MR based 3-dimensional modeling of the normal female pelvic floor with quantification of muscle mass

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Objective: Stress urinary incontinence and pelvic floor prolapse are important women's health issues, which affect 10 million American women at a cost of approximately 10 billion dollars annually [1]. Although significant research has been performed, the anatomic basis of incontinence and prolapse remain elusive and therapies have not been optimized [2]. Conventional 2D MRI has been used to assess the anatomy of the female pelvic floor in cadavers and incontinent women [3]. Three dimensional imaging, although not yet extensively evaluated, has the potential advantages of quantification of muscle volume, which may be valuable in the evaluation of pelvic floor disorders, and more accurate representation of the 3D relationships necessary for surgical planning. Our objective was to use MR based 3D models to demonstrate and quantify the normal appearance of the female pelvic floor in order to better understand the anatomy of the specific anatomic structures responsible for maintaining support.

Materials and Methods: We recruited 10 young (mean age = 27 yrs, range 22-33 years), nulliparous, continent female volunteers. One woman had undergone resection of an ovarian cyst, the remaining women denied previous pelvic surgery. All women underwent MR imaging of the pelvis using a 1.5T magnet (Signa 1.5, GE Medical Systems, Milwaukee, WI) and a pelvic phased array or torso coil wrapped around the pelvis. T2-weighted images were obtained in the axial plane using the following imaging parameters: TR=4200ms, TE (eff)=108ms, 128 phase encodes, 24cm field of view, 3mm slice thickness, interleaved, 2 acquisitions. The entire sequence was repeated adjusting the slice locations to obtain contiguous images 1.5mm in thickness. The images were electronically transferred to a workstation and interleaved. The data were first segmented into anatomically significant components including bones, bladder, urethra, vagina, uterus, rectum, obturator internus and the 3 major components of the levator ani (puborectalis, iliococcygeus, and coccygeus) using manual editing. From these images, 3D renderings of the pelvic viscera as well as supporting muscles and bones were reconstructed using the marching cubes algorithm and a surface rendering method. The final results were viewed on a workstation with graphics acceleration and 3D slicer software (developed in-house) allowing visualization and measurement of source images and 3D models simultaneously. Two radiologists reviewed each case in consensus and recorded width of the levator hiatus, width and signal intensity of the puborectalis, signal intensity of the obturator externus, vaginal shape (H-shape, flattened, or asymmetric), presence or absence of the lateral pubovesical ligaments, angle of the levator plate, distance from the bladder neck to the symphysis and the pubococcygeal line, posterior urethrovesical angle, and volume of the levator ani.

Results: High quality source images were obtained and models generated in all 10 cases. The mean width of the levator hiatus, measured at the level of the transverse urethral ligament, was 41.7 +/- 11.2mm. The right side of the puborectalis was consistently thinner than the left with mean thickness of 2.3+/-0.5mm versus 4.6+/-0.7mm. The average signal intensity of the puborectalis was 45.1+/-12 compared with 30.1+/-5.8 for the obturator externus muscle. The volume of the combined coccygeus, puborectalis and iliococcygeus was 47.2+/- 7 ml, range 39.4-59.4ml. Five women had H-shaped vaginas, while 4 were flat and 1 was asymmetric. The lateral pubovesical ligaments extending from the urethra to the arcus tendineus fascia were visible in all 10 cases. The mean distance from the bladder neck to the pubococcygeal line was 21.7mm+/- 4.2mm and to the symphysis was 21.5+/-5.3mm. In 6 cases, the levator plate was parallel to the pubococcygeal line. In the remaining 4 cases, the levator plate formed an angle with the pubococcygeal line ranging from -4 to 18 degrees, mean=10 degrees. The mean posterior urethrovesical angle was 143.5+/-10 degrees.

Conclusions: There was remarkable consistency of the signal intensity and morphology of the levator ani in young, nulliparous women as demonstrated by axial MR source images and 3D models. The increased signal intensity of the puborectalis compared with the obturator externus may indicate less fat within the muscle supporting the pelvic floor. The volume of the levator ani was somewhat more variable, although all muscles were judged intact. The location of the bladder neck close to the symphysis and above the pubococcygeal line as well as the horizontal orientation of the levator plate were expected findings in continent women. The average posterior urethrovesical angle was larger than that derived from VCUG studies (normal <115 degrees) likely because our measurements were taken from the posterior surface of the urethra, rather than the lumen, generating a more obtuse angle.

References

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