Increasing Anteroposterior Genital Hiatus Widening Does Not Limit Apical Descent for Prolapse Staging during Valsalva's Maneuver: Effect on Symptom Severity and Surgical Decision Making

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Abstract

Objective: Determine if anteroposterior genital hiatus (GH) widening obscures rather than facilitates signs and symptoms, inadvertently altering management decisions for women with pelvic organ prolapse during Valsalva's maneuver, at a given total vaginal length (TVL).

Methods: We performed a retrospective cohort with nested cross-sectional study of patients who underwent pelvic organ prolapse (POP) surgery. Data from obstetric and gynecologic history, pre- and postoperative physical examinations, and PFDI-20 and PFIQ-7 scores were extracted. Study participants were compared in 2 groups: Anteroposterior widened (> 3 cm) and not widened (≤ 3 cm) GH, for baseline leading edge (LE), and POP stage, while controlling for TVL. Baseline PFDI-20 and PFIQ-7 scores were evaluated within GH groups. Delta GH, PFDI-20 and PFIQ-7 scores after apical suspension with and without posterior colporrhaphy were compared to assess the clinical value of the procedure.

Results: Study participants with anteroposterior GH widening during Valsalva's maneuver had greater baseline LE descent and higher POP stage than those without anteroposterior GH widening after controlling for TVL. Baseline PFDI-20 and PFIQ-7 scores were similar within both GH categories controlling for prolapse severity. Adding posterior colporrhaphy to apical suspension resulted in a greater anteroposterior GH reduction without improving delta PFDI-20 or PFIQ-7 scores.

Conclusion: Facilitation through herniation rather than obscuration from anteroposterior GH widening explains why patients will not be undertreated based on signs and symptoms of disease. Adding posterior colporrhaphy to apical suspension more effectively reduces anteroposterior GH widening without differential improvement in symptoms rendering the operation to no more than a cosmetic procedure.

Key Words: genital hiatus; posterior colporrhaphy; mesh augmented apical suspension; native tissue apical suspension; sacrocolpopexy; patient-centered

Single Sentence summary

Connective tissue repairs effectively reduce anteroposterior GH widening without providing differential improvement in symptom bother and impact on activities of daily living because they are incapable of restoring obstetric-related levator ani muscle damage.

Introduction

Pelvic organ prolapse (POP) is a common condition that affects millions of women worldwide, with 1 in 4 women reporting at least one pelvic floor disorder.[1-2] Women have a 12.6% lifetime risk of needing surgery for POP.[3] Approximately 200,000 inpatient surgical procedures for prolapse are performed annually in the United States.[4-5]

POP is diagnosed during physical examination using a staging system, most commonly the Pelvic Organ Prolapse Quantitation (POP-Q) system because it is objective, site-specific, and reliable.[6] Two POP-Q measurement points are the genital hiatus (GH) and perineal body (PB). GH is measured sagitally from the external urethral meatus to the posterior fourchette of the vagina using a ruler. Translabial ultrasound has also been used to measure GH in the POP-Q quantification system.[7-9]

Increasing GH size has been associated with greater POP, with GH ≥ 3.75 cm being predictive of apical support loss.[10] Studies have reported vaginal delivery as a risk factor for GH widening[11] due to traumatic injury to the levator muscles during childbirth.[12-14] Widened GH has been linked to increased risk of POP recurrence, likely related to persistent levator ani damage after surgical repair.[15-16] A wide urogenital hiatus has also been associated with an increased risk of early postoperative emptying disorders after POP surgical repair.[17] In multiple studies, widened GH measurements were linked to a decreased chance of pessary retention, a nonsurgical intervention for POP.[18-20] Evidently GH measurements have an important predictive value, making its inclusion in the POP-Q quantification system vital to the care of women with pelvic organ prolapse.

Anteroposterior GH widening as a consequence of traumatic obstetric injury is evident on examination during Valsalva maneuver. Anteroposterior GH widening appears to consume vaginal topography (Figure 1, x-axis) at the expense of leading edge (LE) descent (Figure 1, y-axis) in select patients on pelvic examination during Valsalva's maneuver. We were therefore concerned that at a given vaginal length, anteroposterior GH widening might obscure descent of the leading edge and therefore prolapse stage, resulting in differences in symptom severity, and impact on activities of daily living. This might inadvertently alter management decisions by health care providers for women with pelvic organ prolapse. For example, patients with a leading edge of 0 may be "inoperable[21]", while a leading edge of +1 to +2 may receive a uterosacral ligament suspension, and a leading edge ≥ +3 may receive obliterative or mesh augmented apical suspension because preoperative prolapse stage is a predictor of symptomatic recurrence[22-24].

We were unable to identify any existing research to allay our concerns. Our primary study objective was to design a study to test the null hypothesis that there would be no difference in baseline descent of the leading edge and therefore stage of prolapse, resulting in differences in symptom severity, and impact on activities of daily living controlling for prolapse stage for women with anteroposterior GH widening compared to those without anteroposterior GH widening during Valsalva's maneuver at a given vaginal length.

Surgical procedures designed to resolve POP and thus alter GH often involve posterior repair. The symptomatic value of posterior colporrhaphy at the time of POP surgery has reemerged as an inquiry of interest.[25] Our secondary study objective was to design a study to test the null hypothesis that there would be no differential change in symptom severity and impact on activities of daily living changes despite changes in GH and PB measurements when comparing prolapse repairs with and without posterior colporrhaphy.

Methods

We generated a computerized convenience sample list of patients who underwent POP surgical repair from an academic tertiary office from January 2009 and February 2015 using Current Procedural Terminology (CPT) codes 57425, 57120, 57282, 57283, 57110, and 58280. We chose a convenience sample because there was no data from the medical literature to calculate an a priori sample size to confidently accept our null hypothesis of no effect of anteroposterior GH widening on LE descent *at a given vaginal length* or PFDI/PFIQ *at a given stage of prolapse*.   Postoperative examinations, symptom bother and impact on activities of daily living assessments were obtained from the last recorded visit between 6 weeks and 18 months from date of surgery.

The POP surgical procedures included reconstructive (vaginal and laparoscopic) and obliterative approaches. All surgeries are typically performed within 30 days of preoperative POP-Q assessments minimizing the likelihood of disease progression prior to treatment. Two fellowship trained Urogynecology attendings with over 20 years of surgical experience directly supervised fellows in the performance of all surgical procedures.

An IRB approval was obtained and data was collected from medical records (electronic and paper). Data included basic demographics such as age, body mass index (BMI), race, and parity. Clinical data included history of operative delivery, laceration during delivery, pertinent past surgical history (including colporrhaphy, apical suspension procedures, and hysterectomy), preoperative POP-Q measurement, POP surgery type and date, date of last follow up visit, and postoperative POP-Q measurement.

POP-Q measurements during Valsalva's maneuver in the supine position were collected at the initial visit and each follow up visit. Standing examination was reserved for patients whose maximum vaginal wall descent based on patient recollection could not be demonstrably reproduced while supine. We defined the first visit examination as the preoperative POP-Q measurement and the last follow up visit as the postoperative POP-Q measurement, performed either by the fellow or attending physician of record. Patients were instructed to follow up at 6 weeks, 3, 6, 12, and 24 months postoperatively. The follow-up interval was defined as the time from surgery to the last postoperative visit recorded.

Responses from PFDI-20 and PFIQ-7 questionnaires were also collected to measure baseline and changes in symptom bother and impact on activities of daily living, respectively (delta scores = postoperative - preoperative scores, resulting in negative delta scores when interventions resulted in a decrease in symptom bother or improvement in impact on activities of daily living, respectively). Delta GH was calculated as the anteroposterior postoperative – preoperative measurements in centimeters resulting in a negative delta measurement when interventions resulted in an anteroposterior decrease or narrowing of the GH width. Delta PB was calculated as anteroposterior postoperative - preoperative measurements in centimeters resulting in a positive delta measurement when interventions resulted in an anteroposterior increase or lengthening of PB width.

<u>Primary objective through nested cross sectional study</u>

Patients were categorized into 2 groups based on anteroposterior GH size: widened GH, defined as > 3 cm, and not widened GH, defined as ≤ 3 cm, based on a compromise between the inflection point data for length of the anterior vaginal wall exposed to intra-abdominal wall pressure during Valsalva's maneuver and the GH width predictive of apical support loss[10,26]. Leading edge of prolapse (LE), and therefore POP-Q stage, was used to establish POP severity. Baseline differences in LE and POP-Q stage between GH groups while controlling for preoperative total vaginal length (TVL) measurement were evaluated using χ^2 test for association. TVL was controlled by stratification into 3 categories: <10 cm, 10 cm, and >10 cm, based on the TVL frequency distribution of our data.

Differences in symptom bother and impact on ADLs between the two GH groups while controlling for POP stage were also evaluated using χ^2 test for association. POP-Q stage was controlled by stratification into 2 categories: a) Stages 0, 1, and 2, and b) Stages 3 and 4, based on POP-Q frequency distribution of our data. Anteroposterior GH measurements were correlated with LE of prolapse to examine physiologic mechanisms for our findings using Pearson's correlation coefficients.

Secondary objective through retrospective (mesh augmented apical suspension) cohort study

We determined the symptomatic value of performing abdominovaginal posterior colporrhaphy preceding laparoscopic sacrocolpoperineopexy compared to laparoscopic sacrocolpopexy with and without posterior colporrhaphy by examining the differential impact of surgical choice on delta PFDI-20, PFIQ-7, CRADI-8, and,CRAIQ-7 as measures of pelvic floor and colorectal symptom bother and impact on activities of daily living affected by changes in delta GH and PB measurements. Surgery type was categorized as follows: Mesh augmented apical suspension procedures were categorized as conventional laparoscopic sacrocolpoperineopexy (LSCP) when an abdominovaginal posterior colporrhaphy without levator plication was performed prior to anterior, posterior, apical vaginal and sacral attachment of mesh. The first stage included a vaginal dissection where a traditional posterior colporrhaphy without levator plication was augmented by the overlaid distal LSCP posterior mesh leaflet attached to the Iliococcygeal fascia laterally and the perineal body distally. The second stage included attaching the mesh to the posterior vaginal wall laparoscopically in the standard technique. Procedures were categorized as conventional laparoscopic sacrocolpopexy (LSC) when traditional posterior colporrhaphy without levator plication or no posterior colporrhaphy were performed based on the surgeon's examination of the patient's anatomy after apical suspension with anterior, posterior, apical vaginal, and sacral attachment of mesh.

Secondary objective through retrospective (native tissue apical suspension) cohort study

We subsequently determined the symptomatic value of performing native tissue apical suspensions compared to a mesh augmented apical suspension and obliterative surgeries, when a posterior colporrhaphy was performed, by examining the differential impact of surgical choice on delta PFDI-20, PFIQ-7, CRADI-8, and CRAIQ-7 as measures of pelvic floor and colorectal symptom bother and impact on activities of daily living affected by changes in delta GH and PB measurements. Native tissue apical suspension procedures were categorized as laparoscopic uterosacral ligament suspension (LUSLS) and vaginal uterosacral ligament suspension (VUSLS). Obliterative procedures included total vaginectomy with levator plication and Lefort colpocleisis. Analysis of Variance (ANOVA) with Bonferroni's test of significance for multiple comparisions was used to compare means for k groups where indicated both restrospective cohorts. We analyzed the clinical significance of vaginal topographic restoration by comparing delta GH to delta PFDI-20, PFIQ-7, CRADI-8, and CRAIQ-7 as measures of pelvic floor and colorectal symptom bother and impact on activities of daily living, respectively, using Pearson's correlation coefficients in both retrospective cohorts.

Normality of the frequency distributions was assessed by visual inspection of the histograms for all analyzed variables. All statistical analyses were performed using SPSS v21.0 (IBM Corp, Armonk, NY). A p-value less than 0.05 was considered significant for all two-tailed statistical comparisons.

Results

Eleven thousand one hundred and fifty nine patients underwent POP surgical repair from an academic tertiary office from January 2009 and February 2015. Six hundred and eighteen patients who had pre- and postoperative physical exams and at least preoperative PFDI-20 and PFIQ-7 scores were included as study subjects. Postoperative Pelvic Floor Distress Inventory (PFDI-20) and Pelvic Floor Impact Questionnaire (PFIQ-7) data were available in 203 of 618 (33%) study subjects. These 618 study subjects had a mean age of 60.5, mean BMI 29.0, mean parity 2.8 (median 3), and a mean follow-up length of 9.8 months (range 1.1 to 53.1 months). Table 1 shows the demographics by GH group. 212 patients underwent LSCP, 176 patients underwent LSC, 77 underwent LUSLS, 96 underwent VUSLS, and 53 underwent obliterative procedures (4 patients had surgery type missing).

Primary objective through nested cross sectional study

Patients with preoperative anteroposterior GH widening had greater baseline LE of prolapse and therefore higher POP-Q stage compared to patients without anteroposterior GH widening, at a given vaginal length during Valsalva's maneuver. This was statistically significant across all 3 TVL categories as shown in Table 2. We found no difference in baseline PFDI-20 and PFIQ-7 scores when comparing patients with anteroposterior GH widening to those without anteroposterior GH widening across both prolapse stage categories during

Valsalva's maneuver (Table 3). Anteroposterior GH width was linearly associated with greater baseline LE of prolapse (r = 0.45, p <0.001).

Secondary objective through retrospective (mesh augmented apical suspension) cohort study

Both patients who underwent abdominovaginal posterior colporrhaphy without levator plication preceding LSCP (-2.2 ± 1.6) and those who underwent LSC followed by posterior colporrhaphy without levator plication (-2.0 ± 1.2) had a greater reduction in delta GH without a compensatory increase in delta PB compared to patients who underwent LSC without posterior colporrhaphy (-1.3 ± 1.1) at the time of POP repair (Table 4).

There was no difference in delta PFDI-20 (-67.2 ± 50.7 vs. -57.9 ± 48.6 vs. -78.1 ± 33.9, p = 0.27), delta PFIQ-7 (-53.2 ± 59.8 vs. -40.5 ± 64.8 vs. -66.7 ±70.7, p = 0.27), delta CRADI (-11.7 ± 19.4 vs. -18.6 ± 26.8 vs.-8.5 ± 15.3, p = 0.07), or delta CRAIQ (-14.4 ± 22.8 vs. -17.3 ± 32.6 vs. -16.7 ± 24.7, p = 0.58) reported by study subjects receiving LSCP, LSC without posterior colporrhaphy, and LSC with posterior colporrhaphy without levator plication, respectively.

Secondary objective through retrospective (native tissue apical suspension) cohort study

Patients who underwent vaginectomy with levator plication (-3.5 ± 2.5) had a greater reduction in delta GH compared to those who underwent conventional LSC (-2.0 ± 1.2), conventional LUSLS (-1.5 ± 1.2), and conventional VUSLS (-1.5 ± 1.5), when a posterior colporrhaphy was performed. Delta GH after conventional LSC was greater than after either conventional LUSLS or VUSLS, when a posterior colporrhaphy was performed, although the mean difference between the groups did not meet our statistical threshold (mean difference -

0.5, p = 0.1). Vaginectomy with levator plication resulted in a greater increase in PB size (1.3 ± 1.4) compared to conventional LSC (0.3 ± 1.3, conventional LUSLS (-0.1 ± 1.5), and VUSLS (0.3 ± 1.7), when a posterior colporrhaphy was performed. There was no difference in delta PFDI-20 (-78.1 ± 33.9 vs. -79.7 ± 40.9 vs. -79.3 ± 63.2 vs. -90.6 ± 47.0, p = 0.08) , delta PFIQ-7 (-66.7 ± 70.7 vs. -89.3 ± 64.3 vs. -64.4 ± 63.6 vs. -83.5 ± 69.5, p = 0.63), delta CRADI (-8.5 ± 15.3 vs. -11.8 ± 11.8 vs. -13.2 ± 22.7 vs. -20.2 ± 16.2, p = 0.77), , or delta CRAIQ (-16.7 ± 24.7 vs. -20.3 ± 30.7 vs. -14.0 ± 26.0 vs. -8.5 ± 11.5, p = 0.82) reported by study subjects receiving posterior colporrhaphy concomitantly with when posterior colporrhaphy was performed concomitantly with LSC, LUSLS, VUSLS, and vaginectomy with levator plication, respectively.

Delta GH was weakly associated with delta PFIQ-7 (r = 0.16, p = 0.04), but was not associated with any difference in delta PFDI-20 (r = -0.01, p = 0.86), delta CRADI (r = 0.01, p = 0.92), or delta CRAIQ (r = 0.11, p = 0.13).

Discussion

Greater genital hiatus size has been evaluated in multiple studies as a predictor of unsuccessful pessary retention,[18-20] POP recurrence,[16] and apical support loss.[15] Anteroposterior GH widening appears to consume vaginal topography at the expense of leading edge (LE) descent in select patients on pelvic examination during Valsalva's maneuver. We were concerned that at a given vaginal length, anteroposterior GH widening might obscure LE descent and therefore prolapse stage, resulting in differences in symptom severity, and impact on activities of daily living compared to patients without anteroposterior GH widening. This might inadvertently altering management decisions by health care providers for women with pelvic organ prolapse.

Our study results are reassuring in proving our concerns unwarranted. Patients with anteroposterior GH widening had greater baseline LE descent and therefore higher stage of POP without changes in baseline PFDI-20 and PFIQ-7 scores controlling for prolapse stage compared to those without anteroposterior GH widening allowing us to reject our null hypothesis for our nested cross sectional study. Adding posterior colporrhaphy to apical suspension resulted in a greater anteroposterior GH reduction without differentially improving PFDI-20 or PFIQ-7 scores and a failure to reject the null hypothesis for our retrospective mesh augmented apical suspension cohort study.

Anteroposterior GH widening during Valsalva maneuver likely represents an expanding defect or “hernia” through which a poorly supported apex descends, facilitating rather than obscuring vaginal wall descent.

The “hernia” hypothesis is supported by an increasing volume of medical literature illustrating the crosswalk from vaginal delivery to pelvic organ prolapse via the following intermediary data sets: 1) vaginal delivery-associated levator ani muscle avulsion, 2) levator ani muscle avulsion-associated genital hiatal changes, and 3) genital hiatal change-associated pelvic organ prolapse.

Vaginal delivery-associated levator ani muscle avulsion was identified by DeLancey et al.[27] when they found a visible defect in the levator ani muscle on magnetic resonance images in 20% of primiparous women compared to none in the nulliparous group. Levator ani muscle avulsion 10 years following childbirth is almost tripled after forceps- compared to vacuum-assisted vaginal delivery (OR 2.74, 95% CI 1.42, 13.62) as measured by transperineal ultrasonography.[28] Vaginal parity is also significantly associated with widened GH on Valsalva, an effect that occurs mostly after the first delivery. This was evidenced by a marked increase in mean GH area (cm^2) between vaginal parity groups 0 (21.47, 95% CI 19.22, 23.72) and 1 (29.05, 95%CI 26.83, 31.28), without further compromise for increasing parity. Levator avulsion as a plausible biologic mechanism was detected in 21% of four-dimensional translabial ultrasound.[9]

Levator ani muscle avulsion-associated genital hiatal changes were identified by Shek et al. using four-dimensional translabial ultrasound. Levator avulsion 3-4 months after vaginal delivery was associated with a 28% increase in hiatal area during Valsalva compared to a 6% increase without levator avulsion.[11] A retrospective study found that patients with levator avulsion (20.7%) diagnosed by transperineal ultrasound and signs of pelvic organ prolapse on examination (49.2%) had significantly larger hiatal areas compared to controls, thus "improv[ing] our understanding of the pathophysiology of pelvic organ prolapse as a form of hiatal hernia."[29]

Genital hiatal change-associated pelvic organ prolapse was identified by DeLancey et al. when they found larger hiatus areas (cm^2), as measured by clinical biometry, associated with increased prolapse severity (grade 0, 5.4 ± 1.71; grade 1, 7.3 ± 1.91; grade 2, 8.3 ± 2.45; grade 3, 11.0 ± 4.90).[15] In a prospective cohort study, patients with symptomatic pelvic organ prolapse were more likely than controls to have greater levator hiatal widths (mm) (40.3 ± 6.3 v 25.7 ± 5.7) after controlling for age parity, and BMI.[30] Similar to our findings, GH measurements (cm) during POP-Q examination increased through stage 3 disease (stage 0-1, 2.74 ± 0.8; stage 2, 3.6 ± 1.0; stage 3, 4.83 ± 1.3), implicating GH as a marker of underlying pelvic muscle damage.[31]

According to Yousef et al, levator ani muscle injury after vaginal delivery results in hiatal opening, predisposing to descent, "cystocele," and exposure of the anterior vaginal wall to pressure differentials. The increased pressure places mechanical stress on the distal connective tissue supports (uterosacral and cardinal ligaments) of the uterus and vagina. There is a strong linear relationship ($r^2 = 0.85$) between hiatal diameter and exposed vaginal wall length. Apical suspension procedures eliminate the exposed length by repositioning the anterior vaginal wall such that it opposes and remains in contact with the posterior vaginal wall, effectively relieving added pressure differentials.[26]

During posterior colpoperineorrhaphy, according to historical tenets, superficial side to side suturing of the fascia of the perineal musculature "will usually reconstitute the perineal body and draw the fascia of the pubococcygeal muscles closer to the upper lateral sides of the perineal body effectively narrowing the widened genital hiatus."[32] Reconstruction of the perineal body through posterior colpoperineorrhaphy is heralded as a necessary "feature of all operations designed to cure prolapse" because it 1) "restor[es] the normal bottle-neck shape to the lower end of the vagina," 2) brings the posterior wall in contact with the lower end of the anterior wall, and 3) maintains the vagina's "sharp forward curve," along with the cardinal ligaments and levator ani muscle, protecting "against the tendency for the vagina to be turned inside out when the intraperitoneal pressure is raised."[33]

Though surgeries such as posterior colpoperineorrhaphy restore anatomy and reduce GH size, it remains unclear whether they prevent prolapse recurrence and positively influence pelvic floor function beyond what is already expected of apical suspension.[31] Our study begins to fill this knowledge gap in providing surgical guidance regarding the need for concomitant posterior colporrhaphy during apical suspension for POP. Conventional LSCP and LSC with posterior colporrhaphy more than LSC without posterior colporrhaphy effectively narrowed a widened genital hiatus without positively or negatively affecting overall general pelvic floor or colorectal specific symptom bother or impact on activities of daily living at 9-12 months postoperatively. Therefore, it is possible that 308 of 372 of our patients received concomitant procedures that provided no differential symptom benefit over conventional laparoscopic sacrocolpopexy alone other than improved vaginal topography. The prospective measurement of change in symptom severity and impact on activities of daily living in randomized study subjects undergoing mesh augmented apical suspension procedures with and without posterior colporrhaphy would be needed to test this hypothesis.

Studies have demonstrated apical support through abdominal sacrocolpopexy regardless of posterior repair provides the anatomic success of improved posterior support,[25,34] but concomitant posterior repair possibly prevents recurrence of distal posterior prolapse. Yau et al. confirmed concomitant posterior colporrhaphy provides sustained improvement of POP-Q point Ap, the most distal measurement of posterior vaginal support, at 34 months compared to no posterior repair.[34] Whether sustained support results in improved posterior POP symptoms is unclear. Lack of randomization for concomitant posterior procedures leading to baseline differences in obstructive defecatory symptom severity precluded a definitive answer to the role of these procedures in symptom resolution one year after sacrocolpopexy. In fact, patients with concomitant posterior procedures reported new bothersome bowel symptoms, including fecal incontinence with physical activity and pain prior to and with defecation compared to sacrocolpopexy alone[25].

Analysis of baseline and 5-year outcomes in the Extended Colpopexy And Urinary Reduction Efforts (E-CARE) trial demonstrated that regardless of preoperative posterior POP severity, anatomic success and decrease in defecatory symptoms are likely[35] regardless of whether surgeons chose to perform concomitant posterior procedures (a choice driven by presence of vaginal laxity or widened hiatus intraoperatively). However, recurrent posterior pelvic organ prolapse (12%) and retreatment (14%) rates were highest in patients who underwent concomitant posterior colporrhaphy at the time of sacrocolpopexy. Obstructed defecation symptom rates ranging from 17-19% were present 5 years after surgery regardless of preoperative POP severity or concomitant posterior procedure.[35] Further prospective longitudinal studies, preferably randomized clinical trials,[25,35] are recommended to validate the performance of LSCP or posterior colporrhaphy concurrently with LSC in providing differential anatomic outcomes or retreatment rates compared to LSC alone given this lack of symptom improvement.

All of our studied prolapse procedures led to a decrease in preoperatively widened GH. The greatest decrease was seen in obliterative procedures, which is most likely due to the high perineorrhaphy performed in conjunction with vaginectomy with levator plication or LeFort colpocleisis resulting in a compensatory increase in PB size. The symptomatic, anatomic, and retreatment rate value of high perineorrhaphy in these patients is unclear.

Our study has several limitations inherent in any retrospective study design. Foremost is the lack of a definitive preoperative indication for posterior colporrhaphy. This limits our ability to provide evidence-based surgical guidance for the value of this procedure in 1) reducing symptom bother and impact on activities of daily living, 2) restoring vaginal topography, 3) or preventing recurrence given the short follow up for study patients[25,35]. In fact multiple indications to perform posterior colporrhaphy without levator plication as an adjunct to the primary procedure must have existed, as posterior colporrhaphy preceded LSCP while it followed LSC as deemed necessary for cosmetic effect. Postoperative data on symptom bother and impact of activities of daily living was present in only 33% of our surgical cohort, decreasing our ability to detect a difference between surgical procedures if one truly exists. This limitation reduces the validity of stratified analyses including a comparison of symptoms attributable to posterior wall defects in the subset of patients with 24 month followup, or differential changes in symptom bother and impact on activities of daily living with or without posterior colporrhaphy by prolapse stage. While it might be tempting to draw a clinical conclusion from the weak statistically significant correlation of delta GH with delta PFIQ-7, this finding is more likely the consequence of type I statistical error from multiple comparison testing following 20 test iterations absent other significant correlations. Finally, differences in followup for vaginectomy with levator plication study subjects, while expected, provides a shorter time for reporting changes in symptom severity or impact on activities of daily living. Nonetheless, it is unlikely that these frail patients would report differential change compared to native tissue apical suspensions if longer followup was available given the findings from our study. Strengths of our study include our large sample size and comparisons of multiple surgical procedures familiar to female pelvic medicine and reconstructive surgeons treating women with pelvic organ prolapse.

Our clinical study contributes to the increasing body of medical evidence to supporting the “hernia” hypothesis during Valsalva’s maneuver. We are no longer concerned patients with POP and widened GH will be undertreated at a given vaginal length during Valsalva’s maneuver. Such patients have a higher baseline stage of prolapse and at least equally bothersome symptoms resulting from obstetric-related levator ani muscle damage compared to patients with non-widened GH measurements as defined in our study. Historical tenets purporting the value of a connective tissue repair for a skeletal muscle injury are not supported by our study or the growing body of medical evidence that apical suspensions alone restore vaginal topography, reduce symptoms, and may prevent retreatment. Specifically, mesh-augmented apical suspension with LSCP or LSC with posterior colporrhaphy without levator plication effectively reduced a widened GH without providing differential improvement in overall and colorectal-specific pelvic floor symptom bother and impact on activities of daily living compared to apical repair without posterior colporrhaphy. Prolapse recurrence is a reality for a percentage of patients and their surgeons because connective tissue repair is incapable of restoring obstetric-related levator ani muscle damage which persists despite short term anatomic restoration. Further studies examining the surgical impact on retreatment are needed to further qualify the value of performing posterior colporrhaphy prior to LSCP or following LSC beyond cosmesis.

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Table 1

Baseline characteristics of patients among the genital hiatus (GH) groups

	GH ≤ 3	GH > 3	P value
Age	59.6 ± 13.0	60.7 ± 12.3	0.43
BMI	27.1 ± 5.9	29.3 ± 14.5	0.16
Gravidity	3.1 ± 1.6	3.3 ± 1.6	0.34
Parity	2.4 ± 1.3	2.8 ± 1.3	0.01

BMI = Body mass index
GH = Anteroposterior GH width (in cm)

Table 2

Baseline evaluation of pelvic organ prolapse (POP) stage and leading edge (LE) within genital hiatus (GH) groups among total vaginal length (TVL) categories

<table>
<tr><th></th><th colspan="5">Stage of POP Distribution</th><th colspan="3">Mean LE Edge</th></tr>
<tr><th>Pre-op
TVL</th><th colspan="2">GH < 3</th><th colspan="2">GH > 3</th><th>P-value</th><th>GH < 3</th><th>GH > 3</th><th>P-value
(mean diff, 95% CI)</th></tr>
<tr><td rowspan="2"><10 cm
n=134</td><td>Stage 1
8.7%</td><td>Stage 2
56.5%</td><td>Stage 1
0.9%</td><td>Stage 2
36.9%</td><td rowspan="2">0.021</td><td rowspan="2">0.9 ± 1.4</td><td rowspan="2">2.8 ± 2.6</td><td rowspan="2"><0.001
(1.9, 95% CI 1.1, 2.6)</td></tr>
<tr><td>Stage 3
30.4%</td><td>Stage 4
4.3%</td><td>Stage 3
48.6%</td><td>Stage 4
13.5%</td></tr>
<tr><td rowspan="2">10 cm
n=288</td><td>Stage 1
8.9%</td><td>Stage 2
66.7%</td><td>Stage 1
1.2%</td><td>Stage 2
33.9%</td><td rowspan="2"><0.001</td><td rowspan="2">0.4 ± 1.9</td><td rowspan="2">2.6 ± 2.5</td><td rowspan="2"><0.001
(2.2, 95% CI 1.4, 2.9)</td></tr>
<tr><td>Stage 3
24.4%</td><td>Stage 4
0.0%</td><td>Stage 3
55.8%</td><td>Stage 4
8.7%</td></tr>
<tr><td rowspan="2">>10 cm
n=189</td><td>Stage 1
10.7%</td><td>Stage 2
67.9%</td><td>Stage 1
1.2%</td><td>Stage 2
49.1%</td><td rowspan="2">0.003</td><td rowspan="2">0.4 ± 1.7</td><td rowspan="2">1.9 ± 2.2</td><td rowspan="2"><0.001
(1.5, 95% CI 0.7, 2.4)</td></tr>
<tr><td>Stage 3
21.4%</td><td>Stage 4
0.0%</td><td>Stage 3
48.4%</td><td>Stage 4
1.2%</td></tr>
</table>

TVL = Total vaginal length
GH = Anteroposterior GH width (in cm)
LE = Leading edge of prolapse (in cm)
CI = Confidence interval
POP = Pelvic organ prolapse

Table 3

Baseline evaluation of PFDI -20 and PFIQ -7 within genital hiatus (GH) groups across pelvic organ prolapse (POP) stages

	Mean PFDI-20			Mean PFIQ-7		
Stage of POP	GH < 3	GH > 3	P-value	GH < 3	GH > 3	P-value
0, 1, and 2 n=281	113.4 ± 66.9	116.4 ± 58.7	0.737	85.2 ± 80.0	79.5 ± 62.9	0.958
3 and 4 n=335	122.2 ± 68.2	109.0± 55.5	0.295	63.9 ± 67.5	67.3 ± 65.6	0.808

GH = Anteroposterior GH width (in cm)
POP = Pelvic organ prolapse
PFDI-20 = Pelvic floor distress inventory
PFIQ-7 = Pelvic floor impact questionnaire

Table 4

Delta GH and Delta PB after mesh augmented apical suspension with and without posterior colporrhaphy

	LSCP N= 203	LSC with posterior colporrhaphy N= 105	LSC without posterior colporrhaphy N= 64	P value
Delta GH	-2.1 ± 1.6*	-2.0 ± 1.2**	-1.3 ± 1.1	<0.001
Delta PB	0.1 ± 1.5	0.3 ± 1.3	0.3 ± 1.1	0.371
Mean Follow-up (mos)	11.4 ± 8.0	9.8 ± 6.4	9.4 ± 6.8	0.08

Delta GH = Change in anteroposterior genital hiatus (postoperative – preoperative in cm)
Delta PB = Change in anteroposterior perineal body (postoperative – preoperative in cm)
LSCP = Laparoscopic sacrocolpoperineopexy
LSC = Laparoscopic sacrocolpopexy

*LSCP v LSC without posterior colporrhaphy, mean difference -0.9, p < 0.001 95%CI -0.4, -1.4
**LSC with posterior colporrhaphy v LSC without posterior colporrhaphy, mean difference -0.8, p = 0.03 95%CI -0.2, -1.3

Table 5

Delta GH and delta PB after prolapse surgery with posterior colporrhaphy

	LSC N =105	LUSLS N = 36	VUSLS N = 82	Obliterative Approach N= 25	P value
Delta GH	-2.0 ± 1.2	-1.5 ± 1.2	-1.5 ± 1.5	-3.5 ± 2.5*	<0.001
Delta PB	0.3 ± 1.3	-0.1 ± 1.5	0.3 ± 1.7	1.3 ± 1.4**	0.002
Mean Follow-up (mos)	9.8 ± 6.4	8.7 ± 6.3	10.0 ± 9.4	5.7 ± 4.4***	0.01

Delta GH = Change in anteroposterior genital hiatus (postoperative – preoperative in cm)
Delta PB = Change in anteroposterior perineal body (postoperative – preoperative in cm)
LSC = Laparoscopic sacrocolpopexy
LUSLS = Laparoscopic uterosacral ligament suspension
VUSLS = Vaginal uterosacral ligament suspension
Obliterative approach = Vaginectomy with levator plication or LeFort Colpocleisis

* Obliterative approach v LSC, mean difference -1.4, p < 0.001 95%CI -0.5, -2.3, Obliterative approach v LSUSLS, mean difference -1.9, p < 0.001 95%CI -0.9, -3.0, Obliterative approach v VUSLS, mean difference -2, p < 0.001 95% CI -1.1, -2.9

** Obliterative approach v LSC, mean difference 0.99, p = 0.14 95%CI 0.14, 1.85, Obliterative approach v LSUSLS, mean difference 1.4, p = 0.001 95%CI 0.4, 2.4, Obliterative approach v VUSLS, mean difference 1.0, p = 0.01, 95%CI 0.2, 1.9

*** Obliterative approach v LSC, mean difference -4.1, p = 0.013 95%CI -0.6, -7.7, Obliterative approach v VUSLS, mean difference -4.3, p = 0.01 95%CI -0.7, -8.0