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PERSPECTIVE FROM THE SAR

Clinical applications of pelvic floor imaging: opinion statement endorsed by the society of abdominal radiology (SAR), American Urological Association (AUA), and American Urogynecologic Society (AUGS)

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Abstract

Pelvic floor dysfunction is prevalent, with multifactorial causes and variable clinical presentations. Accurate diagnosis and assessment of the involved structures commonly requires a multidisciplinary approach. Imaging is often complementary to clinical assessment, and the most commonly used modalities for pelvic floor imaging include fluoroscopic defecography, magnetic resonance defecography, and pelvic floor ultrasound. This collaboration opinion paper was developed by representatives from multiple specialties involved in care of patients with pelvic floor dysfunction (radiologists, urogynecologists, urologists, and colorectal surgeons). Here, we discuss the utility of imaging techniques in various clinical scenarios, highlighting the perspectives of referring physicians. The final draft was endorsed by the Society of Abdominal Radiology (SAR), American Urogynecologic Society (AUGS), and the American Urological Association (AUA).

Introduction

Pelvic floor dysfunction is a broad term encompassing multiple clinical conditions which may involve any combination of pelvic organs: the urinary bladder (urinary incontinence, voiding dysfunction), uterus, and vagina (sexual dysfunction, vulvodynia, dyspareunia), rectum (fecal incontinence and disorders of defecation), and various degrees of pelvic organ prolapse. The symptoms vary in severity and depend on the organs involved. Patients may present with pelvic

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pressure and pain, urinary or fecal incontinence, dyspareunia, incomplete rectal emptying, and pelvic organ protrusion.

Pelvic floor dysfunction is prevalent, affecting approximately 24% of women, where 16% experience urinary incontinence, 9% experience fecal incontinence, and 3% experience pelvic organ prolapse [1]. The prevalence of pelvic floor dysfunction increases with increasing age, parity and weight [1]. The lifetime risk of undergoing a single operation for incontinence or pelvic organ prolapse by age 80 is 11%, with 17–29% of patients requiring reoperation [2–4]. Therefore, conditions constituting pelvic floor dysfunction pose a major healthcare concern, and their prevalence will continue to increase in the future, given aging of the population.

Accurate diagnosis of pelvic floor dysfunction mechanism and assessment of the involved structures can be enhanced by a multidisciplinary approach, which may include evaluation by a urologist, urogynecologist, and/or colorectal surgeon. In many cases the diagnosis can be made based on clinical evaluation; however, imaging may reveal occult findings in certain cases, such as cases where symptoms do not align completely with results of clinical evaluation [5, 6]. Inaccurate assessment of the extent of pelvic organ prolapse may lead to suboptimal choice of treatment, which potentially may increase the chances of recurrence. Studies have shown the utility of imaging in preoperative evaluation [7, 8]. For instance, Rentsch et al. demonstrated that MR defecography revealed multicompartment defects in addition to those apparent on clinical evaluation in up to 34% of cases [7]. However, these studies have not assessed impact of preoperative imaging on long-term outcomes.

Imaging assessment of the pelvic floor is an important complementary tool in the evaluation of pelvic floor disorders. The most commonly used modalities for pelvic floor imaging include fluoroscopic defecography, magnetic resonance (MR) defecography (MRD), and pelvic floor ultrasound. This collaboration opinion paper will discuss the use of these imaging techniques in various clinical scenarios, providing insight from the perspectives of referring physicians. Less commonly used examinations for evaluation of patients with specific complaints related to the pelvic floor include voiding cystourethrogram (stress urinary incontinence), and bowel transit studies (constipation). These less commonly used examinations are not discussed in depth in this manuscript.

This opinion paper was developed by a group of representatives from multiple specialties that are commonly involved in care of patients with pelvic floor dysfunction, including radiologists, urogynecologists, urologists and colorectal surgeons. Subgroups of representatives from each specialty in combination with abdominal radiologists worked on assigned clinical topics. Each group was responsible for identifying the important clinical and diagnostic questions relevant to the assigned topic, for the review of the literature, and drafting of their section. The drafts of all sections were then synthesized by the first author into a single manuscript, and the final draft was reviewed and approved by all the authors and endorsed by the Society of Abdominal Radiology (SAR), American Urogynecologic Society (AUGS), and the American Urological Association (AUA).

Imaging modalities for pelvic floor dysfunction

Fluoroscopic defecography

Fluoroscopic defecography (FD) is a well-established, simple, and rapid examination that most closely resembles the actual processes and position for physiologic defecation. FD was the first of all available imaging techniques to be developed for assessment of pelvic floor dysfunction, initially introduced in 1960s [9]. FD is typically performed upright with the patient seated on a commode. FD provides qualitative and quantitative information on the defecatory process, and remains an important problem-solving tool in the workup and treatment of defecatory disorders. Patient cooperation with the required maneuvers and adequate effort are critical for obtaining a diagnostic examination, and may be difficult to assess; however, the ability to perform various maneuvers in real time helps determine adequacy of patient effort and consequently that of the imaging examination.

Although patients undergoing FD typically present with symptoms of obstructive defecation, complete pelvic floor evaluation (also known as fluoroscopic cystocolpoproctography) can be performed and requires contrast instillation into the urinary bladder, vagina, and rectum. *Spot images and cine video are acquired during pelvic floor contraction (Kegel), strain, defecation, and also a post-evacuation strain maneuver, which in some cases may show the most severe degree of pelvic floor dysfunction*. If contrast is retained in the rectum, the patient may be instructed to demonstrate techniques they use at home to empty the rectum, including modified positioning and digital splinting.

In cases where imaging is deemed necessary, FD including cystocolpoproctography is considered one of the imaging tests of choice by the American College of Radiology (ACR) appropriateness criteria for evaluation of suspected pelvic organ prolapse [10]. *A major advantage of FD over other imaging techniques is the upright physiologic positioning, which allows for easier and more complete rectal evacuation, and in theory should approximate the true degree of organ descent better than MRD and pelvic floor ultrasound, which are most commonly performed in the supine position* [11, 12]. Fluoroscopic defecography is particularly useful in cases of obstructive defecation where the MRD is normal or when patient's symptoms are not explained by the MRD findings. A major disadvantage of FD is the use of ionizing radiation. It should be noted that radiation exposure can be minimized with the use of pulsed fluoroscopy. Additional limitations of FD include the inability to directly visualize pelvic floor soft tissue anatomy, limited availability and expense of the specialized radiolucent commode required for the examination, and greater patient inconvenience due contrast instillation into the urinary bladder, vagina, and rectum by three separate catheterizations in order to visualize those structures. In addition, oral contrast may be administered two hours prior to the onset of the study to improve the diagnosis of enteroceles, making this the longest total patient preparation time requirement of any of the pelvic floor imaging techniques. Finally, fewer physicians are comfortable performing and interpreting FD as a result of increased utilization of MRD over the past 2 decades.

MR defecography

MRD has evolved as one of the essential imaging techniques for pelvic floor dysfunction assessment [13–15]. It can simultaneously and non-invasively evaluate all pelvic floor compartments, and provide not only functional, but also anatomic information about muscles and ligaments with superior soft tissue contrast resolution, without use of ionizing radiation, and with minimal patient discomfort [16, 17]. While anterior and middle (apical) compartment dysfunction can be accurately diagnosed clinically, MRD may help differentiate various types of posterior compartment pathology such as enteroceles, sigmoidoceles, peritoneoceles, rectoceles, levator herniation and rectal intussusceptions and prolapse [18–21].

MRD is most commonly performed in the supine position in a standard 1.5T or 3T scanner. While upright open-bore scanners provide accurate assessment in a physiologic sitting position, the availability of such scanners is limited [22]. Although the supine position is not physiologic, MRD in the supine position and MRD in the sitting position demonstrate similar detection rates of clinically significant pelvic floor abnormalities [23]. While one study had shown that supine MRD may underestimate the degree of pelvic floor descent compared with clinical examination and FD performed in a sitting position, this study assessed only strain images, and did not include defecatory phase [12], and it is known that strain images underestimate the frequency and severity of pelvic floor abnormalities as compared with defecation images [24].

Endorectal contrast (e.g., ultrasound gel) is usually instilled to facilitate defecation, and to improve detection of pelvic organ prolapse and rectal intussusception [25]. *The most important sequences in pelvic floor assessment with MRD are the dynamic portions of the study, consisting of imaging during a cycle of rest, squeeze, strain, and defecation.* The dynamic sequences are most commonly acquired using a steady-state-free precession sequence (BTFE/FIESTA/trueFISP) in a mid-sagittal plane which includes the anorectal junction. Dynamic imaging during actual defecation is preferred over straining, when possible, and should be repeated several times to ensure adequate strain and defecation [17, 26].

As mentioned earlier, one of the strengths of MRI is its ability to provide high resolution images of the pelvic floor anatomic structures. MR can also be helpful in the evaluation of pelvic synthetic mesh implants, urethral bulking agents, urethral slings, vaginal mesh, in particular for regions that are not optimally seen on pelvic floor ultrasound, such as the superior aspect of vaginal mesh implants or the retropubic component of mid-urethral slings [27–29].

Inconsistencies in the literature regarding performance of MRD in various clinical scenarios are likely attributable to wide differences in techniques, including patient positioning, choice of whether to use a defecation phase or only strain, and variation in applied reference lines/landmarks. Clinical exam describes prolapse in relation to the position of the hymen. This is in contrast to MRD, which most frequently uses the pubococcygeal line (PCL), marking the level of the pelvic floor, as a reference point. The hymenal position can be approximated on MRD by use of an alternate reference line, the midpubic line (MPL) [30]. However, a recent literature review demonstrated no single reference line performed better for diagnosis of pelvic organ prolapse [16]. Additionally, a follow-up study on MRD showed the PCL to be the most reliable reference line with the highest intra- and interobserver reliability [31]. *Therefore, it is reasonable to use the PCL in interpretation of MRD, with the understanding that imaging is providing complementary information and not acting as a replacement for clinical exam.*

Pelvic floor ultrasound

Pelvic floor ultrasound is offered in approximately 11% of radiology practices with pelvic floor imaging programs [32]. There are various techniques for ultrasound (US) of the pelvic floor, including translabial or transperineal, transvaginal, and endorectal/transrectal. Of these techniques, the most commonly performed technique employs a translabial or transperineal approach using a mid-frequency convex transducer, applied to the perineum. Translabial ultrasound is an emerging modality for the investigation of functional anatomy of the pelvic floor which can provide dynamic visualization of all three compartments [33, 34]. Images can be obtained as cine-loops at rest and during dynamic maneuvers such as strain or pelvic floor contractions. Recent advances in software capabilities permit rapid acquisition of data volumes which can be reviewed off-line and permit multiplanar, multi-slice imaging analogous to MRD, 3D rendered views, and assessment of the urogenital hiatus and levator ani insertions. Pelvic floor US also allows for assessment of synthetic materials. Although the technique is well-suited for assessment of multiple aspects of pelvic floor dysfunction, it is best utilized in the assessment of pelvic organ prolapse and mid-urethral slings. For pelvic organ prolapse, pelvic floor ultrasound evaluates the dynamic function of all three compartments in real time, while ensuring that adequate strain maneuvers have been performed by the patient. *In the setting of prior pelvic floor surgical repair, it is the most reliable technique currently available to evaluate the presence, position, and some of the potential complications associated with mid-urethral slings* [35]. However, this high level of accuracy may require an experienced operator.

Limitations of pelvic floor ultrasound include the need for a relatively high level of expertise in both performing and interpreting this study, the absence of imaging during evacuation, which may limit the assessment of defecatory disorders, and the inability to assess distant complications related to synthetic mesh implants. Nonetheless, emerging evidence demonstrating high negative predictive values for rectocele, intussusception, enterocele and high positive predictive value for cystocele suggests that there may be an important role for pelvic floor ultrasound as a screening tool in patients with symptoms of pelvic floor defecatory dysfunction [36].

Applications of pelvic floor imaging

Imaging can be an important adjunct to clinical evaluation of patients with pelvic floor disorders. Herein, we discuss the utility of pelvic floor imaging in various common clinical scenarios (Table 1).

Anterior and middle (apical) compartment prolapse

Imaging is complementary to clinical assessment of anterior and middle (apical) compartment prolapse, and is particularly helpful in patients whose symptoms are inconsistent with physical exam findings or when physical examination is challenging, for example, due to pain or mesh exposure. Imaging may be helpful for pre-surgical planning as it helps identify multi-organ involvement including clinically occult abnormalities in other compartments, and to assess for presence of pelvic floor muscle and fascial defects [7]. These findings may alter the need for surgery or the surgical approach. Clinically occult defects in other compartments may increase the risk for prolapse recurrence, if they are not identified preoperatively [13, 21, 37]. For example, in patients with a predominant complaint of severe vaginal prolapse, knowledge of concomitant cystocele and enterocele or rectocele is important to tailor the type of surgical repair. Imaging is particularly useful for identifying cul-de-sac hernias and differentiating these from anterior rectoceles as the clinical presentations often overlap, but the surgical repair for each may be unique, and may have to be combined when the two conditions coexist. Although these defects can be determined at time of surgery, prior knowledge may help direct pre-surgical counseling. In a patient with clinically suspected cystocele, imaging can be performed for confirmation and exclusion of rare cases of urethral diverticulum or Gartner's duct cyst presenting as an anterior vaginal bulge [38, 39]. Additionally, imaging can differentiate between cystourethroceles, associated with stress incontinence, and cystocele with preserved retrovesical angle, typically associated with voiding dysfunction [39]. Finally, imaging may be indicated in rare patients that present with anterior vaginal bulge post cystectomy and may detect enteroceles anterior to the vagina in this setting ("anterior enterocele") [40].

Fluoroscopic defecography for anterior and middle (apical) compartment prolapse

As described previously, FD is considered one of the imaging tests of choice for evaluation of pelvic organ prolapse particularly in patients where clinical symptoms and physical examination findings are discordant [10]. Because a distended rectocele may mask anterior compartment prolapse and vice versa, evaluation for cystocele is performed either prior to rectal filling or after complete rectal evacuation [41]. Studies have shown relatively good concordance between clinical exam and FD for anterior and middle (apical) compartment prolapse [42]. Although FD can confirm these clinically apparent defects, it is usually obtained to evaluate for other associated abnormalities that may be clinically occult, such as cul-de-sac hernias. There is poor correlation between imaging and clinical examination with respect to cul-de-sac hernias, where approximately half of enteroceles seen at FD are not identified on initial physical exam [42–44]. Additionally, up to two-thirds of clinically suspected cul-de-sac hernias are not confirmed on subsequent FD [42]; however, FD can be used as a complement to clinical exam in patients with anterior and middle compartment prolapse with a concomitant posterior vaginal bulge, due to ability to detect enteroceles and sigmoidoceles, and to evaluate for complex multicompartment prolapse and posterior compartment abnormalities prior to surgery.

MR defecography for anterior and middle (apical) compartment prolapse

MRD is also considered one of the imaging tests of choice by the ACR appropriateness criteria for evaluation of

Table 1 Summary of the modalities available for assessment of patients with pelvic floor dysfunction

	Fluoroscopic defecography	MR defecography	Pelvic floor ultrasound
Main advantages	Imaging in physiologic positioning Lower cost	Assessment of all three compartments simultaneously Inherent high soft tissue contrast allows for evaluation of the pelvic floor musculature and fascia	Lower cost Assessment of all three compartments simultaneously
Main limitations	Use of ionizing radiation No assessment of pelvic floor anatomy Contrast instillation required into bladder, vagina and rectum for assessment of three compartments	High cost Imaging in non-physiologic position (supine), resulting in underestimation of degree of pathology	Operator-dependent Requires high level of expertise to perform Imaging in non-physiologic position (supine or semi-upright) Imaging during evacuation is not performed
Clinical Scenarios			
Anterior and middle (apical) compartment prolapse	Complement to clinical exam in patients with a concomitant posterior vaginal bulge, due to ability to detect posterior compartment abnormalities prior to surgery Evaluates for associated middle and posterior compartment abnormalities that may be clinically occult	Evaluates for associated middle and posterior compartment abnormalities that may be clinically occult Able to evaluate the pelvic floor musculature and fascia for defects, which may alter treatment and affect recurrence risk	Evaluates the levator hiatus for ballooning and for levator ani avulsion, a predictor of prolapse recurrence
Defecatory dysfunction and rectal prolapse	Assesses for rectocele, rectal intussusception, descent of the anorectal junction and the degree of change in anorectal angle High sensitivity for detection of rectal intussusception and rectal prolapse Unable to distinguish between full-thickness and mucosal rectal intussusception Distinction between enterocele, peritoneocele, sigmoidocele can be challenging	Differentiates rectoceles and cul-de-sac hernias, characterizes the contents of cul-de-sac hernias Superior in differentiating full-thickness from mucosal intussusception Assesses pelvic floor dyssynergia Evaluates anal sphincter thickness and integrity	Limited utilization in assessment of defecatory dysfunction and rectal prolapse Distinction between enterocele, peritoneocele, sigmoidocele can be challenging
Urinary dysfunction	Requires use of voiding cystourethrogram Assesses post-void residual Detects vesico-ureteral reflux	Detects co-existing multicompartmental abnormalities Assesses ligamentous supporting structures	Assesses bladder neck and urethral mobility during micturition Can assess post-void residual Assesses urethral muscle thickness, urethral sphincter defects
Post-operative Evaluation after Pelvic Floor Repair	Limited role for this clinical scenario	Detects retropubic and distant components or complications of urethral slings and mesh Assesses for fistulae, abscesses, osteomyelitis	Superior assessment of mesh components in sub-urethral space Detects erosion of sling material into adjacent structures Assesses transvaginal meshes, including mesh folding, detachment or erosion

suspected pelvic organ prolapse [10]. Advantages of MRD include absence of ionizing radiation, the ability to simultaneously analyze all three compartments, and direct visualization of pelvic floor contents. *MRD is also unique in its inherent soft tissue contrast and ability to evaluate the pelvic floor musculature and fascia for defects that may alter treatment and affect recurrence risk* [21, 37]. Furthermore, MRD can detect peritoneoceles that are occult on clinical exam. As described previously, in clinical practice the majority of MRD exams are performed supine in a closed configuration magnet. The non-physiologic position may underestimate the presence and degree of pelvic floor abnormalities, particularly if patients are unable to expel the rectal gel during the exam [12]. However, dynamic supine MRD has been shown to perform similarly to upright MRD and FD in diagnosing clinically significant pelvic organ prolapse, although the degree of descent may not be as pronounced [11, 23, 45]. More recently, supine MRD has been shown to be superior to upright fluoroscopic VCUG for assessment of cystoceles and urethral hypermobility [46]. Limitations of MRD include cost and potential contraindications, such as MR-incompatible devices and claustrophobia.

It should be noted that accurate diagnosis and grading of anterior and middle (apical) compartment prolapse on MRI has been shown to be significantly affected by two variables: (1) use of the defecation phase and (2) distention of the rectum. In one study of patients using upright MRD, approximately half of cystoceles and nearly two thirds of uterine/vaginal apex descent were seen only with defecation, and not with strain/Valsalva [24]. Findings were similar, although more modest, in a closed magnet with left lateral decubitus positioning, where almost 40% of cystoceles and approximately 20% of uterine/vaginal apex descent were seen only with defecation, and not with strain/Valsalva [47]. A study of patients with obstructed defecation demonstrated that approximately 50% of cystoceles seen on dynamic MRI prior to rectal filling were either not seen or downgraded when dynamic MRI with Valsalva was repeated after rectal filling [48]. Similarly, approximately 80% of uterine prolapse seen on dynamic MRD prior to rectal filling was either not seen or downgraded when dynamic MRD was repeated after rectal filling [48]. It is important to note that rectal evacuation was not performed in this study [48]. Another study showed higher prevalence and size of anterior and middle (apical) compartment prolapse on defecation images on MRD compared to pre-defecation Valsalva images performed with rectal gel as well as post-defecation Valsalva images performed with limited rectal distention [49]. Anterior and middle (apical) compartment prolapses were also more prevalent and larger on the post-defecation Valsalva images compared to pre-defecation Valsalva images [49]. Therefore, pre-filling or post-evacuation dynamic MRD *and* defecation are essential if MRD is being performed specifically to confirm suspected anterior and middle (apical) compartment prolapse.

Results of studies comparing MRD with clinical examination are widely variable, although concordance is generally found to be good for anterior and middle (apical) compartment abnormalities and poor for the posterior compartment [16, 50, 51]. As with FD, MRD performs better than physical examination for the detection of cul-de-sac hernias [52]. Furthermore, MRD allows for differentiation of cul-de-sac hernias from rectoceles, a distinction that can be challenging on physical examination. Nonetheless, such defects may be discernible at time of surgery. However, in patients with anterior and middle (apical) compartment prolapse, MRD may help with more pre-surgical planning by facilitating detection of cul-de-sac hernias, multicompartment prolapse, and pelvic floor muscle and fascial defects prior to the surgery [37].

Pelvic floor ultrasound for anterior and middle (apical) compartment prolapse

When imaging is deemed necessary, pelvic floor ultrasound may be used for evaluation of suspected pelvic organ prolapse per the ACR appropriateness criteria [10]. *A major advantage of pelvic floor ultrasound is the ability to acquire a series of cine-loops during rest, pelvic floor contraction (Kegel), and strain (Valsalva).* This allows for multiplanar and 3D reconstruction of the pelvic floor during the various maneuvers. Additionally,real-time imaging provides immediate feedback on whether the effort at contraction and strain was adequate, enabling repeat attempts as needed to ensure the highest quality test. While cine clips can be acquired both with conventional FD and MRD, ultrasound has an advantage of no ionizing radiation and a relatively low cost. Scanning is typically performed with the patient in the dorsal lithotomy position, but can be done in a more semi-upright position with the patient's head elevated if needed. US is inexpensive and uses no ionizing radiation. The main drawbacks to US in pelvic floor imaging are limited radiologist familiarity, operator dependence, need for specific equipment such as a 3D probe, and need for specialized training of technologist performing the study.

Clinical exam and US measurements of anterior and middle (apical) compartment prolapse show moderate to strong correlation [53, 54]. There is also moderate to good agreement between clinical exam and US in the distinction between cystourethroceles vs cystoceles with preserved retrovesical angle [55]. Pelvic floor ultrasound is additionally able to evaluate the levator hiatus for ballooning as well as for levator ani avulsion, a predictor of prolapse recurrence, particularly in the anterior compartment [21, 39]. There is a good agreement between US and physical examination in detecting levator ani tears (kappa 0.56–0.61), and US finding of levator ani tears is associated with symptoms of prolapse and ≥ grade 2 cystocele [56]. Studies comparing the performance of pelvic floor ultrasound with FD and MRD are still needed.

Defecatory dysfunction

Patients with defecatory dysfunction may have multicompartment defects. Moreover, adequate treatment of patients with pelvic floor dysfunction relies heavily on accurate assessment of the presence and degree of pelvic floor abnormalities [37, 57]. For examples MR diagnosis of external sphincter atrophy has been shown to predict poorer outcomes after surgical sphincter repair [58, 59]. In patients with significant or complex pelvic floor dysfunction, the differentiation between rectocele, sigmoidocele, and enterocele may be challenging based on clinical examination alone [13, 60]. Imaging is therefore usually obtained to help accurately diagnose defects in the pelvic floor and to guide management. For example, in patients with known anatomic or mechanical defects typically treated surgically, imaging can be used to detect underlying or associated functional causes of defecatory dysfunction such as dyssynergia, which require non-surgical treatments such as biofeedback therapy. Defecatory dysfunction can also result from rectal prolapse or complete rectal intussusception, which is discussed separately.

Fluoroscopic defecography for defecatory dysfunction

FD plays an important role in diagnosis of pelvic floor dysfunction and often alters management [61–63]. FD is considered one of the imaging tests of choice by the ACR Appropriateness Criteria for evaluation of suspected defecatory dysfunction [10]. Upright positioning and imaging during active defecation are particularly advantageous when assessing defecatory dysfunction. The presence or absence and size of a rectocele, enterocele, intussusception, excessive descent of the anorectal junction and the degree of change in anorectal angle can be assessed during this exam. In addition, paradoxical narrowing of the anorectal angle and delayed rectal emptying is seen is patients with pelvic floor dyssynergia. Thus, FD is able to identify both mechanical and functional causes of defecatory dysfunction. FD is also able to assess for degree of barium trapping within rectoceles, which could correlate to patient's complaints of stool trapping and need to splint to defecate, often associated with large symptomatic rectoceles. This information may also guide management, as patients with non-emptying rectocele may be considered for surgical repair, rather than biofeedback alone, which would be a treatment of choice for patients with pelvic floor dyssynergia or isolated intussusception [64].

Rectal intussusception has been strongly associated with impaired defecation [65] and is very well assessed on FD. While FD is more sensitive in diagnosing intussusception, MRI can better differentiate between full-thickness and mucosal intussusceptions [20, 37, 66]. Fluoroscopy can assess multiple pelvic floor compartments for concomitant abnormalities by filling the urinary bladder, vagina and small bowel with contrast. Since a majority of patients have multicompartment defects, it is imperative to have a study that is not limited to one compartment only [67, 68]. FD is also able to assess patients with fecal incontinence; the anorectal angle on FD correlates with the severity of fecal incontinence [69].

MR Defecography for defecatory dysfunction

MRD is considered one of the imaging tests of choice by the ACR Appropriateness Criteria for evaluation of suspected defecatory dysfunction [10]. MRD is able to differentiate rectoceles and cul-de-sac hernias and characterize the contents of cul-de-sac hernias (small bowel, sigmoid colon, peritoneal fat) [19]. The cine dynamic phase images for evaluation of rectal emptying during MRD have been shown to add clinically significant information compared to just static images [24]. *Use of rectal contrast and imaging during active defecation are of utmost importance when evaluating patients with defecatory dysfunction with MRD.*

It has been shown that MRD plays a crucial role in managing patients with pelvic floor disorder and alters surgical management in a significant number of patients of patients with pelvic floor disorders and fecal incontinence [37, 57]. Compared with clinical assessment, MRD is more accurate in diagnosing enteroceles, peritoneoceles, intussusception, rectal prolapse, and abnormal anorectal angles [13, 70]. Furthermore, MRI is superior to fluoroscopic defecography in differentiating full thickness from mucosal intussusception [66].

In addition to characterizing these mechanical etiologies of defecatory dysfunction, MRD is able to detect functional causes of constipation, such as pelvic floor dyssynergia, by demonstrating paradoxical contraction of the puborectalis and levator plate during defecation, resulting in narrowing of the anorectal angle [17]. A pitfall that must be considered during MRD is absence of defecation due to suboptimal patient effort during the examination. Inadequate effort and absence of rectal emptying may decrease sensitivity, especially for rectal intussusception and cul-de-sac hernias. *Thus, patients should be asked to perform multiple defecation attempts and must be given clear instructions to avoid* *confusion between the different maneuvers (e.g., Kegel or squeeze versus defecation).*

Although FD has been shown to be overall more sensitive than physical examination for evaluation of intussusception and enteroceles, the biggest advantage of MRD is the ability to evaluate the interaction of all three compartments and identification of the most dysfunctional one [13]. In addition, due to its superior soft tissue resolution MRD can evaluate supporting structures including pelvic floor muscles and ligaments. MRD can also evaluate anal sphincter thickness and integrity.

Pelvic floor ultrasound for defecatory dysfunction

Depending on specific technique used, pelvic floor ultrasound may be appropriate in certain cases for evaluation of suspected defecatory dysfunction per the ACR Appropriateness Criteria [10]. In general, pelvic floor ultrasound is used less commonly for this indication compared to FD and MRD as at most centers, pelvic floor US is generally performed without rectal contrast, and patients are not evaluated during defecation. Pelvic floor ultrasound can diagnose intussusception, rectal prolapse, and abnormal anorectal angles consistently [71]. Cul-de-sac hernias are readily diagnosed on pelvic floor ultrasound, but the distinction between enterocele, peritoneocele, sigmoidocele can be challenging in less experienced hands [71].

Findings of rectocele on pelvic floor ultrasound are similar to those on FD [39, 72]. Ultrasound is more sensitive for evaluation of levator trauma [73]. Endoanal ultrasound is excellent at evaluating internal anal sphincter thickness and injuries. However, MRI is more sensitive in evaluation of the external anal sphincter, especially once the sphincter atrophies, as it is challenging to detect its borders on endoanal ultrasound [74]. However, despite this limitation, MRI and endoanal ultrasound are similar in their ability to select patients suitable for surgical sphincter repair [75].

At this time, dynamic pelvic floor ultrasound is performed in specialized centers with experienced technologist and sonologists. However, given the exam's cost-effectiveness, real-time imaging and lack of ionizing radiation, this is a rapidly emerging study of choice for urogynecologists [39].

Rectal prolapse

Complete rectal prolapse (extra-anal intussusception), or procidentia, while seemingly a fairly obvious diagnosis to make clinically, is surprisingly often misconstrued. The most common error in diagnosis is related to mistaking hemorrhoidal prolapse or mucosal prolapse from true, full-thickness rectal prolapse. In addition, occult or internal rectal prolapse may be difficult to diagnose clinically, since the symptoms are often vague and may be related more to functional issues and symptoms related to pelvic outlet obstruction. Internal rectal prolapse is essentially a diagnosis made radiologically. Symptoms of prolapse can range widely, from the obvious protrusion of a mass through the anus to symptoms of fecal incontinence and chronic mucus seepage in the setting of intermittent or spontaneously reducing prolapse. Hemorrhoidal prolapse is a more common entity, whose symptoms may often mimic rectal prolapse due to mucus seepage associated with chronic mucosal irritation.

Clinical evaluation remains the best initial mode of assessment, and a thorough history and physical examination will often confirm the diagnosis. If no obvious prolapse is seen on Valsalva, examination while squatting or pushing over commode is helpful. If prolapse still cannot be demonstrated, but is suspected based on history and symptoms, patients can be asked to take a picture during onset of symptoms. Demonstration of hemorrhoidal or mucosal prolapse will show columns of prolapsing mucosa with linear striations, while full-thickness prolapse will show concentric rings of mucosal prolapse. Screening endoscopy is also very helpful to evaluate for luminal lesions or stigmata of prolapse, such as mucosal trauma or solitary rectal ulcers.

When evaluating prolapse, adjunctive imaging is crucial to the detailed assessment. Internal rectal prolapse can be definitively diagnosed on defecography, fluoroscopic, or MR based, so patients with symptoms of obstructed defecation often merit radiologic evaluation. In addition to radiographic imaging, endoscopic evaluation should be performed to exclude any lesions that might be contributing to symptoms or might affect the extent or plan of operative intervention.

Defecography, either fluoroscopic or MRI based, is a reliable diagnostic tool in patients where the diagnosis is not straightforward on clinical assessment [76]. Additionally, in patients with rectal prolapse, coincident middle (apical) and anterior compartment prolapse are not uncommon, and identification prior to intervention may help in pre-surgical planning and patient counseling. Similarly, in the setting of symptoms of pelvic outlet obstruction, differentiation between dyssynergia and possible internal prolapse may affect management as biofeedback therapy is often indicated for patients with dyssynergia [77, 78]. Internal rectal prolapse demonstrated on imaging may be the anatomic basis for obstructive defecation symptoms and can be treated conservatively or surgically depending on a number of patient-related factors. In the setting of prolapse with concomitant constipation, transit studies provide important information that may aid in selection of appropriate management. In patients with normal motility, at least 80% of the markers are either evacuated or reach the rectum by day 5 [79]. Colonic inertia is diagnosed when ≥ 5 radiopaque markers have not reached the rectum by day 5 [79]. A patient with colonic inertia can be treated with concomitant subtotal colectomy at the time of prolapse repair [80]. Failure to address the colonic inertia is associated with high rates of recurrence and diminished quality of life. Similarly, if transit studies show no inertia in the setting of constipation, then sigmoid resection and rectopexy may be considered [80].

Fluoroscopic defecography for rectal prolapse

As described above, the greatest advantage of fluoroscopic defecography is that it mimics physiologic function of the pelvic floor in real-time imaging. Consequently, FD is endorsed by many societies' consensus statements for diagnosis of rectal prolapse including the American Society of Colon and Rectal Surgeons (ASCRS), the Italian Society of Colorectal Surgery and the 2017 Dutch Guidelines [81–83]. FD allows characterization of rectal intussusception as intra-rectal, intra-anal, or external or complete rectal prolapse.

MR defecography for rectal prolapse

When performed with rectal contrast in the seated position, MR defecography is able to assess for presence of and characterize rectal intussusception as intra-rectal, intra-anal or complete external rectal prolapse. Studies have shown that MRD is superior to FD for evaluation of an internal rectal prolapse [20]. Furthermore, as discussed above, MRD is able to differentiate between full-thickness and mucosal intussusception, which can alter management [17]. While mucosal intussusception may be treated either non-surgically or by transanal resection of prolapsed mucosa, full-thickness intussusception may require rectopexy [84, 85].

Pelvic floor ultrasound for rectal prolapse

In current clinical practice, pelvic floor ultrasound has a limited role in assessment of patients with suspected rectal prolapse. As described above, there is an emerging evidence demonstrating high negative predictive values for rectocele and intussusception, suggesting an important screening role in patients with possible rectal prolapse [36].

Urinary dysfunction

Clinically, urinary incontinence is divided in three major types: stress, urgency and overflow, with urgency incontinence being the most prevalent type [86]. Mixed incontinence, where both stress and urgency symptoms coexist, is the second most common type [86]. In most cases, these types can be confidently diagnosed with good clinical history and physical examination [87]. *Imaging does not play a significant role in management of uncomplicated stress urinary incontinence.* Imaging helps to establish a diagnosis in patients with atypical clinical presentation, in patients with mixed symptomatology, hematuria, underlying neurological conditions, associated anterior compartment prolapse, pelvic organ prolapse and previous surgery for incontinence [88]. Based on the modality used, imaging offers information about specific anatomy and function of anterior compartment structures. For example, the presence of urethral distortion detected by VCUG preoperatively is associated with recurrent lower urinary track symptoms after mid-urethral sling [89]. Imaging findings can affect management; for example, the surgical approach may change based on imaging characterization of defects as central/paravaginal. Although a detailed discussion of surgical management is outside the scope of this article, treatment options vary from anterior colporrhaphy to paravaginal fascial repair. If in addition to cystocele, there is urethral hypermobility in a patient with urinary incontinence, a patient may be offered a sling procedure or a bladder neck suspension, such as Burch urethropexy [90, 91].

Fluoroscopic defecography for urinary dysfunction

Although FD or fluoroscopic colopoproctography plays a limited role for assessment of urethral mobility, another fluoroscopic examination, the VCUG, can detect vesicoureteral reflux, mobility of the urethro-vesical junction, urethral diverticula, urethral stricture, cystocele, urine leakage with stress effort, and the site of presumed bladder outlet obstruction [92]. As a component of videourodynamics, fluoroscopic voiding cystourethrogram can be used to simultaneously measure pressures and visualize anatomy. This is particularly useful in patients with neurologic disease who may have a large post-void residual or in patients who have urinary symptoms from bladder outlet obstruction [93].

MR defecography for urinary dysfunction

Of all three pelvic compartments, anterior compartment findings on MRD correlate most closely with physical examination; therefore, the incremental value of MRI in addition to a satisfactory clinical examination for the anterior compartment is small [50, 52]. In the setting of stress urinary incontinence, MRI can detect associated organ prolapse, and evaluate urethral sphincter anatomy and dysfunction [94, 95]. *Prior to surgery, MRI may be used for global assessment of the pelvic floor, including detection of co-existing multicompartmental abnormalities* [94, 95]. This may be particularly applicable when clinical findings are patient symptoms are incongruent. Urethral length and volume, urethral sphincter defects, funneling at bladder neck, urethral hypermobility, urethral kinking, increased vesico-urethral angle and grade of cystocele can be assessed by MRI. *It is important to note that urethral hypermobility is a common* *finding on MRD, and may not be of any clinical consequence unless the patient suffers from incontinence, in which case presence of hypermobility may alter patient management and may be predictive of cure rates after sling repair* [96, 97]. MRI also provides imaging evidence of loss of normal bladder and urethral support, and detects asymmetry of pubococcygeus muscles, abnormal vaginal shape and enlargement of the retropubic space [98, 99]. MRI has also been shown to accurately localize pelvic floor defects, evaluate success or failure of surgical procedures, predict the need for more extensive reconstruction, and identify post-operative complications [13, 100].

Pelvic floor ultrasound for urinary dysfunction

Pelvic floor ultrasound can assess bladder wall morphology, urethral muscle thickness, urethral sphincter defects, bladder neck and urethral mobility during micturition, and also the urethro-vesical angle [101]. Additionally, pelvic floor ultrasound can assess post-void residual, which is particularly important for patients with both urgency and overflow incontinence [101, 102]. The role of ultrasound in urethral hypermobility assessment is limited, as no identifiable pattern to predict urethro-vesical movement has been found [103].

In post-operative patients, transperineal high frequency high resolution 2D and 3D ultrasound can be useful in sling and bulking agent evaluation as discussed later in this paper. Ultrasound is better suited for detection of sling in the suburethral portion, and it has the added advantage of viewing sling deformation and complications with straining or micturition in real time.

Post-operative evaluation after pelvic floor repair

The field of imaging for pelvic floor mesh-related complications is fairly new. Mesh materials have been used over the past decade for the management of stress urinary incontinence and/or pelvic organ prolapse [104, 105]. Most midurethral synthetic slings are made of polypropylene material. Commonly used slings include retropubic slings, transobturator slings and single incision slings. Vaginal mesh can be placed using a transvaginal approach between the anterior vaginal wall and the bladder base to correct the anterior vaginal compartment laxity, or between the posterior vaginal wall and rectum to reduce a rectocele from the posterior compartment. The mesh is secured in place by lateral extension of arms typically into the obturator foramen (anterior arms) and/or to the sacrospinous ligament (posterior arms). Most mesh and slings are placed tension free, i.e., without sutures or anchors holding them in place, but rather by scarring and fibrosis of the arms. Rarely, predominantly older mesh and slings may have anchors to stabilize them once in place.

An alternative to transvaginal mesh is the transabdominal approach mesh sacrocolpopexy (SC), which entails placement of synthetic mesh material at the vaginal apex to secure the prolapsed vault superiorly to the sacral promontory. This mesh can be fashioned to cover the anterior and posterior vaginal compartments, depending on the level of prolapse. The superior portion of the mesh is ideally sutured at the promontory over the anterior vertebral ligament. With the advent of robotic technology, open mesh sacrocolpopexy is often supplanted by laparoscopic and robotic approaches.

Patients may present with multiple and variable complaints after sling and mesh placement, and imaging may be indicated in many cases to help identify the synthetic material [106]. *Imaging is most valuable in patients that present with recurrent pelvic floor dysfunction or with complications of surgery and are unaware of the type of repair procedure they have had, when operative records are not available for review, or in patients with persistent symptoms after reported sling or mesh removal.* In many cases, imaging is extremely useful for pre-surgical planning prior to removal of these materials and allows for more informed patient counseling about expected benefits of the removal procedure and the risk of injury to surrounding structures [27, 29].

Fluoroscopic cystocolpoproctography for mesh/sling evaluation

Fluoroscopy has a limited role in assessment of patients with suspected complications after pelvic floor repair, as the synthetic materials are not directly visualized on this modality. In theory, FD may be used to evaluate for recurrent prolapse; however, MRI and ultrasound are more routinely employed in post-surgical patients because these modalities allow both functional evaluation for recurrent dysfunction, as well as direct visualization of synthetic materials and associated complications.

MR defecography for mesh/sling evaluation

MRD can be used for assessment of complications in patients that present after surgical repair; however, the functional defecography component is most beneficial in patients with suspected recurrent pelvic prolapse or recurrent defecatory dysfunction [10]. MRI allows evaluation for presence or absence of synthetic materials in patients who may have had multiple procedures, particularly when prior surgical details may not be readily available. Furthermore, MRI may be able to detect and further characterize clinically suspected complications such as malposition or migration of mesh or slings, infection, abscesses, fistulae, extensive scarring, and in certain cases, erosion or exposure of mesh or sling material into adjacent structures such as the bladder or rectum [27]. SC mesh detachment as cause for recurrent prolapse can be diagnosed by detecting discontinuity or thinning along the mesh. In general, MRI is superior to ultrasound for detection of retropubic and distant components or complications of urethral slings and mesh, while visualization of structures in the sub-urethral space between the urethra and vagina is superior on ultrasound due to its smaller field of view and more targeted evaluation [28, 107]. For example, MRI may be able to detect superior extension of infection along SC mesh with concomitant osteomyelitis at the sacrum or development of vaginal mesh-related fistulae or abscess in the ischiorectal space or detection of bladder wall erosion of sling material in the retropubic space. MRI is also superior for assessment of the proximity of synthetic material to or secondary distortion of the bladder base or rectal wall. In many cases, both MRI and ultrasound are obtained as they provide complementary information. Specific imaging findings in patients with complications of pelvic floor synthetic material are described in a dedicated paper in this journal issue [29].

Pelvic floor ultrasound for mesh/sling evaluation

Targeted pelvic floor ultrasound can be utilized for evaluation of patients after pelvic floor repair depending on the specific clinical question [10]. Ultrasound is particularly useful for evaluation of the sub-urethral portion of slings and offers better visualization than MRI in this location [28]. *Pelvic floor US is able to locate sling material in relation to the urethra, predict the type of sling, and assess for erosion of sling material into adjacent structures, such as the urethral wall, vagina or bladder* [108, 109]. On a normal study, a sling appears as a hyperechoic liner structure with a characteristic mesh weave pattern. Urethral or vaginal exposure can be suggested on US by measuring the distance of the sling to the urethral lumen on sagittal images and may prompt further investigation with urethroscopy or vaginoscopy. Ultrasound is able to evaluate the configuration of sling material at rest and during straining, and is also able to identify multiple slings. Description of the position of the sling along the urethra allows for improved surgical planning, as slings may not be in the mid-urethral section where they were presumably placed initially, but may have migrated distally or proximally. Assessment of symmetry and depth of the sling material relative to the urethral circumference is also relevant for surgical planning as it provides advance knowledge of sites at risk for urethral injury during a sub-urethral sling release (SSR) procedure. Identification of large peri/para-urethral veins alerts the surgeon to the risk of intraoperative bleeding. Finally, in the common setting of patients who are uncertain as to the type of prior procedure, ultrasound may be able to differentiate synthetic sling materials from biologic or native tissue repair due to absence of the typical highly echogenic mesh weave pattern [27, 29, 71].

Ultrasound may also be able to identify transvaginal mesh in the anterior and posterior compartment, mesh folding or detachment, and violation of the urethra or vagina by these materials [108]. Ultrasound for detection of sling and mesh complications can also be performed using an endovaginal approach [110]. As noted previously, ultrasound is inferior to MRI for evaluation of the trajectory of arms of slings and mesh in distant locations (for example, in the retropubic space or ischiorectal fossae) or suspected complications outside the immediate para-urethral or paravaginal locations, and both examinations may be needed for complete evaluation.

Conclusion

Pelvic floor dysfunction comprises a spectrum of diseases, which often coexist. Imaging plays an integral role in evaluation of patients with pelvic floor dysfunction, particularly when physical examination is not straightforward, or multicompartmental dysfunction is suspected either based on symptoms or physical examination. Fluoroscopic defecography, MR defecography, and pelvic floor ultrasound are available for assessment of these patients. Utilization of the appropriate imaging modality depends on clinical scenario, as well as clinician and patient preferences. Understanding the strengths and limitations of each of the available imaging modalities and knowledge of clinical scenarios where imaging may be beneficial will help appropriate image utilization and ultimately contribute to improved patient outcomes.

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