MR Imaging of Pelvic Floor Relaxation

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Abstract

Magnetic resonance imaging (MRI) has been used as a research tool in evaluation of the female pelvic floor for over a decade. Early studies were limited because of poor resolution and long scan times, which prohibited evaluation of pelvic floor descent. During the past few years, the advent of surface coils and fast T2-weighted imaging techniques has significantly enhanced the value of MR imaging. The entire pelvic floor can now be rapidly imaged during rest and strain to determine whether laxity is global or confined to specific compartments. High-resolution axial images can be used to identify muscle and fascial tears. In several centers, MRI is now routinely performed for pre-operative planning of pelvic floor repairs. Developing techniques include imaging in the upright position using an open configuration magnet and three-dimensional modeling of the muscles of the pelvic floor. Seated imaging is useful for evaluation of pelvic floor disorders such as perineal hernias, which are often better seen in the upright position. Three-dimensional imaging is a time-consuming but useful research tool for visualizing the entirety of the levator ani and quantifying muscle mass. Key words: MR imaging, pelvic floor relaxation, urinary incontinence

Learning objectives

After reading this article and completing the post-test, the physician should be able to:

• understand the risk factors for and anatomic defects of pelvic floor relaxation
• identify on sagittal T2-weighted MR images the findings of significant pelvic organ descent
• identify on axial T2-weighted MR images the findings of loss of integrity of muscular and fascial supports of the pelvic floor
Introduction

Pelvic floor relaxation - abnormal descent of the bladder, uterus and/or vagina, small bowel, or rectum - is a significant women's health issue affecting primarily parous women over 50 years of age. Up to 50% of such women have some degree of genital prolapse the degree of which is significant enough to cause symptoms in 10-20% (1). Patients complain of a wide variety of symptoms but more than 90% cite increased pelvic pressure and protrusion of tissue through the pelvic floor (2). Many also suffer from stress incontinence. Risk factors include age over 50, menopause, multiparity, and obesity. Despite decades of work, little is known about the precise pathophysiology and functional anatomy of the damaged pelvic floor and treatments have not been optimized. In part this is because prior to the advent of MR imaging, there was no radiologic test available that could image both the descent of the pelvic organs and supporting structures simultaneously. The advent of fast T2-weighted pulse sequences, which are required to image pelvic floor structures during valsalva maneuver, has made MR imaging even more valuable. Dynamic MR imaging is becoming the test of choice in the pre-operative assessment of complex pelvic floor relaxation cases. This paper will review MR techniques for and findings of pelvic floor relaxation.

Anatomy

The pelvic floor can be divided into three compartments: the anterior compartment containing the bladder and urethra, the middle compartment containing the vagina and the posterior compartment containing the rectum. Each of these is supported by the endopelvic fascia and the pelvic diaphragm. The muscles forming the pelvic diaphragm are two components of the levator ani - the puborectalis and the iliococcygeus (Figure 1). The iliococcygeus is a horizontal, sheet-like structure that extends from the anal sphincter to a fibrous band on the pelvic wall called the arcus tendineus. The iliococcygeus muscles fuse at the midline anterior to the coccyx to form the levator plate. The puborectalis originates at the symphysis pubis and forms a sling around the rectum. The urethra and vagina extend through the urogenital hiatus. The rectum extends outside the pelvic diaphragm at this level, and is separated from the vagina by the perineal body and anal sphincter. The levator ani muscles are in constant contraction in normal women, thereby keeping the rectum, vagina and urethra closed by pressing them against the symphysis pubis.

The pelvic organs are also supported by a series of fascial condensations called ligaments (3). When the muscles of the pelvic floor are damaged, usually during childbirth, these ligaments take on the burden of preventing descent of the pelvic organs. Elastic condensations of endopelvic fascia called the parametrium and the paracolpium support the uterus and vagina, respectively. The parametria are composed of the cardinal and uterosacral ligaments and are usually not identified on MR images. The paracolpia are composed of two fascial condensations arising from the lateral aspect of the vagina and can sometimes be identified on high resolution MR images (Figure 2) (4). Rupture of these ligaments in association with levator ani weakness leads to uterine or vaginal vault prolapse, and in severe cases, procidentia. The pubocervical fascia extends from the
anterior vaginal wall to the pubis and supports the bladder. Loss of this support can lead to hypermobility and anterior rotation of the urethra, descent of the posterior bladder base and bulging of the anterior wall of the vagina (cystocele), and urinary stress incontinence. The posterior vaginal wall and rectovaginal fascia support the rectum and prevent displacement of bowel (enterocele) into the pouch of Douglas.

**MR imaging**

**Technique**

During the past 10 years, MR imaging has emerged as a competitor to colpocystoedefecography (CCD), voiding cystorurethrography (VCUG), and ultrasound as a technique for evaluation of the pelvic floor. The main advantages of MR imaging are ability to evaluate 3 compartments of the pelvic floor simultaneously during straining and visualization of individual supporting structures. Obtaining high quality, useful images requires careful attention to patient preparation and exam technique. Prior to imaging, the patient should be asked to void prior to prevent a distended bladder from distorting adjacent anatomy and limiting straining. A multicoil array, either the pelvic or torso coil, is wrapped around the lower aspect of the pelvis. It is important to place the coil low enough so that prolapsing structures can be seen. In the absence of a multi-coil array, the body coil can be used.

Following a rapid T1 weighted localizer series in the sagittal or axial plane, a midline slice 10mm in thickness encompassing the symphysis, bladder neck, vagina, rectum and coccyx is identified. If all the relevant structures cannot be imaged on a single slice, 2 contiguous locations can be specified. The patient is then coached on valsalva technique to insure maximum effort. Alternatively, a small balloon catheter can be placed in the rectum and the patient asked to expel it during strain. Using a fast, T2-weighted imaging technique, sagittal midline images are then obtained at rest and at maximal strain. Typical imaging parameters are: TR =10,000ms, TE1/TE2 = 90ms, ETL =8, one acquisition, 10mm section thickness, 24-30 cm FOV, and 256 phase encoding steps. Using these parameters, each image is obtained in less than 3 seconds. The strain images can be repeated with additional verbal coaching if necessary. If a perineal hernia or ballooning of the puborectalis is suspected, this same series of images should be repeated in the coronal plane. A standard axial fast spin echo sequence with a 18-20cm FOV is then used to obtain high resolution images 5 mm in thickness of the puborectalis, pubocervical fascia and fascial condensations supporting the urethra. T1-weighted and contrast enhanced images are not required.

**Findings**

Pelvic floor anatomy is complex and requires review of multiple imaging planes to identify all of the important features. The most important finding to be assessed on sagittal images is pelvic organ descent with respect to the pubococcygeal (PCL) line drawn between the inferior aspect of the symphysis and the last joint of the coccyx (Figure 3). In a pioneering study, Yang et al. used gradient echo images to define normal
descent of the bladder base (1.0 cm below), vagina (1.0 cm above) and rectum (2.5 cm below) with respect to the pubococcygeal line (5). In practical terms, descent of the bladder, vagina/uterus or rectum more than 1 cm below the PCL is usually indicative of significant relaxation and loss of muscular and fascial support and should be conveyed to the referring surgeon (Figure 4). There are other important findings on sagittal images. Caudal inclination of the levator plate with respect to the PCL is indicative of loss of pelvic floor support and is associated with isolated cystocele and global pelvic floor relaxation (6, 7). Rotation of the urethra > 30° anteriorly and superiorly often accompanies moderate to severe bladder descent and can mask stress incontinence. The posterior urethrovesical angle is extremely variable in both the continent and incontinent populations and should not be used as an indicator of pelvic floor support (8). Anterior bulging of the rectal walls more than 2 cm constitutes a rectocele. Its degree of symptomatology remains controversial, although Healy et al. has reported an association with fecal incontinence (9). Descent of small bowel or sigmoid colon greater than 2 cm into the pouch of Douglas is evidence of enterocele and loss of integrity of the rectovaginal fascia. Many physicians believe that enterocele causes a feeling of incomplete defecation and resultant increased straining at stool.

On axial images, the radiologist must review muscle morphology and signal intensity as well as vaginal shape. The puborectalis muscle should extend from the rectum to the symphysis pubis. Any deviation of the muscle from this path may indicate tear of the fascia lateral to the bladder (Figure 5). The width of the levator hiatus at the level of the symphysis rarely exceeds 4.5 cm in healthy volunteers. Increased width and ballooning with strain have been reported as indicators of pelvic floor relaxation (10). Increased signal intensity of the puborectalis in comparison with the obturator musculature may indicate fatty or fibrous change within the muscle and has been reported in association with stress incontinence (11). In separate papers, Klutke et al. and Huddleston et al. reported alteration of the vaginal shape (with normal defined as H-shape) as an indication of paravaginal tears and pelvic floor relaxation (12, 13). Abnormal vaginal shapes include concave anterior, flat as well as asymmetry within the levator hiatus.

Several authors have investigated the concordance of MR findings with those of CCD and at operation and with the exception of Vanbeekvoort et al. report excellent agreement (14-16). In a carefully controlled study of 10 women with clinically identified pelvic floor relaxation in which the vagina, bladder and rectum were opacified, Kelvin et al. found excellent correlation comparing supine MR with CCD (17). MR imaging has also been successfully used to monitor the injection of periurethral collagen as a treatment for Type III, or sphincteric, stress incontinence. (18).

**Developing Techniques**

**Seated imaging**

During the past few years, 2 research groups have published work, evaluating upright MRI of the pelvic floor. Fielding et al. using a 0.5 T open configuration magnet, specially designed commode chair, and rectangular receive/transmit surface coil, acquired images...
of 8 continent volunteers and 8 women with stress incontinence in the upright position at rest and during maximal strain (19). Degree of abdominal strain was monitored using a saline manometer. Sagittal and coronal images were obtained demonstrating maximal descent of the pelvic organs. Axial images were used to assess integrity of the muscular and fascial structures and vaginal shape. While cystoceles and urinary leakage were of greater magnitude in the upright position, there was no significant difference in the number of pelvic floor defects identified. Schoenenberger et al. have reported successful identification of the anorectal angle, anal canal, puborectalis muscle and descent of the pelvic floor in 15 subjects with defecation disorders using MR defecography performed in the upright position using a 0.5T magnet (20). They found the technique particularly useful in identification of spastic pelvic floor syndrome. Because of the need for rapid acquisition of T2-weighted images, it seems unlikely that lower field strength systems will produce images of adequate signal.

**3D imaging**

The formation of 3D models of the muscular supports of the female pelvic floor is a new research tool. The models can be used to quantify muscle volume, simulate lithotomy views, and plan resection of vulvar or pelvic floor tumors. The technique is based on acquisition of thin (3mm), axial T2-weighted images of the pelvic floor encompassing the bones, bladder, urethra, vagina, rectum and major components of the levator ani - puborectalis and iliococcygeus.

A set of semiautomated computer procedures is used to label each voxel in the data set (segmentation). In critical areas, such as near nerves or arteries, manual editing is used to improve the results of the segmentation process. This combination of techniques allows detailed identification of the pertinent structures within a relatively short period of time. The results of segmentation are rendered as a surface image using the dividing triangles and marching cubes algorithms. Features of the rendering programs allow the operator to:

1. assign color and opacity to each rendered anatomic part
2. change the vantage point of the observer relative to the rendering
3. simulate lesion removal
4. zoom in and out on regions of interest

Fielding et al. recently completed a pilot project using a combination of axial MR source images and 3D models to describe the anatomy of the normal female pelvic floor in 10 healthy volunteers (21). The signal intensity of the puborectalis was found to exceed that of the obturator externus in all cases. The average volume of the levator ani was 46.6 ml, width of the levator hiatus 41.7mm. This study showed that muscle morphology, signal intensity and volume is relatively uniform among young, nulliparous women (Figure 6).

Segmentation of the pelvic floor organs and supports is not a trivial matter and requires a highly trained technician several hours to perform. The iliococcygeus can be particularly
difficult to identify in some elderly women and the vagina, rectum, and urethra can be almost inseparable when prolapsed through the puborectalis. A workstation and advanced software are also required and are relatively expensive. For these reasons, 3D imaging currently remains primarily a research tool.

**Conclusion**

The wide variety of available surface coils, pulse sequences, and post-processing techniques makes MR imaging a useful clinical and research tool for evaluation of the support structures of the female pelvis and pelvic floor relaxation. Cases of isolated cystocele will likely not require imaging, however, in cases of global pelvic floor relaxation or when more than one compartment of the pelvis is involved, MR imaging can provide physicians with valuable information for surgical planning. Routine clinical cases should be performed in the supine positions, require only a T1-weighted localizer and sagittal and axial T2-weighted images and use room time of under 20 minutes. With practice, review of the images requires less than 10 minutes. MR imaging can also be used to follow post-operative patients. Seated imaging gives only minimal additional information and should be reserved for cases of suspected perineal hernias, which cannot be seen in the supine position.

**References**


Figure Legends

1. Line drawing of pelvic floor with bladder and urethra removed shows supporting muscles and fascia including the iliococcygeus and puborectalis.

2. Axial T2-weighted image of a 47 year old healthy volunteer. Image obtained at the level of the pubourethral ligament (short arrow) shows lateral pubovesical ligaments (long arrow) to the left and slightly inferior to the bladder neck. Note normal H or butterfly shape of vagina.

3. Sagittal T2-weighted images of a 52 year old healthy volunteer at rest (A) and at maximal strain (B). Long arrows mark the pubococcygeal line (PCL). Distance from the bladder neck (star) and apex of vaginal cuff (solid arrow) to the PCL change only minimally with strain. The levator plate (open arrow) remains parallel to the PCL.

4. Sagittal T2-weighted images of a 58 year old woman with stress incontinence and pelvic floor relaxation on physical exam at rest (A) and at maximal strain (B). At rest, the bladder neck is open however it remains well above the PCL. With maximal strain, there is global pelvic floor relaxation with descent of the bladder, vagina and rectum. No enterocele is seen. The levator plate becomes nearly perpendicular to the PCL (open arrow) and there is significant rotation of the urethra (arrow).

5. Axial T2-weighted image of a 45 year old woman with stress incontinence obtained in the seated position on a 0.5T magnet. There is lateral deviation of the left aspect of the puborectalis indicating loss of support (arrow). Muscle stretching and a paravaginal tear were confirmed at surgery.

6. 3D rendering of 38 year old healthy female volunteer. Color scheme is as follows: pelvic bones - white, hips-pale blue, vagina-pink, muscle (levator ani)-red, bladder/urethra-yellow, rectum-blue.
A Dorsal lithotomy view simulates surgical approach.

B. Sagittal view with symphysis to left (grey) and coccyx to right (pink) shows and near-field pelvic bones removed shows normal appearance of iliococcygeus.

CME questions

1. Damage to which of the following is not a precursor to pelvic floor relaxation:
   - iliococcygeus puborectalis
   - bladder trigone
   - pubocervical fascia
   - rectovaginal fascia

2. Which of the following factors does not contribute to the development of pelvic floor relaxation:
   - menopause
   - obesity
   - childbirth
   - vigorous exercise
   - age greater than 50

3. On sagittal T2-weighted MR images, the following are indicators of pelvic floor relaxation:
   a. descent of pelvic organs more than 2cm below the pubococcygeal line (PCL) T F
   b. caudal inclination of the levator plate T F
   c. anterior and superior rotation of the urethra T F
   d. descent of small bowel more than 2cm into the Pouch of Douglas T F
   e. movement of the uterus from the anteroflexed to the retroflexed position T F
4. On axial T2-weighted images, the following are indicators of pelvic floor relaxation:
   H-shaped vagina T F discontinuity of the puborectalis T F
   ballooning of the iliococcygeus T F
   levator hiatus greater than 4.5cm T F

5. Upright, seated imaging is required to adequately assess pelvic floor relaxation. T F