Pelvic floor anatomy and imaging

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A B S T R A C T

The pelvic floor is a complex, three-dimensional (3D) mechanical apparatus that consists of several components: the pelvic organs and endopelvic fascia, the ligament and perineal membrane, the levator ani muscles and superficial perineal muscles, and the pelvic nerves. The support for the pelvic organs comes from connections to the bony pelvis and its attached muscles. Any damage to the structural and functional interactions of the pelvic floor elements can potentially cause multicompartmental dysfunction. Surgical management of pelvic floor disorders depends on a comprehensive understanding of the structural integrity and function of the pelvic floor. As a result of technological progress, dedicated imaging modalities including static and dynamic 3D and 4D transvaginal, endoanal and transperineal ultrasound, dynamic Magnetic Resonance, and evacuation proctography have been introduced. The “integrated” use of these techniques provides outstanding visualization of the anatomy of the pelvic floor, allowing for accurate assessment of the major disorders—urinary and fecal incontinence, pelvic organ prolapse, and obstructed defecation syndrome.

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Introduction

The pelvic floor is a complex, three-dimensional (3D) mechanical apparatus that has been artificially divided into three different regions (anterior, middle, and posterior compartments). In this article, the term “pelvic floor” is used broadly to include all the structures supporting the pelvic cavity rather than the restricted use of this term to refer to the levator ani group of muscles.

The pelvic floor consists of several components lying between the peritoneum and the vulvar skin. From above downwards, these are the peritoneum, pelvic viscera and endopelvic fascia, levator ani muscles, perineal membrane, and superficial genital muscles. The support for all these structures comes from connections to the bony pelvis and its attached muscles. The pelvic organs are often thought of as being supported by the pelvic floor, but in reality form part of it. The pelvic viscera play an important role in forming the pelvic floor through their connections with structures, such as the cardinal and uterosacral ligaments and are attached to the levator ani muscles when they pass through the urogenital hiatus. As a consequence, any dysfunction of the structural and functional interactions of the pelvic floor elements can potentially cause a multicompartmental disorder. Although patients may present with symptoms (urinary incontinence, voiding dysfunction, fecal incontinence, obstructed defecation, and dyssynergy) that involve only one compartment, 95% of these have abnormalities in all three compartments. Therefore, the specialist (urologist, gynecologist, gastroenterologist, colorectal surgeon, or physical therapist) needs to appreciate that as pelvic floor disorders rarely occur in isolation, evaluation and surgery can impact on the function of the neighboring compartment.

Diagnostic evaluation has a fundamental role to identify all pelvic floor disorders and to provide comprehensive information for a management that encompasses the consequences of therapy on adjacent organs and avoids sequential surgery. The increasing availability of ultrasound equipment in the clinical setting, and the recent development of 3D and 4D ultrasound, have renewed interest in using this modality to image pelvic floor anatomy as a key to understanding dysfunction. The “integrated approach,” by using a combination of different modalities (endovaginal ultrasound—EVUS, endoanal ultrasound—EAUS, and transperineal ultrasound—TPUS) provides a comprehensive evaluation of this region. In this article, we will also present the advantages and limitations of other imaging modalities such as evacuation proctography and dynamic magnetic resonance imaging (MRI).

Pelvic floor anatomy

The pelvic organ support system includes the endopelvic fascia, the perineal membrane, and the levator ani muscles that are controlled by the central and peripheral nervous system. The supports of the uterus and vagina are different in different regions.
According to DeLancey, the cervix and the upper one-third of the vagina (level I) have relatively long suspensory fibers (uterosacral and cardinal ligaments) that are vertically oriented in the standing position, while the mid portion of the vagina (level II) has a more direct attachment (pubocervical and rectovaginal fascia) laterally to the pelvic wall. In the most caudal region (level III), the vagina is attached directly to the structures that surround it (Fig. 1). At this level, the levator ani muscles and the perineal membrane have important supportive functions.

In the upper part of the genital tract, a connective tissue complex attaches all the pelvic viscera to the pelvic sidewall. This endopelvic fascia forms a continuous sheet-like mesentery, extending from the uterine artery at its cephalic margin to the point at which the vagina fuses with the levator ani muscles below. The uterosacral and cardinal ligaments together support the uterus and upper one-third of the vagina. At level II, the pubocervical and rectovaginal fascia form more direct lateral attachments of the mid portion of the vagina to the pelvic walls. These lateral attachments stretch the vagina transversely between the bladder and the rectum. In the distal vagina (level III), the vaginal wall is directly attached to surrounding structures. Anteriorly, the vagina fuses with the urethra, posteriorly with the perineal body, and laterally with the levator ani muscles. Damage to level I support can result in uterine or vaginal prolapse of the apical segment. Damage to the level II and III portions of vaginal support results in anterior and posterior vaginal wall prolapse. The varying combinations of these defects are responsible for the diversity of clinically encountered problems and will be discussed in the following sections.

Apical segment

In level I, the cardinal and uterosacral ligaments attach the cervix and the upper one-third of the vagina to the pelvic walls (Fig. 2). The uterosacral ligaments are bands of tissue running under the rectovaginal peritoneum composed of smooth muscle, loose and dense connective tissue, blood vessels, nerves, and lymphatics. They originate from the posterolateral aspect of the cervix at the level of the internal cervical os and from the lateral vaginal fornix. The cardinal ligament is a mass of retroperitoneal areolar connective tissue in which blood vessels predominate; it also contains nerves and lymphatic channels. When placed under tension, it assumes the appearance of a strong cable as the fibers align along the lines of tension. It originates from the pelvic sidewall and inserts on the uterus, cervix, and upper one-third of the vagina. Both the uterosacral and cardinal ligaments are critical components of level I support and provide support for the vaginal apex following hysterectomy (Fig. 2). The cardinal ligaments are oriented in a relatively vertical axis (in the standing posture) while the uterosacral ligaments are more dorsal in their orientation.

The suspensory ligaments hold the uterus in position over the levator muscles that in turn reduce the tension on the ligaments and protect them from excessive tension. After a certain amount of descent, the level I supports become taut and arrest further cervical descent. Damage to the upper suspensory fibers allows uterine or apical segment to prolapse.

Anterior compartment

Anterior compartment support depends on the connections of the vagina and periurethral tissues to the muscles and fascia of the pelvic wall via the arcus tendineus fascia pelvis. On both sides of the pelvis, the arcus tendineus fascia pelvis is a band of connective tissue attached at one end to the pubic bone and at the other end to the ischiurn, just above the spine. The anterior wall fascial attachments to the arcus tendineus fascia pelvis is also defined as paravaginal fascial attachments. Anterior vaginal wall prolapse (cystocele) can occur either because of “lateral detachment” of the anterior vaginal wall at the pelvic sidewall or as a “central failure” of the vaginal wall itself. However, if the cardinal and uterosacral ligaments fail, the upper vaginal wall prolapses downward while the lower vagina (levels II and III) remains supported.

Perineal membrane (urogenital diaphragm)

The “perineal membrane” is a dense connective tissue that surrounds the urethra and close the anterior part of the pelvic outlet. It lies at the level of the hymen and attaches the urethra, vagina, and perineal body to the ischiopubic rami. The compressor urethrae and urethrovaginal sphincter muscles are associated with the cranial surface of the perineal membrane.

Posterior compartment and anal sphincters

The posterior vagina is supported by connections between the vagina, the bony pelvis, and the levator ani muscles. The lower one-third of the vagina is fused with the perineal body (level III)
that connects the perineal membranes on either side. The mid-posterior vagina (level II) is connected to the inside of the levator ani muscles by sheets of endopelvic fascia. These connections prevent vaginal descent during increases in abdominal pressure. The fibers of the perineal membrane connect through the perineal body thereby providing a layer that resists downward descent of the rectum. If this attachment becomes broken, then the resistance to downward descent is lost.

The muscular structures that maintain fecal continence include the internal anal sphincter (IAS), the external anal sphincter (EAS), and the puborectalis (PR) muscle (Fig. 4). The anal canal is 2–4 cm long. The spatial relationships between the internal and external sphincters are such that the IAS extends above the EAS for a distance of greater than 1 cm. The internal sphincter lay consistently between the external sphincter and the anal mucosa. It is a circular smooth muscle that is the continuation of the circular layer of the muscularis propria of the rectum. This layer increases in thickness below the anorectal junction to form the IAS. The IAS has an important role in maintaining continence and is the main contributor to anal rest pressure. The IAS is approximately 2-mm thick. The intersphincteric space is the plane between the sphincters containing loose areolar tissue. The longitudinal layer (conjoined longitudinal layer or longitudinal muscle) is a sheet of fibroelastic and muscular tissue. This layer is the continuation of the smooth muscle longitudinal layer of the rectum with contribution from the levator ani striated muscle (puboanalis) and fibroelastic components of the endopelvic fascia. Cranially it is predominantly muscular and caudally fibroelastic. The fibroelastic tissue forms a network throughout the sphincter and passes through the subcutaneous EAS as bundles or fibers to insert into the perianal skin. The inferior outer aspect of the anal sphincter is formed by the cylindrical EAS which is a striated muscle under voluntary control. The action of the EAS is voluntary closure and reflex closure of the anal canal and thereby contributes to the sphincter tone to some extent. The EAS has a thickness of 4 mm and it is approximately 2.7-cm high while it is shorter anteriorly in women, approximately 1.5 cm.

Three different parts (deep, superficial, and subcutaneous) of the EAS can be identified at certain levels, which to some extent supports a multilayer anatomy. The “deep” part is intimately related to the PR muscle. The “superficial” part overlies the IAS at the middle level of the anal canal. Fibers of the anterior part of the EAS decussate into the transverse perineal muscle and perineal body. Posterior fibers continues with the anococcygeal ligament. The “subcutaneous” part extends approximately 1 cm beyond the IAS and envelops the lower part of the intersphincteric space.

**Lateral compartment and the levator ani muscles**

Below and surrounding the pelvic organs is the levator ani muscle. There are three major components of the levator ani muscle (Fig. 5). The iliococcygeal portion forms a thin, relatively flat, horizontal shelf that spans the potential gap from one pelvic sidewall to the other. The pubovisceral (also known as the pubococcygeus) muscle attaches the pelvic organs to the pubic bone while the PR muscle forms a sling behind the rectum. The lesser known subdivisions of the levator are pubovaginal, puboanal, and the puboperineal muscles. When these muscles and their covering fascia are considered together, the combined structures are referred to as the pelvic diaphragm.

The opening between the levator ani muscles through which the urethra, vagina, and rectum pass is the levator hiatus. The portion of the levator hiatus ventral to the perineal body is referred to as the urogenital hiatus, and it is through this that prolapse of the vagina, uterus, urethra, and bladder occurs. The urogenital hiatus is bounded anteriorly by the pubic bones, laterally by levator ani muscles, and posteriorly by the perineal body and external anal sphincter. The baseline tonic activity of the levator ani muscle keeps the hiatus closed by compressing the urethra, vagina, and rectum against the pubic bone, pulling the pelvic floor and organs in a cephalic direction. This continuous muscle action closes the lumen of the vagina and forms a relatively

![Fig. 3. Anterior vaginal wall prolapse may occur for the detachment of the pubocervical fascia from the arcus tendineous fascia pelvis (lateral defect).](image-1)

![Fig. 4. The muscular structures of the anal canal include the internal anal sphincter, the external anal sphincter, and the puborectalis muscle.](image-2)

![Fig. 5. Schematic view of the levator ani with its three major components: the iliococcygeal muscle, the pubococcygeal muscle, and the puborectalis muscle.](image-3)
horizontal shelf on which the pelvic organs are supported. Damage to the levators resulting from nerve or connective tissue damage will leave the urogenital hiatus open and result in prolapse.¹⁴,¹⁵

The interaction between the levator ani muscles and the endopelvic fascia is one of the most important biomechanical features of pelvic organ support. As long as the muscles maintain their constant tone closing the pelvic floor, the ligaments of the endopelvic fascia have very little tension on them even with increase in abdominal pressure.¹⁶ If the muscles become damaged so that the pelvic floor sags downward, the organs are pushed through the levator hiatus. Once they have fallen below the level of the hymenal ring, they are unsupported by the levator ani muscles and the ligaments must carry the entire load. Although the endopelvic fascia can sustain these loads for short periods of time, if the pelvic muscles do not close the urogenital hiatus, the connective tissue eventually fails, resulting in prolapse.¹⁶ The interactions between the pelvic floor muscles and endopelvic fascia are responsible for the pelvic organs support. It requires the dorsal traction of the uterosacral ligaments, and to some extent the cardinal ligaments, to hold the cervix back in the hollow of the sacrum. It also requires the ventral pull of the pubovisceral portions of the levator ani muscle to swing the levator plate more horizontally to close the levator hiatus. It is, therefore, this interaction between the directions of these two forces that is so critical in maintaining the normal structural relationships that lessen the tension on ligaments and muscles.¹⁶,¹⁷

Nerves

There are two main nerves that supply the pelvic floor relative to pelvic organ prolapse. One is the pudendal nerve that supplies the urethral and anal sphincters and perineal muscles, and the other is the nerve to the levator ani that innervates the major musculature that supports the pelvic floor. These are distinct nerves with differing origins, courses, and insertions. The nerve to the levator originates from S3 to S5 foramina, runs inside of the pelvis on the cranial surface of the levator ani muscle, and provides the innervation to all the subdivisions of the muscle. The pudendal nerve originates from S2 to S4 foramina and runs through Alcock’s canal which is caudal to the levator ani muscles. The pudendal nerve has three branches: the clitoral, perineal, and inferior hemorrhoidal, which innervate the clitoris, the perineal musculature, and inner perineal skin and the EAS, respectively. Motor nerves to the IAS are derived from (1) L5 presacral plexus sympathetic fibers, (2) S2–4 parasympathetic fibers of the pelvic splanchnic nerve.

Pelvic floor imaging

The knowledge of pelvic floor anatomy and function is essential to effective imaging of pelvic floor defects. With advancing technology, MRI and 3D ultrasound techniques have increased our ability to detect pelvic floor defects and helped us gain insight into pathophysiology of pelvic floor disorders. An integrated approach with a combination of different modalities has been described for a global and multicompartmental perspective of pelvic floor dysfunction.⁸,¹⁸,¹⁹

Ultrasonographic techniques

Transperineal ultrasonography (TPUS)

TPUS is performed with the patient placed in the dorsal lithotomy position, with hips flexed and abducted, and a convex transducer positioned on the perineum between the mons pubis and the anal margin (perineal approach). Imaging is performed at rest, during maximal Valsalva maneuver, and during pelvic floor muscle contraction (PFMC). Conventional convex transducers (with frequencies of 3–6 MHz and field of view at least 70°) provide 2D imaging of the pelvic floor.¹⁰,²¹ In the midsagittal plane, with an acquisition angle of 70° or more, all anatomical structures (bladder, urethra, vaginal walls, anal canal, and rectum) between the posterior surface of the symphysis pubis and the posterior part of the levator ani are visualized. A midsagittal view obtained will include the symphysis pubis, the urethra and bladder, the vagina and uterus, the rectum, and the anal canal (Fig. 6). Using 3D transabdominal probes developed for obstetric imaging (RAB 8–4, GE Healthcare Ultrasound, Milwaukee, WI; AVV 531, Hitachi Medical Systems, Tokyo, Japan; V 8–4, Philips Ultrasound, Bothell, WA; 3D 4–7EK, Medison, Seoul, South Korea), 3D- and 4D-TPUS may be performed.¹⁵ These transducers combine an electronic curved array of 4–8 MHz with mechanical sector technology, allowing fast motorized sweeps through the field of view.

Fig. 6. 2D-transperineal ultrasound: midsagittal view showing symphysis pubis (SP), the urethra (U), bladder (B), the vagina (V), the rectum (R), the anal canal (AC), and the puborectalis muscle (PR). (A) Schematic drawing and (B) ultrasonographic view.
An advantage of this technique, compared with 2D mode, is the opportunity to obtain tomographic or multislice imaging in order to assess the entire PR muscle and its attachment to the pubic rami and to measure the diameter and area of the levator hiatus.

Pelvic organ descent is usually assessed with 2D-TPUS.\textsuperscript{21–23} Anterior compartment prolapse, or “cystocele,” is common in women and may cause symptoms such as pelvic heaviness, the sensation of a lump, and voiding difficulty. Cystocele frequently coexists with other disorders involving the central and the posterior compartments, such as uterine prolapse, rectocele, and enterocoele. Dynamic 2D-TPUS demonstrates downward displacement of the urethra and the presence of cystocele in the midsagittal plane during maximal Valsalva maneuver.\textsuperscript{24,25} Ultrasonography also allows evaluation of mesh implants for anterior compartment prolapse.\textsuperscript{26} This is particularly useful considering that complications such as support failure, mesh erosion, and chronic pain are not uncommon. Sonographic imaging can determine the position, extent, and mobility of implants in the anterior vaginal wall, dorsal to the trigone and posterior to the bladder wall. Ultrasonography also allows evaluation of tapes used in anti-incontinence surgery, whose improper positioning or dislodgement may be associated with failed surgery.\textsuperscript{26}

Uterine prolapse is defined as downward displacement of the uterus beyond the halfway point of the vagina. Vaginal vault prolapse refers to descent of the vaginal apex in a patient who has had a hysterectomy and is commonly associated with enterocoele or sigmoidocele. Continued descent of the apex of the vagina may result in complete eversion of the vagina. These conditions are usually obvious clinically, but dynamic 2D-TPUS can demonstrate the effect of the descending uterus on the bladder neck, urethra, or anorectum, explaining symptoms of voiding dysfunction or obstructed defecation.

Posterior compartment prolapse includes rectocele, rectal intussusception, rectal prolapse, enterocoele, and perineal descent. Symptoms that can be related to these disorders include obstructed defecation, such as incomplete evacuation, straining at stool, and vaginal digitation. Dynamic TPUS is able to demonstrate rectocele, enterocoele, and rectal intussusception with images comparable to those of defecography.\textsuperscript{27–29} Rectocele is measured as the maximal depth of the protrusion beyond the expected margin of the normal anterior rectal wall. A herniation of a depth of over 10 mm has been considered diagnostic (Fig. 9). Rectal intussusception may be detected as an invagination of the rectal wall into the rectal lumen during maximal Valsalva maneuver. The intussusception may also be observed to enter the anal canal or exteriorized beyond the anal canal. Enterocoele is diagnosed ultrasonographically as a herniation of bowel loops into the vagina. It can be graded as small, when the most distal part descends into the upper third of the vagina; moderate, when it descends into the middle third of the vagina; or large, when it descends into the lower third of the vagina. Enterocoele may also coexist with rectocele.\textsuperscript{23}

Pelvic floor dyssynergy, also known as anismus, spastic pelvic floor syndrome, or paradoxical PR syndrome, is a phenomenon characterized by a lack of normal relaxation of the PR muscle during defecation. Dyssynergy is associated with symptoms of obstructed defecation and incomplete emptying. Various TPUS abnormalities have been described during Valsalva maneuver: the anorectal angle becomes narrower, the levator hiatus is shortened in the anteroposterior dimension, and the PR muscle thickens as a result of contraction. This sonographic finding may help to choose biofeedback therapy and to evaluate the results of the treatment.
Endovaginal ultrasonography (EVUS)

EVUS is performed with a high multifrequency (9–16 MHz), 360° rotational mechanical probe (type 2052, B-K Medical, Herlev, Denmark) or with a radial electronic probe (type AR 54 AW, 5–10 MHz, Hitachi Medical Systems). The 3D acquisition is free-hand with the electronic transducer, whereas the mechanical transducer has an internal automated motorized system that allows an acquisition of 300 aligned transaxial 2D images over a distance of 60 mm in 60 s, without any movement of the probe within the tissue. The set of 2D images is reconstructed instantaneously into a high-resolution 3D image for real-time manipulation and volume rendering. An advantage of 3D compared with 2D mode is the opportunity to obtain sagittal, axial, coronal, and any desired oblique sectional image. The 3D image may be rotated, tilted, and sliced so that the operator to vary infinitely the different section parameters, to visualize and measure distance, area, angle, and volume in any plane. The 3D volume can also be archived for offline analysis on the ultrasonographic system or on a PC with the help of dedicated software.

3D-EVUS provides a topographical overview of pelvic floor anatomy. Four levels of assessment in the axial plane can be defined. At the highest level (level I), the bladder base can be seen anteriorly and the inferior third of the rectum posteriorly. Level II corresponds to the bladder neck, the intramural region of the urethra, and the anorectal junction. Level III corresponds to the midurethra and the upper third of the anal canal. At this level, the levator ani can be visualized as a multilayer hyperechoic sling coursing laterally to the vagina and posteriorly to the anal canal and attaching to the inferior pubic rami anteriorly. Levator hiatus dimensions (anteroposterior and laterolateral diameters and area) can be measured (Fig. 10). At the lowest level (level IV), the superficial perineal muscles (bulbospongiosus, ischiocavernosus, and superficial transverse perineal muscles), the perineal body, the distal urethra, and the middle and inferior thirds of the anal canal can be visualized.

3D-EVUS may be utilized to document major levator trauma (Fig. 11). Levator avulsion is the disconnection of the muscle from its insertion on the inferior pubic ramus and the pelvic sidewall, whereas tears may occur in any part of the muscle. Avulsion is a common consequence of overstretching of the levator ani during the second stage of labor and occurs in 10–36% of women at the time of their first delivery. The functional and anatomical consequences of levator ani avulsion are considerable, with a reduction in muscle strength of about one-third and marked alteration of anatomy. The main effect of avulsion is due to enlargement of the levator hiatus that may result in excessive loading and failure of ligamentous and fascial structures, which may, over time, lead to the development of prolapse.

Endoanal ultrasonography (EAUS)

3D-EAUS is firmly established as one of the cornerstones of a colorectal diagnostic work-up, and it is performed with the same probes adopted for 3D-EVUS. During examination, the patient may be placed in a dorsal lithotomy, left lateral, or prone position. However, irrespective of patient position, the transducer should be rotated so that the anterior aspect of the anal canal is superior.

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Fig. 9. 2D-transperineal ultrasound: multicompartmental prolapse. Bladder base descent (cystocele) below the referral line (horizontal line to the inferior margin of the symphysis pubis) during maximal Valsalva maneuver. Rectocele is visualized as the protrusion of the anterior rectal wall beyond the expected margin.

Fig. 10. 3D-endovaginal ultrasound. The levator ani (LA) is visualized as a multilayer hyperechoic sling coursing laterally to the vagina and posteriorly to the anal canal (AC) and attaching to the inferior pubic rami (IPR) anteriorly (OF: obturator foramen; SP: symphysis pubis; T: transducer; and U: urethra).

Fig. 11. 3D-endovaginal ultrasound. The levator ani (LA) is disconnected (avulsion) from the left inferior pubic rami (IPR) (arrows) (A: anal canal; SP: symphysis pubis; and U: urethra).
(12 o'clock position) on the screen, the right lateral aspect is to the left (9 o'clock), the left lateral aspect is to the right (3 o'clock), and the posterior aspect is inferior (6 o'clock). The recording of data should extend from the upper aspect of the PR muscle to the anal verge.

With EAUS, the anal canal is divided into three levels of assessment in the axial plane: (1) the upper level corresponds to the hyperechoic sling of the PR muscle and the concentric hypoechoic ring of the IAS. In males, the deep part of the EAS is identified at this level; (2) in the middle level, the complete ring of the superficial EAS (concentric band of mixed echogenicity), the conjoined longitudinal layer, the complete ring of the IAS, and the transverse perineal muscles are visualized; and (3) the lower level corresponds to the subcutaneous part of the EAS.

EAUS has been recommended by the International Consultation on Incontinence as the gold standard investigation to identify anal sphincter lesions (defects, scarring, thinning, thickening, and atrophy).37,38 Tears are identified by interruption of the circumferential fibrillar echo texture (Fig. 13). Scarring is characterized by loss of normal architecture, with an area of amorphous texture that usually has low reflectivity. Ultrasonography also allows evaluation of anti-incontinence surgery (sphincter repair, graciloplasty, bulking agents injection).39

**Echodefecography (EDF)**

This is a 3D dynamic anorectal ultrasonographic modality performed with the same 360° rotating transducer used for EAUS to evaluate posterior compartment prolapse.40 The patient is examined in the left lateral position. Images are acquired by four automatic scans: Scan 1 (at rest position without gel): the transducer is positioned at 5.0–6.0 cm from the anal margin. It is performed to visualize the anatomic integrity of the anal sphincter musculature and to evaluate the position of the PR and EAS at rest; Scan 2 (at rest—straining—at rest without gel): the transducer is positioned at 6.0 cm from the anal verge. The patient is requested to rest during the first 15 s, strain maximally for 20 s, then relax again, with the transducer following the movement. The purpose of the scan is to evaluate the movement of the PR and EAS during straining, identifying normal relaxation, nonrelaxation, or paradoxical contraction (anismus); Scan 3: the transducer is positioned proximally to the PR (anorectal junction). The scan starts with the patient at rest (3.0 s), followed by maximum straining with the transducer in fixed position (the transducer does not follow the descending muscles of the pelvic floor). When the PR becomes visible distally, the scan is stopped. Perineal descent is quantified by measuring the distance between the position of the proximal border of the PR at rest and the point to which it has been displaced by maximum straining (PR descent). Straining time is directly proportional to the distance of perineal descent; Scan 4: following injection of 120–180 ml ultrasound gel into the rectal ampulla, the transducer is positioned at 7.0 cm from the anal verge. The scanning sequence is the same as in Scan 2 (at rest—15 s, strain maximally—20 s, then relax again with the transducer following the movement). The purpose of the scan is to visualize and quantify all anatomical structures and functional changes associated with voiding (rectocele, intussusception, grade II or III sigmoidocele/enterocele). In normal patients, the posterior vaginal wall displaces the lower rectum and upper anal canal inferiorly and posteriorly but maintains a straight horizontal position during defecatory effort. If rectocele is identified, it is classified as grade I (< 6.0 mm), grade II (6.0–13.0 mm), or grade III (> 13.0 mm) (Fig. 14). Intussusception is clearly identified by observing the rectal wall layers protruding through the rectal lumen. Grade II or III sigmoidocele/enterocele is recognized when the bowel is positioned below the pubococcygeal line (on the projection of the lower rectum and upper anal canal).41,42

**Magnetic resonance imaging (MRI)**

**Static MRI**

Static MRI provides detailed information on pelvic floor anatomy. Current state-of-the-art MR of the pelvic floor includes imaging at a magnetic field strength of 1.5 Tesla (T), using pelvic or phased array coils and T2-weighted fast spin-echo (FSE)
sequences. The spatial resolution can be enhanced by using endoluminal (endorectal, endovaginal) coils. In combination with T2-weighted FSE sequences, endoluminal coils provide improved signal-to-noise ratio (SNR) and high-resolution images. Based on T2-weighted turbo spin-echo sequences, muscles are relatively hypointense, ligaments and fascia hypointense, while fat and smooth muscle are hyperintense. The prominent pelvic floor structures of the posterior compartment visualized at MRI are (1) perineal body and superficial perineal muscles; (2) anal sphincters: the IAS is easily recognized as a circular hyperintense structure. It is approximately 2.9 mm thick on endoluminal MRI. The intersphincteric space is seen as a bright line on T2-weighted MRI. The EAS has a thickness of 4.1 mm on endoluminal imaging; (3) PR muscle and levator ani; and (4) rectum and rectal support.

Endoanal MRI has been demonstrated to be comparable to EAUS in the detection of anal sphincter defects in FI. External phased array coil MRI can replace endoluminal MRI with comparable results. Abnormalities of the levator ani are identified on MRI as present or absent. Defect severity is further scored in each muscle from 0 (no defect) to 3 (complete loss) (Fig. 15). A summed score for the two sides (0–6) is assigned and grouped as minor (0–3) or major (4–6).

**Dynamic MRI**

With the development of fast multislice sequences, MR imaging has gained increasing acceptance for dynamic imaging of pelvic floor. Because the posterior compartment is traditionally in the focus of interest, dynamic MR imaging of the pelvic floor is often called “MR defecography.” Dynamic pelvic imaging may be performed in an open-configuration MR system in the sitting position, or in a closed-configuration MR-system in the supine position. Both techniques are equally effective in identifying most of the clinically relevant abnormalities of the pelvic floor. For evaluation of the posterior compartment, the rectum should be filled with a contrast agent (ultrasound gel or mashed potatoes, gadolinium-based MR contrast agent) to study the actual act of defecation.

The use of reference lines for image evaluation is helpful (Fig. 16). The most used reference line is the pubococcygeal line (PCL), which is defined on midsagittal images as the line joining the inferior border of the symphysis pubis to the last or second last coccygeal joint. The anorectal junction (ARJ) is defined as the cross point between a line along the posterior wall of the distal part of the rectum and a line along the central axis of the anal canal. To determine pathologic pelvic floor descent, the measurements are made on the images, which show maximal organ descent, usually during maximal straining or during evacuation. The anorectal angle (ARA) is defined as the angle between the posterior wall of the distal part of the rectum and the central axis of the anal canal and can be measured at rest, squeezing, and straining. Dynamic MRI may be used to demonstrate posterior compartment prolapse during maximal Valsalva maneuver:

- **Rectocele**: measured as the depth of wall protrusion beyond the expected margin of the normal anorectal wall. Based on sagittal MR-sections through mid of pelvis, rectoceles are graded as small (<2 cm), moderate (from 2 to 4 cm), and large (>4 cm) (Fig. 17);
- **Rectal intussusception**: the infolding of the rectal mucosa occurring during defecation. Depending on the location, an
intrarectal intussusception, limited to the rectum, is distinguished from an intra-anal intussusception extending into the anal canal. The location of the intussusception may be anterior, posterior, or circumferential. The intussusception either involves only the mucosa or the full thickness of the rectal wall

- Enterocoele: defined as a herniation of the peritoneal sac, which contains omental fat (peritoneocele), small bowel (enterocoele), or sigmoid (sigmoidocele), into the rectovaginal or rectovesical space below the PCL. The largest distance between the PCL and the most inferior point of the enterocoele is measured with a perpendicular line. Depending on this distance, small (<3 cm), moderate (3–6 cm), and large (>6 cm) enterocoeles are distinguished

- Dysssynergic defecation: various proctographic abnormalities have been described including prominent PR impression, a narrow anal canal, and acute ARA. However, these observations may be found in normal controls and are in themselves unreliable distinguishing features.

### Conclusion

Care of women with pelvic floor disorders begins with an understanding of the unique musculofascial system that supports the pelvic organs. The principles underlying reconstructive surgery are either restoration of normal anatomy and thereby a presumed return to normal function, or creation of compensatory anatomical mechanisms. Combining different imaging modalities has the potential to complement the advantages and to overcome the limitations of each of these tools and to substantially improve the clinical management of these conditions.

### References


