Visibility of pelvic organ support system structures in magnetic resonance images without an endovaginal coil

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OBJECTIVE: The aim of this study was to determine which elements of the pelvic organ support system are visible on magnetic resonance imaging performed without an endovaginal coil.

STUDY DESIGN: Proton density–weighted pelvic magnetic resonance images were obtained for 20 healthy continent nulliparous women with a mean (±SD) age of 30.1 ± 5.1 years (range, 22-42 years). Standardized analyses of transverse, coronal, and sagittal key images were carried out to describe pelvic organ support system anatomy.

RESULTS: Details of both the muscular and fascial supports were clearly seen. The endopelvic fascia was visible on transverse images and could be seen to laterally attach the proximal vagina to the pelvic wall. Its appearance was consistent with its composition of a network of connective tissue, vessels, and nerves. The upward, lateral, and dorsal direction of its most cephalic suspending fibers was visible on both transverse and coronal images. The different nature of the uterosacral ligament relative to the cardinal ligaments was also demonstrated in transverse images. The endopelvic fascia’s attachment to the pelvic walls was visible in the midvagina. The 3 parts of the levator ani muscle were likewise visible—the pubococcygeus, puborectalis, and iliococcygeus. Fusion of the levator ani muscle and the vagina at the level of the middle urethra could be recognized on transverse and coronal images.

CONCLUSION: Magnetic resonance imaging depicted structures of the pelvic organ supports, including the endopelvic fascia and pelvic floor muscles, without the need for an endovaginal coil. (Am J Obstet Gynecol 2001;184:1156-63.)

Key words: Endopelvic fascia, magnetic resonance imaging, nulliparous women, pelvic floor muscles, pelvic organ support structures

Pelvic organ prolapse and urinary incontinence are caused by structural defects in the connective tissue and muscles that support the pelvic organs. Previously, only limited areas of this multifaceted apparatus could be studied in affected women during surgery. Magnetic resonance imaging (MRI) provides the first opportunity to examine the totality of these soft tissue structures in large numbers of women with symptoms.

The statuses of certain components of this support system have been studied with MRI. Structures involved in urinary continence1-4 and the levator ani muscle have been evaluated.5-7 In addition, the effects of increased abdominal pressure,8,9 pelvic muscle contraction,10 and posture11 have also been studied.
were obtained). All women signed informed consent to participate in this institutional review board–approved study performed at University of Michigan Health Systems in Ann Arbor.

Transverse T1-weighted, T2-weighted, and proton density–weighted images of the pelvic region were acquired with a slice thickness of 4 mm and a slice gap of 1 mm. A 160 × 160-mm field of view and an imaging matrix of 256 × 256 were used. Imaging parameters were identical for coronal T1-weighted, coronal proton density–weighted, and sagittal proton density–weighted imaging. The ratios of repetition time to echo time were 600/15 ms for the T1-weighted sequence and 4000/120 ms and 4000/15 ms for the T2-weighted and proton density–weighted sequences, respectively.

To investigate the MRI appearance of pelvic organ support system structures, MRI scans were examined from 4 female pelvic cadaver specimens (ages 25, 33, 65, and 70 years) whose nature and preparation have previously been described elsewhere.5, 6 With the aid of a pattern matching technique, structures seen on corresponding cadaver and living MRI scans were paired and identified. Histologic identification of tissue types (eg, smooth vs striated muscle) was based on the examination of 1500 serial histologic sections from 8 cadavers 0 to 37 years old13 and on gross anatomic relationships gleaned from gross dissection of 61 cadaver specimens.14

Key images representing the 3 levels of the pelvic organ support system14 were evaluated. In the axial plane evaluation focused on regions at the middle and proximal urethra (level III), the bladder base (level II), and the cervico vaginal junction (level I; Fig 1A). Coronal key images were evaluated at the level of the urethra, 0.5 cm dorsally at the level where the vagina attaches to the levator ani muscle, 2 cm dorsally at the level of the rectovaginal space and rectal pillar, and at the level of the ischial spine (Fig 1B). The sagittal key images were analyzed at the level of the urethra and 2 cm laterally on the right or left (Fig 1C).

Results

Axial images. Images depicting each level of vaginal support are shown in Fig 2. In these and subsequent figures, findings from 3 women, one each with average muscle, thin muscle, and thick muscle, are displayed to give some idea of variation among women. At level I (Fig 2A–C) the uterine cervix was visualized. A portion of the paracolpium and parametrium (open tips) can be seen to arise from the pelvic sidewall in the region of the coccygeus muscle and sacrospinous ligament complex near the level of the ischial spine. The streaked and variegated appearance of this tissue reflects its composition of blood vessels and connective tissue (compare anatomic section, Fig 3). The smooth muscle of the uterosacral attachment sometimes falls along the section line and has a less mottled appearance than the more vascularized mesentery of the cardinal and uterosacral complex (Fig 2C). The different appearances of the uterosacral ligament in parts A, B, and C of Fig 2 suggest that there is variation among individuals in the proportions of smooth musculature, connective tissue, and vessels.

A relatively constant point of attachment of the parametrial tissues to the inner surface of the pelvic wall can be seen overlying the piriformis muscle (Fig 2A). The suspensory fibers at level I run in many directions. Although the smooth muscle fibers within the uterosacral ligament are sometimes seen in their entirety on axial images, the other, more vertical fibers at the cardinal ligament are not cut along their fiber direction in this plane. Their origins and attachments can be seen more fully on coronal images.

At level II (Fig 2D–F) the more direct relationship between the vagina and the pelvic sidewalls is seen. There is a layered appearance to the vaginal wall and its sur-
Fig 2. Axial images according to planes of Fig 1. A, in 22-year-old (A, D, G, and J), 24-year-old (B, E, H, and K), and 34-year-old (C, F, I, and L) nulliparous women without urogynecologic problems. A-C, Level of cervix (Cx) and ischial spine (IS); uterus (Ut) with bright endometrium is also seen. Paracolpium and parametrium suspend (open tips) vagina and cervix from lateral and posterior pelvic sidewall. Smooth muscle of uterosacral ligament (open tips) is best seen in C. GM, Gluteus maximus muscle. D-F, Level of bladder (B) base. Upper vagina between bladder and rectum (R) and its attachment to pelvic sidewall by vascular and connective tissue mesentery (small arrow) are seen. Levator ani muscle (iliococcygeal part, filled arrowhead) arises from arcus tendineus of levator ani muscle (filled arrow). OI, Obturator internus muscle. G-I, At level of proximal urethra, levator ani muscle (pubovisceralis part, filled arrowhead) arises from pubic bone (open arrow). Pubovesicalis muscle (open arrowhead) is clearly seen in H. Vessels (white gap) are visualized between smooth muscle layer of lateral vaginal wall and levator ani muscle at this level. J-L, At level of middle urethra, pubovesicalis muscle is seen as shown in J (open arrowhead). Vessel layer (white gap) between lateral vaginal wall and levator ani muscle (filled arrowhead) has disappeared; direct connection between vagina and levator ani muscle is seen at this level. Small white gap in levator ani suggests fascia between puborectalis and pubococcygeal muscles (especially in J and L).
rounding tissue at this level. The hyperintense (bright) submucosa of the vagina is visible and surrounded by the lower intensity (dark) muscularis of the vaginal wall. Outside this layer a combination of pelvic vessels and connective tissues (endopelvic fascia) that attaches the vagina to the inner surfaces of the levator ani muscle can be seen (Fig 2, small arrow). These tissues characterize the connection of the genital tract to the pelvic walls.

At level II the vagina is seen to stretch from one pelvic wall to the other. There is no single structure separate from the vaginal wall that spans the space between the pelvic walls and could be referred to as the pubocervical fascia or rectovaginal fascia. Rather, these structural layers arise as a combination of the vagina and its attachments to the pelvic wall by the vascular and connective tissue mesentery.

In the more cranial portion of level III, at the level of the urethrovesical junction, the vagina assumes a concave forward configuration as it wraps around the urethra. Here the well-defined structure of the vaginal wall is evident (Fig 2, GI and Fig 4). The vagina has not yet become completely fused with the levator ani muscles at this point, and there is still a small separating space between these structures except for the most anterior portion of the vagina. The periurethral sulci and the attachment of the vagina to the levator ani muscles are present here. In this region the arcus tendineus levator ani is no longer seen, because this is the portion of muscle that arises directly from the bone (Fig 2, G, open arrow).

In the lower part of level III, at the level of the middle urethra (Fig 2, J-L), the vagina is fused laterally to the levator ani muscle. Note the lack of normal vascular space between the vagina and the pelvic sidewall. In this region the anterior and posterior walls of the vagina become thicker relative to level II. The thick pubovisceral parts of the levator ani are seen at this level (filled arrowhead). A small white line dividing the pubococcygeal and pubo-coccygeus muscles can often be observed in women with a thick muscle bulk (Fig 2, L). Incidental note can be made of the pubovesical muscle as it courses anterior to the urethra, passing from the vesical neck to the pubic bones (Fig 2, J, open arrowheads).
Fig 5. Coronal images of 22-year-old (A, D, G, and J), 24-year-old (B, E, H, and K), and 34-year-old (C, F, I, and L) nulliparous women without urogynecologic problems. A-C, At level of urethra (urethral sphincter muscle is seen on right and left sides; small arrow), ventral part of pubovisceralis muscle (filled arrowhead) is seen arising from obturator internus muscle (OI) and leading to level of urogenital diaphragm (open arrow). Ut, Uterus; B, bladder. D-F, At level of posterior urethral wall and lateral vaginal wall, direct connection between smooth muscle layer of vaginal wall (open arrowhead) and levator ani muscle (filled arrowhead) is seen. G-I, At level of rectovaginal space (white gap between levator ani muscle and anterior rectal wall), arising of levator ani (iliococcygeus muscle, filled arrowhead) from its arcus tendineus is visible (filled arrow). Compare thicknesses of puborectalis muscle between H (thin) and I (thick; filled arrowhead). Upward sweep of parametrium is clearly seen (open tips). R, Rectum; asterisk, vessel. J-L, At level of ischial spine (IS), transition from coccygeus muscle (CM) to sacrospinous ligament can be suggested. Configuration of coccygeus muscle varies; compare I and L. GM, Gluteus maximus muscle.
Coronal images. Fig 5, A-C, shows the coronal images that lie parallel to the lumen of the urethra. The inferior ischial pubic rami are seen on either side of the urethra with the labium majus and minus extending below. The internal obturator muscles are clearly visible as they lie on the inside of the pubic bone between the inferior and superior pubic rami. Lying medial to the internal obturator muscle, between the latter and the vaginal wall, is the pubovisceral part of the levator ani muscle (Fig 5, A, filled arrowhead). The plane of section in this orientation is roughly perpendicular to the fibers of the levator ani muscle, displaying it in cross-section. Just below are the perineal membrane (Fig 5, A, open arrow) and the external genital muscles (bulbocavernosus and ischiocavernosus muscle).

In Fig 5, D-F, the width of the vagina and lateral vaginal wall, as well as the posterior urethral wall, is visible in the same section, demonstrating the concave configuration of the vagina at the level of the urethra. The pubovisceral part of the levator ani muscle is seen to fuse with the smooth muscle layer of the vaginal wall (Fig 5, D, open arrowhead) above the level of the perineal membrane.

On the more posterior images (Fig 5, G-I) the levator ani muscle (iliococcygeal part and puborectalis sling, filled arrowhead) are depicted on either side of the rectum. A series of vascular structures (Fig 5, G, asterisk) that extend from the sidewall to the levator ani muscle are visible and should not be mistaken for muscles. Coronal sections are ideal to display the upward sweep of the parametrium and paracolpium (open tips). High proportion of vessels in these structures (open tips). The location of the perineal membrane (Fig 5, D, open arrow) is also displayed here, because it is the most lateral portion of the levator ani muscle (parts D and F of Fig 7 illustrate the variation in muscle thickness, filled arrowhead) arising from the pubic bone before passing toward the rectum. The vertical orientation of the cardinal uterosacral ligaments can often be appreciated on images that show the upper part of the pelvis.

Comment

With a standardized MRI technique without an endovaginal coil, it is possible to image the elements of the pelvic organ support system in healthy women. Not only does MRI yield information for the qualitative description of the structure of the levator ani muscle and the endopelvic fascia, it also enables quantitative analysis to be performed when predefined measuring points are used.

The levator ani muscle is visible in MRI scans on transverse, sagittal, and coronal sections. In accordance with the Nomina Anatomica, it is possible to subdivide this muscle into the pubococcygeal, iliococcygeal, and puborectal muscle on MRI scans as well. New topographic insights cannot be derived from MRI. However, there is a wide normal variation in the morphologic appearance of the levator ani muscle in terms of the depiction of striated muscle tissue (compare the different women in the
images). The study was performed in a homogeneous study population (nulliparous women without urinary incontinence and without prolapse), so this variation probably reflects constitutional differences that may be involved in the genesis of prolapse and urinary incontinence. This variation was especially pronounced for the puborectal muscle. This muscle could hardly be differentiated from the pubococcygeal muscle in some instances, whereas in others it was seen as a strong muscle loop.

MRI is the first modality to depict the ligaments of the pelvic organ support system with subtle detail in living individuals. There are several ways in which the MRI scans substantiate important concepts of pelvic floor anatomy. For example, as Range and Woodburne have previously described, the “cardinal ligament” is a complex structure consisting of a variety of vessels, nerves, and connective tissue, rather than a single band of connective tissue as has sometimes been presumed. We did see a dark band of tissue on proton density–weighted images that corresponded to the smooth muscle contained in the uterosacral ligament, as described by Campbell.

We could not find separate structures representing a separate layer between the vagina and bladder (pubocervical fascia) or between the vagina and rectum (rectovaginal fascia). The existence of the latter has long been a matter of debate. Our findings are consistent with earlier observations that the structural layers restraining movement of the bladder and rectum arise from attachments of the vaginal wall to the pelvic walls, rather than representing layers that are independent of the vaginal smooth muscle. Further observations by independent investigators should help confirm or refute these findings. A full discussion of this contentious issue is beyond the scope of this article.

In conclusion, our findings suggest that MRI yields detailed information on the muscular pelvic organ support system. Although the use of MRI is still restricted to scientific investigation, the information derived is becoming indispensable to a better understanding of pelvic floor structure and function. Before we will be able to define pathologic conditions, however, further comparative anatomic and MRI studies are needed to resolve the differences that still exist between anatomic structural descriptions and the appearance on MRI. Nevertheless, this study shows that it is feasible to compare structures at different levels between different women in pelvic organ support if standardized imaging planes are used. The differences seen in the 3 women whose images are presented here reveal that important individual variation exists. This will need more study before the limits of normal variation can be established. Although we do not know at

Fig 7. Midsagittal (A-C) and parasagittal (D-F) images of 22-year-old (A and D), 24-year-old (B and E), and 34-year-old (C and F) nulliparous women without urogynecologic problems. A-C, At midsagittal level, urethra with sphincter muscle (small arrow), vagina, and rectum (R) are seen. Puborectalis sling (filled arrowhead) surrounds posterior rectal wall, and external sphincter ani muscle (filled arrow) is visualized in perineum (D) and distal to puborectalis muscle (E). B, Bladder; PB, pubic bone. D-F, At parasagittal level, perineal membrane (open arrow) and iliococcygeal muscle (filled arrowhead) are seen. Compare differences in thickness of iliococcygeal muscle between D and F.
present how these findings will influence treatment, it would be surprising if this additional knowledge does not shed light on some of the long-standing mysteries concerning pelvic organ prolapse.

REFERENCES