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A VALIDATION STUDY OF A SUBJECT-SPECIFIC PELVIC MODELLING APPROACH IN ASSESSING THE URETHRAL SUPPORT FUNCTION

Hypothesis / aims of study

Existing computational models for pelvic floor research are either lack of structural integrity or subject-specificity of the pelvic floor. The hypothesis of this study is that a subject-specific computational pelvic model reconstructed from MRI images can accurately capture pelvic floor activities. The aim of this study is to validate a subject-specific pelvic modelling approach in assessing the urethral support function in women which is associated with female stress urinary incontinence (SUI).

Study design, materials and methods

High resolution MR images of the pelvis were taken from an asymptotic female volunteer. A comprehensive pelvic model was developed for the subject from her specific MR images, by using a series of commercially available Computer Aided Design/Engineering (CAD/E) software packages [1]. MR images were initially segmented and contoured in VITREA 4.0 (Vital Images, Inc., Minnetonka, MN) and reconstructed into a 3-dimensional (3D) closed surface for each anatomical part with MIMICS 11.0 (Materialise Group, Leuven, Belgium). The closed surface models were then further imported into MAYA 8.5 (Autodesk, Inc., San Rafael, CA) for artifact smoothing under the guidance of a urologist to minimize the numerical calculation error in the future FE analysis while maintaining the integrity of the natural anatomic structure. The 3D surface models were finally meshed and assembled in ABAQUS 6.12 (Simulia, Providence, RI). The assembled 3D pelvic model contains a total number of 29 anatomical parts including pelvic muscles, ligaments, bones, fat tissue, bladder, urethra, uterus, vagina, colon, rectum and anus (Figure 1).

Dynamic MRI scan was also taken in the midsagittal plane of the subject during Valsalva. An increasing intra-abdominal pressure (IAP) of 80 cmH_2O was employed in the subject's specific-pelvic model for dynamic biomechanical analysis. The validation study was performed by comparing the dynamic deformation generated from the dynamic biomechanical analysis in the midsagittal plane of the pelvis against that captured with the dynamic MR scan. Particular attentions were paid to the bladder neck motion and the urethral angle change.

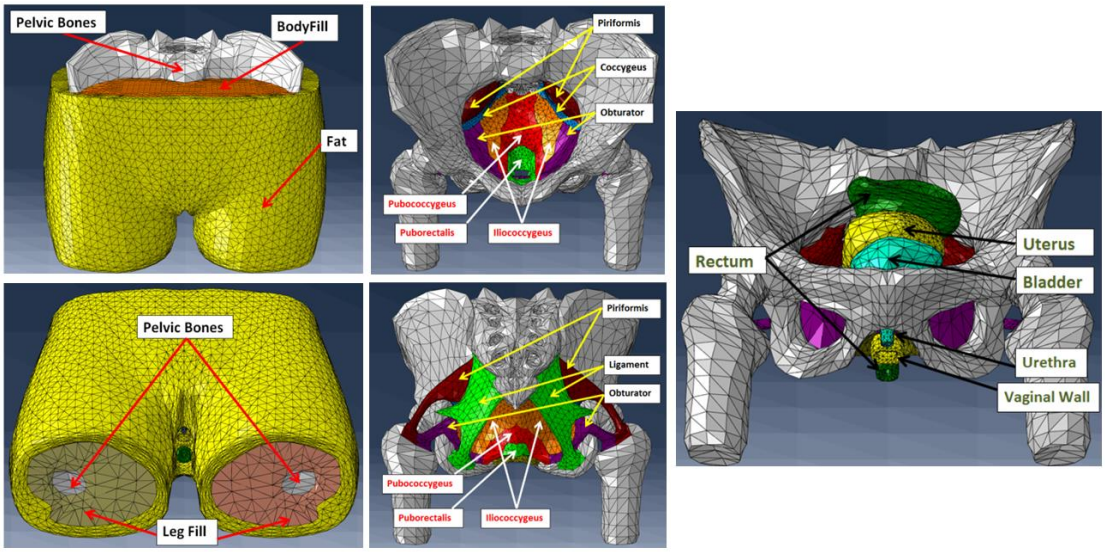

Figure 1. Subject-specific computational pelvic model

Results

Figure 2 compares the pelvic structure changes (dynamic MRI vs. computational pelvic model) at the sagittal plane at resting and Valsalva stages. The dynamic biomechanical analysis results revealed that bladder uterus and rectum slid towards the posterior direction under the elevated IAP. It was also observed that the deformation of the bladder caused the bladder neck displacement and urethral angle change, both of which are significant landmarks commonly used in SUI predictions. The dynamic MRI results demonstrate similar behaviours.

Dynamic MRI Computational Model

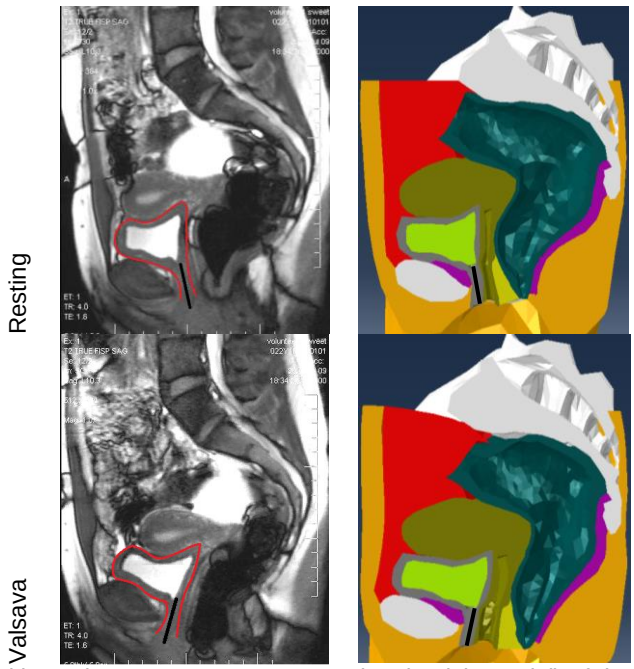

Figure 2. Comparison (dynamic MR scan Vs. Computational pelvic model) of the pelvic structure of the female subject in the sagittal plane, at resting stage and at Valsalva stage. The black solid line in all pictures show the position of urethra, and the red curves in the dynamic MRI show the outline of the bladder.

Interpretation of results

The computational pelvic model showed highly consistent pelvic floor motions and deformations with the dynamic MR imaging. The dynamic displacements of internal pelvic organs (such as rectum, uterus, vaginal wall and urethra) and the urethral angle change were successfully simulated by the subject-specific pelvic modelling approach.

Concluding message

The subject-specific pelvic modelling approach demonstrates great competence in simulating dynamic responses of the pelvic floor and organs, and therefore can be employed for predictive and evaluative tasks in various pelvic floor dysfunctions.

References

1. Zhang, Y., et al., Advanced finite element mesh model of female SUI research during physical and daily activities. Stud Health Technol Inform, 2009. 142: p. 447-452.

Disclosures

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