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The relationship between anterior and apical compartment support

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Abstract

Objective—The purpose of this study was to determine whether the degree of anterior compartment (bladder) and apical compartment (cervix) prolapse are correlated, and whether 2 anterior compartment elements (urethra and bladder) are related at maximal Valsalva.

Study design—Women with a complete spectrum of pelvic support were recruited for a pelvic support study. Dynamic magnetic resonance scans were taken during Valsalva. A convenience sample of 153 women with a mean age of 53.3 ± 12.5 (SD) years with a uterus in situ was studied. Anterior compartment status was assessed by the most caudal bladder point and the internal urinary meatus. The external cervical os was used to assess the apical compartment. The position of the bladder, urethra, and uterus were determined in 20 nulliparous women to determine their reference locations. The distances of each structure below the reference positions were calculated at maximum Valsalva.

Results—Average distances of the bladder base, urethra, and uterus from the reference positions at maximal Valsalva were 4.1 ± 2.4 cm, 3.1 ± 1.3 cm, and 4.3 ± 2.4 cm, respectively. The Pearson correlation coefficient of the relationship between the bladder base and uterine distances was $r = 0.73$ ($r^2 = 0.53$). The Pearson correlation coefficient of the bladder distance and urethral distance was $r = 0.82$ ($r^2 = 0.67$).

Conclusion—Half of the observed variation in anterior compartment support may be explained by apical support.

Keywords

Pelvic organ prolapse; MRI; Cystocele; Uterine prolapse; Biomechanics

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Pelvic organ prolapse is a distressing and debilitating condition for women. It requires surgery in approximately 200,000 American women each year,[1] making it the pelvic floor disorder most often requiring surgical repair.

There are many different combinations of support defects in women who have pelvic organ prolapse. They can involve the anterior compartment, the posterior compartment, or the apical segment. The nature of these problems relates to the structural supports of the vagina and uterus

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with the apical segment determined by relatively long vertical fibers that involve the cervix and upper vagina, while midvaginal support of the anterior and posterior compartments are determined by shorter more direct connections.[2] At the present time, there has not yet been quantitative analysis of the interactions between apical and anterior vaginal wall support to evaluate the interactions between these compartments in the formation of the clinical problem referred to as cystocele, urethra vesical junction (UVJ) hypermobility, and uterine prolapse.

We sought to test a null hypothesis that apical and anterior compartment support are independent factors that do not interact. The purpose of this study is to quantify the relationship, if one exists, of anterior and apical compartment support.

Material and methods

We recruited women representing both normal support, as well as varying degrees of pelvic organ prolapse as part of an ongoing case control study of pelvic organ support at the University of Michigan. Women with prolapse were recruited from the Urogynecology clinic and those with normal support, by advertisement. Women who had previously been operated on for pelvic organ prolapse or urinary incontinence were excluded. A convenience sample was selected from this pool to include women in whom the uterus was in situ, the cervix, bladder, and urethra were visible in the dynamic sagittal images, and a correct Valsalva maneuver was performed as judged by the movement of the abdominal wall and intestinal contents in a caudal direction. This resulted in a sample of 153 women for analysis, who had a mean age of 53.3 ± 12.5 years, 2.7 ± 1.8 vaginal births, and a mean BMI of 26.4 ± 4.5 kg/m^2.

Magnetic resonance (MR) imaging was performed on a 1.5 Tesla system (Signa, General Electric, Milwaukee, WI) using a 4-channel torso phased array coil with the subject in the supine position. Before starting the examination, the patient was instructed in regards to the straining maneuvers to be performed during the examination starting from minimal to maximal straining. For dynamic imaging, a multiphase, single level image of the pelvis in the midsagittal plane was obtained approximately every second for 23 to 27 seconds using a T2-weighted single-shot fast spin-echo (SSFSE) sequence (TR: 1300 ms, TE: 60 ms, slice thickness: 6 mm, field of view 32-36 cm, matrix: 256 × 160, 1 excitation and half-Fourier acquisition). The time needed to acquire each of the images was determined by the patients' weight and was just over a second. A set of 20 successive images were acquired in 23 to 27 seconds during rest and graded Valsalva effort as follows: the operator instructed the patient to hold their breath in inspiration and initiated the scan, and after 5 seconds of imaging during rest, the operator instructed the patient to strain minimally for 5 seconds, moderately for 5 seconds, and maximally for 5 seconds, then to breath normally and relax for another 5 to 7 seconds before ending the acquisition. Usually, 3 images were acquired at rest during suspended inspiration, 12 images during the graded Valsalva effort, and 5 images during post Valsalva relaxation and normal breathing.

The location of the external cervical os, most dependent part of the bladder base, and the internal urinary meatus were marked at rest and at maximum Valsalva (Figure 1). Although the urethral lumen was often not visible, the wall of the urethra was visible and the marking point was placed at the edge of the bladder in the middle of the urethral wall. For the bladder base we chose the most dependent point of the bladder base between the cervix and the urethra. We established a Cartesian coordinate system using the inferior pubic point as the origin, the SCIPP (sacro-coccygeal inferior pubic point) line as the x-axis, and a line perpendicular to the SCIPP line through the inferior pubic point as the y-axis; this places the y-axis roughly in the location of the hymen, although this landmark is not visible in the scans. The x-y coordinates of the locations for each point were based on this system. Point placement was reviewed and confirmed by 2 independent reviewers before measurement.

“Normal” rest position was defined by the location of these landmarks at rest in 20 nulliparous women with proven normal support on pelvic examination. These women were taken from various MRI studies of pelvic floor disorders in women. This “normal” position was used as our reference point for all measurements in this study. Support status for each woman in this study was measured as the distance between a given subject's points and these reference locations. (The rationale for this system is discussed in the Comment section below.)

In a tall woman with a large pelvis, a point may be farther below normal because of body size differences. To see if these size-related factors influenced the data we performed a second analysis where we adjusted measurements by normalizing women's pelvis to a standard SCIPP line length of 11.5 cm.[3]

We calculated the Pearson correlation coeffient comparing the anterior compartment's (most dependent part of the bladder base) and apical compartment's (cervix) distance below “normal” at maximum Valsalva. We also calculated the correlation of 2 components of the anterior compartment (urethra and bladder) at maximum Valsalva. For both calculations, a *t* test was performed in order to determine whether the correlations were statistically significant.

Results

Figure 2 shows examples of variation in cervix, bladder, and urethra descent demonstrating different combinations of support with some women having descent of only the uterus, while others have anterior compartment descent despite a well-supported uterus, and others having descent in both compartments.

The locations of the bladder and the cervix at rest and during maximal Valsalva are shown in Figure 3. The “normal” locations of the bladder and cervix calculated from the nulliparous women are shown for reference. Anterior compartment locations for bladder and urethra are shown in Figure 4 for the subjects at rest and during maximal Valsalva. The “normal” position of the bladder and urethra are the same because the most dependent part of the bladder base and the internal urinary meatus in all of the nulliparous women were in the same location.

The distances from the “normal” resting location of the most caudal bladder point, internal urinary meatus, and external cervical os for women with pelvic sizes normalized to 11.5 cm[3] were 4.1 ± 2.4 cm, 3.1 ± 1.3 cm, and 4.3 ± 2.4 cm, respectively. We analyzed the pre- and post-SCIPP normalization measurements and found the Pearson correlation coefficients were r = 0.99 (most caudal bladder point), r = 0.99 (internal urinary meatus), and r = 0.98 (external cervical os). Given these strong correlations between measurements, the distances measured for actual pelvis sizes and when normalizing the pelvis size were essentially equivalent.

Figure 5 shows the relationship between bladder and cervix location and the distance that each point (bladder and cervix) lies below the reference location for a normalized pelvis size. The square of the correlation coefficient of r = 0.73 suggests that approximately half of the degree of uterine displacement is associated with the degree of bladder displacement (r^2 = 0.53, P < .0001).

Figure 6 shows that the relationship between urethral and bladder location had a correlation coefficient of r = 0.82 and suggests that approximately two thirds (r^2 = 0.67) of the urethral displacement is explained by the bladder displacement (P < .0001) for a normalized pelvis size. The 45-degree line in the data where bladder and urethra have the same value occurs because anatomically the internal urinary meatus could not be below the bladder.

Comment

This study quantifies the relationship between the anterior compartment and the apical compartment revealing an r^2 value of 0.53 indicating that half the size of the anterior compartment prolapse is explained by the size of the apical compartment and vice versa. A substantial number of women had descent of either anterior or apical compartment alone. Therefore, multi-compartment prolapse needs to be considered on an individual basis. A relationship ($r^2 = 0.67$) also exists between descent of the bladder and urethra.

The relationship between apical support and anterior support has implications for our understanding of cystocele. In earlier work, examining the locations of paravaginal defects in women with anterior vaginal wall support loss, it became apparent that the anterior vaginal wall formed a roughly trapezoidal layer on which the bladder was supported.[4] The narrow ventral portion was attached to the pubis at the insertion of the tendinous arch of the pelvic fascia and the wide dorsal part was attached to the ischial spine. The broad dorsal margin of the trapezoid is held upward by the suspending action of the cardinal/uterosacral ligament complex.[2] Because detachment at the pubic bone occurs in only 2% of individuals[4] this suggests that loss of apical support is critical to the development of anterior vaginal wall prolapse. When apical support fails, the top of the trapezoid swings downward like a trap door, resulting in downward displacement of the bladder. The present study confirms that this loss of apical support is involved with the occurrence of cystocele in many women.

Our findings are relevant to the surgical management of cystocele. For a woman with loss of apical or cervical support simply plicating the fibromuscular tissue from side to side during anterior colporrhaphy would not reestablish the elevation of the upper one third of the anterior vaginal wall. The apical resuspension occurs at the time of vaginal hysterectomy by using the cardinal or uterosacral ligaments, ie, a McCall culdoplasty or uterosacral suspension. In women with post-hysterectomy vault eversion, sacral colpopexy, or 4-wall sacrospinous suspension accomplish the same thing. On the other hand, some women do have isolated problems with anterior compartment support despite a well supported apical segment and in these select women cystocele repair alone leads to good results.

The current paradigm for understanding anterior compartment support was articulated by Richardson, who described lateral defects (paravaginal defects), transverse defects where the anterior vaginal wall became detached from the cervix, and midline defects where the vaginal wall itself failed.[5] At the core of this thinking is the assumption that cystoceles are caused by site specific defects whose varying combinations results in different prolapse morphologies. Our findings are consistent with this view; individual women have different combinations of apical and anterior compartment support loss leading to different prolapse patterns (Figure 2).

The findings of this study concern the size of the prolapse but not the location of support structure damage. At present, we have not been able to see the specific sites of connective tissue failure in MR scans. That is, it is not possible to see the detachment of the tendinous arch of the pelvic fascia from the ischial spine known to be associated with most anterior vaginal wall failures.

Several authors have sought to develop tests that locate the site of defect responsible for cystocele. Physical examination, although clinically very helpful, shows poor predictive abilities when compared with intraoperative findings demonstrating sensitivity of up to 50% and specificity of up to 80%.[6] This could be a limitation of physical examination where overall interexaminer agreement was only 42% and intraexaminer agreement only 46%, indicating that using physical examination as a “gold standard” is probably not possible.[7] Both MRI and ultrasound have found abnormalities in vaginal and bladder appearance that have been attributed to paravaginal defects.[8-10] These examiners, however, were not blinded to the

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patient's clinical status. Confirmation that these techniques can separate a midline defect from a paravaginal defect will require imaging studies on women with normal support, central defects, and paravaginal defects reviewed by observers blinded to clinical findings. In all of these assessments, a “gold standard” is needed for comparison. At present, this may not exist. Observation at the time of surgery would seem to be such a standard but existing reports vary considerably on how many women with anterior wall failure have paravaginal defect, ranging from 37.7%,[6] 42%,[11] and 94%.[4] The first 2 of these reports include observations made during vaginal surgery that may not be as sensitive in detecting small defects. Furthermore, strict definitions of how much separation between arcus and fascia constitutes a paravaginal defect and how much of a central defect is present can not completely be evaluated.

We chose to compare prolapse findings during Valsalva with nulliparas at rest for several reasons. First, measuring the distance the compartment moved from rest to maximal Valsalva is problematic because several women had nonreduced prolapse at rest during MR scanning. If the difference between rest and Valsalva had been calculated, these women with severe defects would paradoxically have small values. Second, we felt it more rational to make these measurements starting from a specific point in a Cartesian system rather than measuring from a reference line, such as the SCIPP line, because prolapse is a multidirectional phenomenon. Therefore, a woman with a prolapse that descends in a posterior direction would have a point further from the reference line than a woman with a prolapse that descends anteriorly.

A limitation of this study is that MR scans are obtained in the supine position and there is concern that it is not possible to show true maximal pelvic load in this position. Although it would be ideal to make these measurements in the standing posture, few magnets are available worldwide that accommodate true standing (not sitting) position. Researchers have compared supine dynamic MRIs with imaging in a sitting position in an open configuration scanner. MRIs obtained in the sitting position did lead to greater degrees of descent, however, supine scans during straining were found to be comparable in documenting pelvic floor movement.[12,13] After all, clinicians have examined supine women to quantify prolapse for many years and, with the aid of the Valsalva maneuver, are able to reproduce the prolapse despite the woman being horizontal. Also, all studies of prolapse suffer from the need to examine the prolapse when it is maximally protruded and in our experience, we have found that it is possible to coach patients to get good Valsalva effort in the supine position in the MR scanner.

This project focuses on the interactions of the anterior and apical segments to better understand the biomechanics of prolapse. It quantifies the magnitude of this relationship and re-emphasizes the common need to address more than 1 segment at a time that has long been known to experienced surgeons. These findings will be of benefit clinically if they stimulate more surgeons to carefully evaluate the need for reattaching the upper portion of the anterior vaginal wall to strengthen apical supports at the time of surgery for cystocele.

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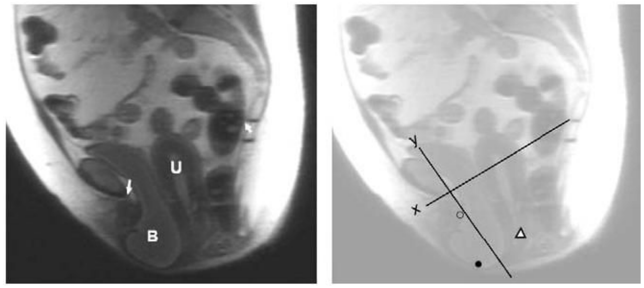

Figure 1.

Left panel shows a sagittal section of a woman with a descent of the bladder (B) and uterus (U). The arrows point to the sacro-coccygeal articulation dorsally and the inferior pubic point ventrally. The right panel shows the SCIPP line (x-axis) and the perpendicular y-axis, most caudal bladder point (*closed circle*), internal urinary meatus (*open circle*), and external cervical os (*triangle*).

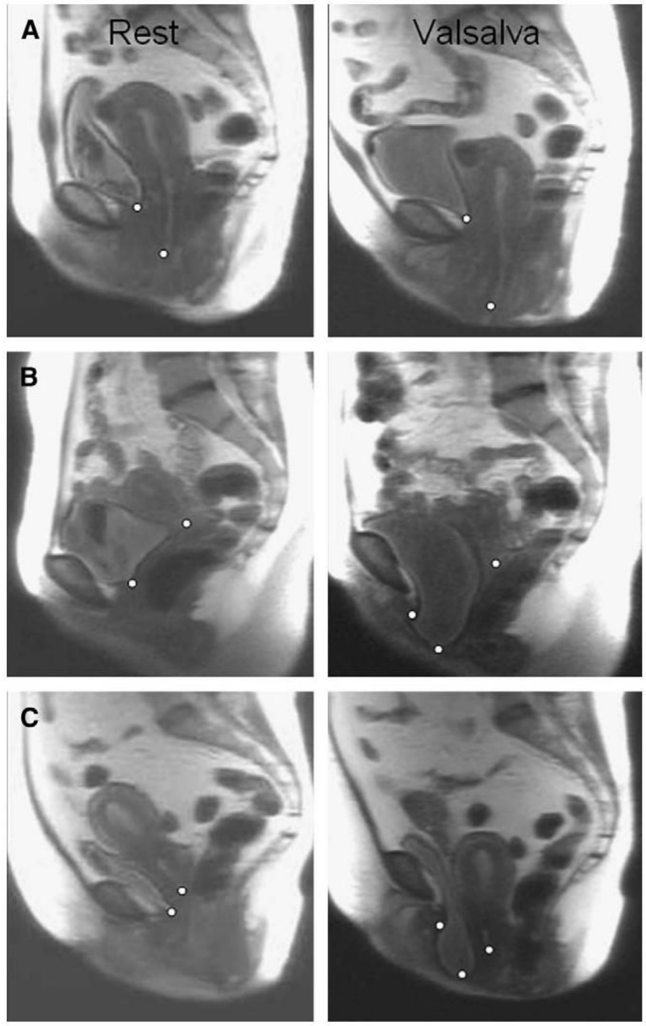

Figure 2.
A, Uterine descent without bladder descent. **B,** Bladder and urethra both descend without uterus. **C,** Similar descent of the bladder and uterus with noticeably less decent of the urethra in contrast to **B**. Note, when bladder base and urethra are in the same location, a single mark is shown.

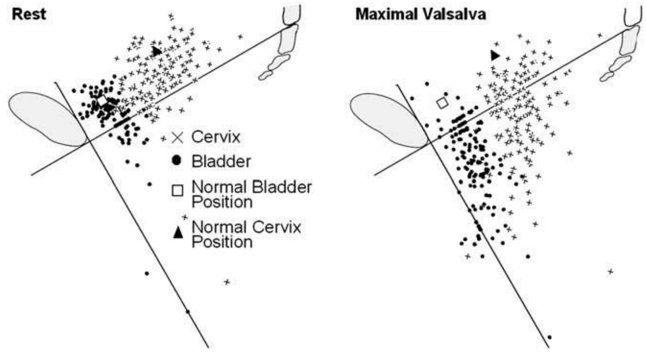

Figure 3.
Location of the bladder and uterus at rest and at maximal Valsalva.

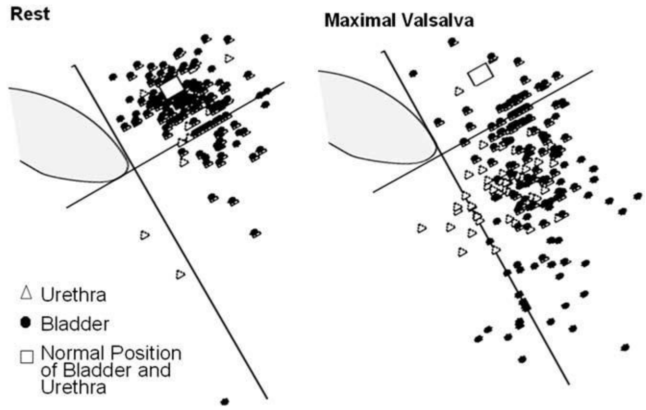

Figure 4.
Enlarged view of the urethra and bladder locations at rest and maximal Valsalva. Because of co-localization, the “normal” position of the bladder and urethra are the same. The figures were enlarged compared with Figure 3 in order to show the overlap of the bladder and urethral locations. In doing so, the most dependent bladder point during maximal Valsalva is not shown.

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Figure 5.
Correlation between bladder and uterus. The distance between the “normal” location and the position during maximal Valsalva maneuver for both the most caudal point of the bladder and the external cervical os.

Figure 6.
Correlation between bladder and urethra. The distance between the “normal” location and the position during maximal Valsalva maneuver for both the most caudal point of the bladder and the internal urinary meatus.