Magnetic Resonance Imaging of the Female Pelvic Floor

Anatomy Overview, Indications, and Imaging Protocols

Rania Farouk El Sayed, MD, PhD

KEYWORDS

- Pelvic floor anatomy • MR imaging anatomy of pelvic floor muscles • MR imaging of pelvic floor
- Indications for MR imaging of pelvic floor dysfunctions
- Indications and imaging protocols of pelvic floor dysfunctions

KEY POINTS

- The "classic 3-compartment approach," "active and passive conceptual approach," and the "multilayered system approach" are established different approaches for description of pelvic floor anatomy.
- The "functional 3-part pelvic supporting systems approach," a new, more function-based classification of pelvic floor support system, is discussed in detail.
- Indications, patients' preparation, and hardware requirements for MR imaging of pelvic floor dysfunction and MR-defecography are included.
- The MR imaging protocols define the most important prerequisites for a diagnostic MR examination according to the concordance of experts from European Society of Urogenital Radiology, European Society of Gastrointestinal and Abdominal Radiology, and Society of Abdominal Radiology societies.

INTRODUCTION

Pelvic floor disorders are often complex with symptoms ranging from vague low back pain to major fecal incontinence and urinary incontinence.

Symptoms are divided arbitrarily into different areas: urinary disorders, fecal disorders, sexual dysfunction, and pelvic discomfort, although symptoms of all types often coexist in the same individual.[1]

When a patient presents for evaluation, she may be unaware that many of her symptoms may be related to pelvic floor dysfunction (PFD). The clinician should elicit a comprehensive history encompassing all pertinent areas. Obtaining a comprehensive history is a particular challenge in reconstructive pelvic surgery, in which anatomic aberrations are often striking, but understanding the symptoms related to them is inadequate. The reoperation rate after initial pelvic floor surgery is reported to be approximately 29%.[2] The commonness of the need for reoperation indicates that better treatments are necessary; however, clinicians specialized in this field affirmed that such improvement will be possible only if research clarifies the causative mechanisms and the reasons that surgery fails.[3]

Magnetic resonance (MR) imaging has been effectively used to evaluate PFD, with very good reported sensitivity, specificity, and positive predictive value. The modality relies on (a) static sequences with a high spatial resolution to delineate the passive and active elements of the pelvic organ support system and (b) fast imaging

Cairo University MRI Pelvic Floor Center of Excellency and Research Lab Unit, Department of Radiology, Cairo University Hospitals, Kasr El Ainy Street, Cairo 11956, Egypt
E-mail address: rania729.re@gmail.com

Radiol Clin N Am 58 (2020) 291–303
https://doi.org/10.1016/j.rcl.2019.11.005

dynamic (cine) sequences during straining and evacuation to detect functional abnormalities.[4] This article reviews in detail the basic essential anatomic information the radiologist needs to know to become competently capable not only of writing a full report based on solid scientific information but also of providing state-of-the art care for patients who present for MR imaging for PFD.[5,6] Full competence means that the radiologist will know the steps for taking a full relevant medical history,[7] can confidently determine which radiologic studies to order to allow for a detailed diagnostic report, to know the mandatory steps for patient preparation, and to assemble the MR imaging findings in a schematic to best meet the needs of the urologist, gynecologist, and proctologist who will treat the patients.

Overview of Pelvic Floor Normal Anatomy

There are several approaches for functional description of pelvic floor (**Fig. 1**):

A. Classic 3-compartment approach
   - The pelvic floor is divided into the following 3 major compartments:
     Anterior: Includes urinary bladder, urethra, and urethral support system
     Middle: Includes vagina (anterior and posterior wall) and uterocervical support
     Posterior: Contains rectum and supporting structure
   - Patients with abnormalities in 1 compartment often have disorders in another[8]

B. Active and passive conceptual approach
   - Pelvic floor components are divided into passive and active structures
     - Passive structures
       - Pelvic bones
       - Supportive connective tissue
     - Active structures
       - Pelvic floor muscles
   - This classification cannot precisely explain pathogenesis of various dysfunctions.[8]

C. Multilayered system approach
   - Considers passive and active components of pelvic floor as an integrated multilayer system[8,9] organized from cranial to caudal into the following:
     - *First layer:* Endopelvic fascia
     - *Second layer:* Pelvic diaphragm
     - *Third layer:* Urogenital diaphragm
     - *Fourth layer:* Perineum

D. Functional 3-part pelvic supporting systems approach (**Fig. 2**)
   - The components of this functional approach are described in full detail in the later discussion, "Static MR Images" of the pelvic floor examination.
   - It is a new, more function-based classification of pelvic floor support system.[5]
   - This approach is based on fact that each passive and active structural component of the pelvic floor plays a role in urinary and fecal continence, preventing pelvic organ prolapse. In this approach, all structures that contribute to the same function are grouped under 1 system.
     - Urethral support system
       - Structures that maintain urinary continence:
         - Urethral support ligaments
         - Level III endopelvic fascia
         - Puborectalis muscle
     - Vaginal support system:

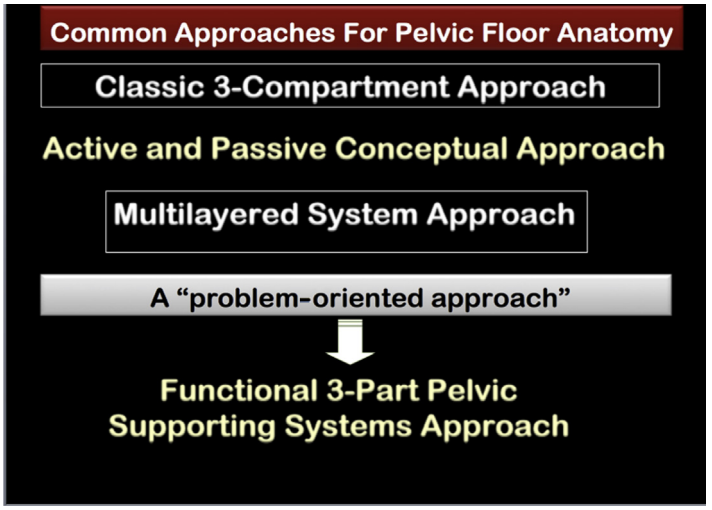

Fig. 1. Four approaches describing the anatomy of the pelvic floor.

- Supporting elements that prevent prolapse:
  - Level I and II endopelvic fascial
  - Iliococcygeus muscle
- Anal sphincter complex:
  - Anal sphincter muscles together with other supporting elements maintain fecal continence

Multilayered System Approach

Essential anatomic and functional information to understand the concept of the "Multilayered system approach" includes the following:

Supportive connective tissue

Supportive connective tissue is a complex network of connective tissue, and variations occur between the main components according to the type of the supportive structures[5]:

A. Ligaments:
- Form a well-defined layer composed of specialized aggregation of connective tissue and have well-organized fibrous collagen
- Include arcus tendineus levator ani (ATLA) and arcus tendineus fascia pelvis ligaments, which are dense, obliquely oriented linear pure connective tissue structures at the pelvic sidewall

B. Endopelvic fascia:
- Forms a diffuse layer that consists of less well-defined connective tissue
- Has a functional correlation, whereby it envelops pelvic organs, including parametrium and paracolpium, giving support to the uterus and upper vagina, respectively[8,10]

Layers of pelvic support

(a) First layer: Endopelvic fascia

- Parametria includes broad, cardinal, and uterosacral ligaments
- Paracolpium refers to connective tissue that attaches vagina to pelvic walls (**Fig. 3**)
  - Anteriorly, pubocervical fascia and ligaments extend from the posterior surface of the pubis to the cervix, giving support to the bladder
  - Posteriorly, rectovaginal fascia inserts into the perineal body, levator plate, and

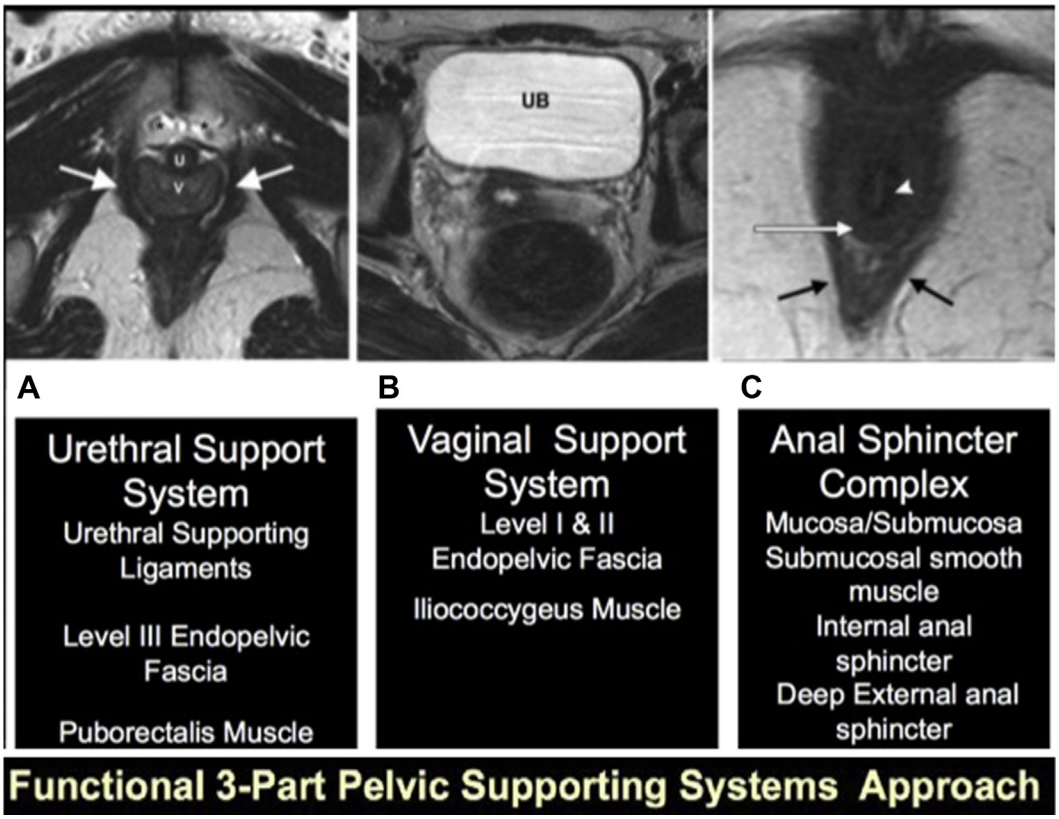

Fig. 2. The Functional 3-Part pelvic support system approach and the components of each system. (*A*) Urethral support system. (*B*) Vaginal support system. (*C*) The anal sphincter complex. Arrow points to internal anal sphincter. Arrowhead points to submucosal smooth muscle. U, urethra; V, vagina; UB, urinary bladder.

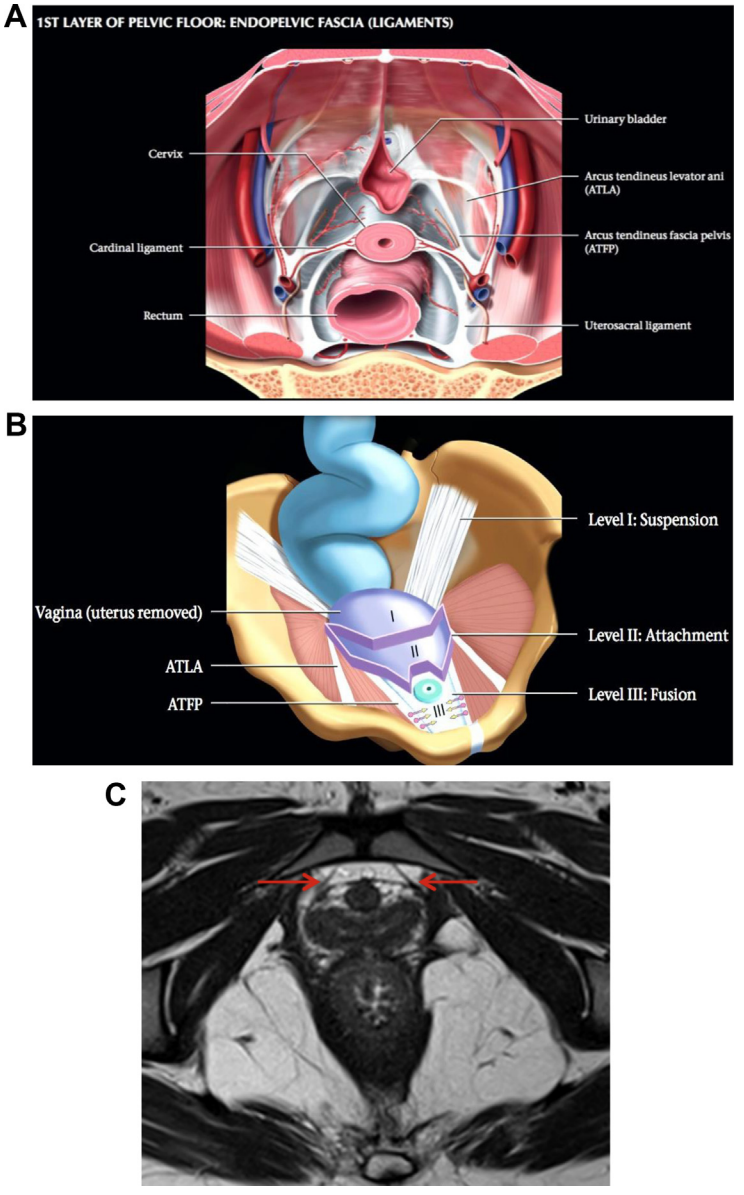

Fig. 3. (*A*) Overview of the pelvis shows the fascia with the bladder, cervix, and rectum cut away. Endopelvic fascia is a continuous adventitial layer, covering the pelvic diaphragm and viscera. It is a complex network of connective tissue composed of collagen, fibroblasts, elastin, smooth muscle cells, and neurovascular bundles. Ligaments are a more well-defined aggregate of connective tissue. (*B*) The type of support the vagina receives at each level (uterus removed). In level I (suspension), the paracolpium suspends the vagina from the lateral pelvic walls. Fibers of level I extend both vertically and posteriorly toward the sacrum. In level II (attachment), the vagina is attached to the arcus tendineus fasciae pelvis and the superior fascia of levator ani. In level III (fusion), the vagina, near the introitus, is fused laterally to the levator ani. (*C*) Axial oblique T2WI TSE MR image shows the arcus tendineus fascia pelvis (ATFP) (*arrows*) on either side of the symphysis pubis. (*From* [(El Sayed RF . Overview of the Pelvic Floor. In: Shaaban AM, Editor. Diagnostic Imaging: Gynecology 2nd Edition. Philadelphia: Elsevier-Amirsys; 2015. 8/2 -8/28 ; with permission.)

uterosacral ligament. It support the rectum and forms a restraining layer that prevents the rectum from protruding forward, blocking formation of a rectocele (**Fig. 3**A)

- Levels of vaginal support
  Pubocervical fascia is divided into 3 levels (**Fig. 3**B, C)
  - *Level I (suspension)*
    - Upper portion of the vagina adjacent to the cervix (cephalic 2 to 3 cm of the vagina)
    - Suspended from above by relatively long connective tissue fibers of the upper paracolpium
    - Functional significance: it provides upper vaginal support
  - *Level II (attachment)*
    - Is a midportion of the vagina
    - The paracolpium becomes shorter at this level
    - Attaches the vaginal wall more directly to arcus tendineus fascia pelvis
    - Stretches the vagina transversely between the bladder and rectum
  - *Level III (Fusion)*
    - Corresponds to the region of the vagina that extends from the introitus to 2 to 3 cm above the hymenal ring

- Near introitus, the vagina is fused laterally to levator ani
- Posteriorly, attaches to perineal body
- Anteriorly, blends with the urethra
- At this level, there is no intervening paracolpium between the vagina and the adjacent structures, as opposed to levels I and II

(b) Second layer: Pelvic diaphragm

- *Definition*: Formed by coccygeus and levator ani muscles and acts as a shelf to support pelvic organs (**Fig. 4**)
- Coccygeus muscle
  - Forms the posterior part of the pelvic diaphragm
  - Arises from the tip of the ischial spine along the posterior margin of the internal obturator muscle, inserts into the lateral side of the coccyx and lowest part of the sacrum
  - The coccygeus muscle is not part of the levator ani, having a different function and origin
- Levator ani muscle
  - Components

    The levator ani is divided anatomically into 3 components and is differentiated according to origin and direction of fiber bundles[11–14] (**Fig. 4**A)

    Puborectalis muscle
    - Arises from the superior and inferior pubic rami
    - Unites with contralateral puborectalis muscle, posterior to the rectum, forming a sling
    - Does not insert onto any skeletal structure

    Pubococcygeus muscle (**Fig. 4**B)
    - Arises from the back of the pubic bone and the anterior part of the obturator fascia
    - Inserts into the lateral aspect of the coccyx

    Iliococcygeus muscle
    - Arises from the fascia overlying obturator internus
    - Inserts into the lateral aspect of the coccyx, overlapping with fibers of pubococcygeus muscle in a staggered arrangement
  - Functional correlation of levator ani muscle
    - Puborectalis muscle:
      - Urethral pressure
        - Puborectalis muscle aids in maintaining urethral pressure
        - Some of its anteromedial fibers attach to the vagina and may assist in direct elevation and support of the urethrovesical neck, thus affecting urethral pressure and continence
      - Pelvic organ support
        - Direct support for rectum
        - Indirect support to vagina, bladder, and urethra by drawing these structures ventrally toward the pubic bone
        - Traction force contributes to more acute anorectal angle (and thus the anal canal is closed). Posterior curve to the vagina and horizontal levator plate
      - Anal continence
        - Constant tone causes anterior displacement of the anal canal, resulting in an acute anorectal angle
        - Acute angulation resists fecal outflow and is essential in maintaining rectal continence
        - Under physiologic conditions, this angle can be altered either to augment continence or to assist defecation
        - To facilitate defecation, the puborectalis is relaxed, and brief Valsalva maneuver augments pelvic floor descent
        - To defer defecation, the puborectalis contracts, causing the rectum to become more perpendicular to the anal canal, which elevates the pelvic floor and lengthens the anal canal[5,14]
    - Iliococcygeus muscle
      - Stretches in a horizontal plane from the rectal hiatus to the coccygeus muscle, where the upper one-third of the vagina and cervix lie upon it
        - This horizontal part assists in development and maintenance of the vaginal axis
        - This muscle is active at rest and contracts further during rectus abdominis contraction to maintain proper vaginal axis
      - Levator plate
        - Is the main part of the levator ani muscle seen on the sagittal MR images
        - Is formed by fusion of the right and left iliococcygeus muscle slings in midline
        - Forms a horizontal shelf that supports pelvic organs in normal asymptomatic volunteers

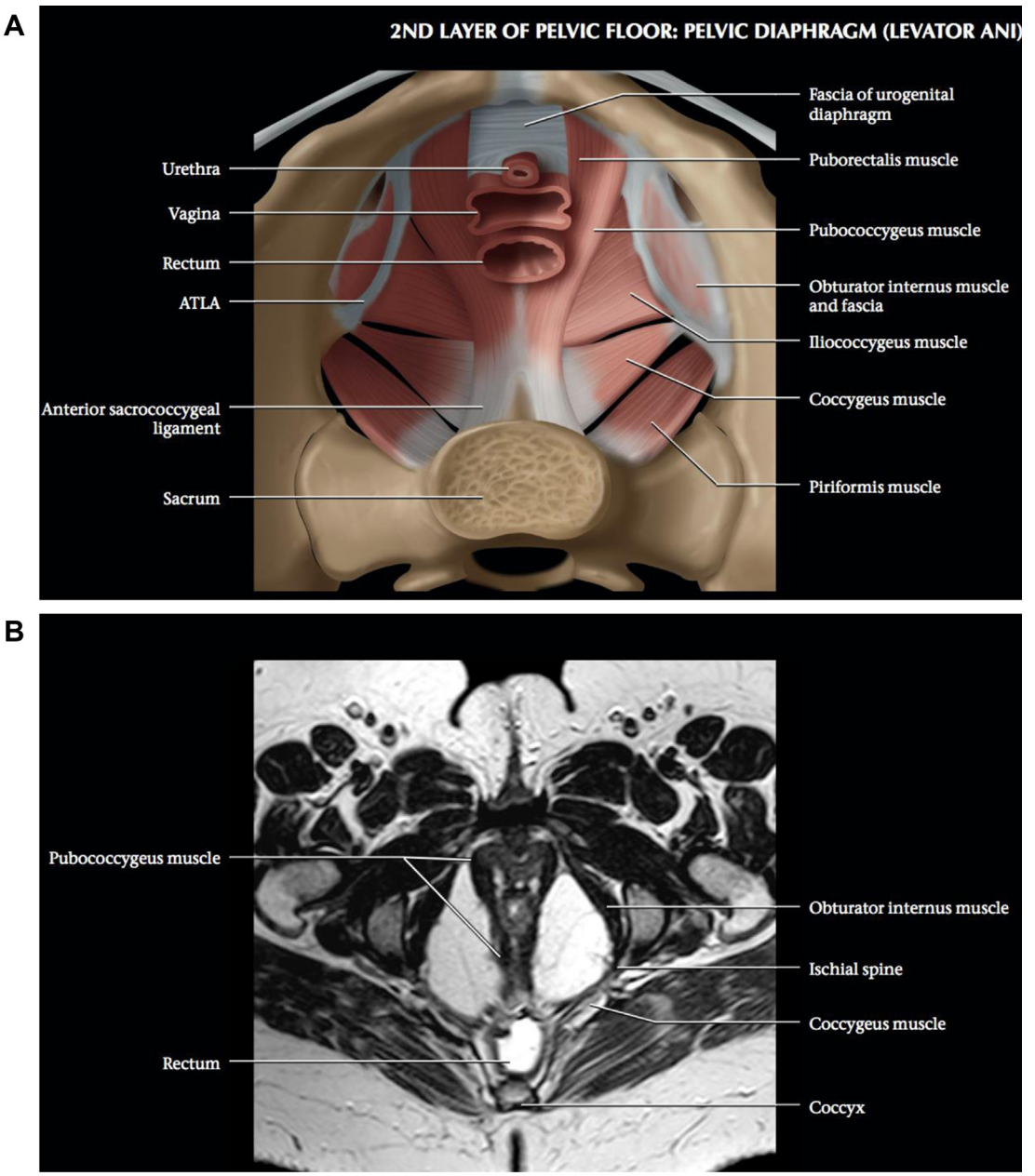

Fig. 4. (*A*) Superior view of the pelvic floor. The puborectalis, pubococcygeus, and iliococcygeus muscles form the levator ani. The obturator internus is covered by a fascial layer, which forms a thick band, the ATLA. This is a crucial area of attachment for the levator ani. The levator ani muscle with the coccygeal muscles forms the pelvic diaphragm (floor). The piriformis muscle contributes to the posterior wall. (*B*) Axial oblique T2WI MR image shows the pelvic floor and parts of the levator ani. The pubococcygeus muscle passes posteriorly. It has a bony attachment that is different from the puborectalis, which forms a sling around the anorectal junction with no bony attachment. (*From* [(El Sayed RF . Overview of the Pelvic Floor. In: Shaaban AM, Editor. Diagnostic Imaging: Gynecology 2nd Edition. Philadelphia: Elsevier-Amirsys; 2015. 8/2 -8/28 ; with permission.)

- Is evaluated during evacuation, straining, and withholding in the sagittal plane
- Contracts by a combination of squeeze and inward lift
- Movement reflects multicomponent action of levator ani, where the puborectalis provides inward squeeze and iliococcygeus provides upward lift[5,15]

(c) Third layer: urogenital diaphragm

- Location and description
  - The cavity of pelvis is divided by the pelvic diaphragm into the main pelvic cavity above, and perineum below (**Fig. 5**).
  - The urogenital diaphragm is a fibromuscular layer directly below the pelvic diaphragm also known as the deep perineal pouch
  - Classically, the urogenital diaphragm is described as a trilaminar structure, which includes deep to superficial[5]
    - The superior fascial layer of urogenital diaphragm is formed by the deep fascia of the pelvic floor
    - The deep transverse perineal muscles are sandwiched between the superior and inferior fascia
    - The inferior fascial layer of urogenital diaphragm forms the perineal membrane
  - Perineal body
    - Is a fascial condensation posterior to the vagina
    - Is an insertion site of the perineal muscle and external anal sphincter

(d) Fourth layer: Perineum

- Location and description
  - The perineum is the superficial soft tissues below pelvic diaphragm.
  - It is a diamond-shaped area bounded anteriorly by the symphysis pubis, posteriorly by the tip of the coccyx, and laterally by the ischial tuberosities (**Fig. 6**).
- Divisions
  - The perineum is divided by an arbitrary line between the ischial tuberosities into the urogenital triangle anteriorly, containing the urethra, the vagina, the perineal membrane, and the external genital muscles and the anal triangle posteriorly[5,14,16] (**Fig. 6**A)
  - Most superficial layers of the perineum is the external genital muscles and includes the superficial transverse perineal, bulbospongiosus, and ischiocavernosus muscles (see **Fig. 6**B)

Pelvic floor muscle and endopelvic fascial interaction

- Normal
  - Muscles give active support to pelvic floor, whereas ligaments give passive support to hold the pelvic organs in place
  - When the levator ani muscle (**Fig. 7**) functions properly, the following occurs:
    - The pelvic floor is closed
    - The ligaments and fasciae are under no tension
    - The fasciae simply act to stabilize the pelvic organs in their position above the levator ani muscle[5,14,16]
- Abnormal
  - When pelvic muscles relax or are damaged, ligaments are put under strain
  - Pelvic organs lie between high abdominal pressure and low atmospheric pressure
  - In this situation, pelvic organs must be held in place by ligaments
  - Ligaments can sustain these loads for short periods
  - If damaged pelvic floor muscles cannot close levator hiatus, connective tissues must support pelvic organs for extended periods
  - Connective tissue will eventually fail to hold the vagina and other pelvic organs in place[5,14,16]

MR Imaging of Pelvic Floor

Indications for MR imaging of PFD

- According to the recently published consensus paper of European Society of Urogenital Radiology and European Society of Gastrointestinal and Abdominal Radiology recommendations, the indications of MR imaging in each compartment are listed in **Box 1** in descending order from those that scored the highest number of agreement among both the group members and the literature review. The indications for MR imaging of the pelvic floor that scored the highest number of agreement among the group members and the literature review are rectal outlet obstruction (92% agreed on), rectocele (92%), recurrent pelvic organ prolapse (POP; 85%), enterocele (85%), and dyssynergic defecation (anismus) (85%).[17]

Patients' preparation and hardware requirements

- All patients undergo cleansing rectal enema (using warm water) the night before MR imaging

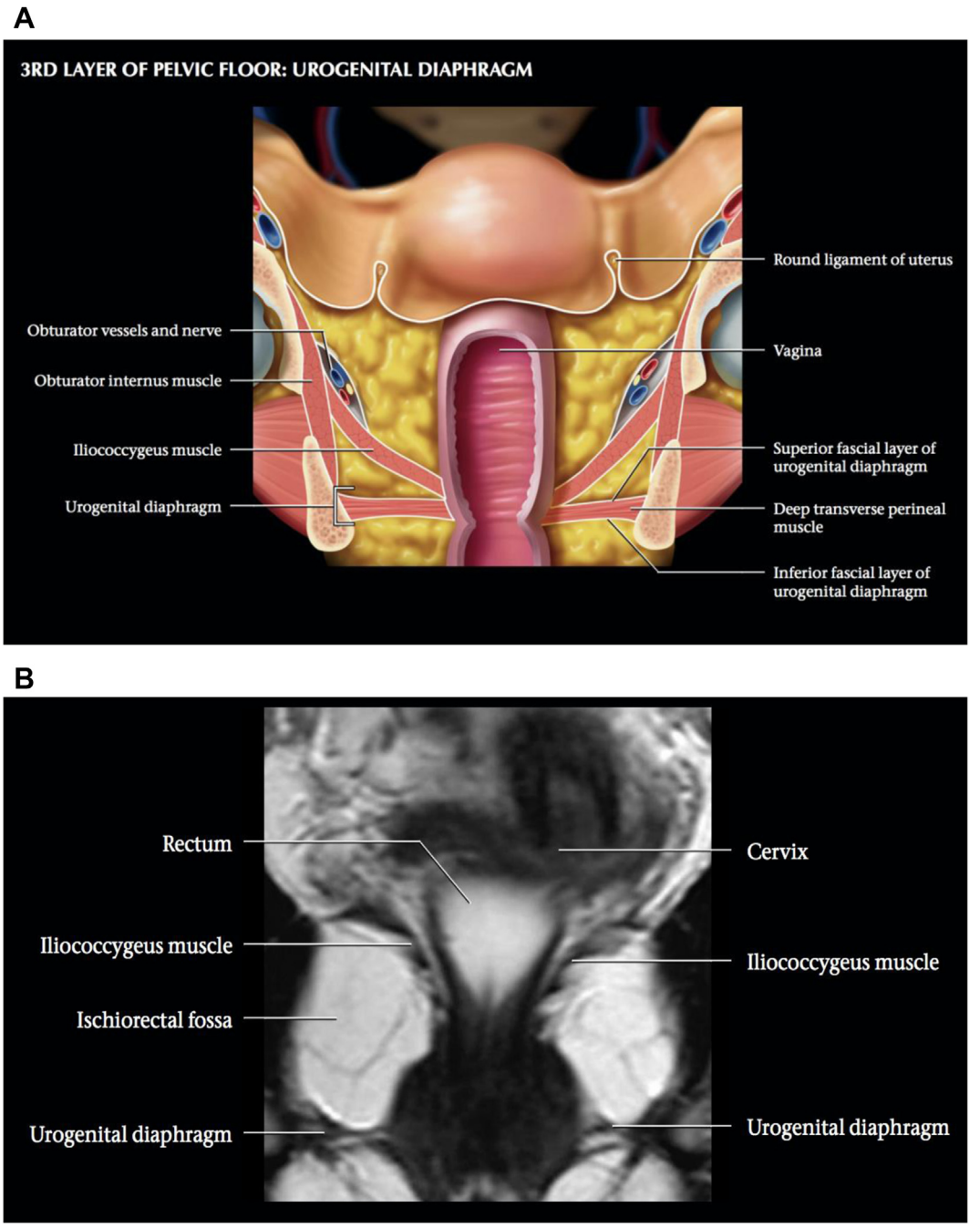

Fig. 5. (*A*) Coronal graphic of the pelvic floor shows the urogenital diaphragm. It is the fibromuscular layer directly below the pelvic diaphragm (levator ani muscles). It is a trilaminar structure with the deep transverse perineal muscle sandwiched between superior and inferior fascial layers. It is part of the perineum, which is located below the levator ani and includes the external genitalia. (*B*) Coronal T2WI MR at the level of the urogenital (UG) diaphragm shows its location below the pelvic diaphragm. The UG diaphragm is part of the perineum. (*From* [(El Sayed RF. Overview of the Pelvic Floor. In: Shaaban AM, Editor. Diagnostic Imaging: Gynecology 2nd Edition. Philadelphia: Elsevier-Amirsys; 2015. 8/2 -8/28 ; with permission.)

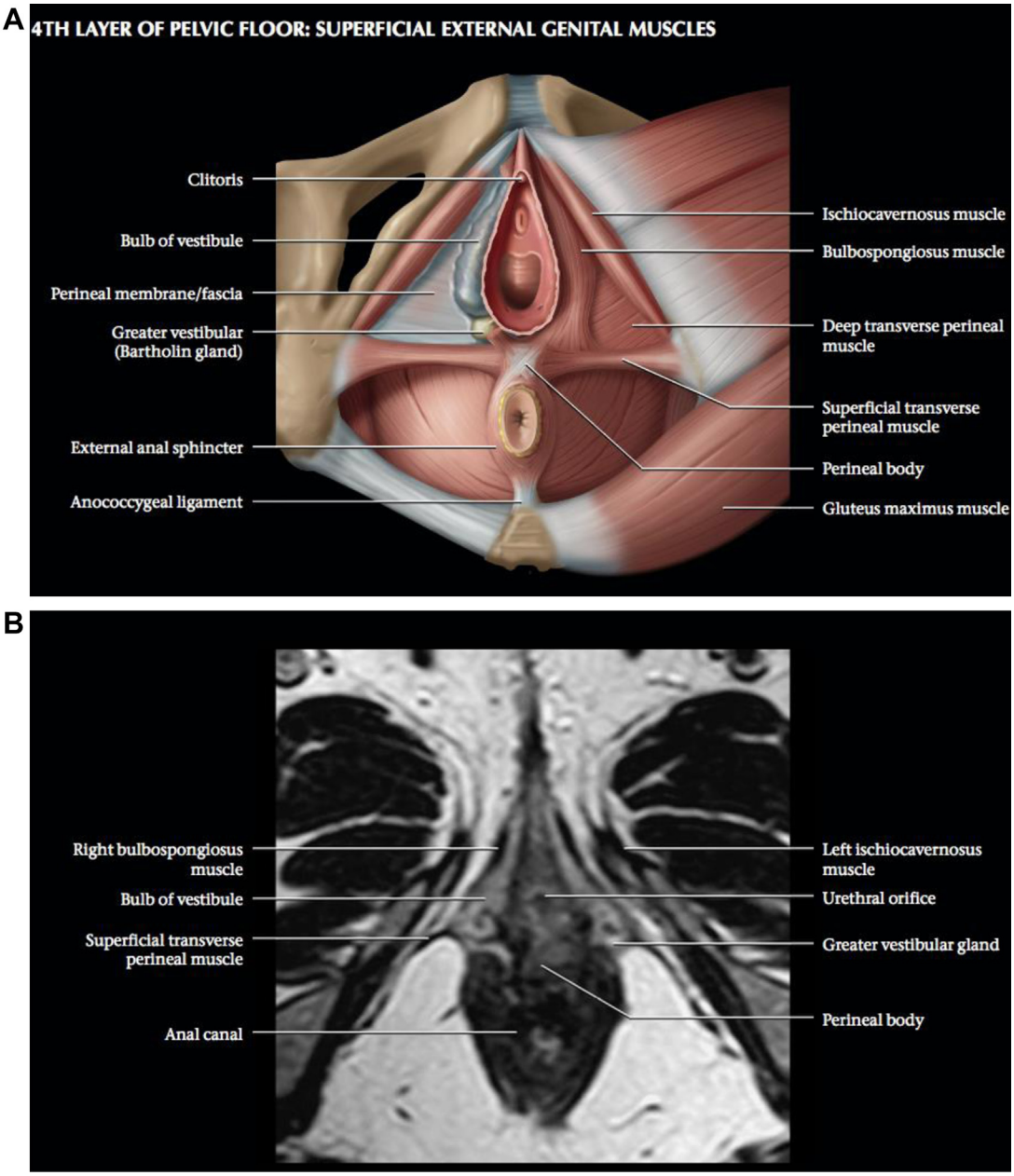

Fig. 6. (*A*) The external genital muscle is located anteriorly in the urogenital triangle, whereas the anal sphincter complex and perineal body are in the anal triangle. The perineal body is a thickened, midline condensation of fibrous tissue at the midpoint of a line joining the ischial tuberosities. At this point, several important muscles converge and are attached: The external anal sphincter, paired bulbospongiosus muscles, paired superficial transverse perineal muscles, and fibers of the levator ani. (*B*) Axial oblique T2WI MR image in a woman at the level of the superficial external genital muscle shows the extension of the bulbospongiosus muscle. (*From* [(El Sayed RF . Overview of the Pelvic Floor. In: Shaaban AM, Editor. Diagnostic Imaging: Gynecology 2nd Edition. Philadelphia: Elsevier-Amirsys; 2015. 8/2 -8/28]; with permission.)

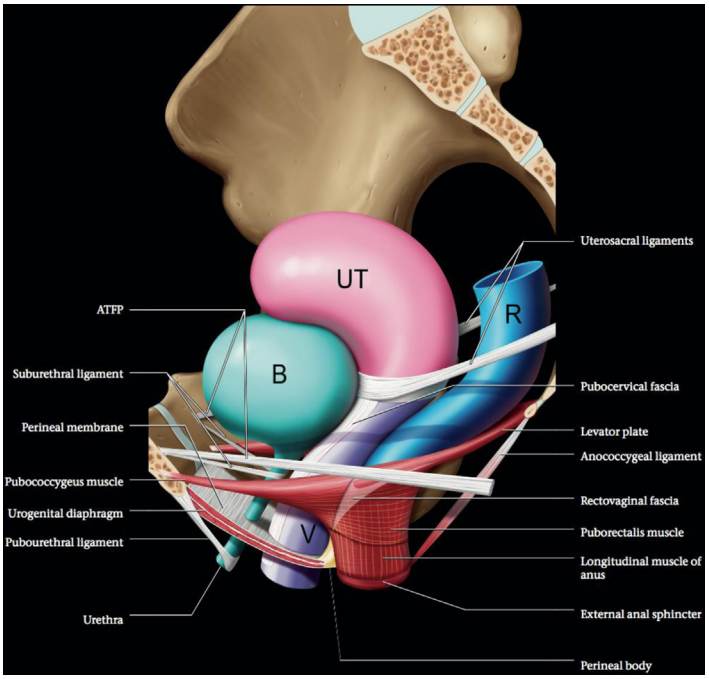

Fig. 7. Graphic of the pelvis illustrates the multilayered system approach that considers the passive and active components of pelvic floor as an integrated multilayer system. From cranial to caudal, the pelvic support system consists of endopelvic fascia, pelvic diaphragm, perineum, and the external genital muscles. The muscles (levator ani) give active support to the pelvic floor, whereas the ligaments give passive support holding organs in place. When the levator ani is functioning properly, the pelvic floor is closed and the ligaments and fasciae are under no tension. When the musculature is damaged and cannot close the levator hiatus, ligaments are put under strain and will eventually fail, resulting in pelvic organ prolapse. B, bladder; UT, uterus; R, rectum. (*From* [(El Sayed RF. Overview of the Pelvic Floor. In: Shaaban AM, Editor. Diagnostic Imaging: Gynecology 2nd Edition. Philadelphia: Elsevier-Amirsys; 2015. 8/2–8/28; with permission.)

- MR protocol requires no oral or intravenous administration of contrast agents
- Full patients' history of pelvic floor disorder should be taken before scanning
- The bladder should be moderately filled; therefore, voiding 2 hours before the examination is recommended
- Ultrasound gel (90 to 120 mL) is placed into the rectum
- The patient is examined in the supine position with the knees elevated (eg, on a pillow with firm consistency) because this was found to facilitate straining and evacuation
- A pad is placed under the patient to add more comfort to the patient when evacuating the rectum and to avoid contamination of the MR table
- Patient training
  - The patient is informed that the evacuation phase is crucial for a complete diagnostic study
  - The radiologist should explain that this phase is important because POP is often only evident when abdominal pressure increases, and this is best achieved during evacuation of the rectum
- Hardware requirements: The patient should be examined at least in a 1.5-T MR imaging unit with a phased array coil, because this is the most agreed-upon field strength
- The coil should be centered low on the pelvis to ensure complete visualization of prolapsed organs
- The recommended patient preparation is summarized in **Box 2**[17,18]

MR imaging protocol

Static MR imaging sequences According to the concordance of experts, high-resolution T2-weighted images (T2WI) (eg, turbo spin echo; fast spin echo) in 3 planes are recommended for static images.[17,19,20]

Dynamic (kinematic) MR imaging sequences

- Dynamic refers to the kinematic part of the study, imaging during evacuation "MR imaging defecography," and "dynamic cine MR" imaging in the 3 orthogonal planes during different grades of staining.[4,18]
- Steady state (eg, fast imaging with steady-state precession [FISP], gradient-recalled acquisition in the steady state [GRASS], fast field echo [FFE]) or balanced state free precession sequence (eg, true fast imaging with steady-state precession [trueFISP], fast imaging employing steady-state acquisition [FIESTA], balanced fast field echo [B-FFE]) in the sagittal plane is recommended for evacuation.

Box 1
Most common indications for MR imaging of pelvic floor dysfunction[a]

Indications

- Anterior compartment
  - Stress urinary incontinence
  - Recurrence after surgical POP repair
- Middle compartment
  - Recurrence after surgical POP repair
  - Enterocele/peritoneocele POP
- Posterior compartment
  - Outlet obstruction
  - Rectocele
  - Anismus
  - Fecal incontinence
  - Recurrence after surgical POP repair
  - Rectal intussusception
- Nonspecific compartment
  - Pelvic pain/perineal pain
  - Descending perineal syndrome

[a] The indications of MR imaging in each compartment are listed in descending order from those that scored the highest number of agreement among both the group members and the literature review.

Data from [El Sayed RF, Alt CD, Maccioni F, Meissnitzer M, Masselli G, Manganaro L, Vinci V, Weishaupt D. Magnetic resonance imaging of pelvic floor dysfunction - joint recommendations of the ESUR and ESGAR Pelvic Floor Working Group. On Behalf of ESUR and ESGAR Pelvic Floor Working Group . European Radiology,2017; 27(5):2067–2085. DOI 10.1007/s00330-016-4471-7].

Box 2
Checklist for the recommended patients' preparation and MR imaging protocols

A. Patient's preparation
- Acquire equipment: preferably a 1.5-T magnet and phased array coil
- Take patient's history of pelvic floor disorder
- Ask the patient to void 2 hours before the examination
- Train the patient on how to perform squeezing, straining, and evacuation
- Use a diaper for protection
- Do rectal filling with ultrasonic gel
- Examine the patient in the supine position with elevated knees on a high pillow

B. MR imaging protocol

1. Recommended static sequences
   - T2-weighted TSE, FSE, RARE in sagittal, transverse, and coronal plane
2. Recommended dynamic SSFP or BSFP sequences in sagittal plane
   - Straining phase
   - Evacuation phase
   - Squeezing phase

BSFP, balanced state free precession; FSE, fast spin echo; RARE, rapid acquisition with relaxation enhancement; SSFP, steady-state free precession; TSE, turbo spin echo.

Data from [El Sayed RF, Alt CD, Maccioni F, Meissnitzer M, Masselli G, Manganaro L, Vinci V, Weishaupt D. Magnetic resonance imaging of pelvic floor dysfunction - joint recommendations of the ESUR and ESGAR Pelvic Floor Working Group. On Behalf of ESUR and ESGAR Pelvic Floor Working Group . European Radiology,2017; 27(5):2067–2085. DOI 10.1007/s00330-016-4471-7].

- The dynamic sequence should not exceed 20 seconds each, because breath holding is required.
- MR imaging during evacuation is mandatory, because certain abnormalities and the full extent of POP are only visible during evacuation.
- The evacuation sequence should be repeated until the rectum is emptied to exclude rectal intussusception (total time duration around 2–3 minutes).
- If no evacuation of the rectal content at all or a delayed evacuation time (>30 seconds to evacuate two-thirds of the rectal content) is present, anismus should be considered.
- Because the performance of adequate pelvic stress during the dynamic sequences is important in order to assess the full extent of PFD, quality control of the study is essential.
  - The study can only be considered diagnostic if a clear movement of the abdominal wall is seen during squeezing and straining.
- The MR imaging protocols[17,18] are summarized in **Box 2**.
- **Fig. 8** illustrates the recommended imaging sequences and the patient maneuvers.

DISCLOSURE

The author has nothing to disclose.

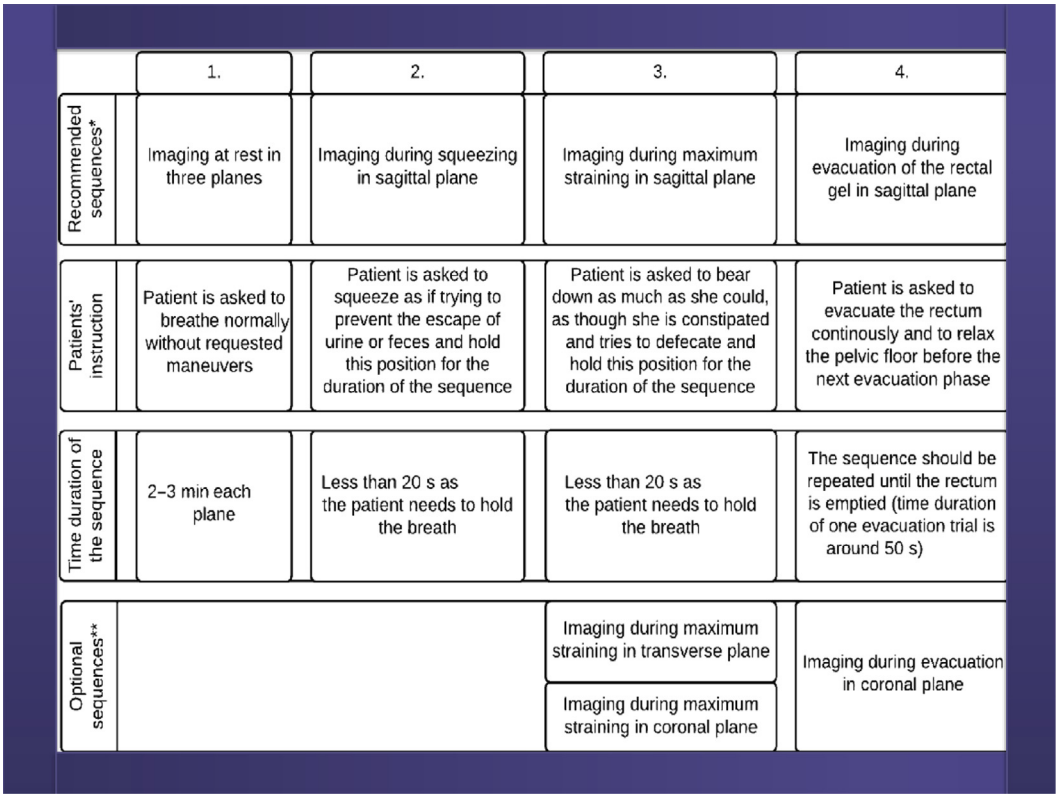

Fig. 8. Schedule of the recommended imaging sequences, the instructions given to the patient, and the time duration per sequence. *, 100% agreement of expert opinion and level of evidence 2. **, Level of evidence 2 without expert consensus (3/8).

REFERENCES

1. Maglinte DD, Kelvin FM, Fitzgerald K, et al. Association of compartment defects in pelvic floor dysfunction. AJR Am J Roentgenol 1999;172(2):439–44.
2. Seynaeve R, Billiet I, Vossaert P, et al. MR imaging of the pelvic floor. JBR-BTR 2006;89(4):182–9.
3. DeLancey JO. The hidden epidemic of pelvic floor dysfunction: achievable goals for improved prevention and treatment. Am J Obstet Gynecol 2005;192:1488–95.
4. El Sayed RF, Mashed SE, Farag A, et al. Pelvic floor dysfunction: assessment with combined analysis of static and dynamic MR imaging findings. Radiology 2008;248:518–30.
5. El Sayed RF. Overview of the pelvic floor. In: Shaaban AM, editor. Diagnostic imaging: gynecology. 2nd edition. Philadelphia: Elsevier-Amirsys; 2015. p. 8/2–8/28.
6. El Sayed RF. The urogynecological side of pelvic floor MRI: the clinician's needs and the radiologist's role. Abdom Imaging 2013;38(5):912–29.
7. Beco J, Mouchel J. Perineology: a new area. Urogynaecol Int J 2003;17:79–86.
8. DeLancey JOL. Functional anatomy of the pelvic floor. In: Bartram CI, DeLancey JOL, editors. Imaging pelvic floor disorders. Medical Radiology (Diagnostic Imaging). Berlin, Heidelberg: Springer; 2003. p. 27–38.
9. DeLancey JO. The anatomy of pelvic floor. Curr Opin Obstet Gynecol 1994;6:313–6.
10. Petros P. Reconstructive pelvic floor surgery according to the integral theory. In: Petros P, editor. The female pelvic floor: function, dysfunction and management according to the integral theory. 2nd edtion. Berlin: Springer; 2007.
11. Fröhlich B, Hötzinger H, Fritsch H. Tomographical anatomy of the pelvis, pelvic floor, and related structures. Clin Anat 1997;10(4):223–30.
12. Strohbehn K, Ellis JH, Strohbehn JA, et al. Magnetic resonance imaging of the levator ani with anatomic correlation. Obstet Gynecol 1996;87(2):277–85.
13. Strohbehn K. Normal pelvic floor anatomy. Obstet Gynecol Clin North Am 1998;25:683–705.
14. Klutke CG, Siegel CL. Functional female pelvic anatomy. Urol Clin North Am 1995;22(3):487–98.
15. Singh K, Reid WM, Berger LA. Magnetic resonance imaging of normal levator ani anatomy and function. Obstet Gynecol 2002;99(3):433–8.

16. DeLancey JO. Functional anatomy of the pelvic floor. In: Bartram CI, DeLancey JO, Halligan S, et al, editors. Imaging pelvic floor disorders. New York: Springer; 2003. p. 27–38.
17. El Sayed RF, Alt CD, Maccioni F, et al. Magnetic resonance imaging of pelvic floor dysfunction–joint recommendations of the ESUR and ESGAR Pelvic Floor Working Group. On Behalf of ESUR and ESGAR Pelvic Floor Working Group. Eur Radiol 2017; 27(5):2067–85.
18. El Sayed RF. Pelvic floor imaging. In: Shaaban AM, editor. Diagnostic imaging: gynecology. 2nd edition. Philadelphia: Elsevier-Amirsys; 2015. p. 8/30–8/39.
19. Lienemann A, Sprenger D, Janssen U, et al. Assessment of pelvic organ descent by use of functional cine-MRI: which reference line should be used? Neurourol Urodyn 2004;23: 33–7.
20. Woodfield CA, Hampton BS, Sung V, et al. Magnetic resonance imaging of pelvic organ prolapse: comparing pubococcygeal and midpubic lines with clinical staging. Int Urogynecol J Pelvic Floor Dysfunct 2009;20:695–701.