UROLOGY

Estimated levator ani subtended volume: a novel assay for predicting surgical failure after uterosacral ligament suspension

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BACKGROUND: Levator ani muscle complex plays an important role in pelvic support and defects or laxity in this muscle complex contributes to pelvic organ prolapse and recurrence after surgical repair.

OBJECTIVE: The purpose of this study was to determine whether estimated levator ani subtended volume can predict surgical outcomes for laparoscopic bilateral uterosacral ligament suspension.

STUDY DESIGN: A retrospective cohort study was performed in patients who underwent laparoscopic uterosacral ligament suspension from 2010-2012. Only patients with a preoperative pelvic magnetic resonance image were included. *Surgical failure* was defined as a composite score that included the presence of anatomic bulge beyond the hymen with sensation of vaginal bulge or repeat treatment for prolapse via pessary or surgery by 1-year follow-up evaluation. Standard protocol pelvic magnetic resonance imaging measurements pubococcygeal line, H-line, and M-line were collected along with the calculation of the width of the levator ani hiatus. Estimated levator ani subtended volume was calculated for each subject. An optimal cutoff point was calculated and compared against categoric values of surgical success/failure. A Fisher exact test, an area under receiver operating characteristics curve, and logistic regression analysis were performed. A probability value of $<.05$ was considered statistically significant.

RESULTS: Ninety-three women underwent laparoscopic bilateral uterosacral ligament suspension during study period. Of these, 66 women had a standardized preoperative pelvic magnetic resonance image per institutional protocol. Thirteen patients (19.6%) met the criteria for surgical failure by 1 year. An optimal cutoff point of 38.5 was calculated by Liu's method for optimization. Among the patients with defined surgical failures, 84.6% (11/13) had an estimated levator ani subtended volume above cutoff point of 38.5. Among the patients with defined surgical success, 39.6% (21/53) had an estimated levator ani subtended volume above the cutoff point (84.6% vs 39.6%; $P = .0048$) with a significant odds ratio of 8.38 (95% confidence interval, 1.69—41.68; $P = .009$). An area under receiver operating characteristics curve of 0.725 (95% confidence interval, 0.603—0.847), sensitivity of 84.6% (95% confidence interval, 54.6%—98.1%), and specificity of 60.4% (95% confidence interval, 46%—73.5%) at 38.5 were predictors of surgical success/failure by 1 year. Logistic regression analysis demonstrated no significant confounders among age, body mass index, stage, or parity.

CONCLUSIONS: Estimated levator ani subtended volume may predict surgical failure for laparoscopic bilateral uterosacral ligament suspension. Patients with a calculated estimated levator ani subtended volume above 38.5 on a preoperative pelvic magnetic resonance imaging were associated with an increased risk for surgical failure by 1 year, regardless of age, body mass index, stage, or parity. Future investigation that will include repeatability, reliability analysis, and a prospective study is warranted.

Key words: levator ani muscle, levator ani subtended volume, magnetic resonance imaging, pelvic organ prolapse, surgical outcome

Approximately 200,000 women will undergo a surgical procedure for pelvic organ prolapse (POP) in the United States each year, with projections of this number expected to double within the next 30 years.[1,2] Additionally, 1 of 6 of these women will undergo a second surgery for recurrence of prolapse.[3] Although the pathogenesis of POP is multifactorial, childbirth and vaginal parity have been identified as strong risk factors for the development of POP.[4,5]

More than 30% of women who deliver vaginally will have direct trauma to their pelvic floor that will result in injury to the levator ani muscle.[5] Pelvic magnetic resonance imaging (MRI) and ultrasonography both independently have demonstrated pelvic floor trauma in women after childbirth.[6-8] Avulsion of the levator ani muscle from insertion points on the inferior aspect pubic bone that resulted in weakening of the muscle complex was detected in 15-36% of parous women on pelvic MRI and ultrasound images.[6-8]

The levator ani muscle encircles the largest potential hernia portal in the human body and is the gatekeeper for passage of pelvic organs resulting in POP.[9] Weakening of this muscle complex is currently the best-defined pathogenesis for POP.[9] Strong correlations have demonstrated enlargement of this portal within the levator ani muscles to be related directly to the presence of POP.[5,10]

Studies have confirmed levator ani avulsion as a risk factor for the development of POP.[11,12] Women with levator ani avulsions that were detected on pelvic MRIs had a 7.3 odds ratio (OR) for POP when compared with a matched control group.[11] Additionally, levator ani avulsion has been demonstrated to be a clinical predictor of cystocele recurrence after anterior colporrhaphy with native

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tissue and anterior colporrhaphy with the usage of mesh.[13,14]

Levator ani muscle morphologic condition that was demonstrated with pelvic 3-dimensional MRI images established a relationship between the size and shape of the entire muscle complex to pelvic floor dysfunction and prolapse.[15] Women with advanced-staged POP demonstrated increased laxity of the muscle complex that altered the anatomic shape of the muscle and correlated to worsening pelvic floor dysfunction.[15]

Anatomic changes in the levator ani muscle complex that result in weakening of the pelvic floor are described in DeLancey's[16] and Norton's[17] "boat in a dry dock" theory. We applied DeLancey's and Norton's theory for our hypothesis that decreased support of the levator ani muscle within the pelvic floor will result in an increased strain on the supportive uterosacral ligaments after a laparoscopic bilateral uterosacral ligament suspension (USLS) and result in increased risk of recurrence for POP after pelvic reconstructive surgery.

The aim of this study was to assess the utility of standard protocol preoperative pelvic MRIs to evaluate levator ani muscle integrity for the prediction of surgical outcomes after an apical reconstructive surgical procedure. Rodrigues et al[18] developed a reliable objective measure of levator ani muscle laxity using a 3-dimensional MRI pelvic measurement defined as levator ani subtended volume (LASV). LASV is an objective measure of volume held within a levator ani muscle complex. Consider the muscle complex as a kitchen bowel that is filled with water; LASV is the measurement of the volume of the water. Their group further developed a simplified method for estimating LASV (eLASV) from standard 2-dimensional MRI measurements as an indirect measurement of the volume that is contained by the levator ani muscle.[19] In this study, we sought to determine whether eLASV can predict surgical outcomes for laparoscopic bilateral USLS.

Materials and Methods

This was an Institutional Review Board–approved retrospective cohort study at a tertiary care center, University of South Florida, of all patients who underwent laparoscopic bilateral USLS from 2010-2012. Patients were identified on review of operative notes during the study time period. Patients were included in the study if they underwent the aforementioned surgery and had a preoperative standard protocol pelvic MRI at our institution within 1 year before their surgical date. Demographic, clinical, surgical, radiologic, and follow-up data were reviewed and collected as a secondary analysis (●●●●; ●●●●; personal communication of unpublished data). Patients were classified as surgical failure based on a composite score defined by the following information: presence of anatomic bulge beyond the hymen with sensation of vaginal bulge or the need for repeat treatment for prolapse via pessary or surgery by 1 year follow-up evaluation.

Imaging protocol

Each pelvic MRI was performed on a standard 3-Tesla system (General Electric Company, GE Healthcare, Buckinghamshire, UK) with the use of an 8-channel torso phased-array coil with the patient in the supine position. Standard imaging for detailed anatomic evaluation of the pelvic floor muscles was performed with the use of T2-weighted fast-recovery-fast-spin-echo sequence acquired in the axial, coronal, and sagittal planes. Before imaging, 60 mL of contrast gel was placed in the rectum for visualization of the colon.

Static standard protocol pelvic MRI measurements at rest were collected from the departmental radiology report from the University of South Florida. The measurements included the pubococcygeal line (PCL), H-line, and M-line measured at rest from 2-dimensional midsagittal pelvic static images as read by a board-certified radiologist. The measurements were collected per previously defined guidelines by Law and Fielding.[20] The PCL was determined as a linear measurement from the inferior border of the pubic bone to the last visible horizontal sacrococcygeal joint. The *H-line* was defined as the distance from inferior symphysis pubis to the posterior anorectal junction that is indicative of the anterioposterior length of the levator hiatus; the M-line was drawn perpendicularly from the PCL to the most distal aspect of the H-line, which is indicative of the descent of the levator hiatus from the PCL.

The width of the levator ani hiatus (WLH) was measured from 2-dimensional axial pelvic static images at rest as previously described in publication.[19] The *WLH* is defined as the widest measurement between the inner boundaries of the levator ani muscles perpendicular to the midline axis of the image and measured immediately inferior to the symphysis pubis as demonstrated in Figure 1. All measurements that were collected for H-line, M-line, and WLH were collected and recorded in millimeter dimensions. The estimated LASV was then calculated for each patient based on previously published mathematical equation: eLASV = −72.838 + 0.598 H-line + 1.217 M-line + 1.136 WLH.[19]

Statistical analysis

Statistical analysis was performed with Stata software (version 13.1, Stata Statistical Software: Release 13; StataCorp LP, College Station, TX). An optimal cutoff point was calculated with the use of Liu's method by maximizing sensitivity and specificity through the usage of the cutoff finder.[21,22] The optimal cutoff point was then compared against categoric values of surgical success/failure via a contingency table. Fisher exact test was performed to correlate eLASV to surgical success/failure. A probability value of $<.05$ was considered statistically significant. An area under a receiver operating characteristics curve was calculated to detect prediction assessment. A logistic regression analysis was then performed to evaluate for confounders.

Results

Ninety-three women underwent laparoscopic USLS during the study period. Of these, 66 patients met the criteria and were included in the study. Mean age was 58.6 ± 12.7 years; mean body mass index (BMI) was 27.7 ± 5.5 kg/m^2; median parity was 2 (range, 1–6), and median

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