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Pelvic architectural distortion is associated with pelvic organ prolapse

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Abstract

Introduction—To determine whether there is an association between architectural distortion seen on MR scans (lateral “spill” of the vagina and posterior extension of the Space of Retzius) and pelvic organ prolapse.

Methods—Secondary analysis of MRI scans from a case-control study of women with prolapse (maximum point $\geq +1$ cm; N = 144) and normal controls (maximum point ≤ -1 cm; N = 126). Two independent investigators, blinded to prolapse status and previously established levator defect scores, determined the presence of architectural distortion on axial MR scans. Women were categorized into 3 groups based on levator defects and architectural distortion.

Results—Among the 3 groups, women with levator defects and architectural distortion have the highest proportion of prolapse (78%; $p < .001$). Among women with levator defects, those with prolapse had an odds ratio of 2.2 for the presence of architectural distortion (95% CI = 1.1–4.6).

Conclusions—Pelvic organ prolapse is associated with the presence of visible architectural distortion on MR scans.

Introduction

Recent advances in pelvic floor imaging such as magnetic resonance imaging (MRI) and ultrasound have objectively demonstrated that knowing the status of pelvic floor muscles and connective tissue can aid in our understanding of the disease mechanisms underlying pelvic floor disorders.(1–4) These images allow us to study the anatomy of living women with known pelvic organ support and continence status, as opposed to the knowledge gleaned from cadaver dissections in which subjects with prolapse are rarely encountered.(5)

The discovery of levator ani muscle defects after childbirth(2,4) and the documentation of their association with pelvic floor dysfunction(3,6,7) have increased our understanding of the disease process. Although at present it is not possible to know whether this visible abnormality comes from mechanical disruption (avulsion) or neurological damage, it is easily recognized on MRI. Women with pelvic organ prolapse have an odds ratio of 7.3 for having major levator

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ani defects seen on magnetic resonance scans, as compared to women without prolapse.(6) Women with new stress incontinence after their first vaginal delivery are twice as likely to have birth associated levator defects.(2)

Connective tissue is an important element of the pelvic organ support system and defects in this system are considered an important contributing mechanism in pelvic organ prolapse.(8, 9) To date, the radiographic and morphologic appearance of injured or damaged connective tissue in MR scans is not as well understood as the appearance of levator ani muscle damage. The increasing quality of magnetic resonance imaging techniques allows us to identify the lateral attachments of the vagina to the pelvic sidewall and the possible architectural distortions that may accompany defects in the connective tissue.

In studying the levator ani muscles in scans of women with pelvic floor disorders and asymptomatic controls, we observed a characteristic abnormal appearance of the vagina in the peri-urethral region of certain women, a phenomenon we have chosen to call “architectural distortion”. This morphologic abnormality is illustrated in Figure 1. It occurs in the same region where characteristic damage to the levator ani muscle is seen. However, architectural distortion is only present in a subset of women with levator defects. In this study, our objective was to determine whether this pattern of architectural distortion has a separate association with pelvic organ prolapse above and beyond the association seen with levator ani muscle defects alone.

Materials & Methods

This is a secondary analysis of the MR scans made during an IRB-approved case-control-study comparing women with and without pelvic organ prolapse.(6) Details of the study design are included in that publication. In brief, women were recruited as cases if their most dependent point on the pelvic organ prolapse quantitative (POP-Q) exam(10) was 1 cm or greater beyond the hymen. Women were included in the study with anterior, posterior, and apical-predominant prolapses. Controls were required to have their most dependent POP-Q point 1 cm or more above the hymen and to lack significant pelvic floor symptoms such as incontinence or defecatory dysfunction. Subjects were recruited between 2000 and 2004 using newspaper advertisements, fliers, the Women’s Health Registry, and the University of Michigan Urogynecology Clinic.

All women had a supine pelvic magnetic resonance (MR) scan performed without an endovaginal or endoanal coil. Scans were performed with the patient at rest (not straining). No bowel preparation was performed prior to the study. Multiplanar, two-dimensional, fast spin, proton density MR images (echo time 15 ms, repetition time 4000 ms) were obtained using a 1.5 T superconducting magnet (General Electric Signa Horizon LX[®], GE Medical System[®], Milwaukee, WI). The axial and coronal fields of view were each 16 × 16 cm; the sagittal images were 20 × 20 cm. All three views had slice thicknesses of 4 mm with a 1 mm gap between slices.

There were 286 axial MR scans available from 151 cases and 135 controls. Sixteen women were excluded from analysis because of poor scan quality due to technical difficulties with the MRI machine or if unreduced prolapse was seen on MRI scan. These scans were excluded because the anatomy was so distorted that this anatomical region could not be adequately evaluated and because blinding for prolapse was not possible in these cases. Our final analysis contained 144 women with pelvic organ prolapse and 126 women without prolapse.

We reviewed all axial images for each individual subject. We then focused on the level of the arcuate pubic ligament, and carefully observed for the hallmarks of architectural distortion in the 3 slices caudad and cephalad to the arcuate pubic ligament. The presence or absence of

architectural distortion was visible in the vast majority of subjects between the level of the arcuate pubic ligament, and 3 slices cephalad to this ligament.

In the parent study, MR scans were evaluated for the presence and severity of levator ani muscle defects.⁽⁶⁾ Levator defects were scored using a previously described method,⁽¹⁾ with established inter-rater reliability.⁽¹¹⁾ In the present study, architectural distortion was evaluated as “present” or “absent” by 2 independent examiners (MH and RM) blinded to subject’s prolapse status, levator defect score and the other examiner’s findings. Based on these results, all subjects were then categorized into one of three groups: 1) No levator defects and no architectural distortion, or “normal morphology” (Figure 1A), 2) Levator defects and no architectural distortion (Figure 1B), or 3) Levator defects and architectural distortion (Figure 1C). “Architectural distortion” was defined as: lateral or posterior “spill” of the vagina from its normal position and posterior extension of the space of Retzius beyond the superior lateral sulcus of the vagina until it comes in contact with the superior surface of the iliococcygeal portion of the levator ani muscle. There were no subjects observed to have normal levator ani muscles and architectural distortion. Disagreements between the two investigators were adjudicated by consensus via discussion with the senior author. The protocol for this discussion was for all three investigators to look at the images together, and to determine a final unanimous decision following their group observations.

We then looked only at the subjects with prolapse and, based on the leading edge of their prolapse on clinical POP-Q examination, determined their predominant compartment of prolapse (anterior, posterior, or apical). We determined what proportion of women in each of the three morphologic groups (see Figure 1) had a predominant prolapse in each of the three compartments (anterior, posterior, or apical).

Chi-square tests, odds ratios, and multivariable logistic regression analysis were performed using SAS software (version 9.1; SAS Institute Inc, Cary, NC, USA).

Results

Subjects’ demographic information is shown in Table I. The three groups did not differ with respect to age, race or BMI. There was a small but statistically significant difference between the 3 groups with respect to parity. Because of this finding, a multivariable logistic regression analysis was performed, and parity was not found to be a significant predictor of morphologic group status ($p=0.096$, $R\text{-square}=0.0169$). When we calculated adjusted odds ratios, adjusting first for parity, then adding age and BMI to the model, we found that none of these three variables is a significant predictor of architectural distortion. Parity is not predictive of architectural distortion, with or without age and BMI as co-variables. We found that women with architectural distortion and levator defects (Figure 1C) have the highest proportion of prolapse (Table II), followed by women with levator defects and normal architecture (Figure 1B), and finally by women with completely normal morphology (Figure 1A).

We made three pair-wise comparisons in order to calculate odds ratios. First, we found that women with prolapse were more likely to have architectural distortion *and* levator defects (Figure 1C) than levator defects alone (Figure 1B), with an odds ratio of 2.2 (95% CI 1.1–4.6; $p<0.001$). Women with prolapse were more likely to have levator defects without architectural distortion (Figure 1B) than completely normal morphology (no levator defects, no architectural distortion; Figure 1A), with an odds ratio of 3.7 (95% CI 2.1–6.6; $p<0.001$). And finally, women with prolapse were more likely to have *both* levator defects *and* architectural distortion (Figure 1C) than completely normal morphology (Figure 1A), with an odds ratio of 8.3 (95% CI 4.0–17.0; $p<0.001$).

As summarized in Table III, we found that women with anterior-predominant prolapse were more likely than those with posterior or apical prolapse to have levator defects and architectural distortion ($p=.004$). Women with a posterior prolapse were more likely to have neither levator defects nor architectural distortion than women with anterior or apical prolapse ($p=.004$).

Inter-rater agreement for the presence of architectural distortion was 87% with a kappa of 0.64 (95% CI 0.54–0.75).

Discussion

We have found a significant positive association between pelvic architectural distortion seen on MR scans and pelvic organ prolapse. This relationship is an additional finding that extends beyond the known association between levator ani muscle defects and prolapse.(6) We hypothesize that this finding of architectural distortion represents a connective tissue disruption that exists in addition to levator defects. However, this hypothesis remains to be proven.

The morphologic classification of pelvic organ prolapse on MRI is still in its infancy. At present, there is a good conceptual and experimental paradigm for evaluating the status of the levator ani muscles.(3,12) As yet, our ability to understand the appearance of connective tissue damage, and our ability to identify, grade, and quantify this damage lags behind the progress that has been made in understanding and classifying muscle abnormalities. This study is an attempt to visualize specific defects in pelvic connective tissue in the same way that, for example, a tear in the rotator cuff is seen, as a characteristic and visually reproducible morphologic subtype. We hypothesize that the loss of the typical configuration of the vagina in an axial MRI scan, described in this study as “architectural distortion,” could represent a connective tissue disruption at the pelvic sidewall. More research will be needed to specifically determine the exact structures involved. One future goal is to be able to classify morphologic subtypes of prolapse in order to evaluate the relationship between specific muscle or connective tissue defects and surgical outcomes. The presence of these specific visible defects may, in the future, affect surgical decision making.

The pathophysiology of pelvic organ prolapse is complex. It is not possible in a single study or discussion to adequately consider all of its aspects and determinants. In broad outline, however, support of the pelvic organs is provided by the combination of connective tissue and its interaction with the levator ani muscles and their sophisticated, though little understood, neural control. In a recent study we have found that women with pelvic organ prolapse have an odds ratio of 7.3 for having a major levator injury compared with age-, race-, and parity-matched women with proven normal pelvic organ support.(6) The present finding of an odds ratio of 8.3 when both levator defect and architectural distortion are present demonstrates the additional effect of architectural distortion above and beyond the effect of levator muscle defects alone.

The fact that not all women with a levator ani muscle defect develop pelvic organ prolapse is consistent with the long held hypothesis that connective tissue failure is also involved in development of pelvic organ prolapse. The importance of the interaction between levator ani defects and connective tissue disruptions has been demonstrated through computer modeling.(13) It is important to emphasize that architectural distortion is a separate factor associated with pelvic organ prolapse – it is not seen in all cases of pelvic organ prolapse. It is associated with, but not necessarily the result of levator defects. To clarify, in women with levator defects, some have architectural distortion present, and some do not. However, levator defects appear to be a necessary condition for architectural distortion to occur; we have not observed any cases of architectural distortion in women who do NOT have levator defects.

This work expands on the previous findings of Aronson,(14) who identified structural abnormalities visible in MRI in four women suffering from stress urinary incontinence and four asymptomatic controls. Visible distortions were clearly seen in women with cystocele. Anterior vaginal wall support was lost in the incontinent group, with the space of Retzius appearing enlarged and asymmetric. In Huddleston's MR study,(15) bilateral fascial defects in MRI were identified in all three levels of support and described as "chevron sign" (Level I), "saddlebags sign" (Level II), and "mustache sign" (Level III). These defects were noted to be corrected postoperatively following paravaginal repair. Many of the subjects shown in these studies, however, also had levator ani muscle defects and the separate contribution of these two structural abnormalities could not, at that point in time, be evaluated. The present study extends these findings by evaluating the frequency with which these morphologic changes are seen both in cases of prolapse and in normal controls, and by determining the magnitude of the relationships involved.

There are several limitations to this study. It is not a population-based study and our findings can not estimate how often these lesions occur in the general population. We have not yet established the exact structural nature of the connective tissue defect seen in "architectural distortion" but we believe it is associated with connective tissue rather than muscle defect because muscle defects can be seen in the absence of this type of distortion. If this does in fact represent a connective tissue defect, it will be a fruitful area for further research. We were not able to blind investigators to the status of the levator ani muscle defects as they are clearly visible in the MR scans at the same level as the architectural distortion. Although the investigators were blinded to the previously determined levator defect score, they were able to look at the levator ani muscles on the MRI scans, and could determine for themselves whether or not there was a muscle defect. In addition, because of the exclusion of subjects with large, unreduced prolapses on MRI, we may have biased our findings against showing a relationship between architectural distortion and prolapse.

As with other musculoskeletal distortions, when the fibromuscular apparatus is damaged, both connective tissue and muscle are involved. One possible explanation for the appearance of "architectural distortion" is that disruption of both muscle and connective tissue may have happened at the time of a birth related avulsion type injury. Conversely, those women who did not have architectural distortion may have sustained a neurologic or ischemic injury which would lead to muscle atrophy, but not avulsion of the connective tissue, thereby maintaining normal appearing pelvic sidewall architecture. However, at this time, these hypotheses remain conjectures, awaiting further scientific testing. Future research in this area will help elucidate the multifactorial disease mechanisms underlying pelvic organ prolapse.

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Figure 1. Illustration of the 3 morphologic groups

Each panel shows an axial pelvic MR scan 1 cm cephalad to the arcuate pubic ligament. Panel A shows an example of normal levators and normal architecture; Panel B shows an example of a unilateral levator defect and normal architecture; Panel C shows an example of a unilateral levator defect and unilateral architectural distortion. The second row contains the same images, unmarked. Abbreviations: U, urethra; V, vagina; R, rectum; LA, levator ani. Filled black arrowheads indicate normal appearing LA; Open black arrowheads indicate LA defect; Open white arrowhead indicates the posterior displacement of the space of Retzius, as seen with “architectural distortion.” The vagina in each image is traced with a white, dotted line. Note the normal appearing vagina in Panels A & B, with anteriorly oriented fornices, and note the lateral “spill” of the vagina in Panel C, consistent with architectural distortion.

Table IDemographics (Mean $\pm$ SD)

	No levator defect; No distortion (N=108)	Levator defect; No distortion (N=97)	Levator defect; Architectural distortion (N=65)	P value
Age (yrs)	54.5 $\pm$ 12.2	57.4 $\pm$ 12.5	55.9 $\pm$ 13.1	0.27
Race (Caucasian)	93%	90%	95%	0.37
BMI (kg/m ²)	26.9 $\pm$ 5.3	26.1 $\pm$ 4.4	25.7 $\pm$ 4.9	0.25
Parity (vaginal)	2.5 $\pm$ 1.8	3.1 $\pm$ 2.0	2.4 $\pm$ 1.2	0.02

Table II

Proportion of women with prolapse in each morphologic subgroup

	No levator defect	Levator defect present	
	No architectural distortion (N=108)	No architectural distortion (N=97)	Architectural distortion (N=65)
Prolapse (N=144)	33 (31%)*	60 (62%)*	51 (78%)*
No prolapse (N=126)	75 (69%)*	37 (38%)*	14 (22%)*

*
p<.001; Percentages are column percent

Table III

Distribution of levator defects and architectural distortion by compartment of prolapse (in subjects with prolapse only)

	Anterior 92 (64%)	Posterior 25 (17%)	Apex 27 (19%)	Total 144 (100%)
No levator defect, no distortion	18 (20%)*	12 (48%)*	3 (11%)*	33 (23%)
Levator defect, no distortion	37 (40%)*	6 (24%)*	17 (63%)*	60 (42%)
Levator defect, architectural distortion	37 (40%)*	7 (28%)*	7 (26%)*	51 (35%)

*
p=.004; Percentages are column percent