727

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COMPUTATIONAL SIMULATION OF URETHRAL HYPERMOBILITY IN WOMEN

<u>Hypothesis / Aims of Study</u>

Urethral hypermobility results from weakening of urethral-supporting structures leading to downward displacement and rotation of the urethra. Urethral hypermobility is the most common cause of female stress urinary incontinence. However the precise mechanism by which this occurs remains unclear. In order to better understand how each anatomical structure of the female pelvic floor contributes to the mechanism of urethral hypermobility, a subject-specific pelvic modelling approach is utilized to perform a dynamic biomechanical analysis that simulates urethral hypermobility in women. The feasibility of this approach is demonstrated in this study by simulating dynamic urethral mobility during a Valsalva maneuver.

<u>Study design, materials and methods</u>

The subject-specific pelvic model generation procedure is utilized to build a computational model of the female pelvis of a female subject from her high resolution MR images, as shown in Fig. 1. The pelvic model consists of over 35 anatomical parts including 10 pelvic muscles, 10 pelvic ligaments, etc., and represents the most comprehensive model in the field. A stiff stick used in Q-tip test is also modelled in the urethra for the urethral hypermobility simulation.

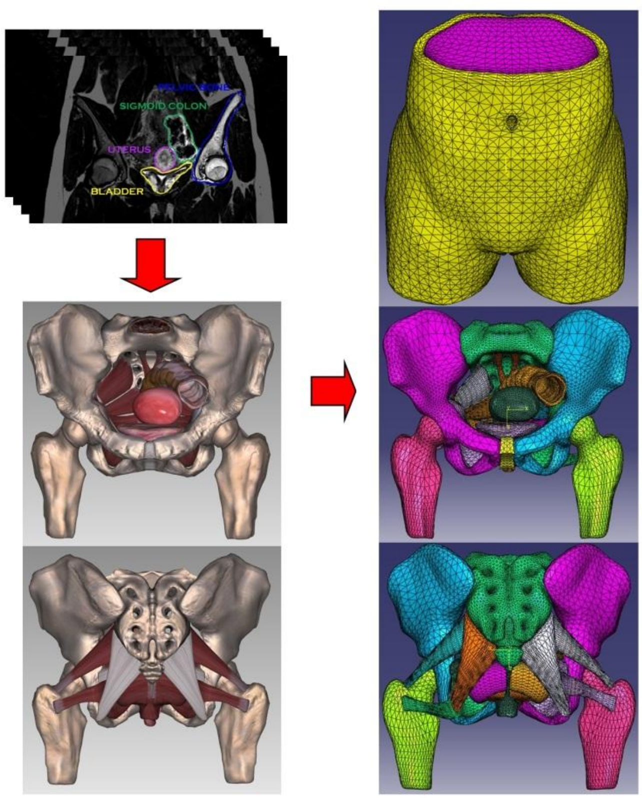

Fig 1: MR image subject-specific pelvic model generation procedure.

A special part is designed in the pelvic model to describe the outer surface of internal organs inside the pelvis as shown in Fig. 2, and intra-abdominal pressure (IAP) is employed as model input via this special part to form the model load of the computational model for the urethral hypermobility simulation. Dynamic fluid-structure interaction finite element analysis is then performed to simulate dynamic biomechanical responses of the urethra and bladder neck induced by the increase of the IAP. The angle difference which is defined as the urethral angle with straining minus the urethral angle at rest is calculated from the simulation results.

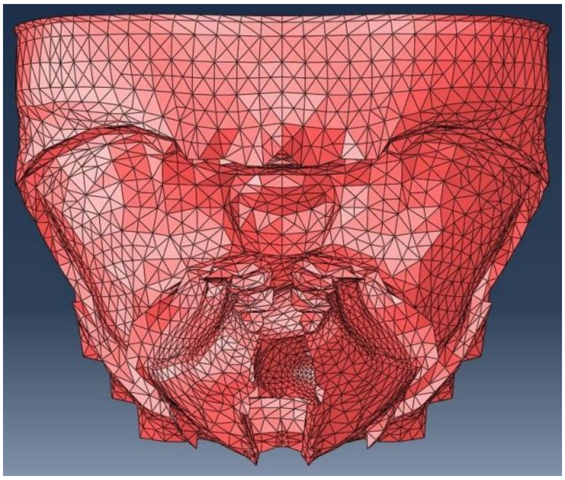
Fig. 2: The special part designed in the pelvic model to model the intra-abdominal pressure input.

Results
As a feasibility study, an IAP of 100 mm Hg was assumed in the present Valsalva simulation. Fig. 3 shows the displacement distribution over the bladder surface induced by the increased IAP and the angle difference between the urethral angle at the peak IAP and the urethral angle at rest. Dynamic biomechanical response of the bladder neck and urethra of this subject indicated her urethral mobility was also achieved from the dynamic FSI analysis results but could not be shown here. A video will be presented at the ICS conference to demonstrate the capability of the subject-specific pelvic modelling approach in dynamically simulating the biomechanical responses induced by IAP changes.

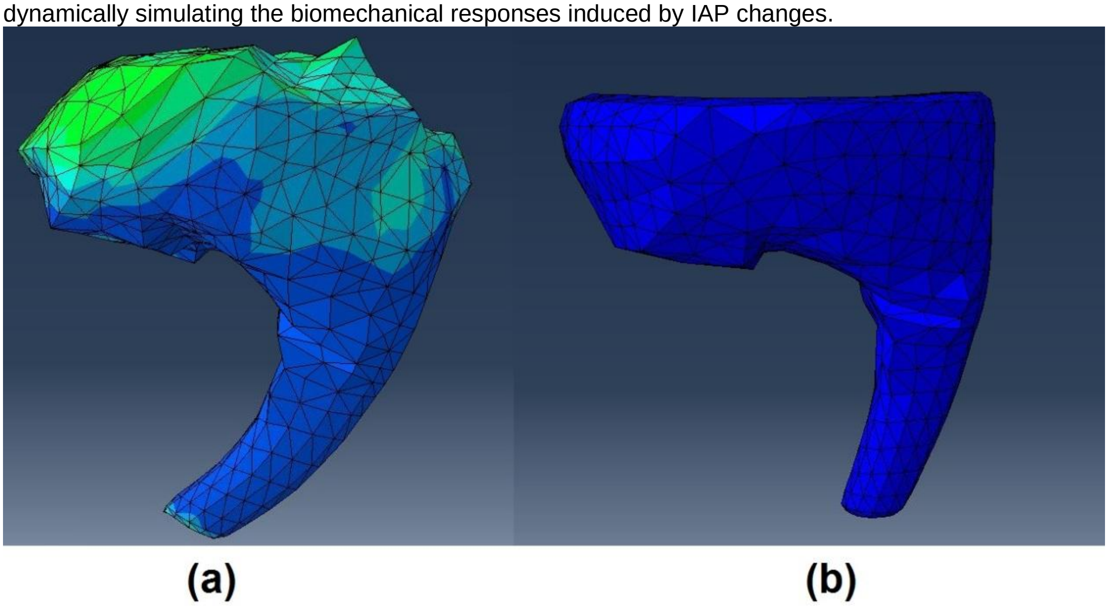

Fig. 3: (a) shows the displacement distribution over the bladder surface induced by the increased IAP. The urethral angle difference is indicated by comparing (a) and (b).

Concluding message
The feasibility of utilizing a subject-specific pelvic modelling approach to assess urethral mobility during a Valsalva maneuver was demonstrated in the present study. The angle difference between the urethral angle at peak IAP and the urethral angle at rest can also be calculated from the simulation results. A future parametric study will be conducted by utilizing the subject-specific pelvic modelling approach to investigate the contribution of changes in anatomical geometry and mechanical tissue properties to the occurrence of urethral hypermobility.

Disclosures
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