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The relationship between superior attachment points for anterior wall mesh operations and the upper vagina using a 3-dimensional magnetic resonance model in women with normal support

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Abstract

Objective—We examined structural relationships between anterior mesh kit suspension points and the upper vagina in women with normal support.

Study Design—Eleven women with normal support underwent supine, multiplanar magnetic resonance pelvic imaging at rest and maximal Valsalva. Using 3-dimensional models generated from these images, anterior wall mesh kit anchoring points were identified along the arcus tendineus fascia pelvis. We then measured the percentage of anterior vagina above and posterior to superior suspension points.

Results—The anterior vagina extended above superior attachment points in 100% of women at rest and in 73% during Valsalva. It extended posterior to them in 82% and 100% (rest and Valsalva, respectively). The mean percentage of anterior vaginal length above superior anchoring sites was $40 \pm 14\%$ at rest and $29 \pm 12\%$ during Valsalva.

Conclusion—The upper vagina lies above and posterior to superior suspension points in the majority of women with normal support.

Keywords

apical support; mesh; recurrent prolapse; vaginal support

Pelvic floor dysfunction affects women so severely that 1 in 10 will require surgery for either urinary incontinence or pelvic organ prolapse.¹ Because age is a recognized risk factor for prolapse,² the anticipated increase in the elderly population will likely result in a substantial increase in the number of women seeking treatment for prolapse.³

Recurrent pelvic organ prolapse after surgery is not uncommon. A recent review found recurrent prolapse rates from 2% to 47%, depending on type of prolapse and surgical procedure.⁴ Clark et al⁵ performed a 5 year prospective observational study identifying a 13% reoperation rate for prolapse, whereas Olsen et al⁶ reported that up to one third of women require reoperation. The occurrence of these operative failures has driven researchers, clinicians, and surgical product companies to search for improvements in

current operative strategies. As a result, several mesh-based suspension kits have recently been developed that suspend mesh sheets to specific fixation points on the pelvic wall.

We have seen several referral patients who have either primary or recurrent prolapse of the uterus or vaginal apex after the use of these mesh kits. These failures seemed to occur in the level I region normally supported by the cardinal and uterosacral ligaments and not as a failure of the mesh to maintain tissue strength in the midvaginal regions where it was placed. Recent anatomical⁷ and clinical⁸⁻¹⁰ research has demonstrated that failure of apical support is the factor most strongly associated with both cystocele occurrence and severity. We hypothesized that if mesh fixation points lie below the level of the upper vagina, they may not provide adequate level I support.

In this project, we compared manufacturer-specified placement of anterior wall mesh kits to 3-dimensional (3-D) vaginal models in women with normal support to evaluate the structural relationship between these suspension points and vaginal position. Specifically, our goal was to establish the relationship between the upper vagina and superior suspension points to evaluate their role in level I support.

Materials and Methods

Magnetic resonance imaging (MRI) scans from 11 normal women were selected from the control group of an ongoing University of Michigan Institutional Review Board–approved (IRB #199-0395), case-control study of pelvic organ prolapse. All women were asymptomatic based on Pelvic Floor Distress Inventory and Pelvic Floor Impact Questionnaires, had negative full bladder stress tests, had not had previous surgery for pelvic floor disorders, and had Pelvic Organ Prolapse Quantification system (POP-Q) points at least 1 cm above the hymenal ring. These 11 subjects all had quality MR images of the pelvis which allowed visualization of the vagina.

Each woman underwent supine MRI at rest and during maximal Valsalva using a 3 Telsa Philips Achieva scanner (Philips Medical Systems, Best, The Netherlands) with a 6 channel phased array coil. Ultrasound gel was placed in the vagina to outline its contour. Turbo spin echo techniques were used for the following imaging in sagittal, coronal, and axial planes. At rest, 30 images were obtained (repetition time [TR] range, 2300-3000; echo time [TE], 30; 4 mm slice thickness, 1 mm gap; number of signal averages [NSA] 2; 256 × 255). For maximal Valsalva imaging, subjects were instructed to take a deep breath and push for approximately 20 seconds during the acquisition. During these 3 valsalvas, 14 images were serially obtained in sagittal, coronal, and axial planes (TR range 1249-1253, TE 80, 6 mm slice thickness, 1 mm gap, sense factor 4, NSA 2, 320 × 178). A research associate was present during the MRI to determine that the prolapse reached the same size that had been identified during POP-Q evaluation.

Computer models of the bony pelvis, uterus, and vagina were made using the 3-D Slicer program (version 2.1b1; Brigham and Women's Hospital, Boston, MA). To do this, the original axial, sagittal, and coronal Digital Imaging and Communications in Medicine static images were aligned, ensuring that structures colocalized in all 3 axes by simultaneous review of 3-D scan planes in the viewer. Satisfactory alignment was possible in all 11 scans. Three-dimensional models were made of the following structures: pelvic bones (axial images), vagina (sagittal images), and uterus (sagittal images) by tracing the structure outlines and creating 3-D models from these outlines (Figure 1).

To align the models obtained at rest and during Valsalva, the 3-D models of the midline pubic symphysis and sacrum were constructed from the sagittal maximal Valsalva images and then aligned with the pelvic bones of the resting model. This identified the translational

coordinates for the sagittal maximal Valsalva images such that subsequently constructed 3-D vaginal and uterine models could be aligned with previously created resting models.

The resting and maximal Valsalva 3-D reconstructions were then imported into I-DEAS modeling software (Imageware, version 11; Electronic Data Systems Corp, Plano, TX). The lines of the arcus tendineous fascia pelvis (ATFP) were constructed from the ischial spine to the insertion on the pubis, the latter being identified by 3-D coordinates identified on the earlier MRIs (Figure 2, A).

The locations of manufacturer-specified anchoring points were reviewed for the following anterior wall mesh kits: Anterior Prolift (Gynecare, Somerville, NJ), Anterior Avaulta (Bard Urological Associates, Covington, GA), and Perigee (American Medical Systems, Minnetonka, MN) as summarized in Table 1.

Based on these descriptions, representative anchoring points were marked along the bilateral ATFP for each subject as follows: (1) superior attachment point, 1.5 cm from ischial spine along ATFP; and (2) inferior attachment, 1 cm from the symphysis along the ATFP at the level of the bladder neck (Figure 2, B and C). (This paper uses the anatomical location of the points, namely “superior” for the more cephalic suspension point near the ischial spine and “inferior” for the more caudal point near the pubic bone. This is opposite to manufacturer nomenclature convention, which labels the fixation points based on their vulvar incisions in which the “superior” incision is used to place the mesh arm that is the more caudally located attachment point, our “inferior attachment.”)

We then established what portion of the vagina was both above and posterior to the superior suspension point. To do this, we placed a line along the anterior vaginal wall surface extending from the introitus to the apex (Figure 3). The upper extent of the line was established at the most superior point at which the anterior vaginal wall could be seen extending laterally to the cervix.

To estimate the proportion of vaginal length that was above the superior suspension points, a plane was constructed perpendicular to the body axis passing through the left and right insertion points (Figure 4, A and B). The intersection of this plane with the anterior vaginal line was marked at rest and at maximal Valsalva. The percentage of anterior vaginal wall length superior to this point was calculated using I-DEAS computer modeling software (Electronic Data Systems). A similar process was carried out using a plane parallel to the body axis to estimate the percent of vaginal length that was posterior to the superior suspension points (Figure 4, C and D). These values were calculated for vaginal position both at rest and maximal Valsalva (Figure 5). All magnetic resonance tracing, 3-D modeling, placement of points, construction of lines, and measurement strategies were reviewed by the first and senior authors.

Means and SDs were used to characterize the study group demographics and determine anterior vaginal length, percent of length above the superior suspension point and percent of length posterior to the superior suspension points.

Results

The mean age of the 11 study participants was 54 ± 11 years (SD). The mean body mass index was 24.9 ± 4.7 kg/m² and median parity was 2 (range, 0-3). All subjects were white and had not had a hysterectomy. Mean anterior vaginal lengths (calculated on 3-D models using I-DEAS [Electronic Data Systems]) at rest and maximal Valsalva were $9.3 \text{ cm} \pm 0.7 \text{ cm}$ (SD) and $8.6 \text{ cm} \pm 1.2 \text{ cm}$ (SD), respectively.

Vaginal position at rest and Valsalva varied among our 11 women. When examining the vagina at rest in the 11 subjects, a portion of anterior vagina was above superior mesh anchoring points in 100% (11/11) and posterior to superior mesh anchoring points in 82% (9/11). The mean percentage of resting anterior vaginal length above superior mesh points was $40 \pm 14\%$ (SD, $n = 11$) and posterior to superior mesh points was $15 \pm 6\%$ (SD, $n = 9$).

Similarly, while examining vaginal position at maximal valsalva, a portion of anterior vagina was above superior mesh anchoring points in 73% (8 of 11) and posterior to superior mesh anchoring points in 100% (11/11). With valsalva, the mean percentage of anterior vaginal length above superior mesh points was $29 \pm 12\%$ (SD, $n = 8$) and posterior to superior mesh points was $24 \pm 24\%$ (SD, $n = 11$) (Table 2).

Comment

This study compared manufacturer-specified placement of anterior wall mesh kits to 3-D vaginal models in 11 women with normal support. Our results indicate that although these strategies reestablish midvaginal support, the anterior vagina extends above and posterior to superior mesh kit suspension points in the majority of these women. We found that the anterior vagina extended above the superior points in 100% of patients at rest and 73% of patients at maximal Valsalva. Similarly, the anterior vagina extended posterior to these points in 82% of patients at rest and 100% of patients at maximal Valsalva.

Current anterior wall mesh kit strategies focus on midvaginal support. In their product literature, some manufacturers have specified that their use be limited to level II defects. The threshold of apical descent that would be associated with an unacceptable apical failure rate is not known but is an important area for investigation. The primary importance of apical support to cystocele, however, is well established.

Several authors described the significant contribution of apical support to cystocele size.⁸⁻¹⁰ Summers et al¹⁰ determined that apical support contributes to half of the variation in anterior compartment prolapse size. Similarly, Hsu et al⁸ utilized linear regression models to determine that 77% of cystocele size can be attributed to apical descent and anterior vagina length. Given these data, we hypothesize that lack of apical support may contribute to prolapse recurrence after use of anterior wall mesh kits.

Although long-term data in the literature are scant, there are several studies that characterized short-term recurrence rates after the placement of these kits showing that most women treated have successful outcomes; however, even in the short-term follow-up, failures do occur. A multicenter retrospective study of outcomes with Gynecare and American Medical System mesh kits reported 5% persistent prolapse at 3 months and 7% recurrent prolapse at 4-22 months. Among those who underwent only the anterior wall kits, prolapse persisted or recurred in 17%.¹¹

In a retrospective review of 120 patients who underwent Apogee or Perigee (American Medical System) repair, Gauruder-Burmester et al¹² reported an anatomic cure rate of 93% at 1 year. Nguyen and Burchette¹³ reported similar rates in a randomized, controlled trial of Perigee (American Medical System) and anterior repair at the 1 year interim safety analysis, 87% and 57%, respectively. Similarly, a multicenter prospective cohort study interim safety analysis revealed a 2 month postoperative anatomic cure rate of 87% after anterior repair with Prolift.¹⁴ However, at 3 months, Fatton et al¹⁵ identified a 30% asymptomatic recurrence rate in their retrospective multicenter cohort study. In this latter study, there were no symptomatic recurrences among their patients who had anterior Prolift; however, 23% of their patients underwent accompanying sacrospinous uterine fixation in addition to the anterior Prolift.¹⁵

What remains unclear is the reason for failure; the limited ability to correct for apical support is a likely candidate. Having data concerning the preoperative state of apical support might be helpful in gaining a better understanding of operative failure.

Several factors must be considered in interpreting the results of this study. Magnetic resonance images were obtained in the supine position, which may limit the descent of pelvic floor. However, it must be remembered that this is a similar position to that used during pelvic examination, and it is the Valsalva that produces the prolapse. Earlier studies have documented equivalent movement of pelvic floor with straining when comparing supine with open scanners that allow a seated position.^{16,17} In addition, a research associate was present throughout imaging to ensure that subjects' Valsalva efforts were maximized and matched their earlier clinical examination.

The final limitation involves placement of the mesh attachment points in our model. These were placed according to manufacturer specifications, and variable placement may occur intraoperatively. In fact, cadaver studies have illustrated a range of positions. Some have shown that the superior arms pass within a range of 2.1-3.3 cm from the ischial spine, whereas the inferior arms pass approximately 2-4 cm more distally along the AFTP, 4.2-5.2 cm from the ischial spine.¹⁸ In the study by Reisenauer et al,¹⁹ the superior arm passed 2-2.2 cm from the ischial spine, a distance of 4.5-5.5 cm from the inferior trocar. If these studies are more indicative of operating room placement, our model underestimates the portion of vagina that is above and posterior to the superior suspension point.

Our results indicate that the position of the normal vagina lies above the superior suspension points in a substantial number of women. This does not mean that these anterior mesh suspension kits are ineffective in alleviating all prolapses as is indicated by the outcome data. However, published data regarding the addition of the sacrospinous uterine fixation to anterior mesh procedures in Fatton's study to address apical support complement the findings of this study.¹⁵

Even though support of the apex may not be ideal, there may be other mechanisms at work in cystocele correction. There may be some element of apical descent caused by the force of abdominal pressure exerted on the cystocele once the anterior vaginal wall is below the level of the levator ani muscles.²⁰ By eliminating the cystocele, it may reduce traction on the ligaments to a point at which they can hold the vaginal apex up. In addition, the stiffening of the vaginal wall by the mesh may also play a role.

Other operations such as McCall culdoplasty and sacrospinous ligament suspension also have empirical success, even though they do not have ideal suspension points. However, by demonstrating that the superior suspension points are below the normal upper vagina, this study may help with failure analysis and assist in defining which patients will and will not have optimal outcomes. For these anterior mesh kits, long-term outcomes data are necessary to determine how to best involve them in our armamentarium of surgical treatments from which we draw tailored plans for each individual patients' prolapse needs.

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References

1. Boyles SH, Weber AM, Meyn L. Procedures for pelvic organ prolapse in the United States, 1979-1997. *Am J Obstet Gynecol* 2003;188:108-15. [PubMed: 12548203]
2. Jelovsek JE, Maher C, Barber MD. Pelvic organ prolapse. *Lancet* 2007;369:1027-38. [PubMed: 17382829]
3. He, W.; Sengupta, M.; Velkoff, V.; DeBarros, K. Washington, DC: United States Government Printing Office; Dec2005 [Oct. 1, 2008]. 65+ in the US: 2005, current population report, special studies. Available at: www.census.gov
4. Carey MP, Dwyer PL. Genital prolapse: vaginal versus abdominal route of repair. *Curr Opin Obstet Gynecol* 2001;13:499-505. [PubMed: 11547031]
5. Clark AL, Gregory T, Smith VJ, Edwards R. Epidemiologic evaluation of reoperation for surgically treated pelvic organ prolapse and urinary incontinence. *Am J Obstet Gynecol* 2003;189:1261-7. [PubMed: 14634551]
6. Olsen AL, Smith VJ, Bergstrom JO, Colling JC, Clark AL. Epidemiology of surgically managed pelvic organ prolapse and urinary incontinence. *Obstet Gynecol* 1997;89:501-6. [PubMed: 9083302]
7. Delancey JO. Fascial and muscular abnormalities in women with urethral hypermobility and anterior vaginal wall prolapse. *Am J Obstet Gynecol* 2002;187:93-8. [PubMed: 12114894]
8. Hsu Y, Chen L, Summers A, Ashton-Miller JA, DeLancey JO. Anterior vaginal wall length and degree of anterior compartment prolapse seen on dynamic MRI. *Int Urogynecol J Pelvic Floor Dysfunct* 2008;19:137-42. [PubMed: 17579801]
9. Rooney K, Kenton K, Mueller ER, FitzGerald MP, Brubaker L. Advanced anterior vaginal wall prolapse is highly correlated with apical prolapse. *Am J Obstet Gynecol* 2006;195:1837-40. [PubMed: 17132485]
10. Summers A, Winkel LA, Hussain HK, DeLancey JO. The relationship between anterior and apical compartment support. *Am J Obstet Gynecol* 2006;194:1438-43. [PubMed: 16579933]
11. Abdel-Fattah M, Ramsay I, West of Scotland Study Group. Retrospective multicentre study of the new minimally invasive mesh repair devices for pelvic organ prolapse. *BJOG* 2008;115:22-30. [PubMed: 18053100]
12. Gauruder-Burmester A, Koutouzidou P, Rohne J, Gronewold M, Tunn R. Follow-up after polypropylene mesh repair of anterior and posterior compartments in patients with recurrent prolapse. *Int Urogynecol J Pelvic Floor Dysfunct* 2007;18:1059-64. [PubMed: 17219252]
13. Nguyen JN, Burchette RJ. Outcome after anterior vaginal prolapse repair: a randomized controlled trial. *Obstet Gynecol* 2008;111:891-8. [PubMed: 18378748]
14. Altman D, Vayrynen T, Engh ME, Axelsen S, Falconer C, Nordic Transvaginal Mesh Group. Short-term outcome after transvaginal mesh repair of pelvic organ prolapse. *Int Urogynecol J Pelvic Floor Dysfunct* 2008;19:787-93. [PubMed: 18074068]
15. Fatton B, Amblard J, Debodinance P, Cosson M, Jacquetin B. Transvaginal repair of genital prolapse: preliminary results of a new tension-free vaginal mesh (prolift technique)—a case series multicentric study. *Int Urogynecol J Pelvic Floor Dysfunct* 2007;18:743-52. [PubMed: 17131170]
16. Bertschinger KM, Hetzer FH, Roos JE, Treiber K, Marincek B, Hilfiker PR. Dynamic MR imaging of the pelvic floor performed with patient sitting in an open-magnet unit versus with patient supine in a closed-magnet unit. *Radiology* 2002;223:501-8. [PubMed: 11997560]
17. Fielding JR, Griffiths DJ, Versi E, Mulkern RV, Lee ML, Jolesz FA. MR imaging of pelvic floor continence mechanisms in the supine and sitting positions. *AJR Am J Roentgenol* 1998;171:1607-10. [PubMed: 9843296]
18. Chen CC, Gustilo-Ashby AM, Jelovsek JE, Paraiso MF. Anatomic relationships of the tension-free vaginal mesh trocars. *Am J Obstet Gynecol* 2007;197:666.e1-6. [PubMed: 18060974]
19. Reisenauer C, Kirschniak A, Drews U, Wallwiener D. Anatomical conditions for pelvic floor reconstruction with polypropylene implant and its application for the treatment of vaginal prolapse. *Eur J Obstet Gynecol Reprod Biol* 2007;131:214-25. [PubMed: 16677753]

20. Chen L, Ashton-Miller JA, Hsu Y, DeLancey JO. Interaction among apical support, levator ani impairment, and anterior vaginal wall prolapse. *Obstet Gynecol* 2006;108:324–32. [PubMed: 16880302]

FIGURE 1. 3-dimensional model construction

Midsagittal proton weighted magnetic resonance image **A**, with superimposed vaginal and **B**, uterine model. The reconstructed pelvic bones used for reference are shown in **C**. © DeLancey 2008.

FIGURE 2. Identification of suspension points along ATFP

A, Superior view of I-DEAS model looking into the pelvis, with the *turquoise line* illustrating the arcus tendineus fascia pelvis (ATFP) bilaterally. **B**, *Red lines* superimposed along the ATFP in the location of the mesh between the attachment points. **C**, A lateral view with the pelvic bones removed to indicate the locations of the superior and inferior attachment points. © DeLancey 2008.

FIGURE 3. Determination of anterior vaginal wall length

A, The anterolateral view of vagina and uterus illustrating anterior vagina extending lateral to cervix. **B,** With removal of the uterus, one can see placement of the line along the length of the anterior vagina. **C,** With the vagina removed, we can see the relationship of the arcus tendineus fascia pelvis (ATFP) and mesh suspension points to the anterior vaginal line. **D,** Lateral view illustrating uterus, vagina, ATFP, and suspension points. © DeLancey 2008.

FIGURE 4. Technique to evaluate the proportion of vaginal length above and behind suspension points

Plane to assess portion above the suspension points shown in **A** and **B** and behind in **C** and **D**. © DeLancey 2008

FIGURE 5. Rest and maximal Valsalva model

A, Lateral view illustrating both resting (*orange*) and maximal Valsalva (*yellow*) vagina in relation to arcus tendineus fascia pelvis and mesh suspension points. **B**, The planes perpendicular and **C**, parallel to the body axis are shown, demonstrating the portion of length above and behind the superior suspension point, respectively. Note that in this example, the maximal Valsalva vagina is below the superior suspension point. © DeLancey 2008

TABLE 1
Manufacturer-specified suspension characteristics

Anterior kits	Advertised intention	Anchoring sites	
		Superior	Inferior
Perigee	Level 2 support, all types of defects: central, lateral, proximal, and distal	Within 2 cm anterior and distal to ischial spine	Level of the bladder neck
Anterior Prolift	Tension-free anterior repair	1 cm from ischial spine along the ATFP	1 cm from the pubic arch along the ATFP
Anterior Avaulta	Proximal positioned at vaginal apex	Ischial spine	Level of the bladder neck

ATFP, arcus tendineus fascia pelvis.

TABLE 2
Vaginal relationship to superior suspension point at rest and maximal Valsalva^a

Relationship	n (%)
RESTING	
Vaginal position (relative to superior attachment points)	
Above or superior to	11/11 (100)
Behind or posterior to	9/11 (82)
VAGINAL LENGTH (RELATIVE TO SUPERIOR ATTACHMENT POINTS), %	
Above or superior (n = 11)	40 ± 14%
Behind or posterior (n = 9)	15 ± 6%
MAXIMAL VALSALVA	
Vaginal position (relative to superior attachment points)	
Above or superior to	8/11 (73%)
Behind or posterior to	11/11 (100%)
Vaginal length (relative to superior attachment points), %	
Above or superior (n = 8)	29 ± 12%
Behind or posterior (n = 11)	24 ± 24%

^aPosition is reported as the number of subjects, whereas percentage of vaginal length is reported as the mean percent ± SD.