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Comparison between dynamic cystocolpoproctography and dynamic pelvic floor MRI: pros and cons: Which is the ''functional'' examination for anorectal and pelvic floor dysfunction?

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Abstract

''Functional'' imaging of anorectal and pelvic floor dysfunction has assumed an important role in the diagnosis and management of these disorders. Although defecography has been widely practiced for decades to evaluate the dynamics of rectal emptying, debate concerning its clinical relevance, how it should be done and interpreted continues. Due to the recognition of the association of defecatory disorders with pelvic organ prolapse in women, the need to evaluate the pelvic floor as a unit has arisen. To meet this need, defecography has been extended to include not only evaluation of defecation disorders but also the rest of the pelvic floor by opacifying the small bowel, vagina, and the urinary bladder. The term ''dynamic cystocolpoproctography'' (DCP) has been appropriately applied to this examination. Rectal emptying performed with DCP provides the maximum stress to the pelvic floor resulting in complete levator ani relaxation. In addition to diagnosing defecatory disorders, this method of examination demonstrates maximum pelvic organ descent and provides organ-specific quantification of organ prolapse, information that is only inferred by means of physical examination. It has been found to be of clinical value in patients with defecation disorders and the diagnosis of associated prolapse in other compartments that are frequently unrecognized by history taking and the limitations of physical examination. Pelvic floor anatomy is complex and DCP does not show the anatomical details pelvic magnetic resonance imaging (MRI) provides. Technical advances allowing acquisition of dynamic rapid MRI sequences has been applied to pelvic floor imaging. Early reports have shown that pelvic MRI may be a useful tool in pre-operative planning of these disorders and may lead to a change in surgical therapy. Predictions of hypothetical increase cancer incidence and deaths in patients exposed to radiation, the emergence of pelvic floor MRI in addition to questions relating to the clinical significance of DCP findings have added to these controversies. This review analyses the pros and cons between DCP and dynamic pelvic floor MRI, addresses imaging and interpretive controversies, and their relevance to clinical management.

Key words: Dynamic pelvic floor MRI—Defecography—Pelvic organ prolapse—Anorectal disorders—Pelvic organ prolapse staging

Defecation disorders and pelvic organ prolapse are common and affect up to 25% of the population, mostly parous women [1, 2]. They cause significant morbidity, affect quality of life, and lead to psychological distress and work absenteeism. Functional/''dynamic'' imaging has become increasingly central to the management of anorectal (AR) and pelvic floor

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dysfunction the clinical treatment of which is often difficult [3, 4]. Defecography was introduced by Burhenne in 1964 [5], and several reports were published on the topic during the 1960s [6–8]. There was a resurgence of interest in the technique in the 1980s [8–13]. This interest was stimulated in part by new information available with manometry and electromyography, and the renewed therapeutic interest in both surgical and biofeedback techniques. The technique described by Mahieu et al. [8, 9] became standard at that time. The term dynamic cystocolpoproctography (DCP) was introduced by Kelvin et al. [14, 15] in 1992. The method was defecography with small bowel and vaginal opacification preceded by cystography. The technique evolved to become a global pelvic floor examination. The rationale for the separate cystographic examination was that rectal distention elevates the bladder base and may mask a cystocele and produce funneling [16]. Without opacification of the pelvic organs, it can be impossible to be sure one organ is not blocking the descent of another organ. A dropped bladder that is unemptied may prevent another organ such as small bowel, sigmoid, or rectum from occupying the space. When the first to descend organ is emptied, another organ falls into this space. The separate performance of cystography and proctography was most recently modified by Maglinte et al. [17] to a single examination of the three compartments to shorten examination time and decrease radiation exposure. In this modification, after the rectal evacuation phase, with an 8F catheter in place and the urinary bladder opacified with a small amount of water-soluble contrast medium (30 mL Isovue 300, Bracco Diagnostics), the rectum or a rectocele emptied at the end of defecation; rest and marked straining/defecating radiographs are obtained. These are the images where measurements are made for prolapses of all compartments except for the grading of enteroceles, sigmoidoceles, and peritoneoceles. Mucosal or transmural intussusceptions are evaluated in the evacuation phase where the degree and direction of intussusceptions are better appreciated. The presence of the catheter and a small amount of contrast in the urinary bladder also allows for precise cystocele and genital prolapse staging using the International Continent Society Pelvic Organ Prolapse Quantification (ICS POP-Q) reference point, the plane of the hymen (PH) as well as measurement of bladder neck mobility. Following emptying of the urinary bladder via the catheter, rest and marked straining/defecating radiographs are obtained. If the rectum or rectocele is not emptied the patient is sent to the toilet to perform maneuvers done in daily life to empty their rectum including digital maneuvers (splinting) and additional emptying of the urinary bladder in patients with urinary retention. This is detectable by the volume of urine opacified by the small amount of contrast medium not suctioned by the catheter. Performance of this part of the examination ensures that all organs are emptied. This maximizes the demonstration of the full extent of pelvic organ prolapses. These are images where the severity of enteroceles, sigmoidoceles, and peritoneoceles are staged. This modification is faster than our prior separate cystographic and proctographic methods. This method utilizes 2.3 min of fluoroscopic time. It usually takes 12 min of radiologist's time including post-processing using digital remote control fluororadiography and timed digital serial acquisition (DSA) with an image obtained per second for 30 s. In women of reproductive age, the DSA is programmed to one image every other second and the cystography segment eliminated when the indication is for constipation. A step by step description of this technique and a supplemental annotated video clip showing the DCP setup and the pre-evacuation, evacuation, and post-evacuation phases are provided online [17] (Supplemental material 1) A clinically relevant imaging prolapse staging based on the ICS POP-Q was also introduced in this review [17].

The pelvic floor anatomy is complex and DCP does not show the structural details pelvic floor magnetic resonance imaging (MRI) provides. Excellent reviews of anatomy, physiology, and functional diagnostic tests in pelvic floor imaging have recently been discussed by several authors [4, 18, 19] and will not be repeated. Technical advances allowing acquisition of dynamic rapid MR images with improved spatial resolution and soft tissue details in a single breath hold and multiplanar capability has made several authors state that MR should replace DCP because DCP utilizes radiation and does not show soft tissue details provided by MRI [20–35]. According to several reports, dynamic pelvic floor MRI not only shows anatomy but also diagnosis prolapses and can lead to a change in surgical therapy [18, 20, 23, 28, 31–33, 35–40]. However, the majority of these MRI studies do not include rectal evacuation (allowing for complete levator ani relaxation) or control for complete organ emptying. This limits the prolapse that can be seen. Predictions of hypothetical increase cancer incidence and deaths in patients exposed to radiation from data extrapolated from atomic bomb survivors [41–45], in addition to controversies relating to the clinical significance of DCP findings have added to the controversies between DCP and dynamic pelvic floor MRI. This review analyzes the pros and cons between DCP and dynamic pelvic floor MRI, address imaging and interpretive controversies, and their relevance to management of these complex disorders. A brief overview of our current method of performing DCP examinations, its underlying rationale and our method of interpretation based on the ICS POP-Q are discussed.

Anorectal dynamics: why ''functional'' imaging?

The term ''pelvic floor'' refers to the pelvic diaphragm (levator ani), the sphincter mechanism of the lower urinary tract, the upper and lower vaginal supports, and the internal and external anal sphincters. Understanding the levels and structure of pelvic floor supports, the restoration of which form the underlying basis for pelvic floor reconstructive surgery, is important for the diagnosis and staging of pelvic floor disorders [17].

Normal defecation involves an interaction between the colon and the rectum. The urge to defecate is initiated by rectal distention from high-amplitude propagating waves that move fecal contents into the rectum. The resulting distention relaxes the internal anal sphincter through the recto-anal inhibitory reflex in preparation for defecation. This allows for sampling to take place where the contents of the rectum come in contact with the sensory-rich areas below the dentate line to identify solids from liquids or gas. Evacuation, when desired, is then initiated by abdominal straining and voluntary pelvic floor relaxation. The anal canal opens and the rectum is squeezed from abdominal contraction. The rectum and about one-third of the left side of the colon will be emptied in normal physiologic defecation from continued mass colonic contractions and, most likely, some proximal rectal contractions [46]. The initiating movement for defecation is pelvic floor descent (PFD), which is defined as the descent of the AR junction from rest to maximum widening of the anal canal. The canal opens completely and in a second or so the rectum starts to empty. Emptying is rapid. When the patient stops straining, tone returns to the internal anal sphincter and levator ani so the anal canal closes and the AR angle becomes more acute; the pelvic floor and AR junction elevate to their normal resting position (the post-defecation reflex). Imaging studies do not invoke these physiological responses, and depend entirely on voluntary control of the pelvic floor and passive rectal emptying [47, 48]. The degree of rectal distention has bearing on functional imaging. Volumes of <300 mL may lower internal sphincter tone, but not increase intra-rectal pressure, whereas volumes of >300 mL may exceed rectal compliance and induce incontinence. Although rectal motor complexes might be activated by rectal distention, this does not seem to occur with volumes used in DCP. Rectal emptying is a passive phenomenon due to raised intra-abdominal pressure squeezing contrast out of the rectum.

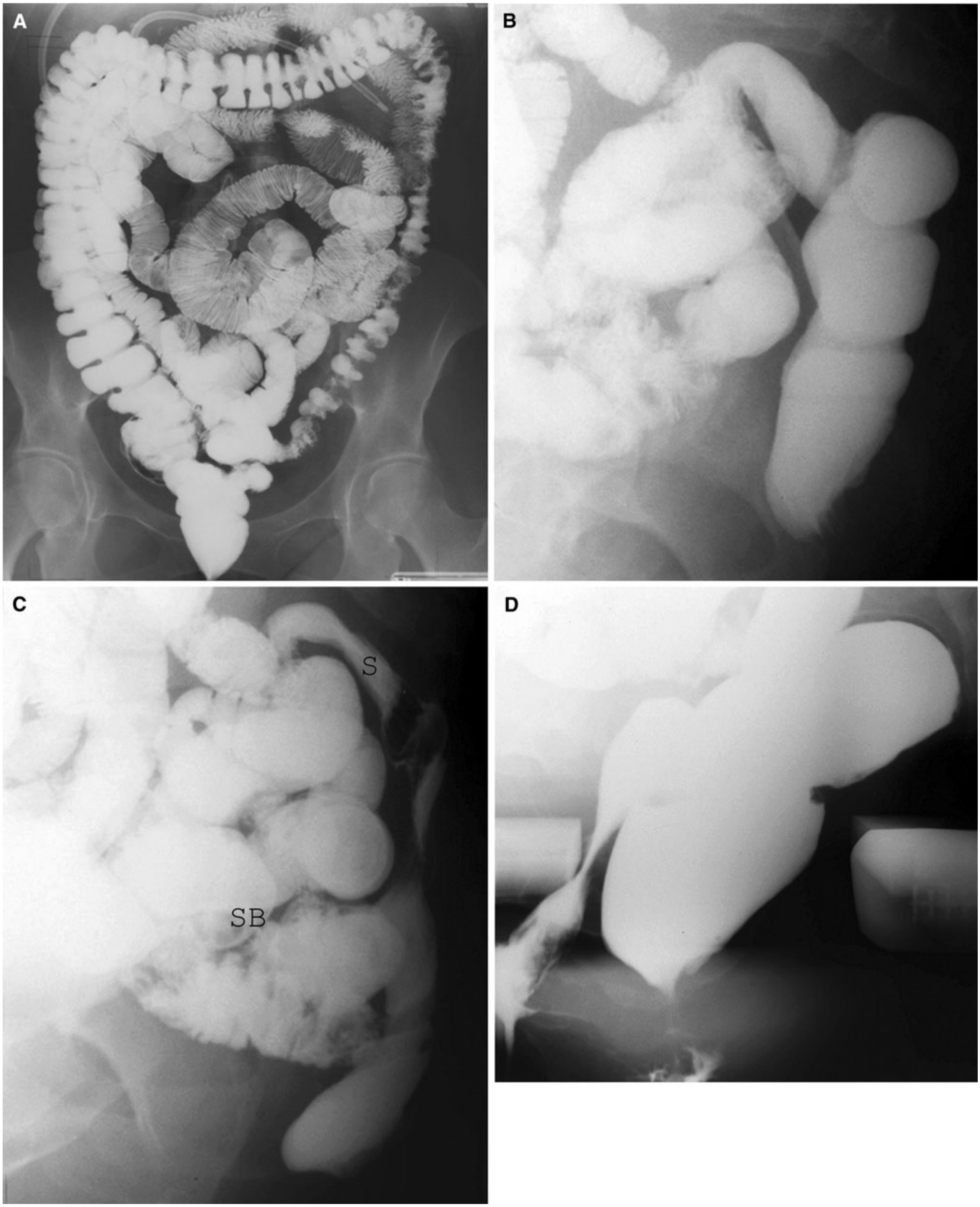
The pelvic floor, unlike other skeletal muscles in the body, remains in a constant tone even during sleep. The only time this tone is interrupted is during defecation or urination; thus, actual evacuation must be part of the examination to show the full extent of pelvic organ prolapse [3, 49, 50] (Fig. 1).

Technique and technology considerations

Although not invasive, the need to opacify multiple pelvic organs make DCP more intrusive compared to MRI which only administers rectal paste in most current MR protocols. The use of intravenous gadolinium with MR to opacify the anterior compartment [51] or the use of intraperitoneal contrast with DCP [52] makes these modifications invasive which are unnecessary.

It is important to explain to the patient the importance of the examination and how the procedure is done. The presence of previously undivulged symptoms should be verified before the examination as embarrassing symptoms may not be volunteered [53, 54]. Respect for the dignity of the patient in an unfamiliar environment is of paramount importance. Privacy should be stressed with these studies.

''Functional imaging'' of the pelvic floor is conducted in an artificial surrounding that embarrass and inhibit the patient, and thus, the images do not represent physiologic defecation. In most MR protocols, the patient is imaged recumbent usually supine with legs extended rather than upright, a position in which patients are usually asymptomatic or less symptomatic. Having patient defecate supine in an artificial environment makes an embarrassing examination even less acceptable. Although some proponents of MRI imaging have stated that women do not mind defecating supine, we disagree with these statements and find this insensitive to patients concerns in our practice although we were the first to report that it could be done technically and did correlate with some DCP findings [55]. To be called functional, pelvic floor examinations should be done sitting in a commode similar to what patients do in life. This ''functional position'' provides the maximum stress to the pelvic floor, resulting in complete levator ani relaxation which is needed to diagnose defecation disorders and show maximum pelvic organ descent for accurate quantification of female organ prolapse that can only be inferred by physical examination [15, 56–61]. Conclusions comparing supine and upright MRI studies demonstrate that sitting MR defecography is not superior to dynamic supine MRI for depiction of clinically relevant bladder descent and rectoceles [20]. These reflect limitations of the reports. The diagnosis of cystoceles and rectoceles is only part of the evaluation of pelvic floor abnormalities. In one report which showed greater degree of pelvic floor laxity on MRI in the sitting position it was concluded that it was not superior to standard supine MRI [62]. In another report [20], all intussusceptions were missed at supine MRI. AR descents of varying degrees and an enterocele, four small cystoceles and an anterior rectocele were also missed at supine MRI in the same report. No abnormalities seen at supine MRI were missed at upright MRI. However, all the missed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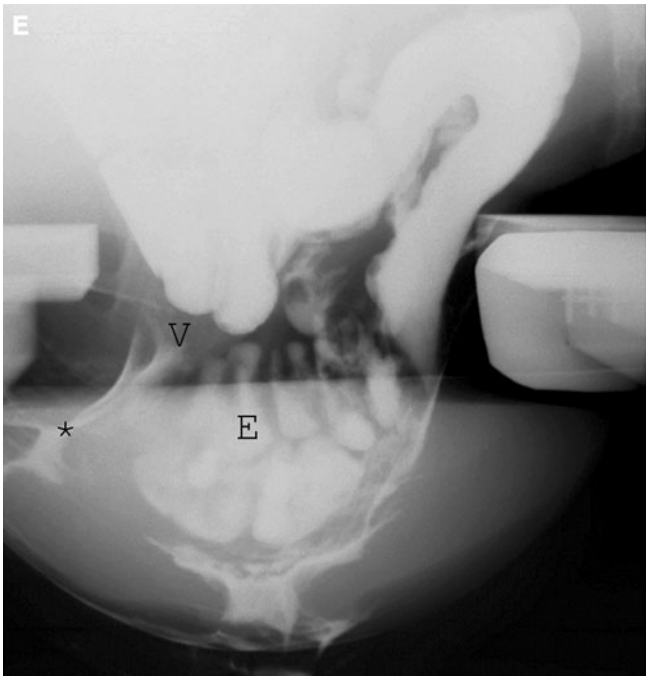


◀**Fig. 1.** Why "functional" imaging? The patient is a 39-year-old female with recurrent lower abdominal and pelvic pain with a prior history of endometriosis referred for enteroclysis prior to pelvic reconstructive surgery for possible small bowel obstruction. Recent DCP showed pelvic organ prolapse. **A** Overview of filled small bowel and colon following barium enteroclysis which did not show small bowel obstruction. **B** Lateral upright rest radiograph obtained following (**A**). No abnormality is seen. **C** Lateral radiograph obtained with patient straining. A small amount of rectal and sigmoid contrast was expelled but there is no evidence of pelvic organ prolapse. S, sigmoid; SB, small bowel. DCP was done on a locally made commode. **D** Rest radiograph of DCP done 1 week before the enteroclysis. Patient referred with a clinical history of constipation and dyspareunia, exclude anismus. The patient had prior hysterectomy. **E** Strain radiograph of DCP showing a Type C enterocele, recto-anal intussusception, Stage 1 posterior vaginal cuff prolapse and a Stage 1 rectocele. *PH; V, posterior vaginal cuff; E, enterocele.

findings at supine MRI were dismissed as not clinically relevant as there were no findings at physical examination. The conclusion was that supine MRI is a valid alternative to upright MRI. Our own comparative study with DCP and dynamic pelvic MRI with patients defecating supine, both methods of examination done on the same patients underestimated the extent of prolapse for sites other than rectoceles by approximately 15% [55]. The underestimates were caused by examining the patients in the supine position which has less gravitational influence than sitting as well as patients not completely relaxing the levator ani. As we gained more experience from our initial report of 10 patients, some patients have stated that their pelvic symptoms were only a problem when standing, sitting, or walking. Rectocele size is more influenced by rectal evacuation than by gravity. The limitations of physical examination have been recognized [14–16, 56, 57] even when done by experienced examiners [15, 16]; hence, the exclusion of abnormalities missed as not clinically relevant in the Bertschinger et al. [20] study because there were no physical examination findings raises questions. Physical examination does not allow for complete levator relaxation and therefore will miss more prolapse than defecography. In another report that showed MRI diagnosing more enteroceles than DCP and physical examination, both MRI and DCP were limited to a single-phase examination in which straining and evacuation of all opacified pelvic organs were performed at the same time. DCP did not involve the opacification of the small bowel in that report. These represent inferior techniques of performing these studies and will miss significant prolapse. In our current modification, diagnosis of peritoneoceles and enteroceles are done following emptying of the urinary bladder and rectum/rectoceles hence recognition of a widened rectovaginal space is maximized for the diagnosis of peritoneoceles or enteroceles. Without complete emptying, these organs block descent of other organs. In addition, in patients with slow intestinal transit, oral contrast may not have reached the small bowel. The contrast in the small bowel makes diagnosis of enteroceles more apparent because of the influence of gravity. In MRI studies done functionally sitting in a commode and defecation is part of the routine, the results will be comparable with DCP [28]. Conclusions and recommendations done with pelvic MRI supine even when done defecating do not consider the high reoperation rate in women who have undergone pelvic surgery [63]. Many pelvic floor surgeons believe that an attempt to correct all pelvic support defects, whether asymptomatic or not [64] should be done at one setting. If comprehensive repair is not done, coexisting asymptomatic support defects may become symptomatic within a relatively short time. The failure to recognize the full extent of pelvic organ prolapses pre-operatively based on physical examination done supine and the compartmental clinical approach to pelvic floor dysfunction (the "politics of the pelvic floor") may explain the high reoperation rate [65]. The reason women develop pelvic floor defects is likely multifactorial [66, 67] and the failure of surgical repair is not well understood. The relatively high rate of repeat surgery may reflect failure to recognize the full extent of prolapses pre-operatively if assessment is based predominantly on physical examination or incomplete methods of imaging where the levator ani is not fully relaxed. MRI done supine may be inadequate for recognition of AR disorders such as internal (intra-anal rectal intussusception) prolapse. These conditions are more reliably diagnosed when patients defecate during DCP or while seated in an open magnet [39, 48, 50, 59]. Currently, however, the relevance of DCP vs. dynamic pelvic floor MRI to patient outcomes has not been adequately addressed in a scientific manner.

The superior contrast resolution of MRI particularly in the anterior compartment requires [28] the use of endovaginal coil [18]. This is invasive and makes an embarrassing examination less acceptable to patients and will affect demonstration of prolapses because of space competition. The coil literally acts like a pessary, a device used to passively treat prolapse! In another report on patients with fecal incontinence, the results of MRI studies have led to a change of surgical therapy in 67% of patients in whom some form of surgery was required to treat fecal incontinence [28]. It should be noted that the anal sphincters can be visualized with the body coil alone or with a phased-array or endoluminal coil [4, 68]. Examination with an endoluminal coil results in higher spatial resolution but a limited field of view. The spatial resolution provided by either a phased-array or a body coil is probably insufficient to aid in the diagnosis of sphincter abnormalities [69]. Rigid endoanal coils are preferred for optimal image quality and results in over-compression of adjacent structures. The use of T1-weighted sequence (e.g., fast spin-echo) with contrast medium increase cost, and their superiority over other sequences has not been established [4, 68]. The endopelvic fascia is not well visualized on conventional MRI; similar to DCP, defects or laxity are inferred indirectly through secondary findings [18]. An endovaginal coil [70] is needed to show these fascial condensations and their clinical significance as related to surgical repair may be irrelevant. Endoanal MRI is time-consuming compared to endoanal ultrasound (approximately 30 vs. 5 min) [69, 71]. In patients with anal incontinence, the findings at DCP can be used to recommend which appropriate imaging approach should be used. If incontinence is noted at rest in the pre-evacuation phase of the DCP which suggest internal anal sphincter damage, endoanal ultrasound is recommended; if incontinence is noted when straining, endoanal MRI is recommended as it has been shown to be more accurate for the evaluation of the external anal sphincter than endoanal ultrasound [4, 28, 68]. Whether, either of these change surgical approach is not well studied. Putting together a separated anal sphincter which was damaged years earlier at childbirth may have little relevance on a 60-year-old patient. The neuromuscular function is probably of more significance and explains the relatively poor outcomes in anal sphincter repair in most long-term studies.

The use of an open MRI system with patients defecating makes it "functional" similar to DCP [28]. With an open architecture magnet, however, one must contend with images of a lower signal-to-noise ratio and soft tissue resolution [18]. To make it a single non-invasive functional study to look at specific organ prolapse and direct visualization of the supporting structures specialized coils are needed to improve soft tissue resolution and visualize the pelvic supporting structures and fascial condensations. Specialized coils will make dynamic pelvic MRI more intrusive. Nonetheless even with the images obtained with current open MR systems, visualizing the soft tissue structures in obese patients to see reference points are better with MRI than DCP. In our experience, patients who weigh >200 pounds and handicapped patients who cannot be seated safely in a stable position with the upright commode with DCP should undergo dynamic MRI done supine particularly if fecal incontinence is the clinical presentation. Placement of two markers aligned (pellets) on the inner lateral support of the DCP commode aids in visualizing the ischial tuberosities and ensures that measurements made [if the pubococcygeal line (PCL) is used] are midline with DCP.

The volume and consistency of rectal pastes for DCP has undergone several modifications since the article of Mahieu et al. [8, 10, 72] and is standardized [17] in most DCP protocols. In MRI protocols, however, gels of varying amounts (from 60 to 120 mL) are used [23, 29, 32, 73]. The consistency and volume results in suboptimal straining particularly in the supine position that may mask the degree of pelvic organ prolapse and results in diminished conspicuity of visceral descent [73]. Some MR protocols using open MR system with appropriate contrast (potato starch consistency) have compared their protocol with MR using gel and have shown that the size and the degree of anterior rectocele evacuation and intussusception size are often underestimated when ultrasound gel is used for rectal enema [51]. In our modification of the DCP, prior to the administration of the rectal paste, high density low viscosity barium (50 mL Polibar, Bracco Diagnostics) is introduced followed by 50 mL of air from the same syringe. This improves rectal mucosal coating and diagnosis of rectal intussusceptions, entities that are important in the surgical management of AR disorders [74]. The vaginal paste allows us to delineate the vaginal fourchettes which are important anatomic landmarks in localizing the PH, the reference point used for the ICS POP-Q [75] which we have adopted to DCP for staging of prolapse [17].

A current problem with DCP is that there is no commercially available commode for DCP examinations to our knowledge. A similar problem with MR is that only a few open magnet MRI systems are currently installed in radiology departments hence most dynamic pelvic MRI are done supine with extended legs. The DCP commode however can be constructed [76] (see Figs. 1, 4). AR and pelvic floor dysfunction cause significant morbidity in women [1, 2, 17]. It appears to be an epidemic nobody talks about [17]; hopefully a manufacturer will resolve this dilemma.

Although variable from country to country, important additional factors that should be considered are economics, logistics, and demonstrable clinical advantages of one method over the other. In our practice, pelvic

MRI costs three to four times more than DCP. If the management consideration is based on diagnosis of prolapse, DCP is reliable, however, if visualizing the structural integrity of pelvic supportive tissues and endopelvic fascia is the relevant question to management, pelvic MRI with endoluminal coil to improve soft tissue resolution is the imaging of choice. Again, the disadvantage the coil has on displacing prolapse cannot be overemphasized if the examination was also done to evaluate pelvic organ prolapse. In most institutions in the United States the additional expense incurred with MRI compared with DCP and the relative lack of accessible time on an MR unit that is subject to heavy demand by other clinical specialties are important factors to consider. The logistics of performing a tailored examination (drainage of an undrained bladder and emptying of rectum or rectoceles) which will tamponade enteroceles or sigmodoceles are important diagnostic considerations [16]. Another factor in our experience is the reluctance of many technologists to perform a longer more complex examination. We were one of the earliest investigators who compared dynamic pelvic MRI done supine to DCP [55]. The attraction of a new technology and the lack of ionizing radiation in addition to economic considerations in private practice made us initially favor pelvic MRI done defecating supine in our prospective comparison of 10 patients, a number too limited to make appropriate recommendations. As we have gained more experience with the technology we have reverted back to DCP. Evacuation is pivotal for the evaluation of AR disorders and pelvic organ prolapse whether done with radiography or MR [17, 61] but making women defecate supine with extended legs without an open architecture magnet is not ‘‘functional’’ in our experience. Some patients in our practice have stated that they are not symptomatic in the supine position but perceive the pressure or bulging when they are sitting or upright. Our current DCP technique is faster than our prior technique [15]. Thus, when the relevant management question is on the anatomic/structural demonstration of the pelvic supporting tissues, a static-high definition MRI gives good soft tissue definition of the muscles and/or connective tissue tears that may alter management—information that can only be inferred with DCP[4, 68, 69, 71]. There is no controversy when soft tissue spatial resolution is the relevant consideration for management.

Controversies in grading/quantification of pelvic organ prolapse with imaging

The radiology community has paid little attention to devising a grading or scoring system that has clinical correlates and understandable to clinicians who use the ICS POP-Q to stage pelvic organ prolapse [75]. Other clinical classification systems from colorectal surgeons for defecatory disorders [77, 78] have also not been addressed. With both DCP and ‘‘dynamic’’ pelvic MRI, grading of prolapses has been defined in reference to the PCL. In fact, there have been variable definitions in the literature where this line should be extended posteriorly from the inferior symphysis border. Most commonly, the line is described to extend from the inferior symphysis border to the sacrococcygeal junction [59]; others extend this line to the tip of the last horizontal sacrococcygeal joint [40], or the tip of the coccyx [9, 13, 72] while others join the inferior symphysis line to the coccygeal joint (joint not specified) [9, 13, 72, 79]. The PCL is considered to represent the approximate line of attachment of the pelvic floor muscles. In normal individuals, the levator plate is parallel to the PCL in normal individuals. Prolapse is inferred by imaging if a pelvic organ extends below the PCL. Two other reference lines, the H and M lines were introduced by Comiter et al. [23] to identify pelvic floor relaxation and prolapse. The H line measures the distance from the inferior symphysis pubic to the posterior AR junction in the midsagittal image and is indicative of the anteroposterior width of the levator hiatus. The M line is drawn perpendicular from the PCL to the most distal aspect of the H line and is indicative of the descent of the levator hiatus from the PCL. In that study, the H and M lines in normal women measured approximately 5 and 2 cm, respectively. These lines can also be drawn with the DCP but has not been adopted. Little is described in the literature quantifying the severity of prolapse using these reference lines.

The ICS POP-Q has no correlates to the PCL and the H and M lines. These lines cannot be inferred clinically. The clinical ICS POP-Q uses the PH as the reference line [75]. This is because patients perceive the pressure/and or sees a bulge when the prolapsing organ abuts or displaces the PH [80]. Singh and Berger [81] proposed a new method of grading with MRI using the same landmark as the clinical grading system. A new reference line, the midpubic line (MPL), corresponded to the PH in their cadaver study. Their early results showed good correlation with their clinical staging. More recent studies showed that the MPL has greater agreement with clinical staging than does the PCL. However, neither reference lines showed good agreement with clinical staging [82]. In a recent literature review [83], none of these reference lines showed clear superiority and this may relate to the fact that there is no complete levator ani relaxation during physical examination. The PCL, however, had the advantage of being the most widely used and is associated with high agreement for the evaluation of anterior and middle compartments. The PCL as a reference point may have validity with colorectal surgeons [43–45, 84–86]. The agreement between methods of examination in the posterior compartment is lower for MRI. There is also high variability of pelvic MRI measurements among readers despite centralized training [83]. Interobserver agreement in the interpretation of DCP is reliable and reproducible [87]. In our experience using DCP, the use of the MPL will overstage prolapses [17]. Using the PCL will also overstage prolapses because it is higher than the MPL. This is because the PH in vivo is more anterior than the MPL in cadavers. It is at or slightly anterior to the anterior pubic line in patients in the sitting position. It is also variable from patient to patient and moves with straining—hence the lack of agreement between methods of staging and the high interobserver variability in measuring reference points with MRI. Anatomically, the external urethral meatus is at the same level as the PH in vivo; it is immediately posterior to the vaginal fourchettes. The vaginal fourchettes are seen on DCP as the most anterior segment of the vagina where the vaginal paste leaks out of the introitus inferiorly and superiorly. Because our current method of performing DCP, where a small urinary bladder catheter is left in place during the pre-evacuation and functional (evacuation) phases, determination of the PH in each patient is simplified (Fig. 2). In our prior report, we determined the PH with an opaque marker (pellet) secured in the urethral meatus and localized it immediately posterior to the vaginal fourchettes [17] on DCPs. A line drawn crossing the posterior margin of the fourchettes parallel to the plane of the anterior cortex of the pubic bone determines the PH. In the DCP POP-Q, this plane is localized in the pre-evacuation or start of evacuation phases and the image selected which clearly shows it as it may be difficult to localize this plane precisely after defecation. The distance is marked from the anterior cortex of the pubic bone and a line parallel to the pubic bone is drawn in the rest and defecating/straining radiographs post-defecation and staging is measured from this line. Staging pelvic organ prolapse with DCP with similar reference point to the ICS POP-Q allows better communication between radiologists and surgeons. Our experience shows that this staging method is understood better by referring clinicians than using the PCL or the H or M lines. Pelvic organ prolapse staged with imaging studies done functionally will not correlate with physical examination (ICS POP-Q) findings since the levator ani is not maximally relaxed with the Valsalva maneuver in the supine position [88]. This is why DCP and dynamic pelvic floor MRI in an open magnet with defecation in prior comparisons with physical examination have shown more abnormalities than the clinical examination [15, 25, 58, 60]. The imaging POP-Q is meant to complement the ICS POP-Q and not to compete with it [17]. The clinical POP-Q looks at different vaginal points whereas the imaging POP-Q is organ specific. DCP has proven value in patients with defecation disorders and in the diagnosis of associated prolapse in other compartments that may be clinically unrecognized [49]. Clinical examination enables the identification of only approximately 50% of enteroceles but fares better in the recognition of rectoceles and cystoceles, an area where dynamic

Fig. 2. Determination of the level of the PH with DCP, the reference point for staging pelvic organ prolapse. Lateral radiograph obtained **A** with the patient in the fluoroscopic table with a marker (*arrow*) secured at the level of the urethral meatus following contrast administration into the urinary bladder. Anatomically in vivo, the hymen is at the same level as the urethral meatus which is immediately posterior to the vaginal fourchettes **B** at rest following placement of vaginal and rectal contrast, **C** during straining, **D** at rest following defecation, and **E** during marked straining following defecation. Level of vaginal fourchettes is marked by *asterisk*. The leading edge of the anterior rectocele is anterior to the level of the PH, a stage 2 ICS posterior vaginal wall prolapse ▶

MRI is claimed to be superior to DCP [20]. The DCP POP-Q is shown in Table 1. The need for a small amount of contrast in the urinary bladder is poorly understood by radiologists who use the PCL as the reference point [89]. Although it appears that the extrinsic pressure by the urinary bladder on the anterior wall of the vagina can be discerned when using the PCL, it is not always the leading edge of a cystocele relative to the PH. It cannot be accurately localized relative to the PH without contrast when using the DCP POP-Q. The presence of the catheter allows for faster drainage of urinary bladder especially those with urinary retention making the examination faster and ensuring that prolapses are not tamponade by an undrained bladder (see Fig. 8). Additionally, mobility of the bladder neck can be measured with the presence of the catheter and the contrast in the urinary bladder (see Fig. 9).

The lesser sensitivity of clinical examination compared to functional imaging is almost certainly related to the patients inability to relax the levator ani completely while performing the Valsalva maneuver. This should be understood to prevent further research trying to correlate imaging studies done functionally with clinical examinations. Vaginal topography staged with the ICS POP-Q clinically will not correlate with visceral position shown by the DCP [88]. The role of imaging in the management of AR and pelvic floor dysfunction is not completely understood. Our analysis of the literature relative to comparison of different imaging methods and the correlation of imaging with physical examination findings suggest that most comparisons are flawed as different landmarks and methods of examinations are used.

Although the factors that lead to failure of surgical repair are not well understood and multifactorial, it appears that the limitations of physical examination in diagnosing all prolapses may lead to incomplete surgeries and may contribute to the high reoperation rate [63]. It is advisable to identify all areas of prolapse pre-operatively and plan accordingly as asymptomatic defects may become symptomatic within a relatively short time and all may require correction: ideally this is done at one surgical setting [90, 91].

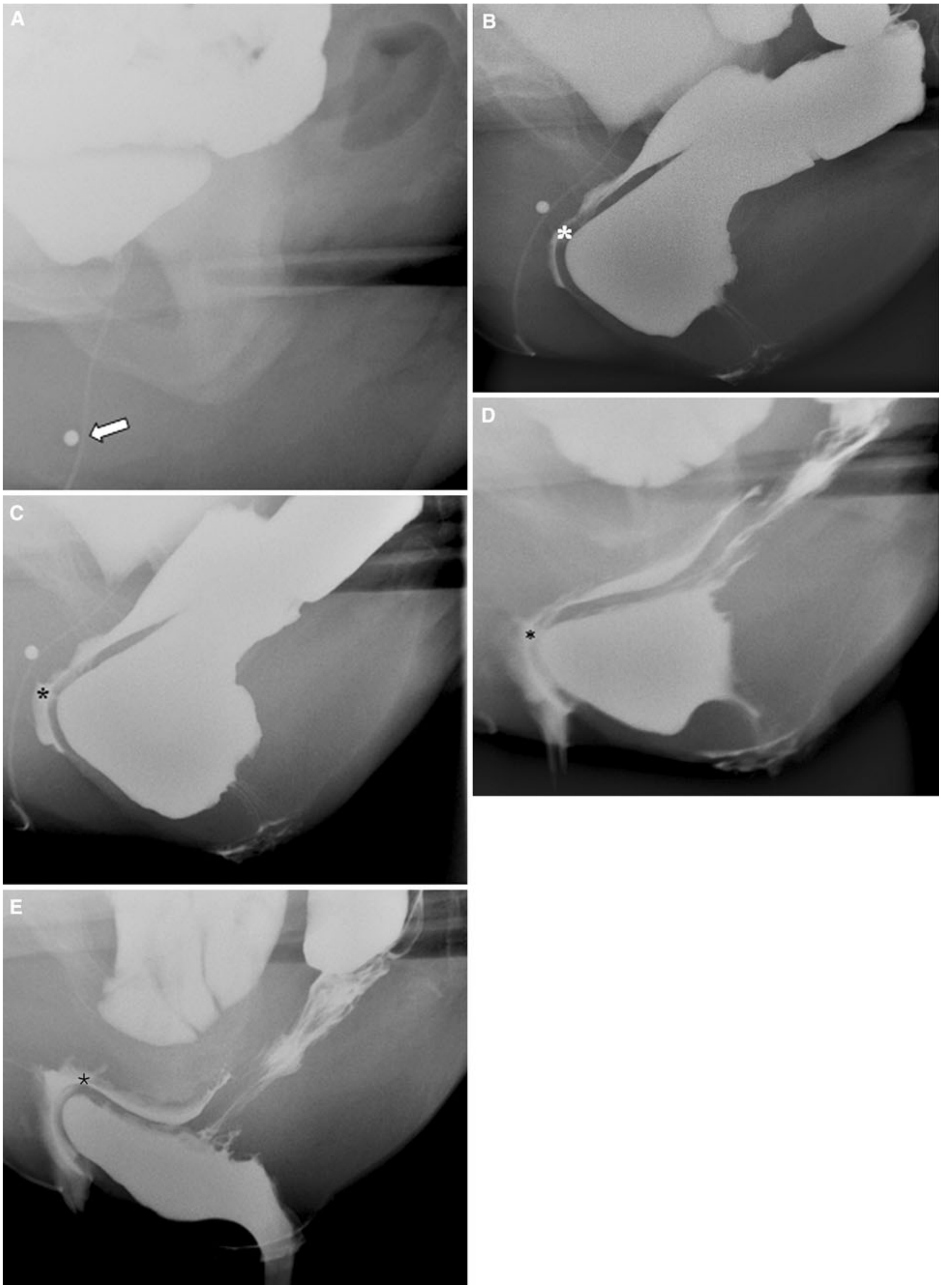

A
B
C
D
E

Table 1. DCP staging of prolapse: the imaging POP-Q

Stage	Description of all organ position	Measurement range
0	3 cm above PH	+3 cm above PH
1	>1 cm above PH <stage 0	>1 to 3 cm above PH
2	≤1 cm above or ≤1 cm below PH	+1 to −1 cm
3	>1 cm below, protrudes ≤2 cm TVL beyond PH	>1 cm to TVL −2 cm
4	Complete eversion of the vaginal cuff or cervix	≥TVL −2 cm beyond PH

TVL, total vaginal length
TVL is measured on rest radiograph obtained after defecation from the vaginal cuff to PH

Although incompetence of the internal and external anal sphincters can be predicted by history and by the rest and strain images obtained in the pre-evacuation sequence of a DCP [46] it cannot objectively demonstrate the structural defects that are shown with MRI using endoluminal coils [69, 92]. The role of DCP is in the diagnosis of commonly associated occult prolapses [49]. It remains the method of choice for patients who present with any symptom of the obstructed defecation syndrome [78].

Radiologists performing "functional" pelvic floor examinations should understand why it is relevant to use the PH as the reference point in staging pelvic organ prolapse [80]. Patients present to their physicians when they feel pressure or see the bulge suggesting laxity of pelvic support when the organs are close to or impinge on the hymen. Most prolapse is not truly symptomatic until it reaches the PH [80]. The use of the PH as a reference point however has limitations. It is a movable structure and measures vaginal points and not organ specific, hence the imaging POP-Q complements the clinical ICS POP-Q well. This is particularly true for posterior cul-de-sac prolapses and internal rectal prolapses. Additionally, AR symptoms do not correlate with the degree of posterior vaginal wall prolapse, nor does the presence of prolapse equate to abnormal physiologic test results. Bowel symptoms may result from primary AR abnormalities, which are demonstrated by functional studies [93]. In many cases, DCP is the only way these conditions may be reliably diagnosed.

Diagnostic/interpretive considerations

Functional and structural disorders of defecation

Differentiating functional from structural causes of obstructed defecation is difficult clinically. Constipation is a symptom, not a sign, and is based on the patient's perception. In the anorectum, most abnormalities are seen during and at the end of defecation. Rest and strain sequences without defecation as performed with some MR protocols are inadequate examinations. Evacuation while sitting on a commode in a position similar to that which precipitates the symptoms is logical. This is not achieved with supine MRI with patients legs extended and in protocols with rest and strain sequences only. DCP findings infer structural disorders by showing the maximum extent of intussusceptions or prolapses as well as demonstrate functional information in the diagnosis of defecation disorders. Dynamic pelvic floor MRI with the use of open architecture magnets achieves similar results with the exception of protocols that do not use fecal consistency rectal contrast and only uses ultrasound gel as rectal contrast. Intra-anal rectal intussusception (internal prolapse) may not be as apparent with MR since the mucosal folds are not well shown using sonographic gel. Determining the level of the ischial tuberosities in obese patients are difficult with DCP. Placing markers (pellets) on the lateral supports of the commode partially alleviate this problem and also helps determine the midline where prolapse severity are measured using a centimeter mid line marker. The DCP prolapse staging can be applied to dynamic pelvic MRI if the vaginal fourchettes can be identified. AR angle measurements have a wide variation or overlap of normality with abnormality [9, 37, 72, 94–96] hence its measurement do not appear to have relevance to management. Over emphasis on angle measurements have led some authors to question the clinical relevance of DCP [97]. Rectocele, rectal mucosal intussusceptions, rectal prolapse, solitary rectal ulcer syndrome (SRUS), descending perineum syndrome, enterocele, and sigmoidocele are common structural pelvic floor disorders that affect AR function.

Dyssynergic defecation. This has been described in the literature with a plethora of other terms such as anismus, pelvic floor dyssynergy, paradoxical puborectalis contraction, non-relaxing puborectalis, pelvic outlet obstruction, and spastic pelvic floor syndrome. The term dyssynergic defecation has been recently recommended by several experts [21, 98]. This is not a clear-cut diagnosis. Historically, this has been diagnosed in patients with a history of prolonged straining during defecation if there is inappropriate puborectalis muscle contraction and if patients are unable to expel a balloon filled with 60 mL of water. It was initially assumed that this would be shown during defecography as a persistent indentation posteriorly, just above the AR junction. This finding has been poorly predictive of the diagnosis [48, 99]. In the study by Halligan et al., prolonged and or/or incomplete evacuation of contrast material was shown to be far more sensitive and specific finding and was present in 83% of patients and none of the control subjects.

Rectal emptying is a passive phenomenon, due to raised intra-abdominal pressure squeezing contrast out of the rectum. The combination of prolonged and incomplete evacuation gave a positive predictive value of 90% compared with a physiologic diagnosis of anismus. A recent study has shown that normal electromyographic results or the ability to expel a 60-mL balloon does not exclude the presence of pelvic floor dyssynergy on defecography [100]. This adds further confusion as to which should be used to guide the recommendation for (and to then measure response) to biofeedback [101, 102]. The success of biofeedback treatments in these patients supports the value of making this diagnosis [68]. This is the importance of categorizing posterior compartment defects into functional and anatomic abnormalities which is reliably done with DCP [46]. In the past because puborectalis muscle dysfunction has been the main focus, a proctographic diagnosis of anismus was conventionally based on a prominent puborectalis muscle impression during voiding together with failure of the AR angle to open. There is little evidence that these findings are specific and simultaneous electromyographic and defecographic study has shown no correlation between muscular activity and AR junction configuration [100]. It is more appropriate to base a proctographic diagnosis on evacuation failure. Healthy subjects void rapidly and completely in contrast to patients with anismus whose evacuation is prolonged and incomplete, a difference that can be quantified by DCP [48]. This has not been done with pelvic MRI. Another study has shown that puborectalis morphology and AR angle measurements did not differentiate patients with anismus from asymptomatic controls but that prolonged and incomplete contrast medium voiding during proctography was highly specific [103] (Fig. 3). The time taken to initiate anal canal opening and the rate of evacuation are more relevant than the final percentage of contrast evacuated because most patients will eventually fully empty their rectum if given enough time. Much of the uncertainty related to the benefits of DCP has been generated because of studies where the possibilities of functional diagnoses have been ignored, or where benefit has been evaluated in terms of outcome, an approach that inevitably includes assessment of any treatment [97, 104]. When this has been applied to evacuation proctography, the test has been overwhelmingly found to be valuable.

Rectocele. This refers to protrusion of the rectal wall, usually anterior towards the vagina. However, posterior rectocele may also occur as well as perineal rectocele. DCP and dynamic pelvic MRI can demonstrate rectocele, measure its size, and identify retention; however, its usefulness in clinical work-up has been limited. Eighty percent of asymptomatic controls may show small rectoceles [72, 94]. It is common in women after childbirth, particularly in patients with pelvic prolapse being present in 78%–99% [15, 105]. They may also be seen in obstructed defecation without prolapse and with dyssynergic defecation [106]. A depth of <2 cm is consid-

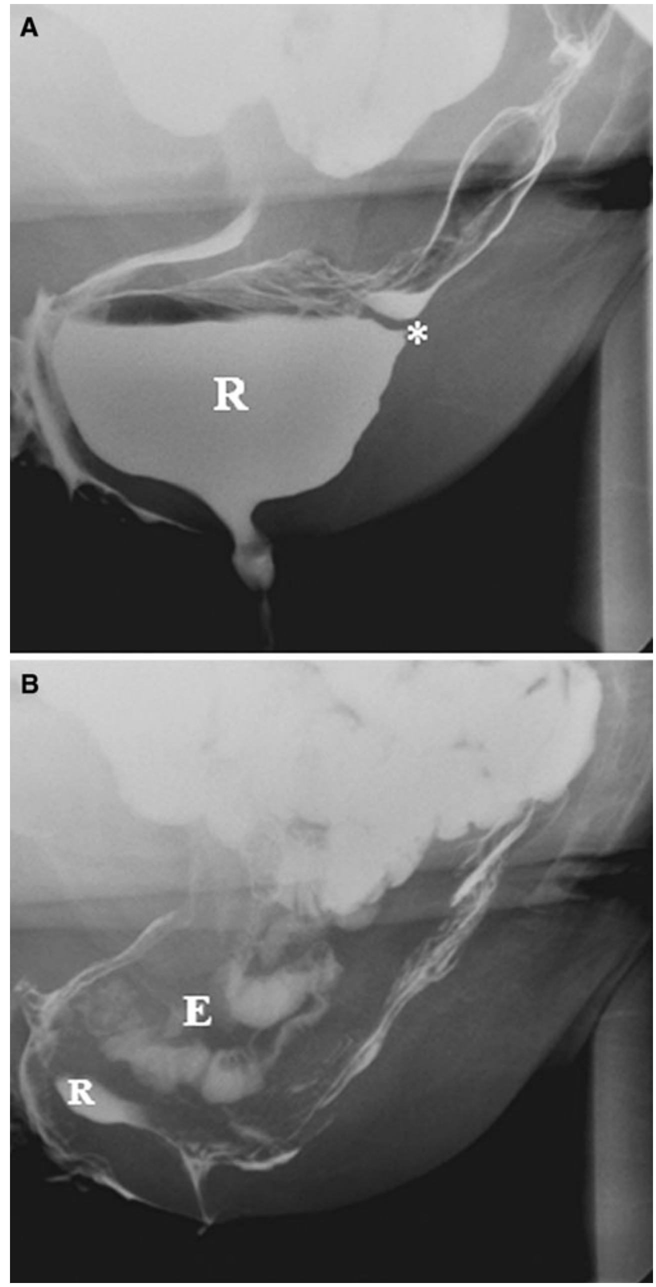


Fig. 3. DCP diagnosis of dyssynergic defecation. A 65-year old multipara with prior hysterectomy referred for DCP because of chronic constipation and "pressure" on her vagina. Lateral radiograph with marked straining **A** at the end of defecation shows a large contrast retaining anterior rectocele (R) and retention of more than two thirds of the rectal contents below the main fold (*asterisk*) consistent with anismus and **B** following vaginal digitations in the toilet show a Stage 2 enterocele (E) not shown in (**A**) because of undrained rectocele (R). The anterior rectocele is a combined distension and displacement type of rectocele; a Stage 2 posterior vaginal wall prolapse

ered within normal limits [72] and may be considered large if > 3.5 cm [107] with conventional DCP grading. If the depth and area of a rectocele are measured when filled and at the end of evacuation, retention of > 10% area defines barium trapping [108]. The size and trapping controversy is what makes grading with traditional radiology reference points limit its usefulness in management hence clinical correlation is required [109]. As stated earlier, patients feel the pressure or the bulge when the leading edge is close to or beyond the PH hence grading rectoceles with the DCP POP-Q has relevance (see Fig. 9). Imaging measurements from the anterior anal margin may have limited the clinical usefulness of proctographic rectocele diagnosis. It may also make it better understood by referring clinicians if anterior rectoceles are categorized into distension rectocele (Type 1) and displacement rectocele (Type 2) with the imaging POP-Q staging since they have different anatomical, clinical, and therapeutic profiles [110] (see Fig. 3). Clinical studies have shown that distension rectoceles are seen in patients with dyssynergic defecation and displacement rectoceles with excessive PFD or prolapse. Digitation provides convincing supporting evidence of the presence of a rectocele and are frequently seen when contrast trapping is present. Clinically, the only two symptoms to improve reliably with surgery are digitations and presence of the bulge. Small postero-lateral herniation of the rectum may result from levator ani damage during childbirth, and if > 4 cm indicates an ischiorectal herrnia [111]. Small anterior outpouchings may be seen after prostatectomy and have been reported in 17% of men with obstructed defection [111, 112] (Fig. 4).

Rectal intussusceptions and the SRUS. Unlike children where rectal prolapse is secondary to an etiology such as malnutrition or cystic fibrosis, it is idiopathic in adults. There is a female preponderance with nulliparous and multiparous women almost equally affected although it is more common with generalized pelvic floor prolapse. Diagnosis is made clinically during forceful straining but defecography suggests that a significant proportion is missed on clinical examination [113]. Early studies with cineradiography have suggested that prolapse is initiated by an in-folding of the rectal wall, which then intussuscepts into the anal canal and protrude beyond the anal verge to form an external prolapse [6]. Intussusceptions are classified as intra-rectal (rectorectal), intra-anal (internal prolapse), and extra-anal rectal intussusceptions (rectal prolapse). Rectorectal intussusception is diagnosed when the rectal mucosal folds intussuscepts but do not go below the level of the upper recto-anal margin. It is diagnosed as internal prolapse if the rectal fold extends below the anal margin and rectal prolapse if it extends below the anal verge (Fig. 5). Imaging protocols that do not show the folds may not be able to make

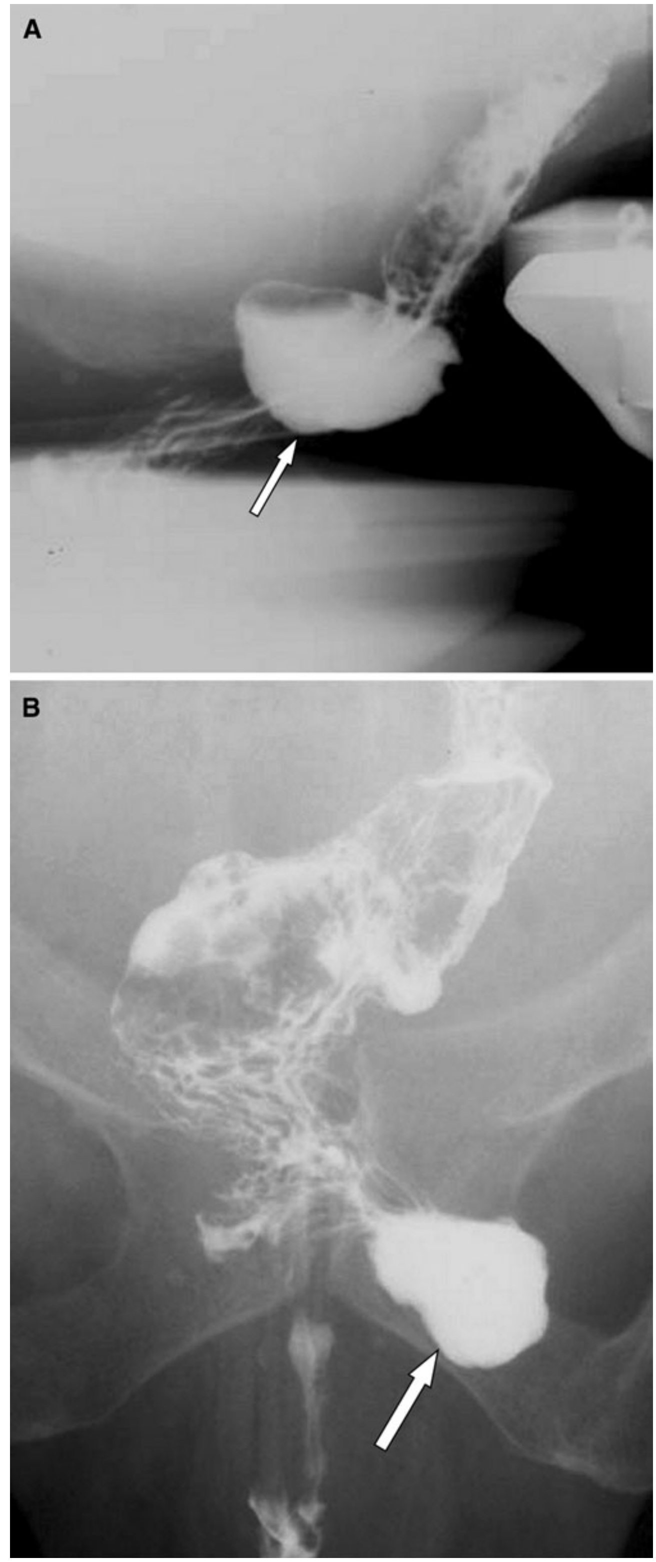


Fig. 4. Rectocele in a male. A 60-year-old male referred for proctography because of constipation; history of prior prostatectomy. **A** Lateral radiograph obtained shows a moderate size outpouching (*arrow*) retaining contrast. **B** Frontal radiograph obtained during straining shows a postero-lateral hernia retaining contrast medium (*arrow*).

these precise classifications unless it is extra-anal. The dynamic change in the anal canal width as the rectal fold enters is the most definite evidence of internal prolapse [114].

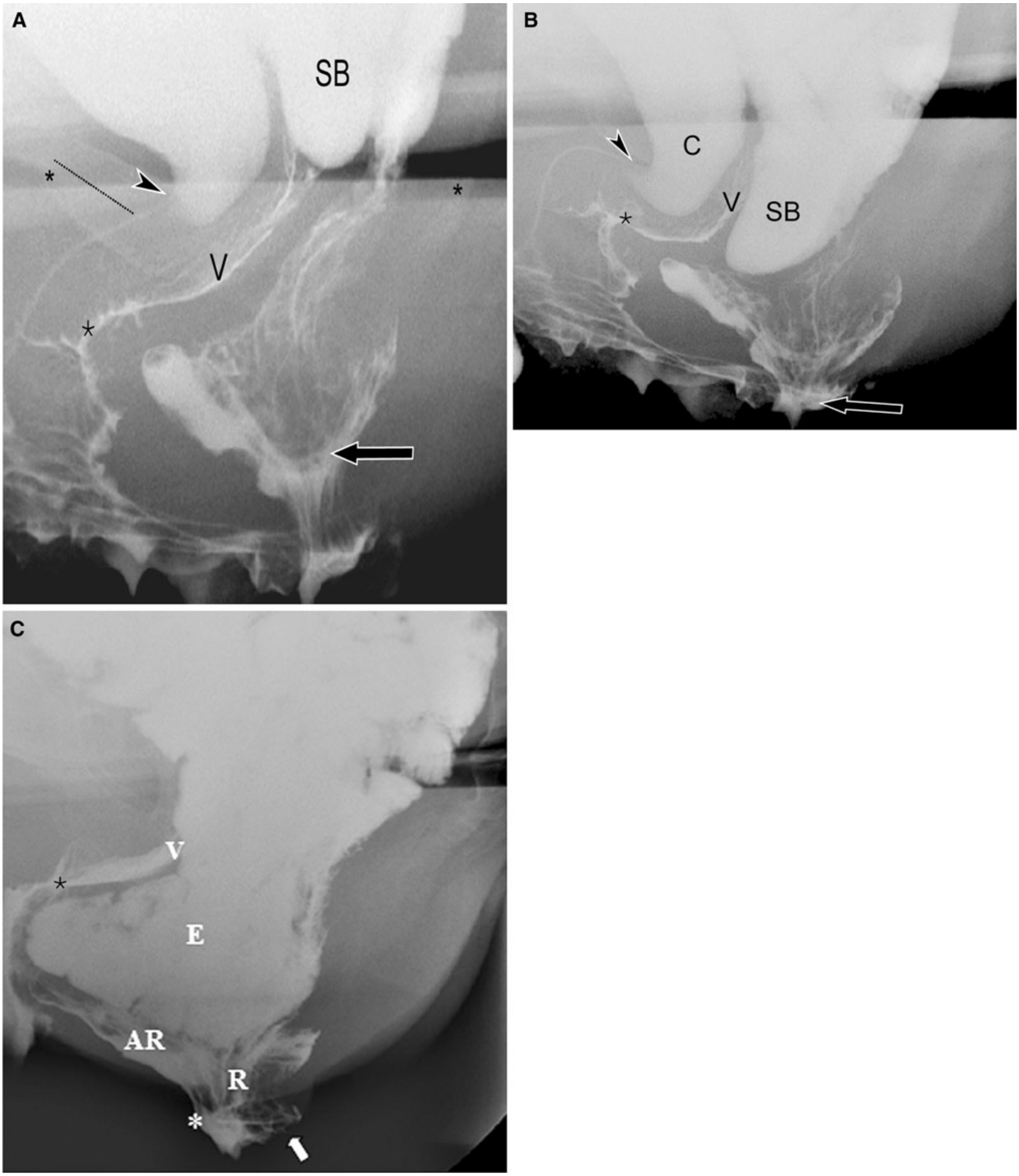
SRUS is almost always associated with either recto-anal or extra-anal intussusceptions. Mucosal ulceration is believed to result from forceful straining against an immobile or a non-relaxing pelvic floor together with trauma from digital manipulations as well as from ischemic necrosis of the intussuscepting rectal mucosa. Patients usually present with rectal bleeding or pain, mucus discharge, straining and tenesmus, and a feeling of incomplete evacuation. About 55% of patients present with constipation, 20%–40% with diarrhea, and 25% are asymptomatic [115]. A quarter of these patients are misdiagnosed and treated as inflammatory bowel disease. The extent and direction of mucosal intussusceptions are reliably shown during the evacuation phase of a DCP. In one ‘‘dynamic'' pelvic MRI study [20], all intussusceptions were missed at supine MR. The term ‘‘solitary rectal ulcer'' is misleading because only erosion or erythema may be seen and more than one ulcer is often present [114]. The word ‘‘syndrome'' was added because it was associated with other AR disorders and dysfunction of pelvic floor musculature [116] (Fig. 5C). A clinical and defecographic diagnosis of rectal prolapse and the presence of SRUS in association with rectal intussusceptions are the best indicators for surgical correction [117]. Since constipation maybe the underlying mechanism for this disorder, surgery should only be performed in highly selected cases as the intussusceptions may merely be a secondary phenomenon [115]. Functional measurements of emptying are therefore important [99, 118].

Descending perineum syndrome and anterior mucosal prolapse. Parks and Hardcastle [119] linked chronic staining to PFD and anterior mucosal prolapse at proctoscopy when the patient strains. DCP can be used to suggest the diagnosis and measure the position of the pelvic floor at rest, when it is stressed by the weight of the abdominal contents in the sitting position, and on evacuation, when opening of the anal canal provides a clear end point. In younger patients, the pelvic floor is higher at rest, with greater descent at evacuation (dynamic perineal descent) of the AR junction. The converse applies to the elderly, with more descent at rest and less change at evacuation (fixed perineal descent) [120]. A low pelvic floor at rest is suggestive of muscle weakness and stretching of the elastic tissue of its fascial supports [121]. Perineal (AR) descent in this syndrome is defined as >3 cm or the AR junction is >3 cm below its normal position (at or above level of ischial tuberosities) at rest [72]. Imaging studies done supine or in the lateral position underestimate perineal descent which becomes maximal only at onset of defecation in the sitting position. The position of the pelvic floor is significantly higher at rest when the patient is in the left lateral position than when seating [20, 73, 122]. Excessive perineal descent at DCP may predict future anal incontinence [123].

Patients with the descending perineum syndrome present with tenesmus, pain, and sometimes bleeding. It was initially described as a proctologic diagnosis. The characteristics of anterior mucosal prolapse at DCP are variable. Inversion of the anterior rectal wall over the anal canal is a common finding with rectoceles [96] but should not enter the upper anal canal. Prolongation of the anterior rectal wall into the upper rectum without widening of the canal is suggestive of anterior mucosal prolapse (Fig. 6). In one study [124], anterior rectocele and abnormal perineal descent were present in 70% of women with anterior mucosal prolapse.

Enterocele, sigmoidocele, and peritoneocele. The incidence of enteroceles may have increased as a result of the widespread performance of prolapse or incontinence procedures that elevate the anterior vaginal wall exposing the posterior vaginal wall to increased intra-abdominal forces. This leads to enterocele formation and vaginal vault prolapse because damage occurs at the level of the vaginal apex. Enteroceles were seen in 64% of patients who had undergone hysterectomy and in 27% of those who had undergone cystopexy. Hysterectomy is not considered the risk factor for future prolapse unless the hysterectomy was performed for prolapse [90]. Urethropexy performed for incontinence pre-disposes to enterocele formation by lifting the anterior vaginal wall forward and opening up the cul-de-sac. Urethropexy has generally been replaced with the urethral sling procedure which is claimed not to increase the frequency of enterocele formation [90]. Enteroceles become evident only at the end of evacuation because of the space occupied by the distended rectum and urinary bladder. Repeated straining and making sure the urinary bladder is emptied after defecation are essential for the recognition of enteroceles. In one study [59], almost half (43%) of enteroceles were seen only following evacuation and emptying of the urinary bladder emphasizing the importance of the post-evacuation/toilet phase of DCP. Evacuation should be as complete as possible because the unemptied rectum/rectocele and urinary bladder can prevent descent of an enterocele (see Fig. 3). Obtaining a post-toilet radiograph and emptying the urinary bladder with a catheter particularly those with urinary retention offers the best opportunity to diagnose enteroceles. Intra-vaginal enteroceles, unlike those that prolapses into the rectovaginal space, often compete with a cystocele; if the cystocele is not sufficiently drained, the presence of a coexisting enterocele may be overlooked or minimized [17, 49] (Fig. 8).

Enteroceles may be overdiagnosed owing to a lack of a clear definition of its diagnosis. A range



from to 2 to 5 cm has been considered normal small bowel descent below vaginal apex [90]. Additionally, the vaginal apex moves. Enteroceles, sigmoidoceles, and peritoneoceles have been conventionally graded using the PCL but this may have little clinical significance.

Controversy has existed as to whether enteroceles cause pressure on the rectum and obstruct rectal evacuation (the so-called defecation block). A prior report has suggested that it does [125] while a more recent study claimed that enteroceles do not obstruct rectal evacuation [54]. A more recent report has shown that enteroceles

◀**Fig. 5.** Rectal intussusceptions. A 55-year-old nullipara with history of prior hysterectomy referred for DCP because of a sensation of vaginal pressure and constipation. **A** Lateral image obtained at rest following defecation shows near complete emptying of the rectum and an anterior rectocele. *Note* rectal intussusception into the proximal anal canal (*arrow*). SB, small bowel; V, vaginal vault; *arrowhead* urethrovesical junction; *larger inferior asterisk* PH (note clear delineation of both anterior and posterior vaginal fourchettes immediately anterior to *asterisk*), *small asterisks* in inferior symphysis margin (anterior) and tip of coccyx (posterior) indicates level of PCL. *Straight line* between anterior and posterior cortices of pubic bone indicates mid pubic line. **B** Lateral image during maximum straining at defecation shows a Type B enterocele (SB) prolapsing behind vaginal vault which was not seen at rest. Rectal intussusception is now noted to be below the anal verge (extra-anal). Also note Stage 2 cystocele displacing anterior vaginal wall inferiorly. A hypermobile bladder neck is also seen gauged by the degree of inferior displacement of the urethrovesical junction (*arrowhead*) from rest to strain (>10 mm). **C** Rectal prolapse and SRUS. Lateral radiograph of a 55-year-old patient referred for DCP because of rectal bleeding and severe pelvic pressure. Intussusception of the rectum (R) through the anal canal with a short segment seen below the anal verge (*arrow*). Associated Stage 1 vaginal cuff prolapse (V), Stage 2 (Type C) enterocele (E), and anterior rectocele (A) are seen. Global pelvic floor descent can be inferred by the marked increase distance from the AR junction (*asterisk*) to the level of the ischial tuberosities.

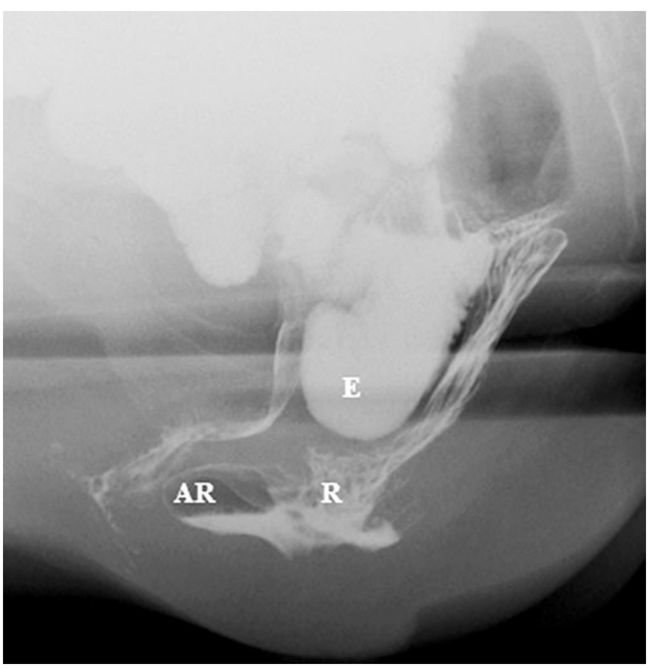


Fig. 6. Syndrome of the descending perineum and anterior mucosal prolapse. DCP performed on a 65-year-old patient because of tenesmus and symptoms of obstructed defecation. There is extension of the anterior rectal (R) wall into the anal canal without widening of the anal canal. Note Stage 2 anterior rectocele (A, displacement type) and a Stage 1 enterocele (E, type B).

cause symptoms of obstructed defecation [78]. A clinical radiologic classification has been proposed by Morandi et al. [78]: Type A when the small bowel extends below the PCL during marked straining and returns back at rest without reaching or compressing the rectal ampulla, Type B when the enterocele descends below the PCL to extend through the rectovaginal space to compress the rectal ampulla at the end of evacuation, and Type C when the enterocele compressed the rectal ampulla at the beginning of defecation and moves towards the anal canal during defecation. This likely corresponds to the traditional radiologic grading using the PCL: minimal: <3 cm below PCL, moderate: 3–6 cm, and severe: >6 cm below PCL. In that report, Type C was associated with symptoms of obstructed defecation, while Type B was associated frequently with abnormal perineal descent and anterior rectoceles. This classification using DCP appears relevant and merits further research. It appears that severe enteroceles produce symptoms of obstructed defecation. Rather than a linear measurement, volume of small bowel descending may be more relevant in the grading of enteroceles. Other symptoms typically associated with an enterocele are a sensation of pelvic pressure or dragging when standing or bearing down. The diagnosis of a previously undiagnosed enterocele may change the surgical approach from a transvaginal to a transabdominal route of entry. In many patients referred for DCP, this is an important information needed by the pelvic floor surgeon before surgery [90].

A sigmoidocele is a redundancy of the sigmoid colon that extends caudally into the cul-de-sac [77]. They are less common than are enteroceles and are found in approximately 5% of proctograms [126]. This condition will be underdiagnosed at proctography if the sigmoid is not opacified but should be suspected on the basis of widening of the rectovaginal septum and air seen within fecal residue hence the value of administering a small amount of gas following administration of high density barium mixture before administration of the feces consistency rectal paste. Lax presacral fixation of the rectosigmoid is seen by DCP and should be reported as it may be a risk factor for future development of a sigmoidocele.

There is no agreed upon standard definition of a sigmoidocele. It has been defined as a sigmoid colon extending >4.5 cm below the PCL [126]. According to conventional radiologic classification this would constitute a moderate sigmoidocele. Sigmoidoceles are usually not detected at physical examination, even when large and are often associated with constipation [59, 77, 126]. The redundant sigmoid colon may compress the rectum and obstruct defecation. Stasis of solid debris in the redundant sigmoid gives rise to further discomfort and straining. A classification with clinical/surgical implications has been proposed by Jorge and Wexner [77] to provide a more objective approach to surgical treatment.

The proposed classification was based on descent of the lowest portion of the sigmoid loop during marked straining at defecation relative to the PCL and the ischiococcygeal line (drawn from the ischial tuberosity to the tip of the coccyx).

Sigmoidoceles were classified as first degree when the intra-pelvic loop of sigmoid abutted but did not descend below the PCL, second degree when the sigmoid loop descended below the PCL but remained above the ischiococcygeal line, and third degree when the sigmoid loop descended caudal to the ischiococcygeal line (Fig. 7). The proposed classification yielded excellent correlation between the degree of sigmoidocele and clinical symptoms. All third-degree sigmoidoceles who underwent colonic resection reported symptomatic improvement [77]. There is only a minor difference of this classification from standard radiologic grading except for the addition of the ischiococcygeal line; it is simple and will be of value to colorectal surgeons to formulate an objective surgical approach.

Genital prolapse. Uterine prolapse involves descent of the uterus into the vagina and often beyond the introitus. Vaginal vault prolapse involves descent of the apex of the vagina toward, through, or beyond the vaginal introitus after a previously performed total hysterectomy. Vaginal vault prolapse is almost always associated with prolapse of other pelvic organs the most common of which is an enterocele. This reflects a loss of apical level support due to damage of the uterosacral–cardinal complex. Provided that adequate vaginal opacification is maintained at DCP, the location of the cervix and/or vaginal apex can be determined on DCP images. When there is partial or complete eversion, however, it may be difficult to determine the location of the vaginal apex. They are, however, clinically obvious. The direction of vaginal vault displacement is a valuable diagnostic adjunct. Although this is usually apparent from physical examination, what organ is behind that wall is not always evident. Anterior vaginal displacement is indicative of posterior vaginal wall prolapse, which traditionally is considered to be due to pressure from a rectocele. DCP, however, has shown that approximately one-third of patients with posterior colpoceles have an enterocele or a sigmoidocele [59]. Conversely, inferior/posterior displacement of the vaginal wall (anterior vaginal wall prolapse) is typically due to pressure from a cystocele, although in a minority of patients this finding may be due to an intra-vaginal enterocele [59]. These are usually underdiagnosed (Fig. 8). In either case, it represents loss of anterior vaginal wall support

Cystocele. This is the result of a defect in the support of the anterior vaginal wall. The vaginal muscularis attaches laterally to attaches laterally to the arcus tendineus pelvis and posteriorly to the cervix. Symptoms

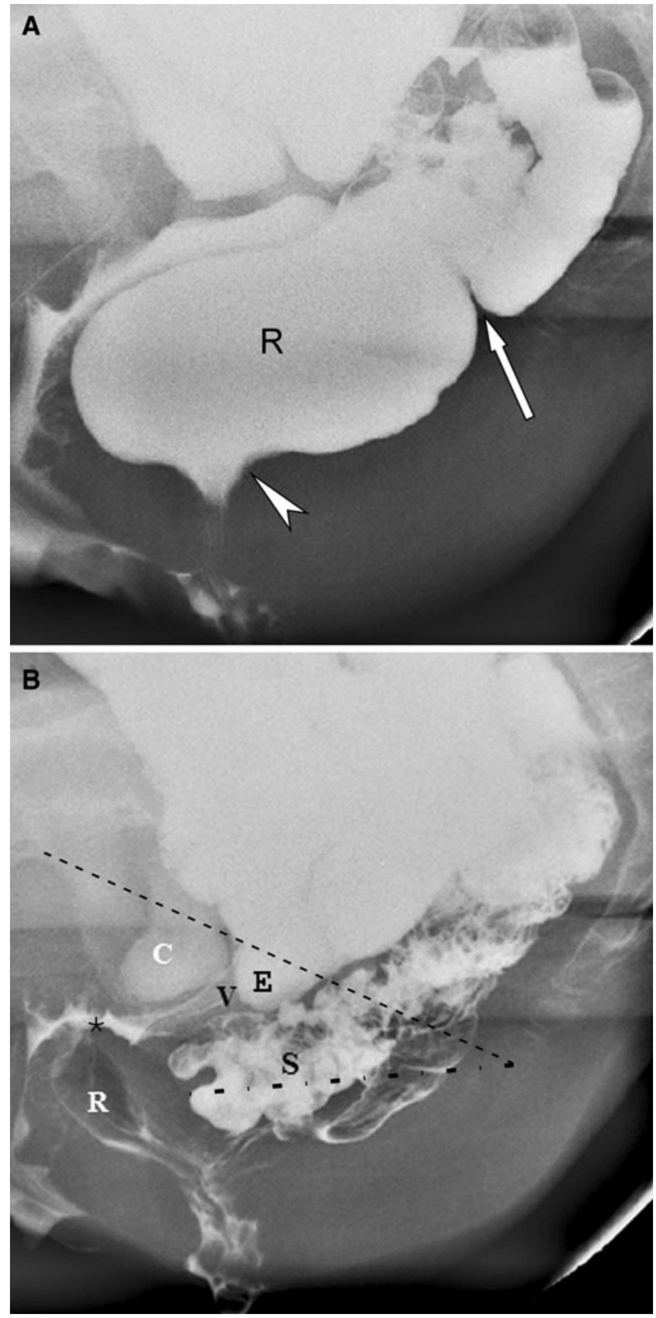


Fig. 7. Diagnosis of sigmoidocele and associated pelvic organ prolapses. A 57-year-old multipara with a history of a remote hysterectomy and more recently a urinary bladder suspension was referred for DCP because of worsening constipation and urinary incontinence. **A** Lateral rest radiograph following evacuation shows retention of almost all the rectal contrast below the main fold (*arrow*) consistent with dyssynergic defecation. R, rectum; *arrow* main fold; *arrowhead* posterior AR angle. **B** Lateral strain radiograph obtained following posterior vaginal wall digitations in the toilet shows a third-degree sigmoidocele (S), a displacement type anterior rectocele preventing the sigmoidocele from prolapsing further, a Stage 1 vaginal vault (V) prolapse and a Stage 2 recurrent cystocele (C). *Dashed line* PCL, *dashed dotted line* ischiococcygeal line.

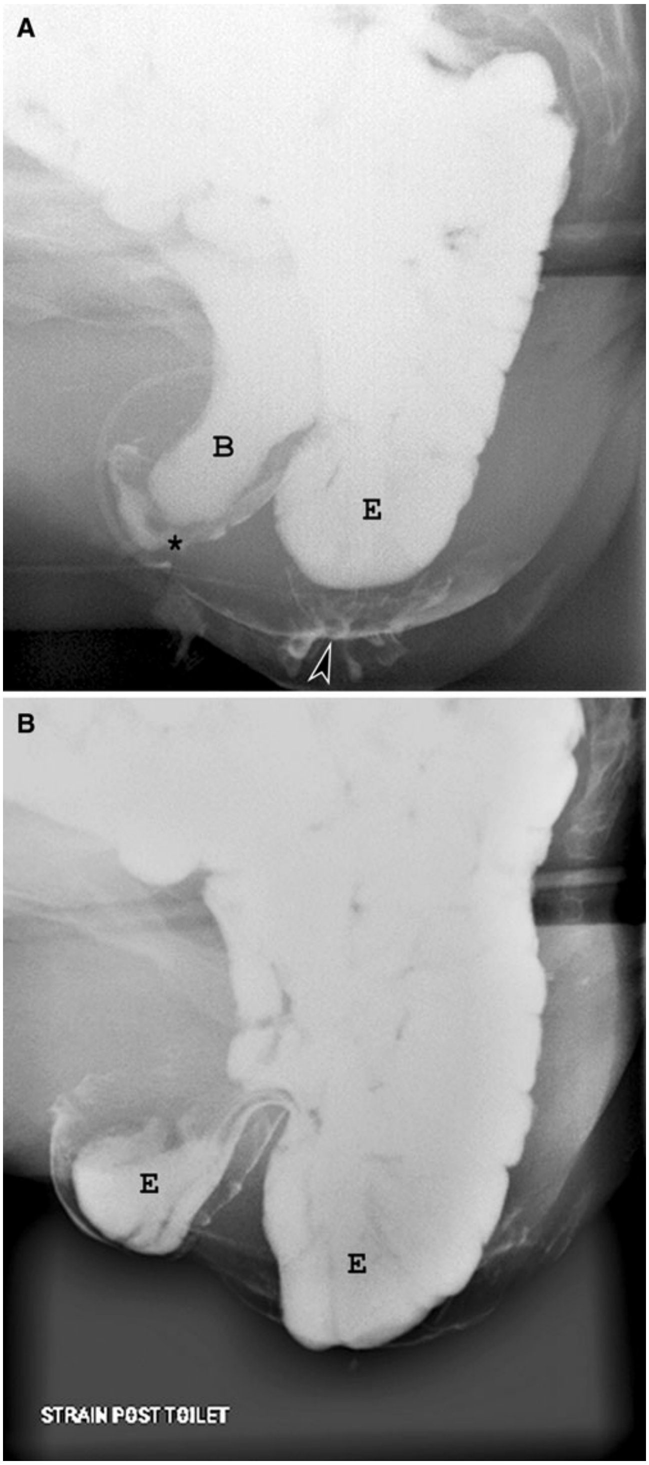


Fig. 8. Diagnosis of intra-vaginal enterocele. A 58-year-old patient referred for DCP because of excessive straining at defecation and sensation of incomplete emptying and urinary incontinence. **A** Lateral strain radiograph obtained following the evacuation phase shows a Type C enterocele, Stage 2 cystocele and internal prolapse (*arrowhead*). *PH. **B** Lateral strain radiograph obtained following suction of urinary bladder through 8F catheter and additional evacuation in the toilet shows an intra-vaginal enterocele (E) not shown in (**A**) because of a filled urinary bladder.

caused by a cystocele may be minimal until it reaches the vaginal introitus; the most common symptoms are feeling of heaviness or "something bulging." Similar to other prolapses symptoms start to manifest clinically when the leading edge of the prolapsing organ abuts the PH. Large cystoceles may also lead to voiding dysfunction. Cystoceles are usually larger after rectal evacuation and are, therefore, optimally assessed by measuring the degree of displacement of the anterior vaginal wall during maximum straining after defecation. The presence of the 8F catheter in our method of examination [17] also allows measurement of bladder neck mobility during maximum straining. This should be no >1 cm [40]. The urethral axis is normally $<35\%$ of vertical (Fig. 9). Funneling (beaking) of the bladder neck at rest may suggest an incompetent urethral sphincter; however, it is a non-specific sign and may also be seen in continent women [127]. In general, symptomatic cystoceles are treated surgically with a variety of techniques. Some employ restorative measures such as paravaginal repair while others do a form of colpocleisis, anterior colporrhaphy. What has been recognized more recently is the high degree of correlation between apical and anterior vaginal wall prolapse [128]. Surgeons have focused on the vaginal apex to correct anterior wall descent because of the strong association between the vaginal apex and the cystocele. An anti-incontinence procedure is frequently included because elevation of the bladder often unkinks the bladder neck and unmasks urinary incontinence.

The association of compartment defects with defecatory disorders

The frequency of associated pelvic abnormalities in patients presenting with AR disorders is high. In a study of patients with symptoms of defecatory disorders, DCP showed that 71% had cystoceles, 65% had a hypermobile bladder neck, and 35% had vaginal vault prolapse of $>50\%$ [49]. In another report [129], 50% of patients with urinary stress incontinence and 80% of patients with uterovaginal prolapse had symptoms of obstructed defecation (prolonged rectal evacuation and need for digital assistance) (see Figs. 3, 7, 8). Thus, a global functional pelvic floor examination is needed in patients with defecatory disorders. The interrelationships of pelvic organ prolapse and the competition for space cannot be overemphasized [16]. Much of the uncertainty related to the value of DCP has been because of reports where the possibilities of functional defecatory disorders has been ignored or where benefit has been evaluated in terms of outcome, an approach that inevitably includes assessment of any treatment [97, 104]. When a particular imaging technique is able to assist clinical understanding and management, it makes a relevant contribution in its assessment [130]. When this has been applied to investigation of DCP, the test has been found to be

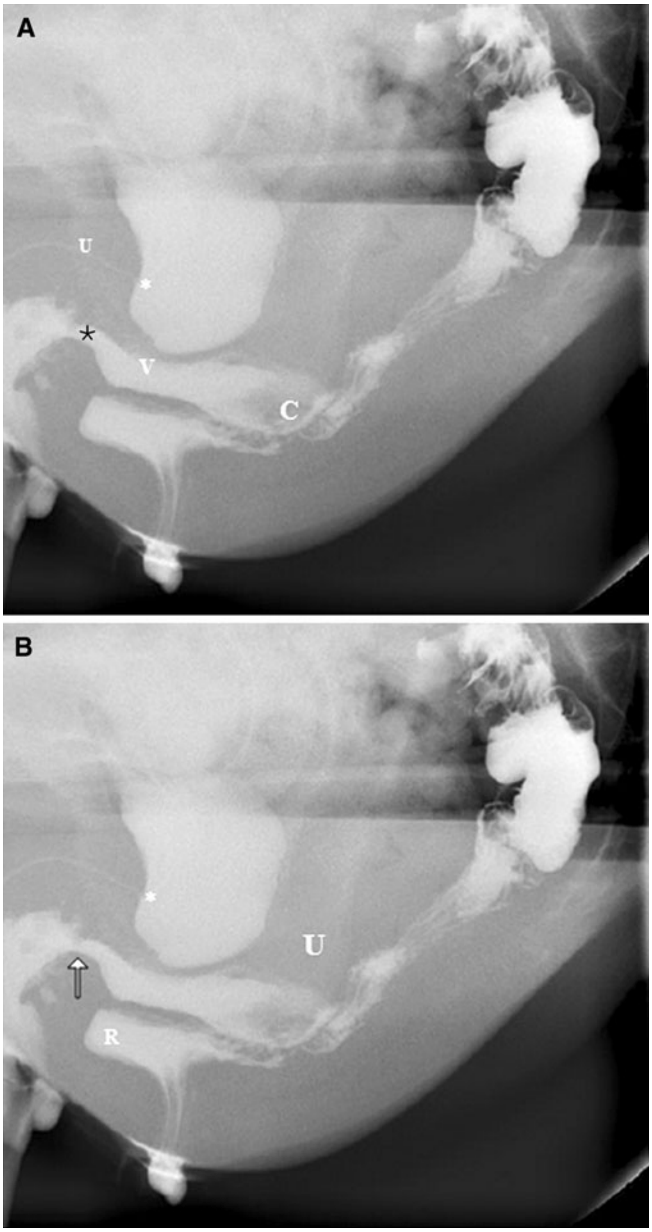


Fig. 9. Diagnosis of anterior vaginal wall prolapse. DCP performed of a 70-year-old patient who presented with a feeling of "something bulging" and urinary voiding dysfunction. **A** The axis of the urethra (U) is horizontal even at rest. Also note axis of the vagina (V) and Stage 1 uterine prolapse. C, cervix; U, urethra marked by catheter; *white asterisk* level of bladder neck; *black asterisk* PH. **B** Lateral strain radiograph shows displacement of the urethrovesical junction (*white asterisk*) by >1 cm from rest. The horizontal axis of the urethra and vagina is only minimally increased. A Stage 2 displacement anterior rectocele (R) is seen. The leading edge of the anterior rectocele (R) is at the same level as the PH (*arrow*) but measured from the anterior anal margin, the symptomatic rectocele would have been classified as small with conventional proctographic classification.

overwhelmingly valuable [131]. There is currently no prospective controlled study in which patient outcomes both with and without DCP or dynamic pelvic MRI have been evaluated [4].

Radiation considerations

Cancer is the bioeffect of concern with CT and radiography and is of no concern for MR. The fear of low-level radiation causing increase incidence of cancer and cancer deaths has resurfaced based on recent reports of estimated radiation risks associated with full body CT screening [41, 43, 45, 84, 86, 132–135]. An estimated risk of 0.08% with a single examination to 1.9% risk for 30 full body screening CTs has been shown based on extrapolations from Hiroshima atomic bomb survivors [136]. They also estimated radiation induced cancer as 1.5%–2.0% of all current cancers [41, 43, 84, 86, 134–137]. This became relevant because among the different categories of medical procedures, the greatest contribution is from CT examination (increase use of CT at a rate of 8%–15% over the past 7–10 years (62 million scans in 2006) [138–140]. This is not a new controversy as radiologists are familiar with the "linear non threshold model" which states that any radiation dose is thought to increase risk of developing cancer as opposed to the "concept of hormesis" which states that low doses of radiation including levels of radiation delivered by CT are harmless or may actually be therapeutic (stimulation of immune system) [138, 141, 142]. Accumulated evidence does not point to the increase cancer and death incidence in this direction. In a study involving air line pilots who receive 0.4 mSv/100 h of flight time averaging 2 mSv per year (with some crews receiving 10 mSv), no increase in cancer has been seen in longitudinal studies spanning 30–50 years [143]. In a recent large cohort study [144], no increased cancer risk in children exposed to low X-ray radiation doses was found. A more recent review [145] concluded that the cancer risks associated with imaging are very low for an individual compared with the life-time risk of developing cancer from all other causes. In spite of the exponential increase in utilization of CT, the Centers for Disease Control and Prevention has reported that there is decreasing incidence in recent years of all common cancers in the US (including lung, breast, colorectal, and prostate cancers). The cancer risk of low-level radiation made MRI an alternative. Many reports were embraced regardless of the science due to the fear of low-level radiation-inducing cancer. The low-level radiation from radiography and from CT is not comparable to the radiation from the atomic bomb survivors. The mean effective dose equivalent of DCP ($\pm$standard deviation) has been estimated to be $3.2 \text{ mSv} \pm 2.7$ using standard fluoroscopy and video tape [146]. Newer digital systems utilized allow a substantial reduction in dose [4]. The DSA we employ in our remote control digital systems also allows improved spatial resolution compared to video tape. The resolution of the images obtained during the functional phase is similar to spot imaging and can be programmed to decrease radiation to patients of reproductive age. The American Association of Physicists in Medicine (AAPM) updated a Position Statement on Radiation Risks from Medical Imaging Procedures [147]: ''Risk of medical imaging at effective doses below 50 mSv for single procedure or 100 mSv for multiple procedures over short time periods are too low to be detectable and may be non existent. Predictions of hypothetical cancer incidence and deaths in patient populations exposed to such low doses are highly speculative and should be discouraged. These predictions are harmful because they lead to sensationalistic articles in the public media that cause some patients and parents to refuse medical imaging procedures, placing them at substantial risk by not receiving the clinical benefits of the prescribed procedures.'' In the functional imaging of defecation disorders the cancer extrapolations have led to ''non functional'' alternatives rationalized because of the lack of ionizing radiation. This includes ''dynamic'' pelvic MRI done in the supine position. In the choice of imaging for the evaluation of defecation disorders and pelvic organ prolapse, merits of the examination rather than the hypothetical fear of low-level radiation causing increase incidence of cancer and death should be the primary reason for selection.

Comments

''Functional'' imaging whether done with DCP or with dynamic pelvic MRI do not represent physiological defecation and are conducted in artificial surroundings that embarrass and inhibit the patient. Our analysis of the different controversies between DCP and dynamic pelvic MRI appears to reflect the authors' preference. Most comparative studies use less rigorous gold standard such as physical examination whose shortcomings are well known. In several examinations, the authors did not compare both examinations on the same patients in the same position. When done functionally in an open magnet system, dynamic pelvic MRI images are of a lower signal-to-noise ratio and soft tissue resolution hence details of the pelvic supporting structures are not well defined. It has resulted in significant interobserver variations in determining reference points [18, 82]. Its improved soft tissue resolution with the use of appropriate endoluminal coil makes it difficult to use as a functional study to determine occult-associated pelvic organ prolapses as the coil itself blocks organ descent. It would be of benefit when all the limitations of functional pelvic floor MRI are overcome so more attention is given to improve the accuracy for subtle albeit important findings and not simply dismiss findings because of the lack of correlation with physical examination findings. DCP is a mature technology. Dynamic pelvic floor MRI is an evolving technology and its precise role in functional imaging of the pelvic floor still remains to be determined. Conclusions reached by investigators on its use are conflicting. It has the potential to be a valid ''functional'' method for evaluating AR disorders and associated pelvic organ prolapse. Further developments and research on the use of functional MRI for defecatory disorders and pelvic organ prolapse can make it a valid alternative to DCP. It is likely that pelvic MR with increase soft tissue resolution with endoluminal coils will complement DCP where the need to see structural details of the pelvic supportive tissues and endopelvic fascia are required for surgical management. Their clinical significance as related to surgical repair has not been evaluated and may be irrelevant. Currently, both methods infer pelvic organ prolapses from different reference points most of which do not have physical examination correlates.

Conclusions

The role of ''functional'' imaging of the pelvic floor is to complement deficiencies of physical examination. In practices where an open magnet is available, appropriate consistency rectal contrast agent is utilized and due attention to the competition for space of pelvic organ prolapse is given; local expertise and logistics will determine the choice of imaging. Regardless of imaging bias, radiologists experience will be the most relevant factor [4]. Practitioners should try both methods and in their best professional judgment decide which of the two methods is the most functional and logistically practical to perform in their own practices. DCP is time tested, well-established, and a widely available method. The ability of DCP to enable evaluation of function and infer anatomical structural integrity while the pelvic floor is being subjected to normal gravitational stress, similar to the daily maneuvers that precipitate patients' symptoms makes this technique an important adjunct to physical examination. With current technical modifications to opacify all pelvic organs [95], it has evolved from a method to evaluate the anorectum for functional disorders (defecography) to its current status as a practical, ''near functional'' method for evaluating defecation disorders and associated pelvic organ prolapses with meaningful clinical information. ''Functional'' pelvic MRI has the potential to be an alternative or complementary examination. It has the technology required to demonstrate anatomical details of pelvic supporting structures including fascial condensations which are only inferred by DCP. The fascial defects seen by pelvic MRI however have not correlated with a change to surgical management in our practice. Currently, the evidence suggests that DCP is the ''functional'' examination for the diagnosis of AR and pelvic floor dysfunction [3, 17, 49].

Reflections

"The society which scorns excellence in plumbing because plumbing is a humble activity and tolerates shoddiness because it is an exalted activity will have neither good plumbing nor good philosophy. Neither its pipes nor its theories will hold water."John Gardner, Author

References

1. DeLancey JO (2005) The hidden epidemic of pelvic floor dysfunction: achievable goals for improved prevention and treatment. Am J Obstet Gynecol 192(5):1488–1495
2. Sung VW, Hampton BS (2009) Epidemiology of pelvic floor dysfunction. Obstet Gynecol Clin North Am 36(3):421–443
3. Maglinte DD, Kelvin FM, Hale DS, Benson JT (1997) Dynamic cystoproctography: a unifying diagnostic approach to pelvic floor and anorectal dysfunction. AJR Am J Roentgenol 169(3):759–767
4. Stoker J, Halligan S, Bartram CI (2001) Pelvic floor imaging. Radiology 218(3):621–641
5. Burhenne HJ (1964) Intestinal evacuation study: a new roentgenologic technique. Radiol Clin 33:79–84
6. Broden B, Snellman B (1968) Procidentia of the rectum studied with cineradiography. A contribution to the discussion of causative mechanism. Dis Colon Rectum 11(5):330–347
7. Brown BS (1965) Defecography or anorectal studies in children including cinefluorographic observations. J Can Assoc Radiol 16:66–76
8. Mahieu P, Pringot J, Bodart P (1984) Defecography: I. Description of a new procedure and results in normal patients. Gastrointest Radiol 9(3):247–251
9. Mahieu P, Pringot J, Bodart P (1984) Defecography: II. Contribution to the diagnosis of defecation disorders. Gastrointest Radiol 9(3):253–261
10. Ekberg O, Nylander G, Fork FT (1985) Defecography. Radiology 155(1):45–48
11. Hoffman MJ, Kodner IJ, Fry RD (1984) Internal intussusception of the rectum. Diagnosis and surgical management. Dis Colon Rectum 27(7):435–441
12. Kuijpers HC, Bleijenberg G (1985) The spastic pelvic floor syndrome. A cause of constipation. Dis Colon Rectum 28(9):669–672
13. Bartolo DC, Roe AM, Virjee J, Mortensen NJ (1985) Evacuation proctography in obstructed defaecation and rectal intussusception. Br J Surg 72:S111–S116
14. Kelvin FM, Maglinte DD, Benson JT (1994) Evacuation proctography (defecography): an aid to the investigation of pelvic floor disorders. Obstet Gynecol 83(2):307–314
15. Kelvin FM, Maglinte DD, Hornback JA, Benson JT (1992) Pelvic prolapse: assessment with evacuation proctography (defecography). Radiology 184(2):547–551
16. Kelvin FM, Maglinte DD (1997) Dynamic cystoproctography of female pelvic floor defects and their interrelationships. AJR Am J Roentgenol 169(3):769–774
17. Maglinte DD, Bartram CI, Hale DA, et al. (2011) Functional imaging of the pelvic floor. Radiology 258(1):23–39
18. Law YM, Fielding JR (2008) MRI of pelvic floor dysfunction: review. AJR Am J Roentgenol 191(6 Suppl):S45–S53
19. Barleben A, Mills S (2010) Anorectal anatomy and physiology. Surg Clin N Am 90(1):1–15 (table of contents)
20. Bertschinger KM, Hetzer FH, Roos JE, et al. (2002) Dynamic MR imaging of the pelvic floor performed with patient sitting in an open-magnet unit versus with patient supine in a closed-magnet unit. Radiology 223(2):501–508
21. Bharucha AE (2006) Update of tests of colon and rectal structure and function. J Clin Gastroenterol 40(2):96–103
22. Cappabianca S, Reginelli A, Iacobellis F, et al. (2011) Dynamic MRI defecography vs. entero-colpo-cysto-defecography in the evaluation of midline pelvic floor hernias in female pelvic floor disorders. Int J Colorectal Dis 26(9):1191–1196
23. Comiter CV, Vasavada SP, Barbaric ZL, Gousse AE, Raz S (1999) Grading pelvic prolapse and pelvic floor relaxation using dynamic magnetic resonance imaging. Urology 54(3):454–457
24. Eguare EI, Neary P, Crosbie J, et al. (2004) Dynamic magnetic resonance imaging of the pelvic floor in patients with idiopathic combined fecal and urinary incontinence. J Gastrointest Surg 8(1):73–82 (discussion 82)
25. El Sayed RF, El Mashed S, Farag A, Morsy MM, Abdel Azim MS (2008) Pelvic floor dysfunction: assessment with combined analysis of static and dynamic MR imaging findings. Radiology 248(2):518–530
26. Elshazly WG, El Nekady Ael A, Hassan H (2010) Role of dynamic magnetic resonance imaging in management of obstructed defecation case series. Int J Surg 8(4):274–282
27. Hecht EM, Lee VS, Tanpitukpongse TP, et al. (2008) MRI of pelvic floor dysfunction: dynamic true fast imaging with steady-state precession versus HASTE. AJR Am J Roentgenol 191(2): 352–358
28. Hetzer FH, Andreisek G, Tsagari C, Sahrbacher U, Weishaupt D (2006) MR defecography in patients with fecal incontinence: imaging findings and their effect on surgical management. Radiology 240(2):449–457
29. Hilfiker PR, Debatin JF, Schwizer W, et al. (1998) MR defecography: depiction of anorectal anatomy and pathology. J Comput Assist Tomogr 22(5):749–755
30. Lamb GM, de Jode MG, Gould SW, et al. (2000) Upright dynamic MR defaecating proctography in an open configuration MR system. Br J Radiol 73(866):152–155
31. Law PA, Danin JC, Lamb GM, et al. (2001) Dynamic imaging of the pelvic floor using an open-configuration magnetic resonance scanner. J Magn Reson Imaging 13(6):923–929
32. Lienemann A, Fischer T (2003) Functional imaging of the pelvic floor. Eur J Radiol 47(2):117–122
33. Mortele KJ, Fairhurst J (2007) Dynamic MR defecography of the posterior compartment: indications, techniques and MRI features. Eur J Radiol 61(3):462–472
34. Rentsch M, Paetzel C, Lenhart M, et al. (2001) Dynamic magnetic resonance imaging defecography: a diagnostic alternative in the assessment of pelvic floor disorders in proctology. Dis Colon Rectum 44(7):999–1007
35. Roos JE, Weishaupt D, Wildermuth S, et al. (2002) Experience of 4 years with open MR defecography: pictorial review of anorectal anatomy and disease. Radiographics 22(4):817–832
36. Gousse AE, Barbaric ZL, Safir MH, et al. (2000) Dynamic half Fourier acquisition, single shot turbo spin-echo magnetic resonance imaging for evaluating the female pelvis. J Urol 164(5): 1606–1613
37. Healy JC, Halligan S, Reznek RH, et al. (1997) Magnetic resonance imaging of the pelvic floor in patients with obstructed defaecation. Br J Surg 84(11):1555–1558
38. Gufler H, Laubenberger J, DeGregorio G, Dohnicht S, Langer M (1999) Pelvic floor descent: dynamic MR imaging using a half-Fourier RARE sequence. J Magn Reson Imaging 9(3):378–383
39. Schoenenberger AW, Debatin JF, Guldenschuh I, et al. (1998) Dynamic MR defecography with a superconducting, open-configuration MR system. Radiology 206(3):641–646
40. Yang A, Mostwin JL, Rosenshein NB, Zerhouni EA (1991) Pelvic floor descent in women: dynamic evaluation with fast MR imaging and cinematic display. Radiology 179(1):25–33
41. Brenner D, Elliston C, Hall E, Berdon W (2001) Estimated risks of radiation-induced fatal cancer from pediatric CT. AJR Am J Roentgenol 176(2):289–296
42. Hall EJ, Brenner DJ (2008) Cancer risks from diagnostic radiology. Br J Radiol 81(965):362–378
43. Brenner DJ, Hall EJ (2007) Computed tomography—an increasing source of radiation exposure. N Engl J Med 357(22):2277–2284
44. Brenner DJ, Hall EJ (2004) Risk of cancer from diagnostic X-rays. Lancet 363(9427):2192 (author reply 2192–2193)
45. Brenner DJ, Hricak H (2010) Radiation exposure from medical imaging: time to regulate? JAMA 304(2):208–209
46. Maglinte DD, Bartram C (2007) Dynamic imaging of posterior compartment pelvic floor dysfunction by evacuation proctography: techniques, indications, results and limitations. Eur J Radiol 61(3):454–461

47. Halligan S (1995) Re: The benefits or otherwise of evacuation proctography (defecography). Abdom Imaging 20(3):280–281
48. Halligan S, Malouf A, Bartram CI, et al. (2001) Predictive value of impaired evacuation at proctography in diagnosing anismus. AJR Am J Roentgenol 177(3):633–636
49. Maglinte DD, Kelvin FM, Fitzgerald K, Hale DS, Benson JT (1999) Association of compartment defects in pelvic floor dysfunction. AJR Am J Roentgenol 172(2):439–444
50. Flusberg M, Sahni VA, Erturk SM, Mortele KJ (2011) Dynamic MR defecography: assessment of the usefulness of the defecation phase. AJR Am J Roentgenol 196(4):W394–W399
51. Solopova AE, Hetzer FH, Marincek B, Weishaupt D (2008) MR defecography: prospective comparison of two rectal enema compositions. AJR Am J Roentgenol 190(2):W118–W124
52. Bremmer S (1995) Simultaneous defecography and peritoneography in defecation disorders. Dis Colon Rectum 38:969–973
53. Halligan S (1996) Dynamic cystoproctography and physiological testing in women with urinary stress incontinence and urogenital prolapse. Clin Radiol 51:785–790
54. Halligan S, Bartram C, Hall C, Wingate J (1996) Enterocele revealed by simultaneous evacuation proctography and peritoneography: does "defecation block" exist? Am J Roentgenol 167(2): 461–466
55. Kelvin FM, Maglinte DD, Hale DS, Benson JT (2000) Female pelvic organ prolapse: a comparison of triphasic dynamic MR imaging and triphasic fluoroscopic cystocolpoproctography. AJR Am J Roentgenol 174(1):81–88
56. Altringer WE, Saclarides TJ, Dominguez JM, Brubaker LT, Smith CS (1995) Four-contrast defecography: pelvic "floor-oscopy". Dis Colon Rectum 38(7):695–699
57. Brubaker L, Heit MH (1993) Radiology of the pelvic floor. Clin Obstet Gynecol 36(4):952–959
58. Hock D, Lombard R, Jehaes C, et al. (1993) Colpocystodefecography. Dis Colon Rectum 36(11):1015–1021
59. Kelvin FM, Hale DS, Maglinte DD, Patten BJ, Benson JT (1999) Female pelvic organ prolapse: diagnostic contribution of dynamic cystoproctography and comparison with physical examination. AJR Am J Roentgenol 173(1):31–37
60. Saclarides TJ, Brubaker LT, Altringer WE, Smith CS, Dominguez JM (1996) Clarifying the technique of four-contrast defecography. Dis Colon Rectum 39(7):826
61. Vanbeckevoort D, Van Hoe L, Oyen R, et al. (1999) Pelvic floor descent in females: comparative study of colpocystodefecography and dynamic fast MR imaging. J Magn Reson Imaging 9(3):373–377
62. Fielding JR, Griffiths DJ, Versi E, et al. (1998) MR imaging of pelvic floor continence mechanisms in the supine and sitting positions. AJR Am J Roentgenol 171(6):1607–1610
63. Olsen AL, Smith VJ, Bergstrom JO, Colling JC, Clark AL (1997) Epidemiology of surgically managed pelvic organ prolapse and urinary incontinence. Obstet Gynecol 89(4):501–506
64. Gill EJ, Hurt WG (1998) Pathophysiology of pelvic organ prolapse. Obstet Gynecol Clin North Am 25(4):757–769
65. Burnett LS, Buckley SL (1993) Surgical failures in the management of pelvic floor relaxation. Curr Opin Obstet Gynecol 5(4): 465–470
66. Karasick S, Spettell CM (1997) The role of parity and hysterectomy on the development of pelvic floor abnormalities revealed by defecography. AJR Am J Roentgenol 169(6):1555–1558
67. Karasick S, Spettell CM (1999) Defecography: does parity play a role in the development of rectal prolapse? Eur Radiol 9(3):450–453
68. Stoker J, Bartram CI, Halligan S (2002) Imaging of the posterior pelvic floor. Eur Radiol 12(4):779–788
69. Stoker J, Rociu E (1999) Endoluminal MR imaging of anorectal diseases. J Magn Reson Imaging 9(5):631–634
70. Kim JK, Kim YJ, Choo MS, Cho KS (2003) The urethra and its supporting structures in women with stress urinary incontinence: MR imaging using an endovaginal coil. Am J Roentgenol 180: 1037–1044
71. Stoker J, Rociu E, Zwamborn AW, Schouten WR, Lameris JS (1999) Endoluminal MR imaging of the rectum and anus: technique, applications, and pitfalls. Radiographics 19:383–398
72. Shorvon PJ, McHugh S, Diamant NE, Somers S, Stevenson GW (1989) Defecography in normal volunteers: results and implications. Gut 30(12):1737–1749
73. Fielding JR (1996) Imaging of the female pelvis in the supine and upright position. J Magn Reson Imaging 88:750–756
74. Gagliardi G, Pescatori M, Altomare DF, et al. (2008) Results, outcome predictors, and complications after stapled transanal rectal resection for obstructed defecation. Dis Colon Rectum 51(2):186–195 (discussion 195)
75. Bump RC, Mattiasson A, Bo K, et al. (1996) The standardization of terminology of female pelvic organ prolapse and pelvic floor dysfunction. Am J Obstet Gynecol 175(1):10–17
76. Bernier P, Stevenson GW, Shorvon PJ (1988) Defecography commode. Radiology 155:891–892
77. Jorge JM, Yang YK, Wexner SD (1994) Incidence and clinical significance of sigmoidocele as determined by a new classification system. Dis Colon Rectum 37(11):1112–1117
78. Morandi C, Martellucci J, Talento P, Carriero A (2010) Role of enterocele in the obstructed defecation syndrome (ODS): a new radiological point of view. Colorectal Dis 12:810–816
79. Healy JC, Halligan S, Reznek RH, et al. (1997) Dynamic MR imaging compared with evacuation proctography when evaluating anorectal configuration and pelvic floor movement. AJR Am J Roentgenol 169(3):775–779
80. Barber MD, Brubaker L, Nygaard I, et al. (2009) Defining success after surgery for pelvic organ prolapse. Obstet Gynecol 114(3): 600–609
81. Singh K, Reid WM, Berger LA (2001) Assessment and grading of pelvic organ prolapse by use of dynamic magnetic resonance imaging. Am J Obstet Gynecol 185(1):71–77
82. Woodfield CA, Hampton BS, Sung V, Brody JM (2009) Magnetic resonance imaging of pelvic organ prolapse: comparing pubococcygeal and midpubic lines with clinical staging. Int Urogynecol J Pelvic Floor Dysfunct 20(6):695–701
83. Lockhart ME, Fielding JR, Richter HE, et al. (2008) Reproducibility of dynamic MR imaging pelvic measurements: a multi-institutional study. Radiology 249(2):534–540
84. Brenner DJ (2004) Radiation risks potentially associated with low-dose CT screening of adult smokers for lung cancer. Radiology 231(2):440–445
85. Brenner DJ (2006) It is time to retire the computed tomography dose index (CTDI) for CT quality assurance and dose optimization. For the proposition. Med Phys 33(5):1189–1190
86. Brenner DJ, Sachs RK (2006) Estimating radiation-induced cancer risks at very low doses: rationale for using a linear no-threshold approach. Radiat Environ Biophys 44(4):253–256
87. Pfeifer J, Oliveira L, Park UC, et al. (1997) Are interpretations of video defecographies reliable and reproducible? Int J Colorectal Dis 12:67–72
88. Kenton K, Shott S, Brubaker L (1997) Vaginal topography does not correlate well with visceral position in women with pelvic organ prolapse. Int Urogynecol J Pelvic Floor Dysfunct 8(6):336–339
89. Altman D, Mellgren A, Kierkegaard J, et al. (2004) Diagnosis of cystocele—the correlation between clinical and radiological evaluation. Int Urogynecol J Pelvic Floor Dysfunct 15(1):3–9 (discussion 9)
90. Hale D (2008) Clinical and surgical pelvic organ prolapse. In: Bartram CI, DeLancey JOL (eds) *Medical radiology. Diagnostic and radiation oncology: pelvic floor disorders*, 2nd edn. Heidelberg: Springer, pp 165–186
91. Benson T (1992) *Female pelvic floor disorders: investigation and management*. New York: Norton
92. Frudinger A, Bartram CI, Halligan S, Kamm M (1998) Examination techniques for endosonography of the anal canal. Abdom Imaging 23(3):301–303
93. da Silva GM, Gurland B, Sleemi A, Levy G (2006) Posterior vaginal wall prolapse does not correlate with fecal symptoms or objective measures of anorectal function. Am J Obstet Gynecol 195(6):1742–1747
94. Felt-Bersma RJ, Luth WJ, Janssen JJ, Meuwissen SG (1990) Defecography in patients with anorectal disorders. Which findings are clinically relevant? Dis Colon Rectum 33(4):277–284
95. Ferrante SL, Perry RE, Schreiman JS, Cheng SC, Frick MP (1991) The reproducibility of measuring the anorectal angle in defecography. Dis Colon Rectum 34(1):51–55

96. Bartram CI, Turnbull G, Lennard-Jones JE (1988) Evacuation proctography: an investigation of rectal expulsion in 20 subjects without defecatory disturbance. Gastrointest Radiol 13(1):72–80
97. Ott DJ, Donati DL, Kerr RM, Chen MY (1994) Defecography: results in 55 patients and impact on clinical management. Abdom Imaging 19(4):349–354
98. Bharucha AE, Wald A, Enck P, et al. (2006) Functional anorectal disorders. Gastroenterology 130:1510–1518
99. Halligan S, Bartram CI, Park HY, Kamm MA (1995) Proctographic features of anismus. Radiology 197(3):679–682
100. Bordeianou L, Savitt L, Dursun A (2011) Measurements of pelvic floor dyssynergia: which test result matters? Dis Colon Rectum 54(1):60–65
101. Rao SS (2010) Advances in diagnostic assessment of fecal incontinence and dyssynergic defecation. Clin Gastroenterol Hepatol 8(11):910–919
102. Rao SS, Go JT (2009) Treating pelvic floor disorders of defecation: management or cure? Curr Gastroenterol Rep 11(4):278–287
103. Halligan S, McGee S, Bartram CI (1994) Quantification of evacuation proctography. Dis Colon Rectum 37:1151–1154
104. Hiltunen KM, Kolehmainen H, Matikainen M (1994) Does defecography help in diagnosis and clinical decision-making in defecation disorders? Abdom Imaging 19(4):355–358
105. Kenton K, Shott S, Brubaker L (1999) The anatomic and functional variability of rectoceles in women. Int Urogynecol J Pelvic Floor Dysfunct 10(2):96–99
106. Mellgren A, López A, Schultz I, Anzen B (1998) Rectocele is associated with paradoxical anal sphincter reaction. Int J Colorectal Dis 13(1):13–16
107. Siproudhis L, Ropert A, Lucas J, et al. (1992) Defecatory disorders, anorectal and pelvic floor dysfunction: a polygamy? Radiologic and manometric studies in 41 patients. Int J Colorectal Dis 7(2):102–107
108. Halligan S, Bartram CI (1995) Is barium trapping in rectoceles significant? Dis Colon Rectum 38(7):764–768
109. Greenberg T, Kelvin FM, Maglinte DD (2001) Barium trapping in rectoceles: are we trapped by the wrong definition? Abdom Imaging 26(6):587–590
110. Pucciani F, Rottoli ML, Bologna A, et al. (1996) Anterior rectocele and anorectal dysfunction. Int J Colorectal Dis 11(1):1–9
111. Grassi R, Pomerri F, Habib F, et al. (1995) Defecography study of outpouchings of the external wall of the rectum: posterior rectocele and ischio-rectal hernia. Radiol Med 90(1/2):44–48
112. Chen HH, Iroatulam A, Alabaz O, et al. (2001) Associations of defecography and physiologic findings in male patients with rectocele. Tech Coloproctol 5(3):157–161
113. Bremmer S, Udén R, Mellgren A (1997) Defaeco-peritoneography in the diagnosis of rectal intussusception: a contribution for the discussion of causative mechanism. Acta Radiol 38(4):578–583
114. Pomerri F, Zuliani M, Mazza C, Villarejo F, Scopece A (2001) Defecographic measurements of rectal intussusception and prolapse in patients and in asymptomatic subjects. AJR Am J Roentgenol 176(3):641–645
115. Felt-Bersma R, Tiersma ES, Cuesta M (2008) Rectal prolapse, rectal intussusception, rectocele, solitary rectal ulcer syndrome, and enterocele. Gastroenterol Clin North Am 37:647–648
116. Rutter KR, Riddell RH (1975) The solitary ulcer syndrome of the rectum. Clin Gastroenterol 4(3):505–530
117. Goei R (1990) Anorectal function in patients with defecation disorders and asymptomatic subjects: evaluation with defecography. Radiology 174(1):121–123
118. Halligan S, Nicholls RJ, Bartram CI (1995) Evacuation proctography in patients with solitary rectal ulcer syndrome: anatomic abnormalities and frequency of impaired emptying and prolapse. Am J Roentgenol 164:91–95
119. Parks AG, Porter NH, Hardcastle J (1966) The syndrome of the descending perineum. Proc R Soc Med 59(6):477–482
120. Pinho M, Yoshioka K, Ortiz J, Oya M, Keighley MR (1990) The effect of age on pelvic floor dynamics. Int J Colorectal Dis 5(4): 207–208
121. Bremmer S, Mellgren A, Holmstrom B, Lopez A, Uden R (1997) Peritoneocele: visualization with defecography and peritoneography performed simultaneously. Radiology 202(2):373–377
122. Jorge JM, Ger GC, Gonzalez L, Wexner SD (1994) Patient position during einedefecography: influence on perineal descent and other measurements. Dis Colon Rectum 37(9):927–931
123. Berkelmans I, Heresbach D, Leroi AM, et al. (1995) Perineal descent at defecography in women with straining at stool: a lack of specificity or predictive value for future anal incontinence? Eur J Gastroenterol Hepatol 7(1):75–79
124. Tsiaoussis J, Chrysos E, Glynos M, Vassilakis JS, Xynos E (1998) Pathophysiology and treatment of the anterior rectal mucosal prolapse syndrome. Br J Surg 85(12):1699–1702
125. Wallden L (1952) Defecation block in cases of deep rectogenital pouch. Acta Chir Scand 103(3):236–238
126. Fenner DE (1996) Diagnosis and assessment of sigmoidoceles. Am J Obstet Gynecol 175(6):1438–1441 (discussion 1441–1432)
127. Pannu HK, Kaufman HS, Cundiff GW, et al. (2000) Dynamic MR imaging of pelvic organ prolapse: spectrum of abnormalities. Radiographics 20(6):1567–1582
128. Rooney K, Kenton K, Mueller ER, FitzGerald MP, Brubaker L (2006) Advanced anterior vaginal wall prolapse is highly correlated with apical prolapse. Am J Obstet Gynecol 195(6):1837–1840
129. Halligan S, Spence-Jones C, Kamm MA, Bartram CI (1996) Dynamic cystoproctography and physiological testing in women with urinary stress incontinence and urogenital prolapse. Clin Radiol 51(11):785–790
130. Dixon A (1997) Evidence based diagnostic radiology. Lancet 350: 509–512
131. Harvey CJ, Harvey CJ, Halligan S, et al. (1999) Evacuation proctography: a prospective study of diagnostic and therapeutic impact. Radiology 211:223–227
132. Brenner DJ (2002) Estimating cancer risks from pediatric CT: going from the qualitative to the quantitative. Pediatr Radiol 32(4):228–233 (discussion 242–224)
133. Brenner DJ (2010) Should we be concerned about the rapid increase in CT usage? Rev Environ Health 25(1):63–68
134. Brenner DJ (2010) Slowing the increase in the population dose resulting from CT scans. Radiat Res 174(6):809–815
135. Brenner DJ, Elliston CD (2004) Estimated radiation risks potentially associated with full-body CT screening. Radiology 232(3): 735–738
136. Mahesh M, Hevezi JM (2009) Multislice scanners and radiation dose. J Am Coll Radiol 6(2):127–128
137. Brenner DJ, Shuryak I, Einstein AJ (2011) Impact of reduced patient life expectancy on potential cancer risks from radiologic imaging. Radiology 261(1):193–198
138. Cohen MD (2009) More on the risks associated with radiation. J Am Coll Radiol 6(6):463
139. Thrall JH (2009) Radiation exposure: politics and opinion vs science and pragmatism. J Am Coll Radiol 6(3):133–134
140. Mahesh M, Hevezi JM (2009) Slice wars vs dose wars in multiple-row detector CT. J Am Coll Radiol 6(3):201–202
141. Pierce DA, Preston DL (2000) Radiation-related cancer risks at low doses among atomic bomb survivors. Radiat Res 154(2):178–186
142. Cohen BL (2002) Cancer risk from low-level radiation. AJR Am J Roentgenol 179(5):1137–1143
143. Pukkala E, Aspholm R, Auvinen A, et al. (2002) Incidence of cancer among Nordic airline pilots over five decades: occupational cohort study. BMJ 325(7364):567
144. Hammer GP, Seidenbusch MC, Regulla DF, et al. (2011) Childhood cancer risk from conventional radiographic examinations for selected referral criteria: results from a large cohort study. AJR Am J Roentgenol 197(1):217–223
145. Amis ES Jr (2011) CT radiation dose: trending in the right direction. Radiology 261(1):5–8
146. Goei R, Kemmerink G (1990) Radiation dose in defecography. Radiology 176(1):137–139
147. Health Physics Society. McLean V. Radiation risk in perspective. www.hps.org/document/risk_ps010-1.pdf. Accessed July 18, 2011.