

Dynamic MR defecography of the posterior compartment: Indications, techniques and MRI features

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Abstract

Pelvic floor weakness is characterized by abnormal symptomatic displacement of pelvic organs. It represents a complex clinical problem most commonly seen in middle-aged and elderly parous women. Its diagnosis remains difficult in many cases, since these disorders typically present with nonspecific symptoms, such as pelvic pain, incontinence and constipation. Fluoroscopic colpocystodefecography has been proven to surpass physical examination in the detection and characterization of functional abnormalities of the anorectum and surrounding pelvic structures. Similarly, MR defecography, performed either with an open- or closed-configuration unit, appears to be an accurate imaging technique to assess clinically relevant pelvic floor abnormalities. Moreover, MR defecography negates the need to expose the patient to harmful ionizing radiation and allows excellent depiction of the surrounding soft tissues of the pelvis.

In this manuscript, we review the techniques and indications of MR defecography, and illustrate the MRI features of a vast array of morphologic and functional pelvic floor disorders, with emphasis on the posterior pelvic compartment (anorectum).

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1. Introduction

At present, functional pelvic floor abnormalities represent a common health care problem. It is the indication for more than 300,000 surgeries in the United States annually, and it is estimated that approximately 15% of older multiparous women suffer from some sort of pelvic support defect [1]. These conditions often impact significantly the quality of life and result in a variety of symptoms, including chronic pelvic pain, urinary or fecal incontinence, and constipation [2]. Typically, constipated patients with functional anorectal abnormalities complain of rectal evacuation difficulties in terms of excessive straining, incomplete evacuation, and need for manually assisted defecation [2]. Since physical examination is not reliable, an objective assessment of rectal evacuation that is reproducible and allows quantification is extremely valuable to help evaluate these symptoms. Fluoroscopic defecography is conventionally used to document the evacuating process and evaluate functional and anatomical anorectal disorders [3]. Although this technique has tremendously improved the current knowledge about defecatory

disorders, it fails to recognize frequently associated abnormalities of the anterior and middle pelvic compartments [3,4]. The development of fast MRI sequences provides a new alternative to study all pelvic visceral movements in a dynamic fashion. MR defecography has several important advantages over conventional defecography [5,6]. First, MR imaging lacks exposure of the patient to harmful ionizing radiation. Secondly, MR imaging provides excellent soft tissue resolution of all pelvic floor compartments and supporting structures, including pelvic floor muscles and fascial planes. Therefore, MR defecography is a much more comprehensive exam that allows assessment of coexisting bladder and uterocervical prolapse, which is vital when planning surgical treatment [5,6]. Nowadays, MR defecography is the method of choice for recognizing rectal intussusception, the mechanism by which rectal prolapse occurs. It also provides objective information about rectocele size and emptying and demonstrates coexistent enteroceles or sigmoidoceles, many of which are missed on physical examination [7].

2. Techniques

In the literature, considerable variation regarding the optimal method of performing MR defecography exists [6–12]. Most

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studies have been reported with the use of closed-configuration magnets. With this technique, due to the inherent constraints of the closed magnet design, the patient is lying down in the magnet in supine position [6–9]. Vertically open-configuration magnets, on the other hand, are less available but have the significant advantage that they allow imaging the patient in a truly physiologic fashion in the erect sitting position [10–12]. In addition to the choice in magnet design, other technical factors debated in the literature include: the use and type of contrast material to opacify rectum, bladder, vagina and small bowel; the imaging plane and manoeuvres during which images are obtained; and the use of markers, tampons, or catheters to identify pelvic structures. In this section, we describe in detail the open-configuration MR defecography technique used in our institution, and discuss the advantages and disadvantages of alternative techniques.

2.1. Open-configuration magnet

2.1.1. Patient preparation

Before the patient is brought into the magnet, optimal patient preparation is mandatory. All subjects should drink four cups

of water (approx. 32 oz) over 30 min prior to imaging; this is done to opacify the small bowel during imaging. Preferentially, the bladder should feel full at the time of imaging; 20 cc of gadolinium–DTPA (Magnevist; Schering, Berlin, Germany) is injected intravenously using a butterfly needle immediately prior to the study. This approach highlights the full bladder during imaging, creating a nice contrast against adjacent structures. Thereafter, the patient is placed in a right decubitus position and 240 ml of aqueous sonographic gel is instilled into the rectum using a small rectal catheter. Other investigators have advocated the use of barium-sulphate paste or in-house prepared suspending agents, such as mashed potatoes doped with 1.5 mL of gadolinium–DTPA (Magnevist; Schering, Berlin, Germany) [10].

2.1.2. Imaging technique

MR defecography in our institution is performed with a 0.5-T superconducting, open-configuration unit (Sigma SP, GE Medical Systems, Milwaukee, Wisconsin). A MR-compatible adjustable wooden seat is set-up in the gap between the two magnet rings and a single loop transmit–receive coil is placed



Fig. 1. Open-configuration magnet MR defecography. Technical aspects. (A) Photograph shows the superconducting open-configuration magnet system. (B) Photograph shows the removable wooden chair that fits exactly in the space between the two vertical magnets. On top of the chair is the flexible transmit/receive radiofrequency (RF) coil. (C) Photograph obtained through the side opening of the vertical magnet shows a volunteer in erect sitting position on the chair with the RF coil interposed between the chair and the volunteer.

on the chair so that the patient is sitting over the opening of the coil (Fig. 1). A sagittal localizer sequence is acquired using a fast T1-weighted spoiled gradient recalled echo (SPGR) acquisition (30 cm FOV, 10 mm thick slices, matrix 256×128 , 45° flip angle). The mid-sagittal slice is chosen and transcribed to a new series where one slice is repeated 15 times as the patient is instructed through manoeuvres. This mid-sagittal sequence begins with the patient at rest; one near

real-time image is acquired every 2 s for a total of 15 images per scan.

The scan is repeated consecutively as images are obtained with the patient at rest, during maximal sphincter contraction (squeezing), during straining, and during defecation. The resulting images are displayed in a cine loop mode to observe relationship of anatomy during manoeuvres. At the end of the examination, a set of axial T2-weighted fast spin-echo (FSE)

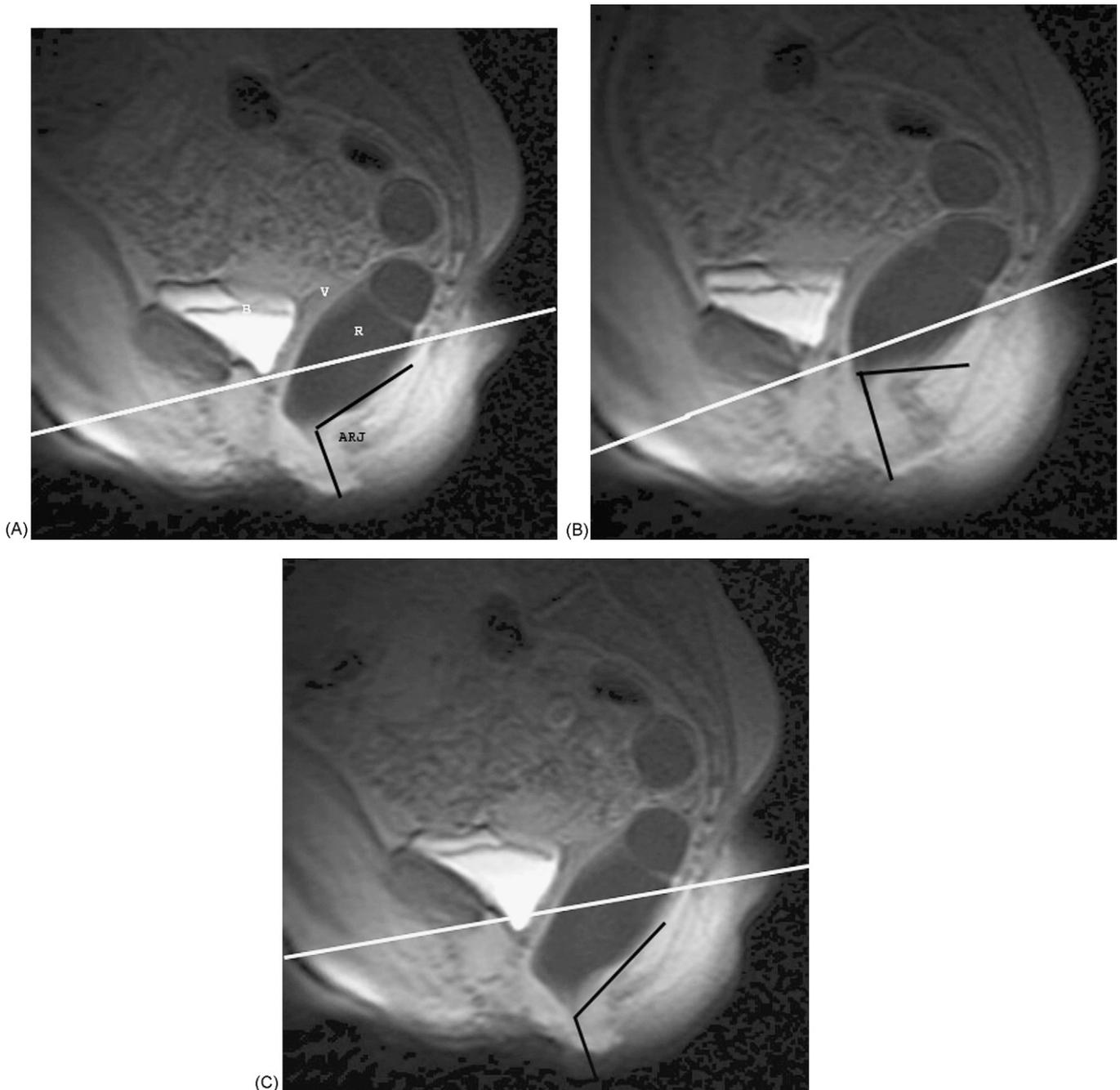


Fig. 2. Normal pelvic floor movements. (A) Mid-sagittal T1-weighted SPGR image obtained at rest after IV administration of 20 cc of gadolinium–DTPA, 240 cc ultrasound gel intrarectally, and 32 oz of water show normal position of the bladder B, vaginal vault V, and rectum in relationship to the pubococcygeal line (white line). The black lines make the anorectal angle (ARA) and their crosspoint represents the anorectal junction (ARJ). (B) Mid-sagittal T1-weighted SPGR image obtained during squeezing in the same patient show normal minimal elevation of the pelvic floor and sharpening of the ARA. (C) Mid-sagittal T1-weighted SPGR image obtained during straining in the same patient show normal minimal descent of the pelvic floor and widening of the ARA.

images (90° flip angle, TR 3100, TE 102, FOV 20 cm, ETL 8, matrix 256 × 128, 8 mm thick slices) is routinely acquired post evacuation to evaluate anatomical relationships of pelvic floor organs and assess the pelvic floor muscles.

2.2. Closed-configuration magnet

MR defecography studies with the patient in the supine position are typically obtained on 1.5-T systems using a pelvic phased-array surface receiver coil [6–9]. After an initial localizer, half-Fourier single-shot turbo spin-echo or fast spin-echo images (e.g. HASTE, SSFSE) are obtained in the sagittal plane during pelvic floor relaxation and during maximal pelvic strain.

No opacification of the bladder, vagina, small bowel, or rectum is typically used. Some investigators fill the rectum with 100 mL of sonographic gel or barium-sulphate paste to optimize rectal distention [6].

3. Normal anatomy

An understanding of the complex anatomy of pelvic floor organs and their associated support mechanisms is crucial for accurate assessment of pelvic floor function or dysfunction. Typically, the pelvic floor is divided into three compartments: the anterior compartment (bladder and urethra, and prostate in males), the middle compartment (uterus, cervix, or vagi-

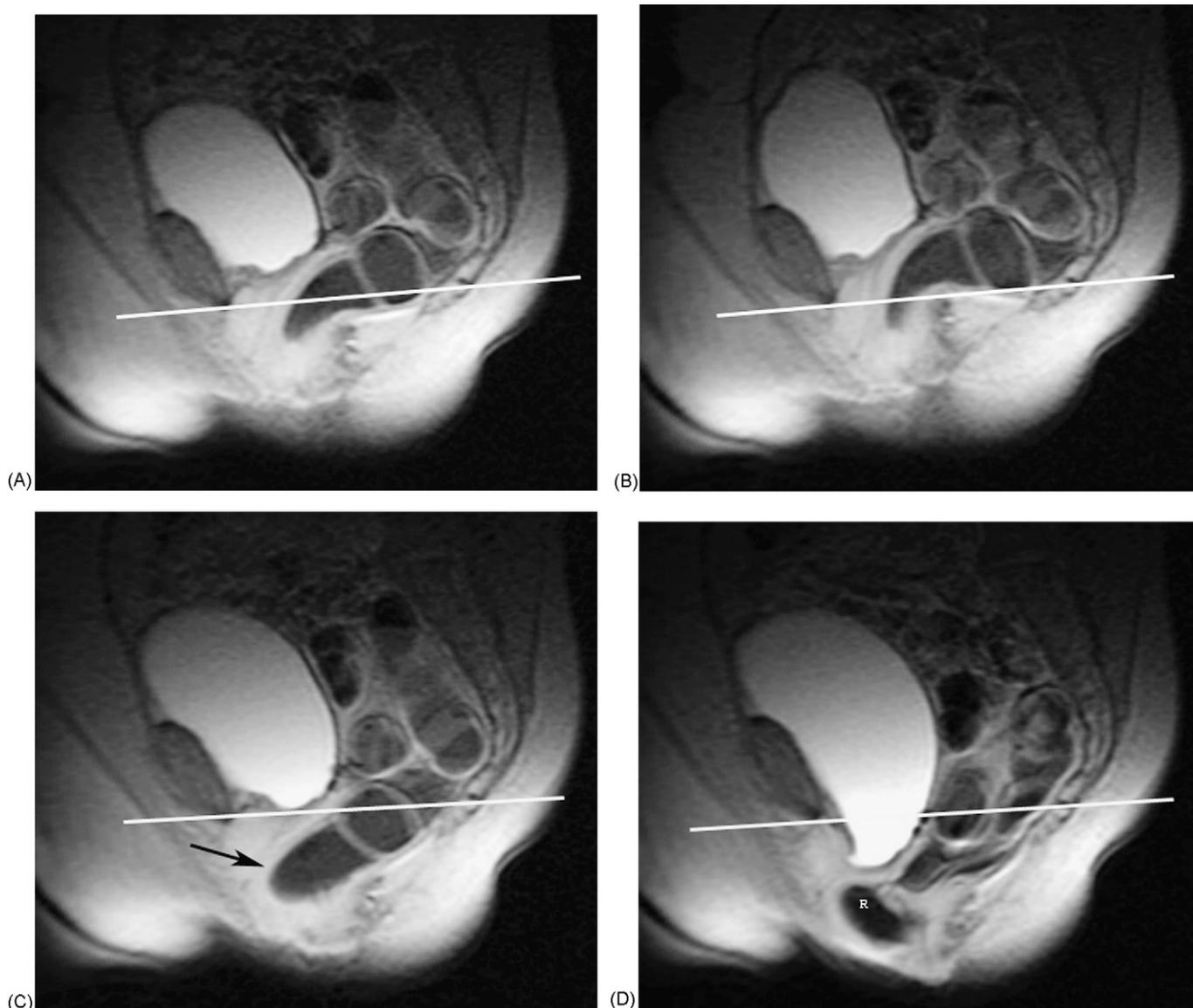


Fig. 3. Anterior rectocele. (A) Mid-sagittal T1-weighted SPGR image obtained at rest show normal position of the bladder, vaginal vault, and rectum in relationship to the pubococcygeal line (white line). (B) Mid-sagittal T1-weighted SPGR image obtained during squeezing in the same patient show normal minimal elevation of the pelvic floor and sharpening of the ARA. (C) Mid-sagittal T1-weighted SPGR image obtained during straining in the same patient shows abnormal descent of ARJ and bulging of the anterior rectal wall (arrow) at least 2 cm beyond its normal expected course. The latter is consistent with an anterior rectocele. (D) Mid-sagittal T1-weighted SPGR image obtained during defecation shows a small cystocele, a small sigmoidocele, abnormal descent of the vagina and incomplete emptying of the anterior rectocele®.

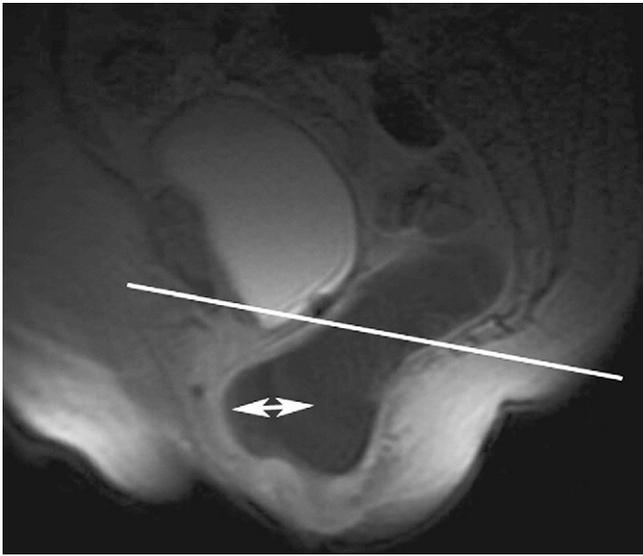


Fig. 4. Anterior rectocele. Mid-sagittal T1-weighted SPGR image obtained during straining shows abnormal descend of ARJ in relationship to the PCL and bulging of the anterior rectal wall (arrow) at least 2 cm beyond its normal expected course.

nal vault), and the posterior compartment (anorectum) [7]. The support of the pelvis is provided by an interaction of bony structures (the pelvic bones), muscles, and ligaments [2]. The muscular support of the pelvis constitutes of a group of paired muscles, the pelvic diaphragm, that include the levator ani muscle complex and coccygeus muscles; the levator ani muscle complex is made up of the puborectalis muscle, the pubo-coccygeus muscles, and the ileococcygeus muscles. All these muscles originate on the pubic rami and pass lateral to the vagina and rectum, thereby creating a sling around the genital hiatus and rectum. Moreover, they are responsible for the “pelvic floor” laterally and posteriorly. When the levator ani contracts, the genital hiatus closes and pelvic organs are supported from below.

Several ligaments and fascia are also important to maintain appropriate pelvic suspension [13]. The perineal body is located between the introitus of the vagina and the anal canal. It is the site of attachment for the perineal membrane, the levator ani muscles, the external anal sphincter, and the rectovaginal (endopelvic) fascia. The latter is also called the Denonvilliers aponurosis and represents thin connective tissue in the rectovaginal septum that extends, along with the cardinal and uterosacral ligaments, from the posterior aspect of the cervix and posterior vaginal wall posteriorly towards the sacrum. The

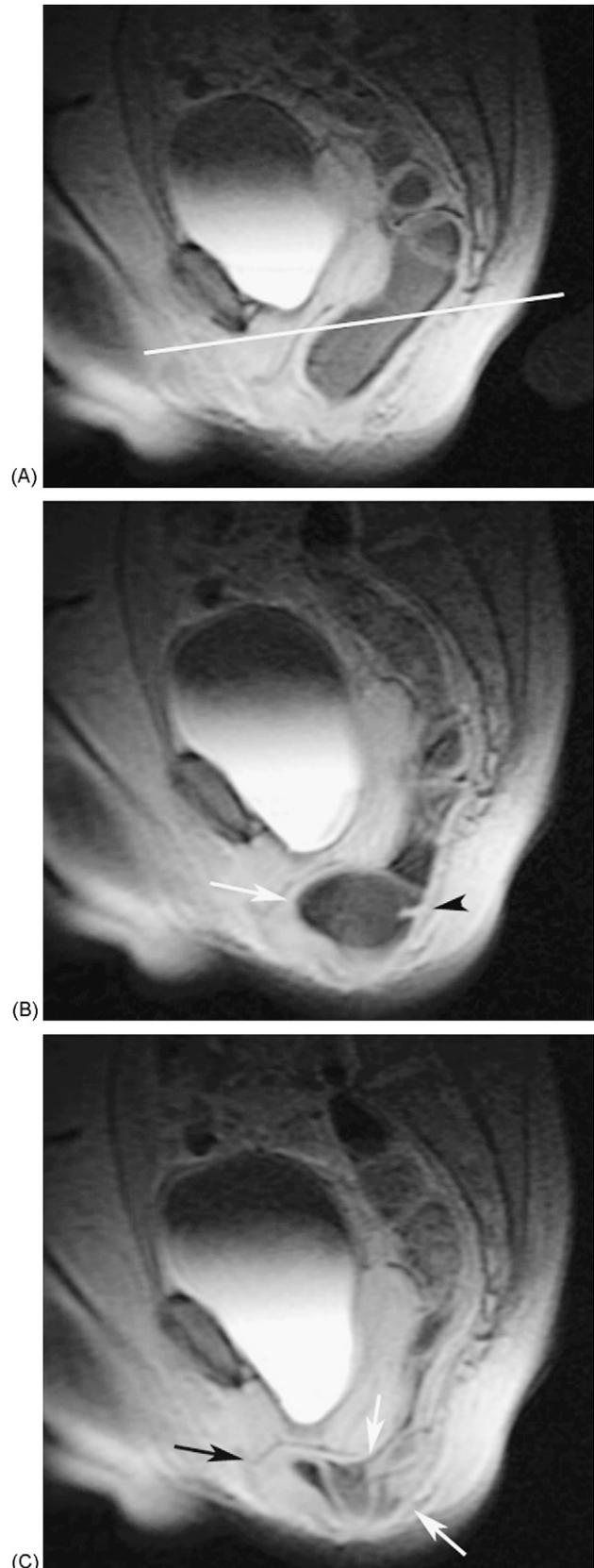


Fig. 5. Rectal intussusception. (A) Mid-sagittal T1-weighted SPGR image obtained at rest show normal position of the bladder, vaginal vault, and rectum in relationship to the pubococcygeal line (white line). (B) Mid-sagittal T1-weighted SPGR image obtained during straining shows abnormal descend of ARJ in relationship to the PCL and a small rectocele (white arrow). Also note small mucosal intussusception (black arrowhead). (C) Mid-sagittal T1-weighted SPGR image obtained during defecation shows progression of intussusception with full-thickness internal rectal prolapse (white arrows). Also note small cystocele and abnormal descend of the uterus and vagina (black arrow).

lateral support of the perineal body is provided through the lateral attachments of the perineal membrane to the ischiopubic rami. Due to this dual lateral and superior support system, downward mobility of the perineal body is limited; however, if these attachments are separated, the perineal body may become more mobile.

The anterior vaginal wall supports the bladder and urethra. The anterior supportive layer, called the pubocervical fascia, provides a support system for the bladder and urethra, by attaching to the pubic bones inferiorly, the obturator internus muscles laterally, and the cervix and uterus superiorly [13].

4. Normal functional movements

The normal dynamic process of defecation and movement of other pelvic organs is nicely demonstrated on near real-time mid-sagittal multiphase T1-weighted SPGR images (Fig. 2). The most important anatomical landmark in the evaluation of pelvic floor movements is the pubococcygeal line (PCL); the latter connects the inferior aspect of the symphysis pubis with the last coccygeal joint. At rest, in a normal patient, the base of the bladder, the upper third of the vagina, and the peritoneal cavity (containing fat, small bowel, or sigmoid colon), should

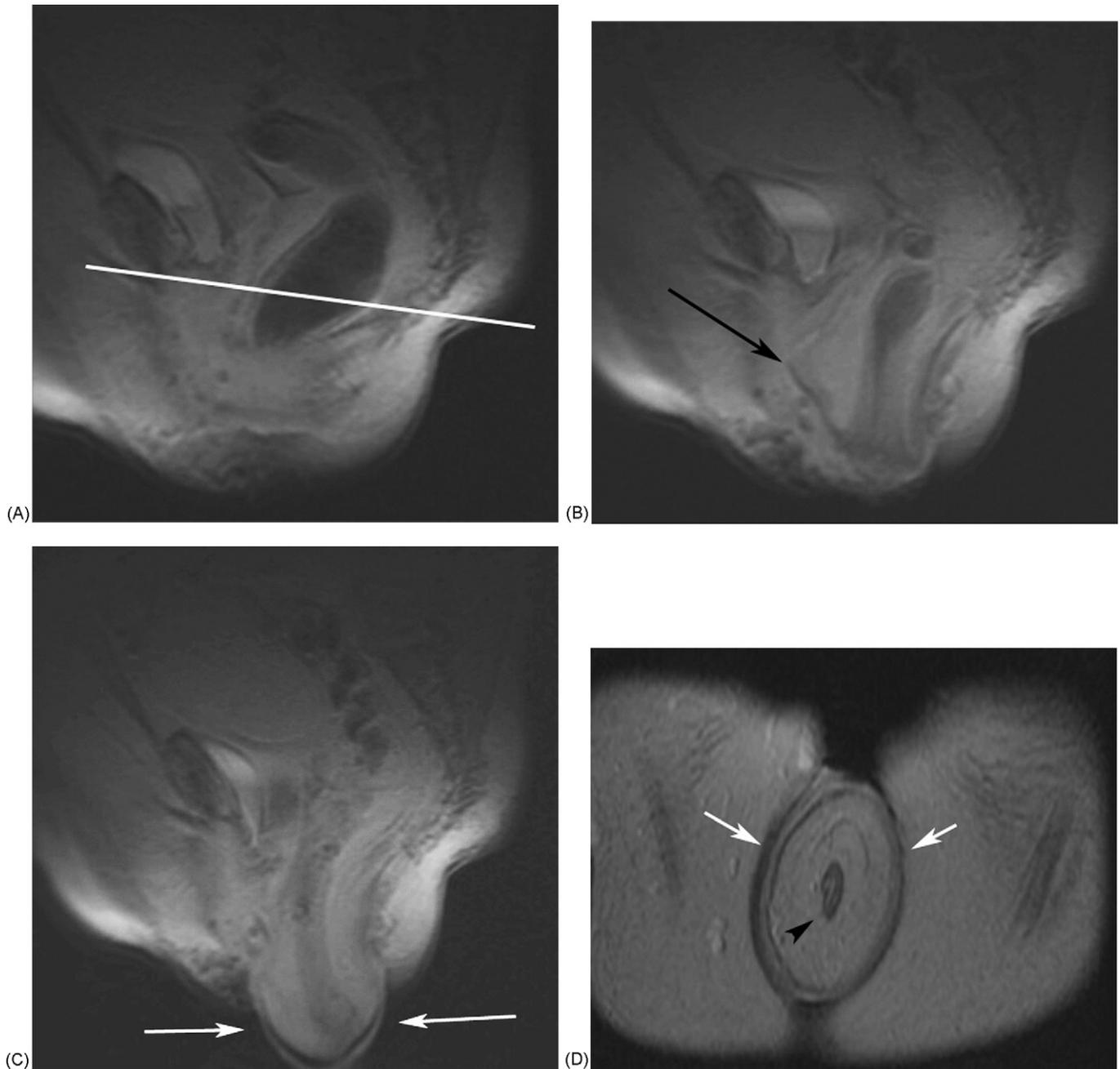


Fig. 6. Rectal prolapse. (A) Mid-sagittal T1-weighted SPGR image obtained at rest show normal position of the bladder, vaginal vault, and rectum in relationship to the pubococcygeal line (white line). (B) Mid-sagittal T1-weighted SPGR image obtained during straining shows abnormal descent of the rectum with internal prolapse and incomplete emptying of an anterior rectocele (arrow). (C) Mid-sagittal T1-weighted SPGR image obtained during defecation shows full-thickness rectal prolapse (arrows). (D) Axial T2-weighted FSE image below the anal canal shows rectal prolapse (arrowhead) and associated prolapse of mesorectal fat (arrows).

project superior to the PCL. The anorectal junction (ARJ), the crosspoint formed by a line along the posterior border of the rectum and a line along the central axis of the anal canal, typically projects within 3 cm below the PCL [9,13–15]. The anorectal angle (ARA), the angle between the two lines that intersect at the ARJ, is normally between 108 and 127° [9,13–15].

During squeezing (maximal pelvic floor contraction), there is elevation of the pelvic organs in relationship to the PCL and sharpening of the ARA by 15–20° (due to contraction of the puborectal muscle). A change in ARA of 10° or less is considered abnormal.

During straining and defecation, the pelvic floor muscles relaxes and, therefore, a mild descent (<2 cm) of the pelvic organs is noted [9,13–15]. In addition, the anorectal angle becomes more obtuse, typically 15–20° more than when measured at rest [9,13–15]. During defecation, the anal canal opens and the contrast material is evacuated.

5. Anorectal disorders

5.1. Rectocele

An anterior rectocele is a condition characterized by bulging of the front wall of the rectum into the posterior wall of the vagina [16]. The underlying etiology of a rectocele is weakening of the support structures of the pelvic floor and thinning or tear of the rectovaginal fascia. Identified factors that may increase the risk of a woman developing a rectocele include vaginal birth trauma (multiple, difficult, or prolonged deliveries; forceps delivery; perineal tears), constipation with chronically increased intra-abdominal pressure, hysterectomy, aging, and congenital or inherited weaknesses of the pelvic floor support system [17]. Although uncommon, men may also develop a rectocele. Symptoms related to the rectocele may be primarily vaginal or rectal. Vaginal symptoms include vaginal bulging, dyspareunia, and the sensation of a mass in the vagina. Rectal symptoms include defecatory dysfunction, constipation, and sensation of incomplete evacuation.

On MR defecography, especially during straining or defecation, rectoceles are commonly found, and small bulges of the anterior rectal wall might be normal findings. Several approaches to quantify the extend of rectoceles have been reported. Some investigators draw a reference line upward along the anterior wall of the anal canal while others measure the depth of the wall protrusion beyond the expected margin of the normal anterior rectal wall (Fig. 3). We use the latter approach as we believe it is more reproducible. As mentioned before, small (<2 cm) anterior bulges of the rectal wall may be normal; rectoceles should be considered abnormal if their size exceeds 2 cm, if a suprasphincteric rectal pocket is identified that does not empty during defecation, or if the patient's symptoms are reproduced [14,16,17] (Fig. 4).

5.2. Rectal intussusception

Rectal intussusceptions are defined as invaginations of the rectal wall [7]. Their location may be anterior, posterior, or

circumferential. The intussusception may involve the full thickness of the rectal wall (i.e. mural) or only the mucosa [18,19]. Rectal intussusceptions are classified as intrarectal (if they remain in the rectum), intraanal (if they extend in the anal canal) or extraanal (if they pass the anal sphincter; the latter is called rectal prolapse) [18,19]. Small intrarectal intussusceptions may be detected in asymptomatic patients; however, if the invagination becomes intraanal, patients most likely experience sensation of incomplete defecation due to outlet obstruction [7].

MR defecography has several advantages over evacuation proctography in the diagnosis of rectal intussusception [7,10]; first, it allows differentiation between mucosal versus full-thickness descent; and second, it provides information on movements of the whole pelvic floor. A recent study showed that 30% of patients with rectal intussusception studied had associated abnormal anterior and/or middle pelvic organ descent [19]. Therefore, if surgery is planned for rectal intussusception, MR defecography provides useful additional information that may need to be addressed simultaneously if a good functional outcome is to be achieved (Fig. 5).

5.3. Rectal prolapse

Rectal prolapse is defined as an extrarectal intussusception (a mucosal or full-thickness layer of the rectal wall extends through the anal orifice) [20]. Typically, rectal prolapse begins with an intrarectal intussusception and progresses to full prolapse. The incidence of rectal prolapse is estimated at approximately four cases per 1000 people; in the adult population, the female to male ratio is 6:1 [20]. Common symptoms include constipation, sensation of incomplete evacuation, fecal incontinence, and rectal ulceration with bleeding [21]. Although rare, untreated rectal prolapse can lead to incarceration and strangulation.

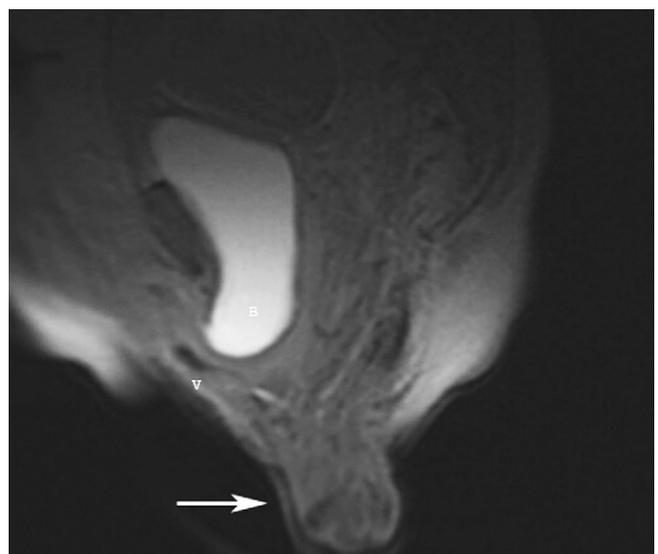


Fig. 7. Rectal prolapse. Mid-sagittal T1-weighted SPGR image obtained during defecation shows full-thickness rectal prolapse (arrows), cystocele (B), and vaginal vault prolapse (V). Abnormal descent of all three pelvic compartments is also known as descending perineal syndrome.

On MR defecography, rectal prolapse manifests itself as abnormal inferior descent of the rectum through the anal sphincter [21–23] (Fig. 6).

5.4. Rectal descent

Rectal descent represents a posterior pelvic floor compartment abnormality and is defined as descent of the anorectal junction below the pubo-coccygeal line. Abnormal descent (>3 cm) of the posterior pelvic floor is often combined with abnormal descent of the middle and anterior pelvic floor compartments and supports the concept that pelvic floor weakness is often generalized [7]. The so-called descending perineal syn-

drome defines this general pelvic floor weakness (Fig. 7). The syndrome is initially characterized by symptoms of constipation and perineal pain but over time fecal and urinary incontinence dominate the clinical picture. Recognized underlying causes include pudendal nerve impairment (due to childbirth trauma or neuropathy) and chronic straining.

On MR defecography, abnormal rectal descent is defined as inferior movement of the anorectal junction below the pubo-coccygeal line [7]. Small descents (<3 cm) may be seen in asymptomatic patients. Although abnormal rectal descent can occur at rest, it typically is seen during defecation or straining. In cases of abnormal rectal descent, decreased raising of the rectum at maximal contraction is also typically observed.

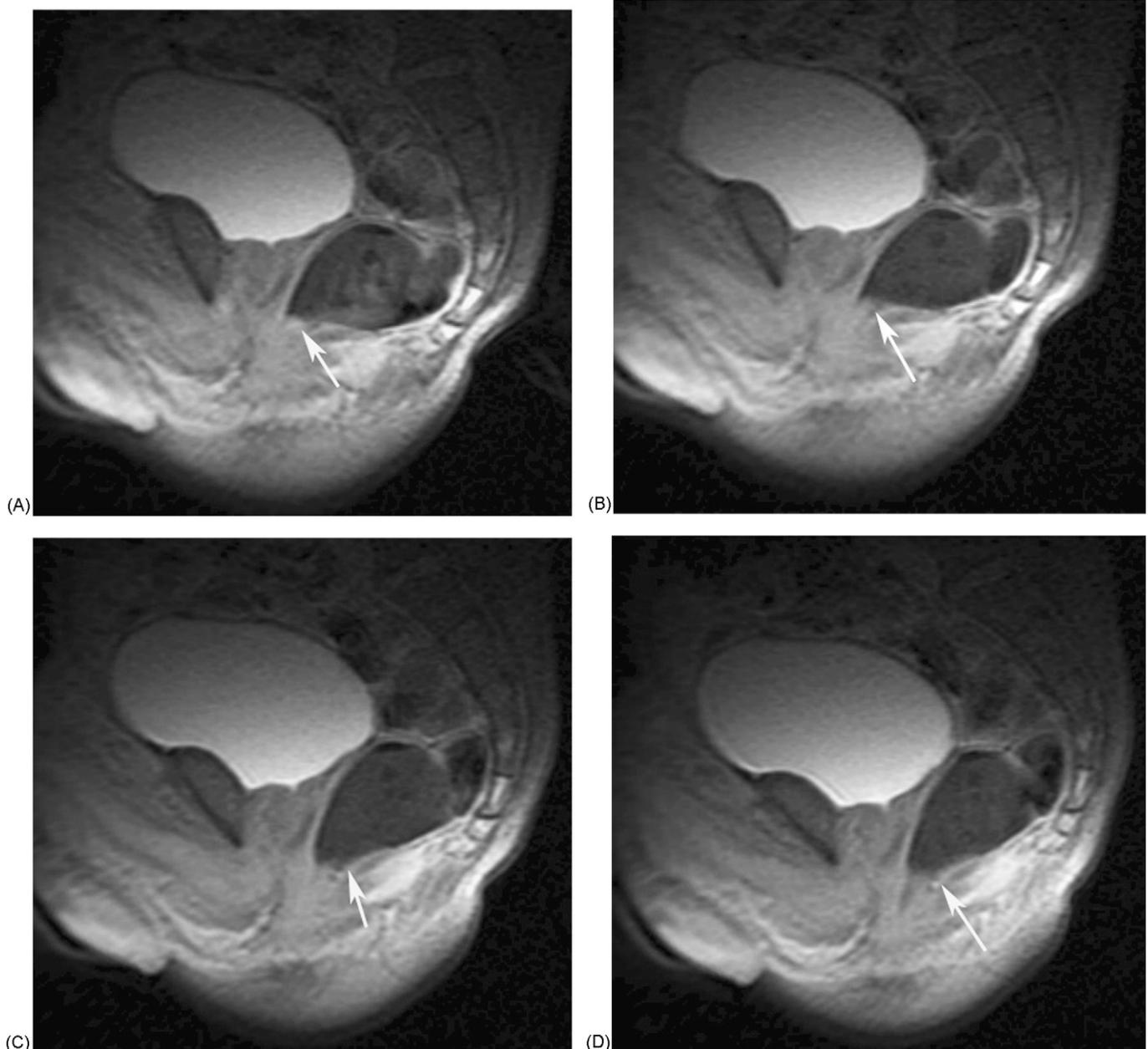


Fig. 8. Anismus. (A–D) Mid-sagittal T1-weighted SPGR images obtained during rest (A), squeezing (B), straining (C) and defecation (D) in a male patient suffering from constipation show lack of variability of the ARA and persistent contraction of the puborectalis muscle (arrow) during all phases.

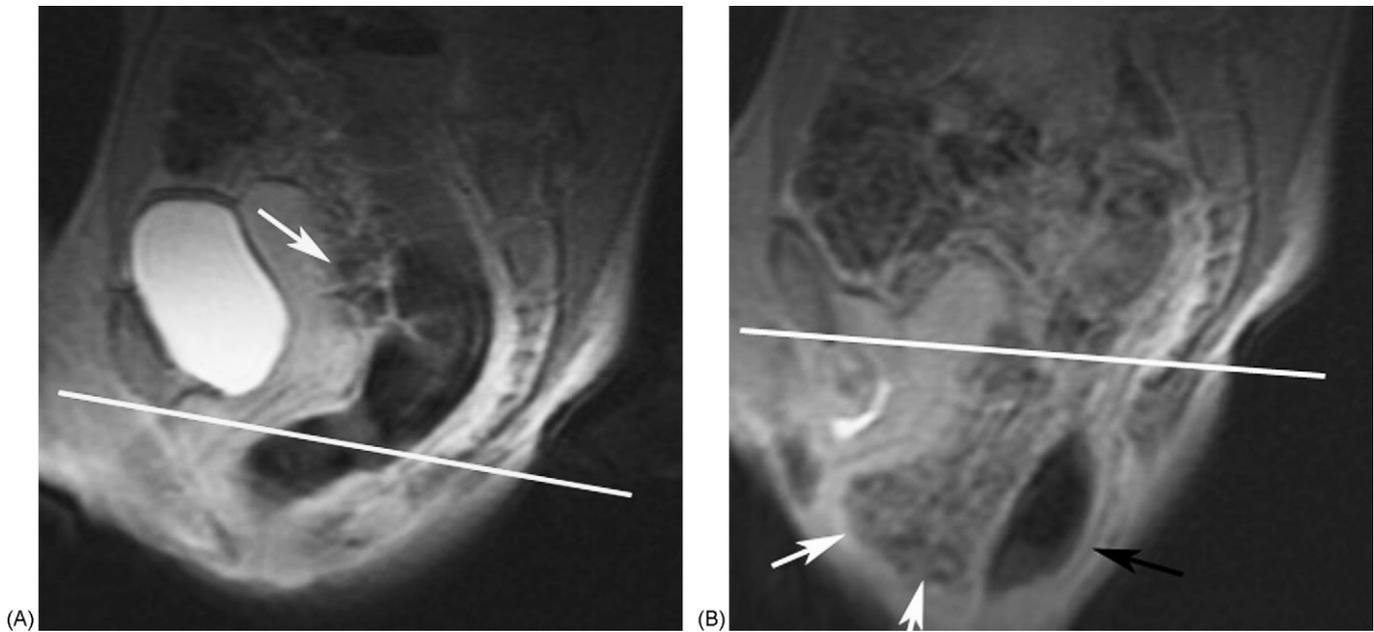


Fig. 9. Enterocele. (A) Mid-sagittal T1-weighted SPGR image obtained at rest show normal position of the bladder, uterus and vagina, rectum, and small bowel (arrow) in relationship to the pubococcygeal line (white line). (B) Mid-sagittal T1-weighted SPGR image obtained during defecation shows third degree enterocele (white arrows) and abnormal descent of bladder, uterus, and rectum (black arrow).

5.5. Anismus

Anismus, or spastic pelvic floor syndrome, is characterized by lack of normal relaxation of the puborectal muscle during defecation [24]. Usually, in a normal patient at rest, the puborectal muscle sustains the inferior border of the rectum to maintain continence. Anismus presents as constipation and incomplete defecation and manifests itself on MR defecography as paradoxical contraction of the puborectal muscle during straining and defecation (Fig. 8). Moreover, there is lack of normal descent of the pelvic floor during the same manoeuvres, the puborectal muscle may become hypertrophic, and an associated anterior rectocele may be seen. As a result, patients with anismus suffer from obstructed defecation [25].

6. Associated disorders

6.1. Enterocele

An enterocele is defined as a protrusion of peritoneum, which may contain mesenteric fat (peritoneocele), small bowel or sigmoid colon (sigmoidocele), that descends from its natural position along the anterior rectal wall inferiorly and presses into the posterior wall of the vagina [26]. Enteroceles occur primarily in patients who have had their uterus removed due to separation of the anterior (pubocervical) and posterior (rectovaginal) wall fascia. Symptoms are variable and largely depend on the size and location of the enterocele; they include sensation of a heavy feeling in the vagina, constipation, or incomplete emptying of the bowel.

On MR defecography, there is enlargement of the rectogenital fossa and abnormal descent of fat, small bowel or sigmoid colon [7]. This may become more obvious when a patient strains or at

the end of the defecation (Fig. 9). Classification of enteroceles is made by the position of the lowest loop of the abnormally located small bowel during defecography. A first-degree enterocele is at the level of the pubococcygeal line; a second-degree enterocele is below the pubococcygeal line but above the ischiococcygeal line; and a third-degree enterocele is below the ischiococcygeal line. Because of its inherent ability to characterize soft tissue, MR defecography allows differentiation between fat, small bowel, and sigmoid; distinguishing these contents with conven-

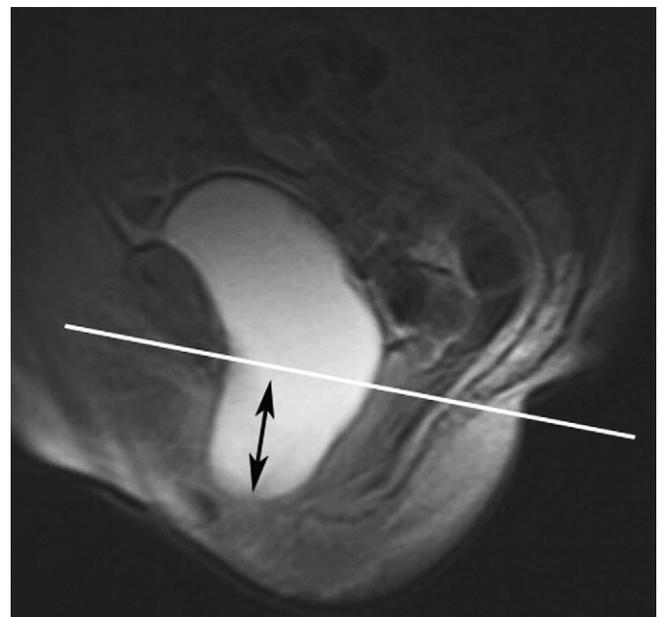


Fig. 10. Isolated cystocele. Mid-sagittal T1-weighted SPGR image obtained during defecation shows moderate cystocele (black arrows) and normal position of vaginal vault and rectum in relationship to the PCL (white line).

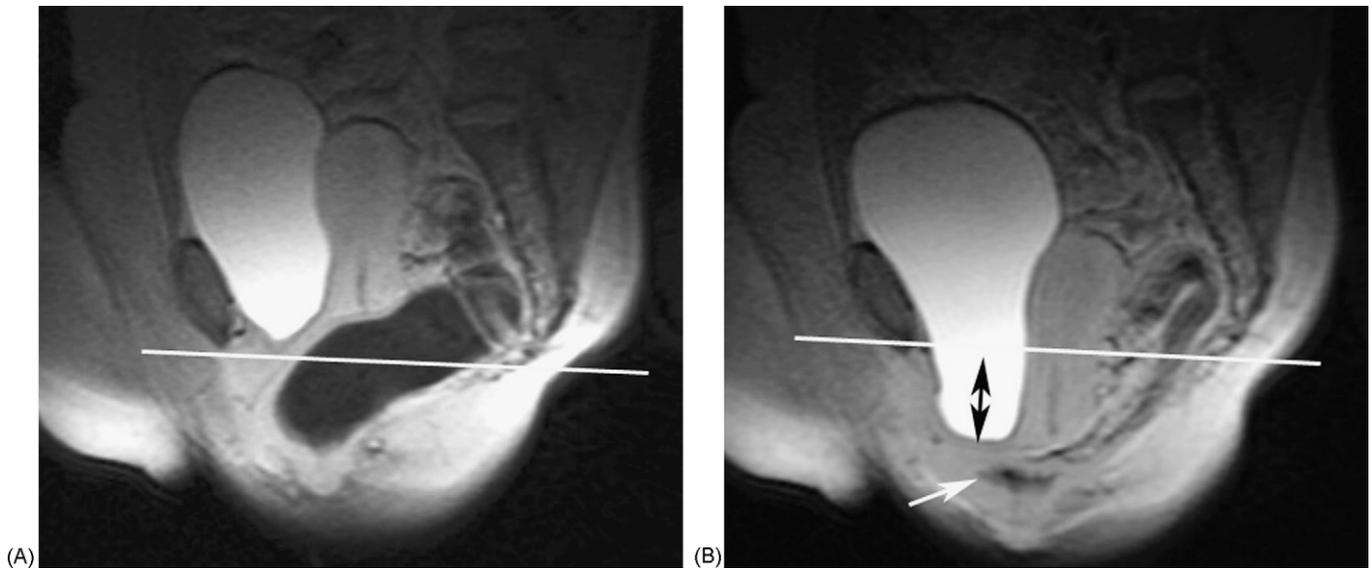


Fig. 11. Descending perineal syndrome with cystocele. (A) Mid-sagittal T1-weighted SPGR image obtained at rest show normal position of the bladder, uterus and vagina, rectum, and small bowel in relationship to the pubococcygeal line (white line). (B) Mid-sagittal T1-weighted SPGR image obtained during defecation shows moderate cystocele (black arrows) and abnormal position of vagina, uterus and rectum in relationship to the PCL (white line). Note presence of unemptied anterior rectocele (white arrow).

tional defecography is limited without opacification of the small bowel, sigmoid or peritoneal cavity [26].

6.2. Cystocele

If there is a break in the pubocervical fascia anywhere throughout its length or at its attachment to the arcus tendineus it will result in a lack of support of the bladder or urethra. A break in the pubocervical fascia can be in the middle of the fascia (midline defect), apically (where anterior vaginal wall meets the cervix) or laterally (paravaginal defect). A cystocele is defined as protrusion or bulging of the bladder into the anterior wall of the vagina [27]. Postmenopausal women are more susceptible to develop a cystocele because estrogens help to keep the supporting muscles and ligaments of the vagina and bladder in good tone. Once estrogen levels drop, these muscles/ligaments become thinner and weaker, which may allow the bladder to bulge into the vagina. A cystocele can occur as an isolated finding, or it may happen along with other pelvic floor abnormalities (descending perineal syndrome). Once a cystocele is present, the patient may suffer from two kinds of problems: unwanted urinary leakage and incomplete emptying of the bladder.

On MR defecography, cystoceles are graded based on the location of the base of the bladder in relationship to the PCL; small if within 3 cm, moderate if within 3–6 cm, and large if more than 6 cm below the PCL (Figs. 10 and 11).

6.3. Utero-vaginal prolapse

Vaginal vault prolapse usually refers to an apical vaginal relaxation in a patient who is post hysterectomy. As the apex of the vagina continues to descend it pulls the rest of the vagina down resulting in apical tears of the anterior and posterior fascia

from its lateral points of attachment. Continued descent of the vaginal apex may result in complete eversion of the vagina.

The uterosacral ligaments primarily support the upper 20% of the vagina (apex) and the uterus. When the uterosacral ligaments break the uterus begins to descend into the vagina. Further uterine descent pulls the rest of the vagina down resulting in apical tears of the pubocervical fascia and rectovaginal fascia from its points of lateral attachment. Continued uterine and vaginal prolapse can result in a complete uterine and vaginal prolapse such that the uterus falls outside the vaginal opening.

7. Conclusions

Pelvic floor dysfunction is a complex condition that can involve some or all of the pelvic organs. Near real-time dynamic MR defecography, especially using open-magnet design with the patient in sitting position is an extremely useful technique for detection and characterization of a vast array of pelvic floor abnormalities and provides a means for optimal patient management.

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