# 399

Tang A[1], Kauffmann C[1], Madill S[2], Pontbriand-Drolet S[2], Dumoulin C[2]
***1.** CHUM, Université de Montréal, **2.** Institut Universitaire de Gériatrie de Montréal*

## 3-DIMENSIONAL EVALUATION OF LEVATOR ANI MUSCLE MORPHOLOGY AND MOVEMENT USING REST AND DYNAMIC MAGNETIC RESONANCE IMAGING OF THE PELVIC FLOOR IN CONTINENT AND INCONTINENT WOMEN: A PROOF-OF-CONCEPT STUDY

Hypothesis / aims of study
A novel semi-automated segmentation technique based on a shape-deformable high-resolution model of the levator ani muscle was developed to describe the morphologic movement characteristics of the muscle. Comparisons were performed for muscle movement direction and amplitude between rest, maximal contraction and Valsalva maneuver.

Study design, materials and methods
Women 60 years and older were recruited and included in the study if they were independently ambulatory and were either continent or reported at least weekly symptoms of mixed or stress urinary incontinence (MUI or SUI). Women were excluded if they reported other conditions or were taking medications likely to interfere with the study. Women who had contraindications to MRI scanning were also excluded. An experienced pelvic floor physiotherapist taught the women to perform PFM contractions correctly; this was confirmed by both vaginal palpation and dynamometry. MRI imaging in the axial plane was performed with a Siemens 3.0T Magnetom Trio, using an IPAT torso/pelvis coil centered at the symphysis pubis. Twenty high resolution slices were performed at rest in the axial plane with T2 weighted FSE sequences (field of view 24 x 24 cm, matrix= 512 x 256, 5 mm thick/1 mm gap, TR = 5120 ms, TE 134 ms, Bandwidth 130 Hz/pixel, scan duration 146 s). Dynamic acquisitions were performed with 8 slices in the axial plane with T2 weighted SSFSE sequences (field of view 24 x 24 cm, matrix 192 x 192, 10 mm thick / 0 mm gap, TR = 560 ms, TE 33 ms, Bandwidth 434 Hz/pixel, scan duration 10 s) during pelvic floor muscle maximal voluntary contraction (PFM MVC) and Valsalva respectively. The Valsalva effort was controlled by having the women blow into a standardized tube.

A high-resolution model of the levator ani was first created from a pelvic CT of a 67-year-old asymptomatic woman. MRI segmentation was performed in three steps: **A)** identification of 5 levator ani insertion points: lateral levator ani insertion at acetabulum level, midline coccygeal bone and bilateral anterior insertion of puborectalis muscle on pubic bone. **B)** Manual segmentation of the levator ani muscle at rest, PFM MVC and Valsalva was performed (Figure 1). **C)** The 3D levator ani model was deformed to fit the segmentation (Figure 2A). **D)** Movement amplitude and direction was measured for pairs of segmentation: [PFM MVC vs rest] and [Valsalva vs rest]. **E)** Antero-superior movement was coded in green and postero-inferior in red. Larger movement amplitude was represented with higher saturation values (Figure 2B and 2C). Length of maximum amplitude in either direction to detect muscle elevation or descent was recorded in millimeters. Comparisons were made using Student t test for independent samples. Significance was defined when $p<0.05$.

Results
Twenty women were evaluated with this semi-automated segmentation method: 9 continent asymptomatic volunteers and 11 incontinent (7 with MUI and 4 SUI). The segmentation technique was successful for all acquisitions and patients. The mean age of incontinent women was 69.8 ± 4.0 (mean ± SD) and asymptomatic volunteers were 68.1 ± 3.7. Maximal levator ani elevation during PFM MVC was 11.3 ± 4.8 mm for continent and 16.6 ± 15.1 mm for incontinent women, $p = 0.33$, difference not significant. Maximal levator ani descent during Valsalva was 14.1 ± 5.7 mm for continent and 15.9 ± 9.9 mm for incontinent women, $p = 0.63$, difference not significant.

Interpretation of results
Levator ani segmentation using MRI was previously performed at rest in the axial plane [1]. Most dynamic acquisitions were limited to the mid-sagittal plane [2]. We showed that it is possible to segment axial images acquired during a contraction or Valsalva. Lower resolution of fast acquisitions are compensated by using a shape deformable model of the levator ani [3]. Maximal muscle amplitude can be calculated from the 3D mesh renderings of the levator ani. Colored parametric maps allow rapid identification of underlying avulsion, tear or muscle weakness, which can be confirmed anatomically on multiplanar MRI images.

Concluding message
Pelvic floor segmentation using a shape-deformable high-resolution model is feasible. 3D models with color-coded maps may be used to detect movement amplitude and direction, thus quickly revealing avulsion, areas of weakness and paradoxical movement. Future studies with larger sample size may determine if there are movement differences between women with stress urinary incontinence, mixed urinary incontinence, prolapse and asymptomatic volunteers.

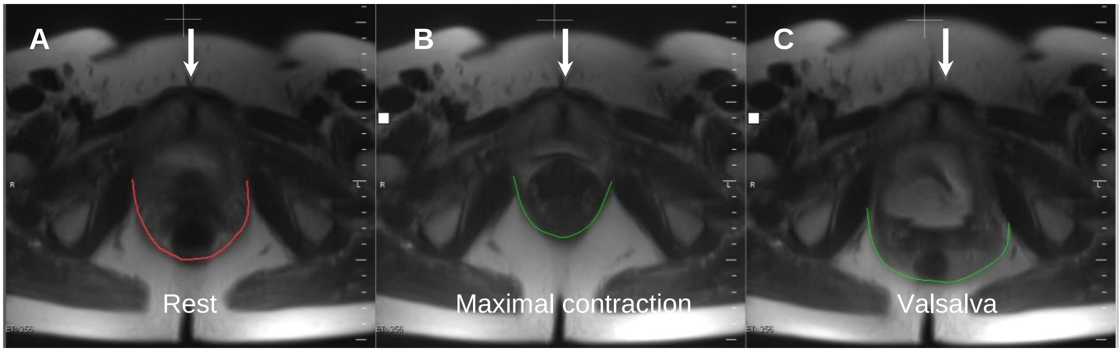


**Figure 1:** Axial MRI images at rest (A), maximal contraction (B) and Valsalva (C) in 71-year-old woman with mixed urinary incontinence. Levator ani muscle segmentation (green lines) is performed at the same level. Pubic symphysis (white arrow) and ischium are seen on all three images.

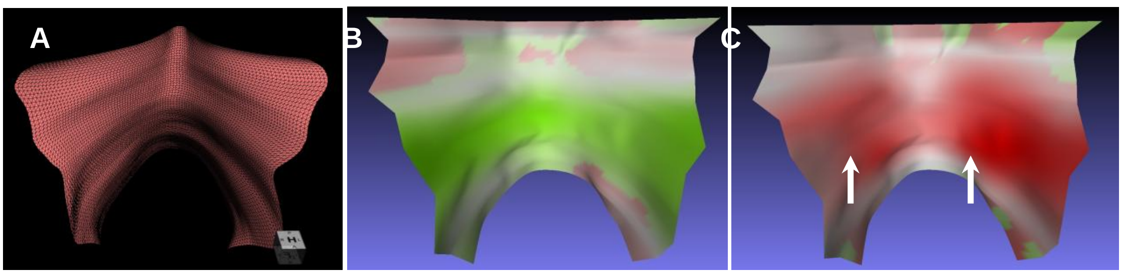


**Figure 2:** 3D mesh rendering of levator ani at rest viewed in the antero-posterior axis (A).
Morphologic changes between maximal contraction and rest (B), and Valsalva and rest (C) are shown with color coded. Green pixels indicate mostly antero-superior movement during contraction whereas red pixels indicate postero-inferior levator movement during Valsalva. Areas of saturated red color (white arrows) reveal symmetrical levator descent at a glance.

References

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| ***Is this a clinical trial?*** | **No** |
| ***What were the subjects in the study?*** | **HUMAN** |
| ***Was this study approved by an ethics committee?*** | **Yes** |
| ***Specify Name of Ethics Committee*** | **Comité mixte d'éthique - Regroupement Neuroimagerie / Québec** |
| ***Was the Declaration of Helsinki followed?*** | **Yes** |
| ***Was informed consent obtained from the patients?*** | **Yes** |