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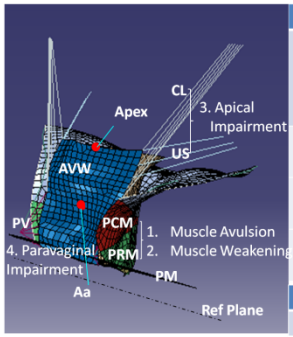
ON THE RELATIVE CONTRIBUTIONS OF MUSCULAR AND CONNECTIVE TISSUE SUPPORT SYSTEM TO THE ANTERIOR VAGINAL WALL SUPPORT: A BIOMECHANICAL 3D FINITE ELEMENT MODEL SENSITIVITY ANALYSIS

Hypothesis / aims of study

To investigate the effect of combinations of levator weakening or avulsion combined with apical and paravaginal connective tissue impairments to the decent of anterior vaginal wall using a biomechanical 3D finite element models.

Study design, materials and methods

A subject-specific 3D finite element model was developed based on an MRI of a woman with anterior vaginal wall prolapse and unilateral levator avulsion using 3D Slicer v 2.6 and simplified using Imageware 13.0 ^{TM}. A normal model and a bilateral defect model have been constructed by mirroring the normal and defect side respectively. The models were then imported into Abaqus 6.8 ^{TM}, a finite element analysis program, assigned the tissue properties and loaded with 165 cmH_2O intra-abdominal pressure. Four different impairments in the support system were investigated using these models. Levator ani muscle avulsion injury was simulated using model with unilateral, normal and bilateral muscle geometry. Levator ani muscle weakening and two connective tissue impairments in apical support and paravaginal support were simulated by assigning impaired material property. We conduct the sensitivity analysis to characterize the effect of each impairment structure on the anterior vaginal wall support. The sensitivity analysis were performed using a using a 2^3x3 factorial design (one variant of the Design of Experiments method) in Abaqus 6.8 ^{TM} to assess all possible combinations of site impairments as shown in Figure 1. Anterior vaginal wall descent was been evaluated at point Aa and apex relative to a hymenal reference plane. The relative theoretical contributions of those four types of impairment to the descent of anterior vaginal wall have been quantified as their effect on Aa and apex decent, which were determined by calculating the their main effect, an aggregate measure that estimates the overall impact on the dependent variable by comparing all of the models.



Independent Variables	Levels
1. Muscle Avulsion	No avulsion (normal)
	Unilateral avulsion
	Bilateral avulsion
2. Muscle Weakening	Normal
	90% Weakening
3. Apical Impairment	Normal
	90% Impairment
4. Paravaginal Impairment	Normal
	90% Impairment
Dependent Variables	
Aa and Apex distance to reference plane	

Figure1. Left panel shows the unilateral defect finite element model resting geometry in oblique view where the right pubococcygeal muscle is missing including: AVW: anterior vaginal wall; PCM: pubococcygeus muscle; PRM: puborectalis muscle; ICM: iliococcygeus muscle; CL: cardinal ligament; US: Uterosacral ligament; PV: Paravaginal support; PM: perineal membrane. Four different impairments were selected as independent variables and the levels of impairment used in sensitivity analysis showed in the table on the right. Aa and apex locations are shown as the red dots and their distance from reference plane used as dependent variables.

Results

Results are shown in Figure 2.

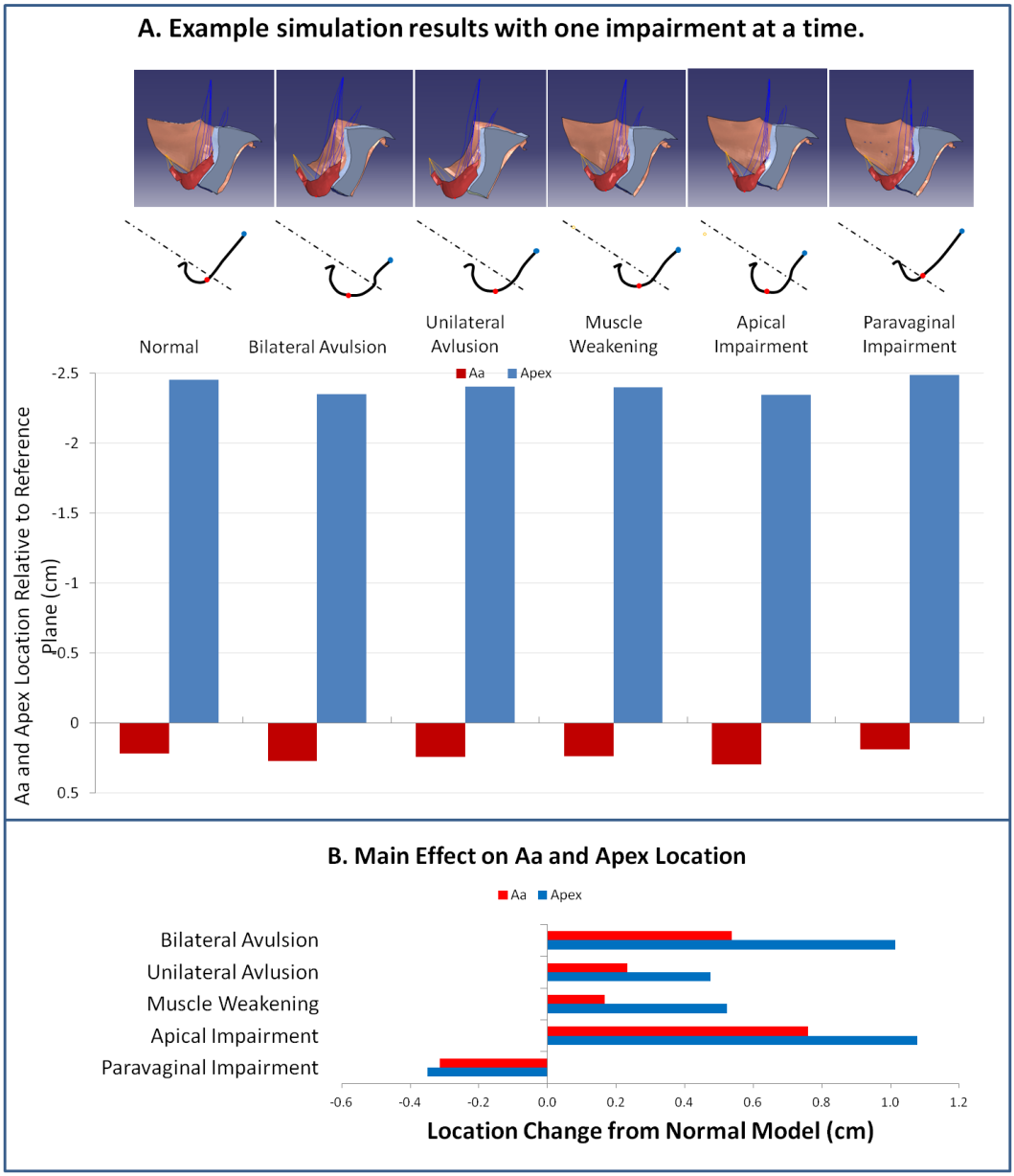


Figure 2. Panel A. Example simulation results with one impairment at a time. Simulation results and tracing of deformed anterior vaginal wall in mid-sagittal plane were shown in standing view. The dotted line indicates the reference plane and red and blue dots mark the location of Aa and apex location. Bar graph shows the Aa (Red) and Apex (Blue) location relative to reference plane with positive number indicating the number of center meters outside of the body. Panel B. Result of sensitivity analysis shows the main effect of four impairments on Aa, and Apex of anterior vaginal wall location deviated from normal model.

Interpretation of results

Apical support and the bilateral levator ani muscle avulsion are most influential parameters in the anterior vaginal wall descent. Surprisingly the influence of paravaginal impairment is in opposite direction as other types of impairment.

Concluding message

Sensitivity analysis of 3D finite element model of anterior vaginal wall support system reveals that apical connective tissue support and bilateral levator ani avulsion are two most influential impairment sites to the anterior vaginal wall support.

Disclosures

Funding: R01HD38665 1P50HD44406 HD004438 **Clinical Trial:** No **Subjects:** HUMAN **Ethics Committee:** University of Michigan Institutional review board **Helsinki:** Yes **Informed Consent:** Yes