connected to the outside by a tube, urethra, which is about 4cm long, vagina, which is 10-12cm long, and anus, also about 4 cm long. The blood from your periods, and your baby also, pass through the vagina. Urine and faeces pass through the urethra and anus. Muscles compress these tubes to close them, and stretch them open for emptying. The bone in front of your bladder is called the pubic bone, and the bone behind your rectum is called the sacrum (tail bone).



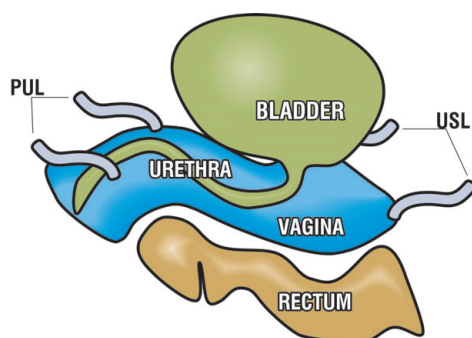
2. The organs and their outlet tubes

The importance of your ligaments

“Problems of bladder, bowel, prolapse, and some types of pelvic pain, mainly originate from the vaginal ligaments, not from the organs themselves” –Integral Theory 1996.

The bladder sits on top of the vagina, and is partly attached to it. Muscles pull against the ligaments to close or open the bladder. Therefore loose ligaments may weaken the muscle contraction to cause problems with closure (incontinence) or opening (passing urine).

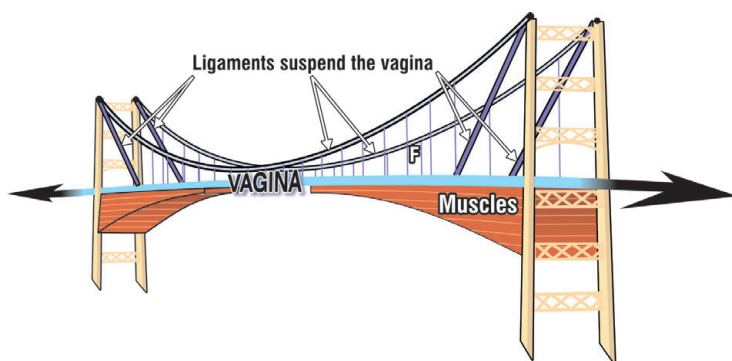
The diagram below indicates what your vagina, bladder, and bowel would look like if you had no ligaments to suspend them, a blob of tissue, with no form, no structure, and no strength.



3. Unsuspended ligaments have no shape, strength or function.

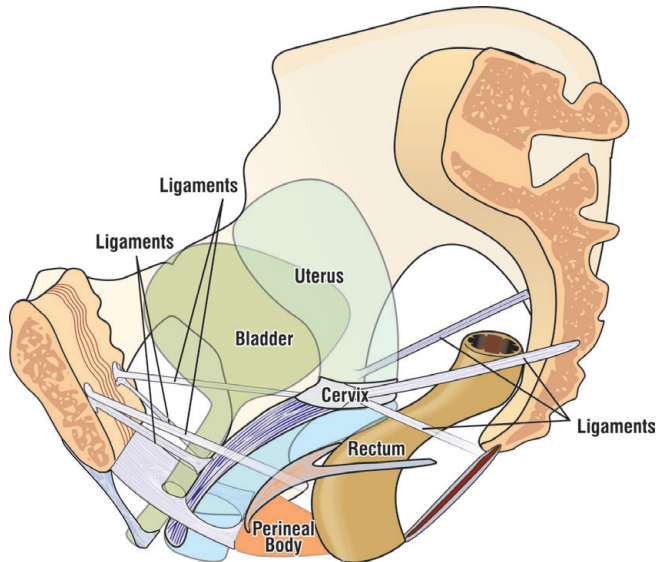
A3

A ligament is like a thick cord in a suspension bridge. In fact, the vagina is suspended exactly like a suspension bridge, with the ligaments above, and the muscles (arrows) below.



4. The vagina is suspended from above, like a suspension bridge, with the ligaments above, and the muscles (arrows) below. Muscles (arrows) stretch these structures to give them form and strength.

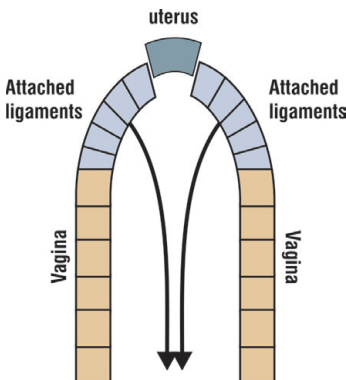
Your organs are suspended from above by the vaginal ligaments- exactly like a suspension bridge. You can see that all the ligaments are attached to the vagina and/ or uterus. The vagina supports the bladder above, and the rectum (bowel) below, so anything which damages the vaginal structure, can also affect the bladder and rectum.



5. The ligaments suspend the organs from above like a suspension bridge

The lower part of the uterus is called the cervix, and it is situated right at the back of your vagina. The cervix is where your Pap smear is taken from. Separating the lower end of the vagina from the rectum is a solid mass of tissue called the perineal body. If this is damaged, the rectum (bowel) may bulge forwards into the vagina. This is called a “rectocele”.

The uterus is an anchoring point for the ligaments – it needs to be preserved if possible.

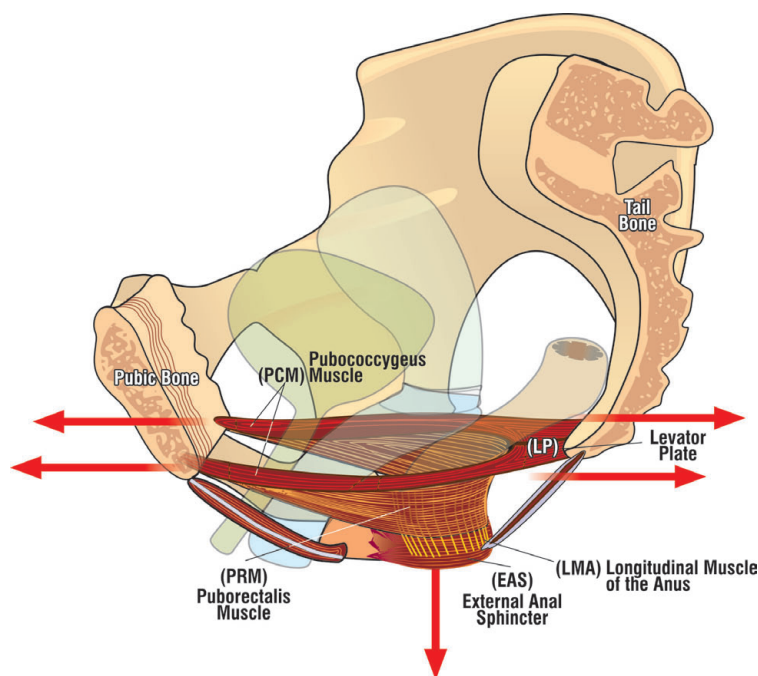


6. The uterus functions like the keystone of an arch. Remove the arch, and the whole structure is put at risk of a downward collapse.

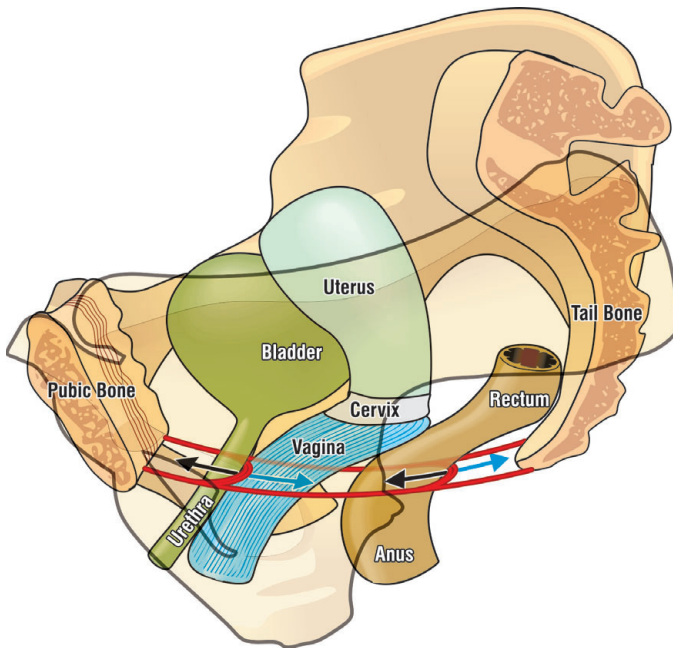
The role of the uterus in maintaining the function of the pelvic floor is greatly underestimated. Some doctors routinely recommend removal of the uterus during surgery for prolapse. It is preferable to retain the uterus wherever possible, as many important ligaments are attached to it. During the menopause (cessation of the periods), the ovaries cease production of the hormone oestrogen. Since oestrogen is essential for maintaining the strength of the ligaments, the detrimental effects of hysterectomy on prolapse and incontinence become especially evident after the menopause. Hysterectomy (removal of the uterus) reduces the blood supply to the back ligaments, weakening them further. All these factors predispose to prolapse. Prolapse is a general term for bulging of the bladder, uterus or rectum into the vagina.

The Pelvic Muscles

The pelvic muscles (dark red) extend from the tail bone to the pubic bone. They support your vagina, bladder and bowel from below. The red arrows indicate the directions where the muscles contract, backwards to open these organs, forwards to close them.



7. The muscles support the organs, vagina, bladder, and bowel from below, and also, open and close them by 3 directional muscle forces (arrows).



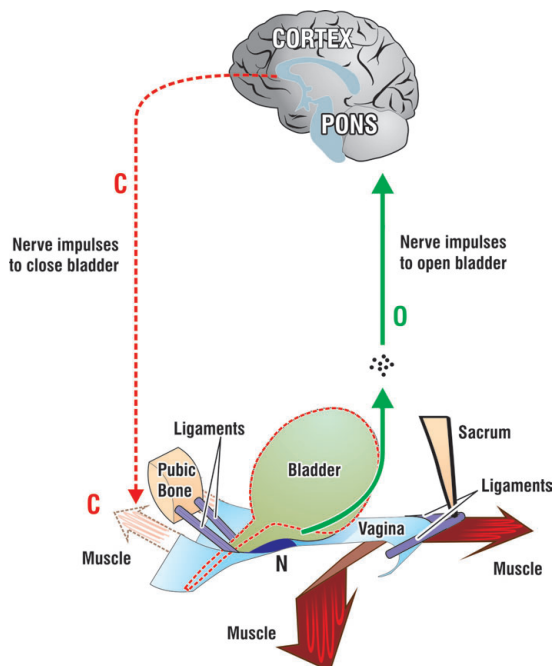
8. The red lines represent your pelvic muscles. Extensions from these muscle fibres loop around the openings of the bladder (urethra) and bowel (anus). Put simplistically, when the muscles pull backwards (blue arrows), the urethra and anus are pulled open so that the woman can evacuate her urine and faeces. When the muscles pull forwards (black arrows), the urethra and anus are closed. Normally all your organs, even the vagina, are in the closed position.

We saw from the suspension bridge diagram, that the muscles pull against the ligaments. So if your ligaments are loose, the muscle strength weakens, and may not be able to keep your bladder or bowel emptying tubes closed. As a consequence of this, you may feel a leakage of urine, wind or faeces. This is called “incontinence”. Another related condition is failure to close the vaginal tube, so you may feel water entering your vagina during swimming. If your damaged ligaments do not allow your muscles to open these same emptying tubes, you may have to strain to empty your bladder or bowel. This condition is called “evacuation disorder” or “emptying disorder”.

A Symphony Orchestra

Your vagina, bladder, bowel, muscles, and ligaments are like instruments in an orchestra. The brain is the conductor, and ensures that all the instruments work harmoniously to produce the right music. Every instrument in the orchestra has a specific job. Damage to even one instrument will affect the performance. The brain directs the orchestra to open the bladder (and bowel) or to close it. Depending on what structure is damaged, the bladder may not be able to close properly, and the patient

leaks (“incontinence”); or she may not be able empty her bladder, or she may have both problems. Nerves at the base of the bladder (‘N’ in the diagram which follows) sense when the bladder is full, and send impulses to the brain. These are perceived as urgency, a desire to go to the toilet.



A3

9. The cortex of the brain gives directions for closure (C), and opening (O). Nerves “N”, at the base of the bladder sense when the bladder is full, and send impulses to the brain. Depending on the situation, the the brain, sends directions either for closure (C), or opening (O). Like instructions from the orchestra conductor, these directions, “C” and “O”, engage all the muscles, nerves, ligaments and tissues required for each function. The Pons, a lower part of the brain, works as a co-ordinating station.

The brain and its nerves—a sophisticated feedback system

Your brain works like the computer at a big telephone exchange. Think of your nerves as telephone wires going out to the bladder, the vagina and bowel. These organs have sensors which send signals back to the brain via another set of nerves, to inform it as to what is happening. Your brain receives and processes these signals, and depending on what is required, sends out orders via a series of nerves. Most of this co-ordination occurs in “automatic mode”. You are not aware of what is happening. Sometimes, you can actually instruct the brain. For example, if it is inconvenient for you to empty your bladder or your bowel, you simply pull the muscles upwards to close off the urethral and anal tubes. Sometimes you push down when you wish to assist emptying your urine and faeces. If, during intercourse, you wish to narrow the vagina, you pull the muscles upwards. This action grips the penis, and increases the sensation for both partners.

Appendix 3: CHAPTER 2

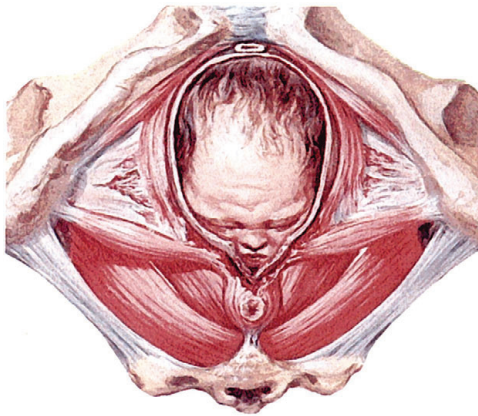
HOW THE LIGAMENTS BECOME LOOSE TO CAUSE SYMPTOMS AND PROLAPSE

The structure of ligaments

A ligament is a complicated elastic structure which needs to be both elastic and strong. It relies on its collagen content for strength. Whilst elastin gives ligaments their flexibility, it is collagen which gives them strength. Collagen is what you see in a scar. Collagen fibres work like the steel rods in cement. Single collagen fibres are “glued” together to give ligaments strength, and elastin gives them elasticity.

How ligaments are stretched and damaged during pregnancy and labour

As we saw from the suspension bridge diagram, the muscles pull against the ligaments which support the bridge. If your ligaments are loosened during childbirth, for instance, you may develop a prolapse (a feeling of something coming down), a “dragging” pain low in your abdomen, symptoms in your bladder, for example urgency, frequency, getting up at night, or even problems with bowel emptying or incontinence.



1. The baby's head stretches and loosens the ligaments and other tissues at childbirth

Commencing 6 months before childbirth, the “glue” between the collagen rods begins to soften in response to hormones from the placenta (“afterbirth”). This explains the onset of bladder, bowel, and pain symptoms at this time. Some 24-48 hours before delivery, however, this softening accelerates, and the collagen rods lose 95% of their strength. During delivery, the baby’s head greatly stretches these collagen rods. Of course, the rods “re-glue” soon after delivery, but often they “re-glue” in a loose and extended position. Neither the ligaments nor the muscles can now work properly, and this may lead to a “fallen womb” (prolapse of the uterus), a bulge of the bladder (cystocele) or rectum (rectocele), and a wide range of bladder, bowel and pelvic pain symptoms. Women who have had Caesarian sections may also become incontinent, but less frequently. Loose ligaments may occur in women who have never had children. Such women are born with loose ligaments, or they may have a congenital defect in their collagen. All these conditions are potentially curable by creation of artificial ligaments, as will explained later.

The effect of age and menopause

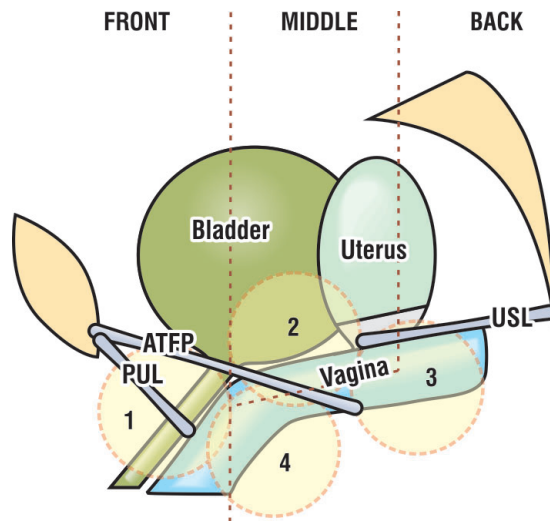
As discussed previously, collagen gives ligaments strength, and elastin gives them elasticity. Both deteriorate markedly after the menopause, and this explains the vast increase in prolapse and incontinence which occurs after this event. A partly damaged ligament which is only just functioning before the menopause, may lose enough collagen after it to “give way”. This may result in organ prolapse, abnormal symptoms, or both. The oestrogen hormone replacement therapy (“HRT”) helps to slow down the degeneration of collagen. HRT can be applied vaginally, or by patches, creams, tablets, injections. Though oestrogens may be associated with an apparent increased risk of breast cancer, this has to be weighed against their benefits, prevention of osteoporosis, hip fractures, thickening of the vaginal wall in sexually active patients, even perhaps prevention of heart disease. Vaginally inserted oestrogen tablets are considered safe, as they act locally. We recommend these for every post-menopausal woman, even into the most mature age.

A3

Site of damage and its consequences

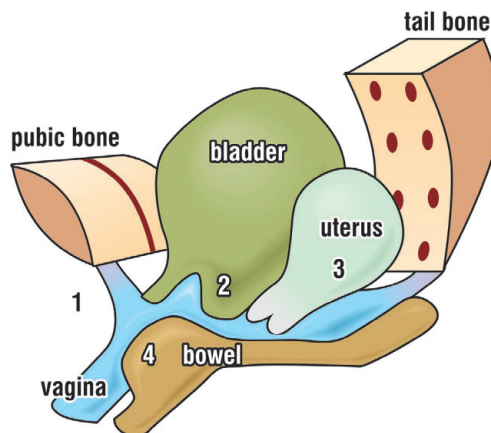
The circles in diagram 10 represent the baby’s head descending through the vagina during childbirth. This may stretch and loosen the ligaments (thick grey lines). The numbers 1-4 indicate damage to specific ligaments which may cause

1. Stress incontinence (urine leakage with coughing or exercise).
2. Cystocele (bulging of the bladder into vagina).
3. Prolapse of the uterus (“fallen womb”).
4. Rectocele (bulging of the bowel into vagina). All may occur to varying degrees in the same patient.



10. The baby's head (circles) damages the ligaments and vaginal tissues to varying degrees as it descends through the vagina

It is evident that a head descending down a vulnerable vaginal canal is unlikely to damage just one single structure. All structures will be damaged to a greater or lesser extent. This explains appearance of a cystocele, for example, months or years after apparently successful surgery for prolapse of the uterus. Further prolapse can occur in up to 30% of cases after a successful repair. The problem is that once the vaginal tissues are damaged, it is difficult to repair them. It is like repairing frayed cloth. You repair one area, only to see it give way in another area. That is why we have to create artificial ligaments by using tapes.



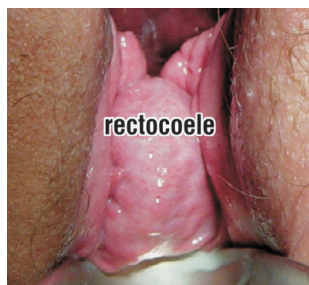
11. This diagram illustrates the cystocele "2", rectocele "4" and uterus "3", all pushing into the vagina, as "lumps", like a glove turning inside out. All are caused by looseness in the suspensory ligaments and their associated tissues.

If you held a mirror at your vagina and strained, this is what a cystocele would look like. The lump “balloons” out from above. The cause is damage to the middle ligaments and the tissues of the front wall of the vagina, ‘2’, in the preceding diagrams.



12. A cystocele bulging out of the vaginal entrance during straining.

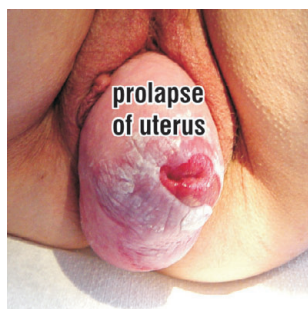
The diagram which follows shows what typical rectocele looks like. Separating the lower end of the vagina from the rectum is the perineal body. If this is damaged, the rectum may bulge forwards into the vagina from below.



13. A rectocele bulging out of the vagina during straining.

A3

The diagram which follows is what a severe prolapse of the uterus (“fallen womb”) looks like. The cause is damage to the ligaments and the tissues supporting the uterus, ‘3’, in the preceding diagrams.



14. A uterus chronically bulging out of the vagina. The white areas are caused by chronic friction.

A perspective on organ prolapse

The organs bulge to varying degrees. Clearly a severe prolapse, such as the uterine prolapse above, requires treatment. If the bulge is minor, and there are no associated symptoms, there is no need for treatment. However, you may have severe symptoms which may require treatment, even though the prolapse is minor.

How do I know if I have a problem?

If you answer “yes” to one of the following, you have a problem

1. You lose urine during exertion or coughing.
2. You can’t “hold on” and you wet yourself.
3. You can’t empty your bladder properly.
4. You have bowel soiling.
5. You feel a lump in your vagina (prolapse)
6. You have lower abdominal or pelvic pain.

How serious is my problem? – Assessment by the patient

The question “how serious is my problem” is not so easy to answer, as symptoms vary, and patients’ perceptions vary. A simple rule is to seek help if it is interfering with your quality of life. If the problem is mild and not bothersome, no action is required.

Assessment by the clinic

The doctor has a different perspective, a) to assess which ligaments have been damaged, and b) to assess the seriousness of the problem. An accurate assessment is paramount. The doctor uses various tests to decide which treatment to recommend. Later in the book, we devote a full chapter to this subject, “A visit to the Clinic”. In Chapter 6 we present the experience of one patient as she goes through the whole process, assessment, consent, and decision for treatment.

Symptoms – what they mean

A symptom is a warning bell from the brain that something is wrong with some part of the body. As regards the pelvic floor, most bladder and bowel symptoms are secondary to damage in one or more related ligaments, not from the organ itself. The challenge is to find which ligaments are causing the problem.

The Diagnostic Diagram indicates which ligaments are causing symptoms and prolapse

The Diagnostic Diagram below is a simplified version of what we use in our Clinic. To use this diagram, tick every column which describes your symptoms, and it will tell you where the damage is.

The front and back ligaments are purple. The middle ligaments are not shown in this diagram

There are 3 columns, one for each ligament group and the symptoms and prolapses (lumps) associated with damage to these ligaments.

Definitions for Symptoms

- Stress incontinence Urine loss on effort, such as coughing, exercise.
- Abnormal emptying Inability to empty the bladder.
- Urgency An uncontrollable desire to pass urine.
- Frequency Going more than 8 times a day to the toilet to pass urine.
- Nocturia Getting up more than twice per night to pass urine.
- Faecal incontinence Uncontrolled soiling from the bowel.
- Obstructed defaecation Difficulty in emptying the bowel.
- Pelvic pain. Pain in the lower abdomen, lower back, or during intercourse.

Symptoms occur in groups – an aid to diagnosis

For example, urgency symptoms are indicated in all 3 columns. Symptom grouping is the only way we can deduce which column (ligament) is causing the urgency. Fortunately, urgency almost always occurs in tandem with at least one other symptom.

Characteristics of pain caused by back ligament looseness

- Low abdominal ‘dragging’ pain usually unilateral, often right-sided
- Low sacral pain (pain near the tailbone)
- Pain on deep penetration with intercourse
- Post-coital ache the next day
- Tiredness
- Irritability
- Pain worsens during the day, and is relieved by lying down
- Pain is reproduced on pressing the cervix or the back wall of the vagina if a patient has had a hysterectomy.

Characteristics of ‘vulvodynia’

A burning pain over the entrance of the vagina and anus. Extremely sensitive to touch. Often associated with dragging lower abdominal pain and sometimes, painful bladder conditions.

Characteristics of bladder emptying difficulty

Typical symptoms are a slow stream, starting and stopping, dribbling after micturition has been completed, a feeling that the bladder has not emptied. Often such patients have chronic urinary infections.

Characteristics of faecal incontinence

Typical symptoms, in order of severity, are uncontrolled wind loss, liquid soiling, solid faecal soiling. There are 2 main categories, patients with faecal incontinence caused by an anal sphincter torn at childbirth, and another where no obvious cause can be found. The anal sphincter constricts the lower part of the anus. It is what you feel when you contract your muscles to delay bowel emptying. Where no obvious cause can be found, it is called “idiopathic incontinence”. It is the latter type of incontinence which we believe is caused by damage to the front or back ligaments.

Characteristics of lumps (prolapse) in the vagina Initially, these only appear during straining. It is not easy to self-diagnose where a lump in the vagina is coming from. The 3 main causes, bladder (cystocele “2”) uterus (“3”) and bowel (rectocele “4”), can only be definitively diagnosed by a vaginal examination, as not all lumps are accompanied by symptoms. In a symptomatic prolapse, the symptoms may give an indication of where the problem is. For example if a patient has a lump plus nocturia, pelvic pain and urgency, it is highly likely that she has weak back ligaments, as per the Diagnostic Diagram.

Index

A

afferent impulses 40,112,233,235,243
anatomical prolapse 47
anatomy
 dynamic 7
 functional 8
 of pelvic floor function 17
anatomy, static 4
anchoring, insertion points 257
anterior ligamentous defect 113
anterior sling
 operations 259
anterior striated muscles 39
anterior vaginal wall 34
anterior zone
 indications for surgery in 146
 repair of anatomy 149
 structures of 146
 symptoms 106
 ultrasound assessment of 247
 x-rays 250
antibiotics
 pre-operative 130
 preoperative 130
apareunia 127
apex, vagina 44
apical defect 200

apical fascia 188
arcus tendineus fascia pelvis 7,105,247
aspirin 129
assessing probability 105
attractor 234
autologous fascia 203

B

balance and imbalance of pelvic muscle
 forces 57
balance in the system 61
basis of urodynamics 227
beta haemolytic streptococci 130
biomechanics, definition of 44
birth trauma 63
bladder
 abnormal emptying 3
 acontractility 240
 active closure 8,32
 base stretch receptors 40
 capacity 115
 compliance 115
 dysfunction 48
 function and the cortex 240
 hydrostatic pressure of a full 39
 instability 242

- instability, opening and closure reflexes 242
- micturition reflex activation 233
- smooth muscle 115
- underactivity 63,117
- bladder neck 57,246
 - closure mechanisms 179
 - excess elevation 228
 - skin graft to 182
- bladder sensation 115
- bowel dysfunction 3
- Bridge repair
 - retention cyst 211
- Bush, Professor Mark 261
- butterfly effect 119

C

- Canadian Interstitial Cystitis Society 263
- cancer 228
- cardinal ligament 166,195
- central nervous system 39
- cervical anchoring 256
- cervical ring 161,189,195
- cervical ring extension 166
- cervix 47,187
 - wedge resection 200
- Chaos Theory 118,234,239,242,244
- childbirth and connective tissue 48
- chronic pelvic pain 3
- classification, halfway system 83
- Clinical Assessment Pathway 80,82
- collagen 43,44,46,127,131
 - age 142
 - breaking strength of ligament 127
 - degradation 260
 - of the cervix 127
- competing 'attractors' 243
- connective tissue 43
 - and incontinence 59
 - and pregnancy hormones 46
 - balance and imbalance 57

- causes of damage 48
- damage 50
 - effect of age on 46
 - form and function 47
 - incontinence 59
 - in pelvic floor function 43
 - monofilamentous mesh 137
 - role of tension 40
 - stress extension curve 50
 - structural effects of damage 48
 - structural effects of damaged 48
- connective tissue laxity 50,63
- constriction ring 171
- continence 235
- continuous leakage 62
- continuous leakage, urine 114
- contradictory data, Chaos Theo 240
- cortex 40,41,114,227,240
- cortical inhibition 115
- cough transmission ratio 116,230,232
- cystocoele 62,105,161,168,247
 - bridge repair of 170
 - double breasted repair of 173
 - repair 173
 - repair with TFS 174
- cystometric diagnosis 227
- cystometric filling 115

D

- decompensation 211
- detrusor 39
- detrusor 'spasms' 40
- detrusor acontractility 63,117
- detrusor contraction 236
- detrusor dyssynergia 117
- detrusor expulsion pressure 240
- detrusor instability
 - 50,63,114,227,235,240,242
 - and Chaos Theory 240
 - control of 236
 - control of by pelvic floor 236

cough activated 116
 diabetic patients 129
 Diagnostic Summary Sheet
 anatomical basis for 106
 dissection plane 128
 double breasted repair 173
 Douglas 128
 dribble incontinence 62
 dynamic anatomy 7
 dynamics of the striated pelvic floor muscles
 30
 dynamic equilibrium 240
 dynamic mapping with 'simulated opera-
 tions' 252
 dysfunction 47
 dyspareunia 127,131
 dyssynergia 117

E

elastometer 238
 embolism 129
 enterocoele 191,196,200
 external anal sphincter 7,228
 external striated muscle forces 36
 external urethral ligament 105
 clinical signs 108
 repairing 149
 extrinsic opening mechanism 115

F

faecal incontinence 107
 fascia
 cadaveric 142
 prolapsed 138
 tensile strength of 128
 tensioned 138
 fascia, interconnectedness 190
 tensile strength of 128

fascial sheets 188
 Fascia of Denonvilliers 188
 fast-twitch muscle fibres 40
 fast-twitch striated PCM muscles 243
 feedback control, mathematical testing of
 244
 feedback equation 240
 fibromuscular supports of the vagina 187
 finite element model 260
 Fistula 143
 fistula formation 209
 foetal head 162
 form and structure 10
 fractals 239
 frequency 41,63
 functional anatomy 8

G

genuine stress incontinence 62,101,116
 giant cells 137
 glycosaminoglycans 43
 Goebell-Franegenheim-Stoeckel sling 153
 Goeschen 183
 granulation
 Mersilene tape 144

H

haematoma 209
 haemostat 232
 Hagen-Poiseuille's Law 229
 hammock 30,105,230,232,247
 laxity 46
 repairing 149
 role of 146
 herniation 127,190
 hormones 46
 24 hour urinary diary 97,274
 hydrostatic pressure 41,233

at the bladder base 44
 of the urine 228
 hysterectomy 47,187
 hysterectomy scar 201

I

incontinence
 daytime 265
 I-plasty 181
 idiopathic faecal incontinence 259
 inability to micturate 115
 incontinence 62,240
 daytime
 symptoms, variability with structures 105
 indications
 for posterior zone surgery 194
 infection
 clinical 145
 low grade 209
 low grade 145
 infracoccygeal sacropexy 197
 inhibitory centres 40,241
 initiation of flow 62
 insensible urine loss 194
 insensitive stretch receptors 105
 insertion of the tunneller 197
 Integral Theory 259
 Integral Theory Diagnostic Support System
 101,261
 Integral Theory Diagnostic System 77
 internal anal sphincter 250
 location 249
 International Continence Society 113,226
 interrupted flow 62
 interstitial Cystitis 3
 interstitial cystitis 263
 intra-abdominal pressure 161
 intra-abdominal pressure, origin of 230
 intraurethral resistance 58,240
 intrinsic sphincter defect 46,115,147,149
 intussusception, vaginal 44,187

ischial spine 196
 ischiorectal fossa 209

L

labium minus 181
 labium minus flap graft 184
 laxity and pelvic pain 46
 laxity in connective tissue 121
 laxity in the hammock 46
 lax hammock 107
 lax perineal body 249
 lax posterior ligaments 226
 lax uterosacral ligaments 62
 lax vaginal membrane 50
 leakage
 unconscious 147
 levator plate 7,30,36,148,187,190
 ligamentous insertions 44
 ligaments and fascia, composition of 19
 longitudinal muscle of the anus 7,30,34,249
 lower layer muscles of the pelvic floor 27,28
 low bladder capacity 63
 low compliance 240

M

macrophages 136,137
 mechanical closure defects 62
 mechanical failure 59
 mechanical imbalance 59,61
 mechanical opening defects 62
 membrane 40
 mesh
 dyspareunia 142
 erosion 142
 foreign body reaction 143
 infection 143
 monofilament 133
 multifilament 133

obdurator fossa 138
 posterior sling 138
 posterior wall 204
 rejection 143
 scar tissue 142
 sexual activity 142
 sheets 142
 surfacing 143
 tissue tension 129
 mesh rejection 143
 microtransducers 235
 micturition 8,32,229,233,235,240
 after contraction 237
 controlled temporary unbalancing of 58
 neurological control mechanisms for 241
 normal 58
 normal 'after contraction' 237
 obstructed 61
 peripheral neurological control mechanism 40
 micturition reflex 39,50,114,233,241,242
 at low bladder volume 112
 central and peripheral 40
 mathematical testing of 244
 non-linear perspective 241
 normal 39,40
 premature activation of 234
 voluntary control of 235
 micturition x-ray 237
 middle and posterior prolapse 166
 middle and posterior zone x-rays 251
 middle zone
 cystocoele 248
 defect symptoms 108
 prolapse 167
 structures of the 161
 surgical repair of 167
 middle zone ultrasound
 assessment of 247
 identifying mesh 248
 midurethra 30,251
 mid urethral anchor 233
 minimally invasive surgerySur 118
 monofilament fibrils 134

motor urgency 63,113,148
 multifilament fibrils 134
 multiple operations 216
 muscle damage 43
 muscles
 contractile strength of 43
 muscles of the pelvic floor
 interaction of 31
 upper and lower 31
 muscle contraction 50
 muscle forces 50
 muscle spindles 39

N

nerve endings in ligaments and fascia 39
 neurological dimension 39
 neurologically-based dysfunctions 62
 neurological control mechanism for micturition 40
 neurological mechanisms 40
 neurological reflex 32
 nocturia 3,41,63,110,227
 nocturia, posterior defect 113
 nocturnal enuresis 107,265
 non-linear 226
 non-linear perspective of the neurological control 241
 non-linear system 240
 nullipara 63
 nulliparous 260

O

oestrogen 260
 operations
 multiple 216
 outflow obstruction 238
 overflow incontinence 62,117

P

pad tests 97
 explanatory notes 275
 paediatric urology ,266
 paraurethral approach 150,153
 paravaginal defect 161
 patient questionnaire 270
 pelvic anatomy, definition of 17
 pelvic diaphragm 228
 pelvic floor
 contraction 115
 forces 252
 function and dysfunction, overview 9
 mapping function and dysfunction of 226
 muscles of 30
 surgery 44
 pelvic muscle
 imbalance of forces 57
 relationship to to organs 6
 pelvic muscles 40
 pelvic pain 63,109
 pelvis organs
 and muscles 5
 urethra and bladder 4
 perineal body 7,28,203,251
 perineal ultrasound 275
 peripheral neurological control mechanism
 112
 peripheral neurological defects 63
 periurethral striated muscle 241
 Pictorial Diagnostic Algorithm 79
 pinch test 232,233
 Pousseuille's Law 36
 polypropylene
 mesh 131,209
 tapes 196,240
 posterior muscle fibres 40
 posterior striated muscles 39
 posterior TFS 201
 post-micturition dribble 62,117
 posterior fornix syndrome 194,263
 Posterior IVS

enterocoele 200
 operation for vaginal vault prolapse 196
 with apical defect repair 200
 Posterior IVS tape, role of the 200
 posterior zone
 indications for surgery 194
 structures of 187
 ultrasound assessment of 249
 posterior zone defect 227
 symptoms 109
 posterior zone fascia, interconnectedness
 of 187
 precervical arc of Gilvernet 20
 premature micturition reflex 114
 pressure transducers 228
 prolapse 77,200,226
 middle zone 167
 minor degrees of ,76
 uterine 190
 vaginal 190
 pubic symphysis 7
 pubocervical fascia 7,161,162,188,190
 pubococcygeus muscle 7,30,241
 puborectalis muscle 7,29,61,228
 anatomy of 29
 pubourethral ligament 7,30,105,230,247
 atrophy of 113
 strengthening of 148

Q

questionnaire responses, explanatory notes
 273
 quilting sutures 182

R

rapid cough stress test 97
 rectal perforation, risk of during vaginal
 repair 209

rectocoele
 direct repair 202
 rectocoele, high 194
 rectovaginal fascia 7,187,188,191,199
 rectovaginal space 193
 rectum 36
 perforation 209
 posterior wall 249
 reflexes, opening and closure 242
 reflex incontinence 116
 retention cyst
 bridge repair 211
 retention cyst following bridge repair 211

S

sacrum 7
 sail analogy 46
 scarring, foreign body induced 131
 sensory urgency 63,113,235
 sheet of mesh 204
 simulated operation 162
 dynamic mapping with 252
 sinus
 abdominal 145
 perineal 145
 skin graft to bladder neck 182
 sling
 midline 150
 paraurethral 153
 posterior repair 199
 suburethral 150
 suprapubic 153
 trans-obturator 154
 slow-twitch fibres 30
 slow-twitch muscle contraction 57
 slow twitch closure muscles 46
 smooth muscle 31
 space
 organs 138
 spaces
 organs 21

spindle cells 40
 squeezing 235
 staphylococci 130,146
 static anatomy 4
 streptococci 146
 beta haemolytic 130
 stress incontinence
 58,59,105,147,149,232,259
 posterior sling 213
 stress incontinence, mild 194
 stretch receptors 32,39,41,50,63,113,115,23
 3,235,243
 structure 43
 Structured Assessment Pathway 81
 Structured Assessment, Practical application
 102
 structure, suspension bridge analogy 10
 Structured Assessment Pathway 93
 structures of the middle zone 161
 structures of the posterior zone 187
 subclinical damage 211
 subtotal hysterectomy 47
 suburethral sling, tension-free 149,150
 surgery
 conceptual basis of 118
 conservation of tissue 120
 surgical repair
 of the middle zone 167
 paravaginal 169
 surgical restoration of vaginal elasticity 181
 symptoms
 ‘camouflage’ of 212
 persistence of 212
 post-operative dynamics of 212
 recurrent after surgery 211
 variability 104

T

tape
 erosion 209
 tape erosion in the vagina 145

- Tensile Strength of fascia 128
 - tension-free midurethral sling 150
 - tension-free suburethral sling, midline vaginal Ap 150
 - tension-free tape, suprapubic approach 150,153
 - tension-free tapes, midline vaginal approach 150
 - tethered vagina
 - Martius Skin Graft 183
 - tethered vagina syndrome 113,179
 - tethering, temporary 180
 - TFS
 - posterior sling 201
 - TFS paravaginal repair 173
 - three directional muscle forces 57,121,252
 - thrombosis 129
 - tissue
 - intestinal 142
 - porcine 142
 - tissue weakness 128
 - trampoline analogy 9,43
 - transducer 247
 - transverse rugae 162
 - trigone 20,232
- ## U
- ultrasound 93,227
 - assessment of the anterior zone 247
 - assessment of the middle zone 247
 - assessment of the posterior zone 249
 - at rest 255
 - during straining 255
 - funnelling on 108
 - midurethral anchoring 232
 - Trans Perineal 246
 - using the probe 246
 - ultrasound probe 246
 - unconscious incontinence 62,114
 - unconscious leakage 147
 - uncontrolled urine leakage 180
 - uninhibited micturition 113
 - unmyelinated nerve fibres 46
 - unstable opening and closure of the bladder 243
 - unstable urethra 114
 - urethra 36
 - collapsed 238
 - diameter of 61
 - functional obstruction 62
 - funnelling 226
 - funnelling on ultrasound 108
 - lower two thirds of 30
 - normal state of 33
 - obstructed 238
 - resting closed 33
 - upper parts of the 30
 - urethral cavity 149
 - urethral closure
 - at rest 57
 - mechanism 231
 - pressure 230
 - urethral constriction 131,148
 - urethral dilatation 238
 - urethral function during storage 115
 - urethral opening and closure 31,32,44
 - urethral opening and closure, dynamics of 30
 - urethral opening during micturition 36
 - urethral posterior wall 237
 - urethral pressure 115,235
 - dynamics of 230
 - measurement 231,233
 - profile 231
 - urethral relaxation 236
 - urethral resistance 61,117,227
 - and the pressure-flow relation 229
 - urethrocoele 147
 - urethrovesical geometry 246
 - urethrovesical junction 108
 - urethrovesical unit at rest 33
 - urgency 41
 - urge frequency 227
 - urge incontinence 240
 - urinary incontinence 2

urination, frequency of 2
 urine flow 238
 urine loss
 uncontrollable 240
 urodynamics 93,275
 anatomical perspective 227
 finite element model for 238
 of micturition 233
 urodynamic bladder instability 234
 urodynamic measurement 228
 urodynamic measurement, anatomical basis
 of 228
 urodynamic testing 226
 urogenital tissue 127
 uterine conservation 47
 uterine fibrosis 228
 uterine prolapse 190,195
 uterosacral ligaments 7,105,187,247
 uterosacral ligaments, damage to 194
 uterovaginal prolapse 48
 uterus 47
 as a 'keystone' 187
 conservation of 119,188

V

vagina 36,61
 avoid excision of 127
 biomechanics of the 44
 excision of 202
 fibromuscular supports of the 187
 vaginal membrane 39,50,233,242
 vaginal posterior wall 250
 vaginal prolapse 44
 vaginal surgery, day-care 126
 vaginal swab 130
 vaginal vault
 fascial support for 192
 prolapse 195
 valsalva closure pressure 231
 vault prolapse 195
 vesico-ureteric reflux ,266

vesicovaginal space 165
 vulvar vestibulitis 259,262
 Vulvodynia
 see Vulvar Vestibulitis 262
 vulvodynia 3

W

website, Integral Theory 262
 White
 operation 169

X

x-ray, anterior zone 248,250
 x-ray, coughing and straining 220
 x-ray, internal anal sphincter location 249
 x-ray, micturition 36
 x-ray, middle and posterior zone 251
 x-ray, posterior zone 249
 x-ray, role of in the diagnosis of ligamentous
 an 250
 x-ray, squeezing 220
 x-ray, urethral opening during micturition
 36
 x-ray, urethra micturition 36
 x-ray, urethra resting 33
 x-rays, diagnosis of ligamentous laxity 250

Z

zone of critical elasticity 57
 zone of critical elasticity 161
 zone of critical elasticity (ZCE) 179
 zone of damage
 diagnosis of 261

