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Jaap Stoker
Clive I. Bartram
Steve Halligan

Imaging of the posterior pelvic floor

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J. Stoker (✉)
Department of Radiology,
Academic Medical Center,
University of Amsterdam, P.O. Box 22700,
1100 DE, Amsterdam, The Netherlands
e-mail: j.stoker@amc.uva.nl
Tel.: +31-20-5662532/5669111
Fax: +31-20-5669119

C.I. Bartram · S. Halligan
Intestinal Imaging Centre,
St. Mark's Hospital, London HA1 3UJ,
UK

Abstract Disorders of the posterior pelvic floor are relatively common. The role of imaging in this field is increasing, especially in constipation, prolapse and anal incontinence, and currently imaging is an integral part of the investigation of these pelvic floor disorders. Evacuation proctography provides both structural and functional information for rectal voiding and prolapse. Dynamic MRI may be a valuable alternative as the pelvic floor muscles are visualised, and it is currently under evaluation. Endoluminal imaging is important in the management of anal incontinence. Both endosonography and endoanal MRI can be used for detection of anal sphincter defects. Endoanal MRI has the advantage of simultaneously evaluating external sphincter atrophy, which is an important predictive factor for the outcome of sphincter repair. Many aspects of constipation and prolapse remain incompletely understood and treatment is partly empirical; however, imaging has a central role in management to place patients into treatment-defined groups.

Keywords Proctography · Endosonography · MRI · Incontinence · Prolapse · Pelvic floor · Constipation

Introduction

Posterior pelvic floor disorders such as prolapse and anal incontinence are relatively common particularly in females, and increase in incidence with age. Factors that weaken the pelvic floor include age-related neuropathy, vaginal delivery causing direct trauma to the pelvic floor structures or neuropathy, and changes associated with menopause.

Current diagnostic work-up comprises a clinical history, physical examination and various physiological tests. During the past two decades imaging has become an increasingly important part of investigation, and dedicated imaging techniques have been developed and become more widespread. These have provided new insights into the pathogenesis of pelvic floor disorders, e.g. the significance of occult anal sphincter tears in anal incontinence. Radiologists becoming involved in this field will experience an increasing demand for these examinations as clinicians come to rely more heavily on imaging studies for diagnosis, and to select patients for appropriate therapies.

This paper reviews the advances in imaging of the posterior compartment of the pelvic floor, and the current role of these techniques in the investigation of patients with common posterior pelvic floor disorders as presenting to the coloproctologist, notably constipation, prolapse and anal incontinence.

Anatomy of the posterior pelvic floor

The pelvic floor is a complex integrated multi-layer system providing active and passive support, with fascia and ligaments providing the passive support, and the muscles of the pelvic floor the active support. The pelvic floor has three layers: the pelvic fascia with its associated specialised ligaments; the striated muscle of the leva-

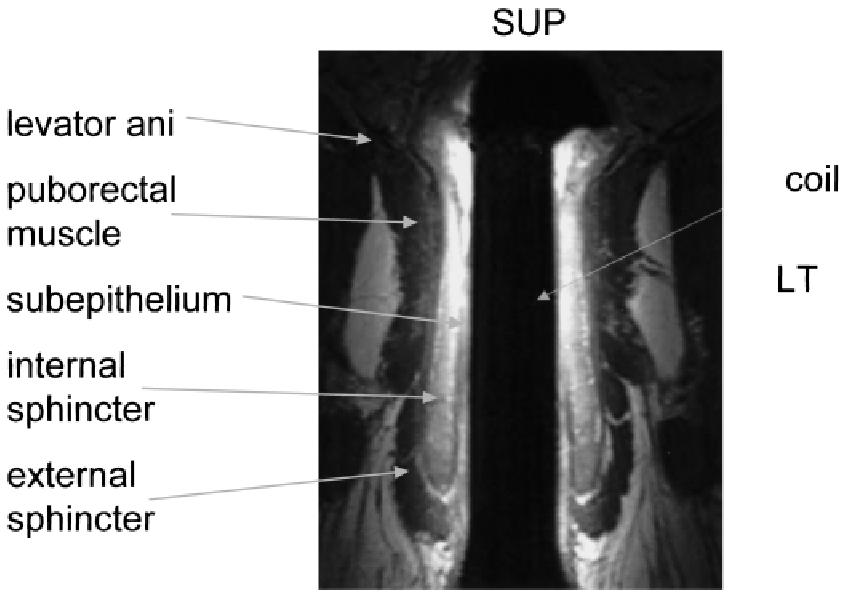


Fig. 1 Normal anal anatomy at coronal T2-weighted turbo spin-echo (TSE) image in a 40-year-old man. *SUP* superior; *LT* left

tor ani; and associated muscles of the urogenital diaphragm. Included in the posterior pelvic floor are the sphincteric muscles of the anus, which also have a smooth muscle component.

The levator ani is the major muscle of the pelvic floor, and comprises three components: the ileococcygeus; coccygeus; and puborectalis muscles, which function as a single functional unit [1]. The sling-like puborectalis passes beside the urethra, vagina and anorectum with attachments to the vagina and anorectum. This sling closes the urogenital and anorectal hiatae, providing a supportive platform during normal activity and standing. Above the pelvic floor, ligaments (e.g. round ligaments, uterosacral ligaments) add to the support.

The anal sphincters form two cylindrical layers (Fig. 1), between which lies the longitudinal muscle. The internal sphincter forms the innermost muscular layer, and is the terminal condensation of the circular rectal smooth muscle (Fig. 1). The longitudinal muscle is the continuation of the longitudinal muscle of the rectal wall, with striated muscle components from the puboanalis and a considerable fibroelastic content derived from the pubocervical fascia. The external sphincter is the outermost muscle of the distal anal canal (Fig. 1) and is composed of several parallel bundles of striated muscle [2]. It is a circular structure and is the anterior part and is shorter in women by approximately 1.5 cm [3]. The deep part of the external sphincter is intimately related to the puborectalis.

Constipation

Evacuation proctography

Evacuation proctography (defecography) describes the imaging of rectal evacuation using a barium paste. The procedure is of most value for investigating patients who complain of difficult or incomplete rectal emptying. The technique is straightforward: the rectum is filled with a barium paste and the patient seated on a specially designed commode [4]. Following a single lateral rectal view to document resting rectal and pelvic floor configuration, the patient is asked to evacuate as rapidly and completely as possible during filming (usually at one frame per second). Low-dose protocols may be used with digital systems to give low minimal dose with adequate spatial resolution. As part of the standard examination dilute oral barium suspension is given approximately 1 h before to demonstrate enterocoeles [5]. Some workers employ a vaginal marker. Proctography may be supplemented by opacifying the bladder to include imaging urinary voiding and bladder configuration, which has been termed dynamic cystoproctography [6]. Abnormalities may be either structural or functional. Structural lesions include varying degrees of rectal prolapse, excessive pelvic floor descent, and rectocoele or enterocoele formation.

Structural findings

Proctography is frequently requested to diagnose internal rectal prolapse, which is difficult to demonstrate clinically. Anterior mucosal prolapse is a common proctoscopic diagnosis with no clear-cut correlation on proctography.

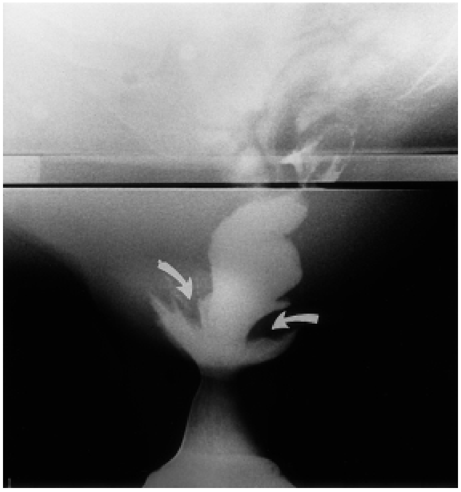


Fig. 2 Evacuation proctogram, lateral view during evacuation. There is a high-grade distal rectal intussusception evidenced by circumferential rectal wall invagination (*arrows*)

Rectal intussusception may be defined as intra-rectal, intra-anal or external. The division into high or low grade is an attempt to describe the severity of prolapse (Fig. 2), with low-grade intussusception frequent in asymptomatic individuals, and therefore likely to be a normal finding [7]. Intussusception occurs only when the rectum collapses [8]. Screening in the antero-posterior plane shows that the rectum folds over as it empties, which may be used to confirm intra-anal intussusception (Fig. 3). The intussusception creates a sensation of incomplete evacuation but does not cause mechanical rectal blockage as the intussusception develops typically only when the rectum is empty. Intra-rectal intussusception is not a defined entity. Many patients with solitary rectal ulcer syndrome have intra-anal intussusception. Although surgery may cure both the intussusception and the ulcer, symptoms often persist suggesting a multifactorial aetiology to this syndrome [9].

Rectocoele and enterocoele are common (Fig. 4). Indeed, some degree of rectocoele formation is present in most asymptomatic women, suggesting that only rectocoeles >2 cm in depth should be considered abnormal [7]. Large rectocoeles do not impede evacuation, but sequestration of stool within a rectocoele leads to a sense of incomplete evacuation and the need for digital manoeuvres to complete evacuation. Significant retention of contrast within a rectocoele when the rectum has emptied confirms barium trapping. A deep rectogenital space may fill with bladder, uterus, sigmoid colon (sigmoidocoele) or small bowel (enterocoele) [10]. The original concept of rectal blockage from enterocoeles is incorrect [10], but large enterocoeles extending into the perineum may be symptomatic, giving rise to either perineal discomfort or a sense of incomplete evacuation. Although

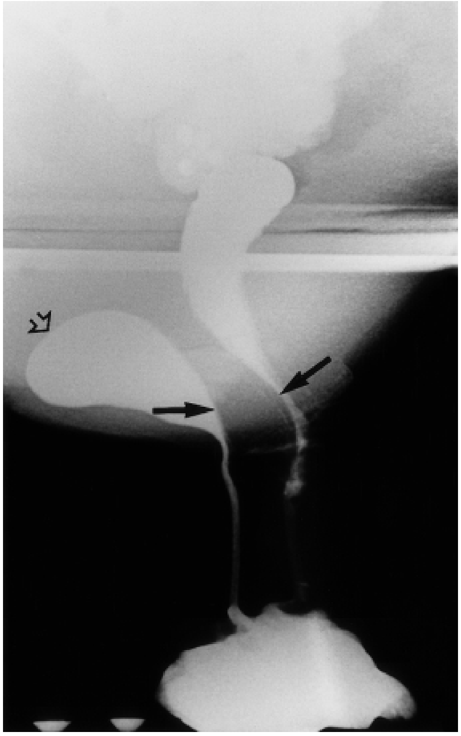


Fig. 3 Evacuation proctogram. Lateral view during evacuation reveals a large anterior mucosal prolapse that enters the anal canal (*between black arrows*). There is an associated rectocoele (*open arrow*)

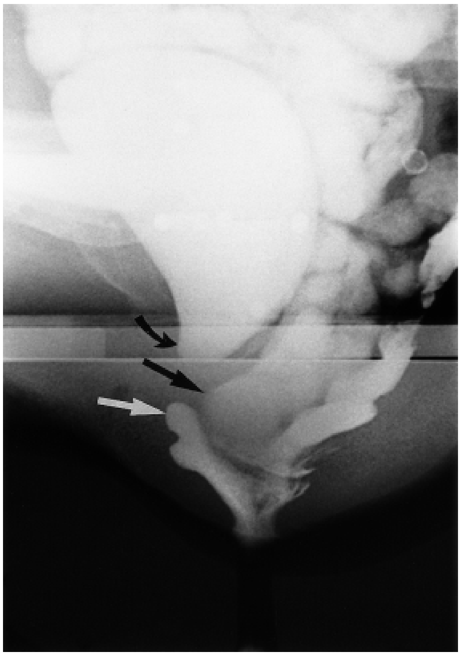


Fig. 4 Dynamic cystoproctogram during rectal evacuation reveals a cystocoele (*curved black arrow*), enterocoele (*straight black arrow*) and rectocoele (*white arrow*)

the size of the rectogenital pouch is easily appreciated at the time of surgery, pre-operative assessment is more accurate proctographically than clinically.

By relating the position of the anorectal junction to a bony landmark, such as the ischial tuberosities, proctography provides a simple method to determine the position of the pelvic floor at rest and during evacuation.

Excessive pelvic floor descent has been associated with pudendal neuropathy and chronic straining (descending perineum syndrome), and is common in constipated subjects. Surgery directed specifically at restoration of normal pelvic floor configuration is contentious, as it is unusual to see excessive descent in isolation. Normally there is a constellation of associated abnormalities such as intussusception, rectocoele and perineal ballooning.

Functional evacuation disorders

Rectal evacuation is a functional event requiring coordination between voluntary and involuntary nervous pathways as well as smooth and striated muscles. It has long been recognised that some patients experience difficulties with rectal evacuation because of an inability to coordinate this necessarily complex series of events. Evacuation of a rectal balloon with simultaneous electromyography of the pelvic floor musculature has shown that some patients inappropriately contract the pelvic floor muscles when they should be relaxing, thereby inhibiting voiding [11].

This phenomenon has attracted a varied terminology, including anismus, paradoxical puborectalis contraction and spastic pelvic floor syndrome. The cause of this syndrome is unknown, although a convincing association with sexual abuse suggests a psychological origin in some patients. There is also an association with slow colonic transit in young women, although there is some evidence to suggest that the slow transit is merely a secondary phenomenon to inhibited evacuation. Predictably, considerable controversy surrounds diagnosis of anismus: it cannot be demonstrated in many constipated patients, it has been described as a laboratory artefact and it may be found in asymptomatic subjects. Nevertheless, there seems to be a generally strong association with symptoms and, most convincingly, the success of biofeedback treatment supports the value of making this diagnosis.

The diagnosis of anismus has been based historically on finding inappropriate puborectal contraction. It was assumed that this would be visible during proctography as a persistent indentation posteriorly just above the anorectal junction. In practice, this is a poorly predictive sign. A study of 24 patients with proven anismus found no significant difference between puborectalis configuration and that of controls [12]. Prolonged and/or incomplete contrast evacuation was far more specific, present in 20 of 24 patients (83%) compared with none of the controls [12]. The combination of prolonged and incomplete voiding gave a positive predictive value of 90% compared with a physiological diagnosis of anismus [13].

Interpretation

Constipation is a symptom not a sign, and is based on the patient's perception. Stool frequency may be established on direct questioning, but differentiating structural and/or functional causes of “difficult” defaecation that a patient often describes as constipation is difficult clinically.

Structural abnormalities of the pelvic floor may occur from various causes, including surgical procedures (e.g. higher prevalence of enterocoeles after hysterectomy) and vaginal delivery. Vaginal delivery may result in damage of the rectovaginal septum leading to rectocoele with barium trapping.

Patients with a functional evacuation disorder tend to strain excessively and chronically. This may damage the pelvic floor and lead to specific structural abnormalities visible during proctography, namely intussusception, pelvic floor descent, perineal ballooning, rectocoele and enterocoele. For this reason, an underlying functional diagnosis should always be considered when these are seen. This is especially relevant whenever prolonged or incomplete proctographic evacuation is encountered, or when there is difficulty with initiating or sustaining evacuation. Such an approach will ensure that patients are not subjected to unnecessary surgery based on purely proctographic findings, when these are really secondary manifestations of an unrecognised function. There is also growing evidence to suggest that surgical repair is only beneficial when anismus has been excluded or treated successfully. The role of proctography is to sort patients into treatment-defined groups based on the relative perceived contributions of structural and functional abnormalities [6], and is of considerable help to physicians in this scenario [14].

Over the past decade it has become clear that pelvic floor disorders rarely occur in isolation, with the result that global pelvic floor investigation is requested increasingly. Dynamic cystoproctography is a response to this demand and is highly accurate [6]; however, it is relatively time-consuming, invasive and the pelvic floor muscles are not visualised directly. Dynamic pelvic floor MR imaging has the advantages that it does not involve ionising radiation, is quick and requires no special preparation. Patients are imaged supine at rest and during a straining/Valsalva manoeuvre using appropriate fast sequences (Fig. 5) [15, 16]. Although any plane can be acquired, the sagittal plane provides most relevant clinical

Fig. 5 Sagittal dynamic MRI (T2-weighted TSE) **a** in rest and **b** during straining reveals a cystocoele (*C*) and descent of the medial and posterior compartment of the pelvic floor. *H* head. (Courtesy of V.P.M. van der Hulst)

information, especially when viewed as a cine loop. Because functional evaluation of rectal evacuation is so important, some investigators instil rectal contrast and advocate evacuation within the bore of the magnet, a procedure that is clearly easier within an open configuration machine. Dynamic pelvic floor MR imaging with simple rest/stress views is of most interest to urogynaecologists, and without evacuation studies the important coloproctological conditions, such as intussusception, may be missed.

Anal incontinence

Incontinence can be divided into passive when there is leakage without awareness, which is often related to internal sphincter damage, or urge when there is inability to defer defaecation, which is more likely to be due to external sphincter damage [17].

In the elderly incontinence is common and neurogenic in origin. In younger age groups diminished rectal compliance, anal surgery, diarrhoea and neurological diseases maybe specific causes, but the most important single aetiological factor is childbirth.

Vaginal delivery may result in a pudendal neuropathy from stretching of the nerves, and damage to the pelvic floor with tears of the anal sphincter, pelvic floor muscles or fascia. The role of pudendal neuropathy was emphasised by neurophysiological testing using single-electrode EMG testing and measuring the pudendal terminal motor latencies of the pudendal nerve; however, endoanal sonography showed that perineal examination could not be used to exclude anal sphincter tears [18], and proved more accurate, as well as much easier, than EMG mapping.

Occult sphincter tears were found to be common after vaginal delivery and in a prospective study with 202 consecutive women, 28 of 79 primiparous women (35%) and 21 of 48 multiparous women (48%) had a sphincter tear after delivery which was in the majority not detected at physical examination [19]. More recent work based on a refined appreciation of the endosonographic anatomy, and perhaps altered obstetric practice, suggests an incidence of 11% [20]. Most structural damage occurs at the first delivery, with cumulative pudendal neuropathy at each subsequent delivery. This increases the risk of frank incontinence developing in women who have an asymptomatic sphincter tear at the first delivery [21].

Endosonography

Although the sphincter can be imaged transperineally [22], endosonographic examination with a dedicated unit is preferred with a 10-MHz mechanically rotated transducer to give a 360° axial image. Women should be examined prone [23]. The normal anatomy is complex but has a basic four-layer pattern with the subepithelial tissues of moderate reflectivity, the internal sphincter of low reflectivity, the longitudinal muscle layer and external sphincter of variable reflectivity (Fig. 6). Interface reflections are important in distinguishing layers, and fat planes between the longitudinal muscle and external sphincter and at the outer border of the external sphincter help define these layers. The external sphincter shows a striated pattern typical of voluntary muscle. Muscle bundles are visible in the upper part of the longitudinal layer, and the muscularis submucosae ani may be seen as a thin low reflective layer in the subepithelial tissues. A good correlation (r=0.96) for the external thickness between endosonography and endocoil MRI has been demonstrated [24].

With rectal intussusception or prolapse the internal sphincter and subepithelium may be abnormally thickened [25]. Complete division of the internal sphincter

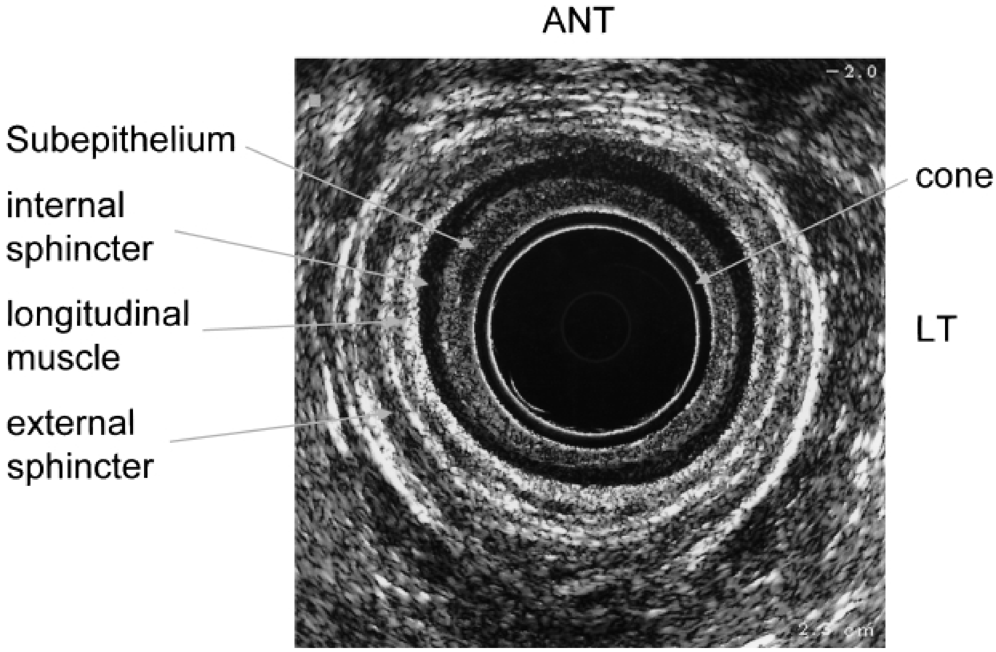


Fig. 6 Normal anal endosonographic anatomy

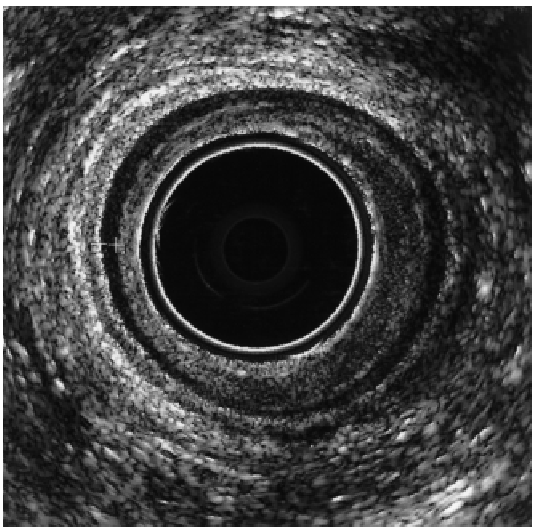


Fig. 7 Internal sphincter degeneration. The internal sphincter measures only 1.3 mm in a 70-year-old man with passive faecal incontinence

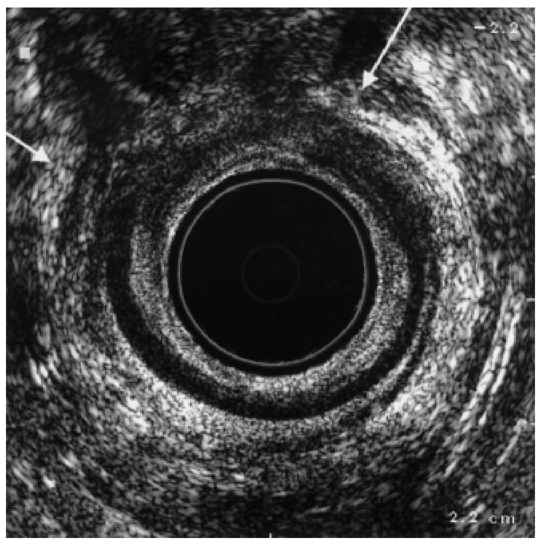


Fig. 8 Obstetric trauma with tears in both sphincters (10–1 h; *arrows*)

during sphincterotomy may lead to incontinence, but in patients over 50 years of age with passive incontinence and an internal sphincter thickness of <2 mm, internal sphincter degeneration may be present (Fig. 7) [26]. Internal sphincter disruption is clearly visible as a break in the sphincter ring.

Tears of the external sphincter heal with fibrosis, which is homogeneously of low reflectivity, are subtler to detect requiring careful assessment of the sonographic symmetry of the sphincter. Tears are often patchy and extend into the longitudinal layer. Obstetric trauma always involves the anterior half of the external sphincter (Fig. 8). If the internal sphincter is also torn, this usually involves the same segment as the external sphincter tear. Isolated internal sphincter tears probably do not occur. Tears are recorded axially by hours reading from a clock face, and longitudinally by the level of canal (high, mid or low).

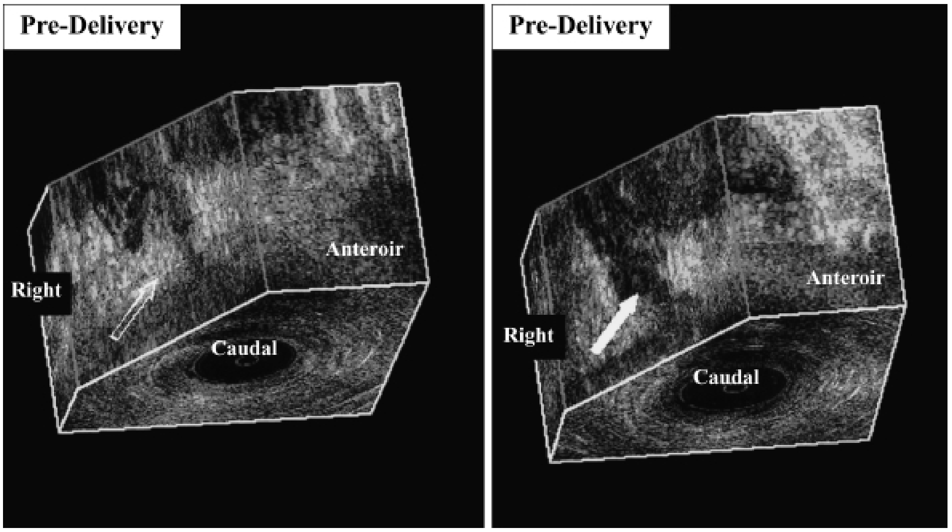


Fig. 9 Paired 3D studies showing tear in the right external sphincter after vaginal delivery (*arrows*)

Three-dimensional endosonography is now available commercially. The diagnostic value of this has to be determined, but it will probably be helpful in sorting out obstetric tears of the anterior sphincter tears [20], which are sometimes difficult to interpret axially. Multiplanar imaging allows the length of sphincter tears to be measured accurately (Fig. 9).

Endoanal MRI

Endoanal MRI has a complementary role with endosonography. It has the advantages of multiplanar imaging and of defining the striated components of the sphincter with great clarity.

Technique

Several manufacturers have developed endoanal coils of diameter ranging from 7 to 19 mm. Coil diameter is a compromise between effective volume (field of view) and sphincter distension. The endoanal coil is covered with a condom and a small amount of lubricant (e.g. sonography gel) is applied. It is important to minimise motion artefacts with the small voxel size used during endoluminal imaging. An external coil holder may be helpful but can increase patient discomfort. Perhaps more important are clear patient instructions, pads to maintain a comfortable patient position and smooth muscle relaxants (hyoscine butylbromide or glucagon) preferably intramuscularly for prolonged effect, to reduce peristaltic movement.

The optimal imaging sequence for MRI in anal incontinence has not been established, but the use of T2-weighted turbo spin-echo seems a simple and accurate technique. As a minimum, axial and coronal imaging planes should be imaged, orthogonal or parallel to the anal sphincter to reduce partial-volume effects. As the anal sphincter muscles are relatively small structures, thin slices of 3-mm thickness are used. Phase-encoding direction should be adjusted to prevent artefacts in the anterior part of the anal sphincter in anal incontinence. As in endosonography, tears are recorded axially by hours reading from a clock face. With endoanal MRI tears can be recorded longitudinally with centimetres from the lower edge of the sphincter or, as in endosonography, by the level of canal (high, mid or low).

Recent research has evaluated the role of high-resolution MRI of the anal sphincter using phased-array coils [27]. This study has demonstrated the potential value of this technique, but its role in anal incontinence has yet to be determined.

Interpretation

The mucosa and submucosa/(sub)epithelium are relatively hyperintense on T2-weighted sequences (Figs. 1, 10). The relatively hypointense muscularis submucosae ani is seen within the subepithelial layer. The internal sphincter is a ring-like relatively hyperintense structure separated from the hypointense external sphincter and puborectalis by the relatively hyperintense intersphincteric space, in which hypointense longitudinal muscle bundles are visible.

Endoanal MRI has been demonstrated to be accurate in detecting external and internal anal sphincter defects (Figs. 10, 11, 12). Until now, two comparative studies of endosonography and endoanal MRI in faecal incontinence have been published. A retrospective study of 22 patients with sphincter defects compared anal endoso-

Fig. 10 Posterior internal sphincter defect (*thick arrows*) at axial T2-weighted TSE endoanal MRI in a 45-year-old man with soiling. *ANT* anterior; *LT* left

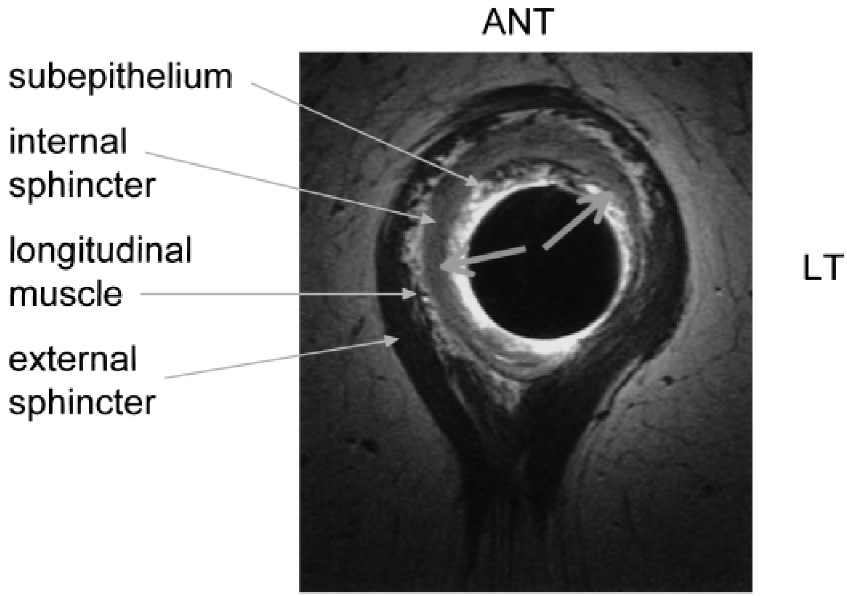
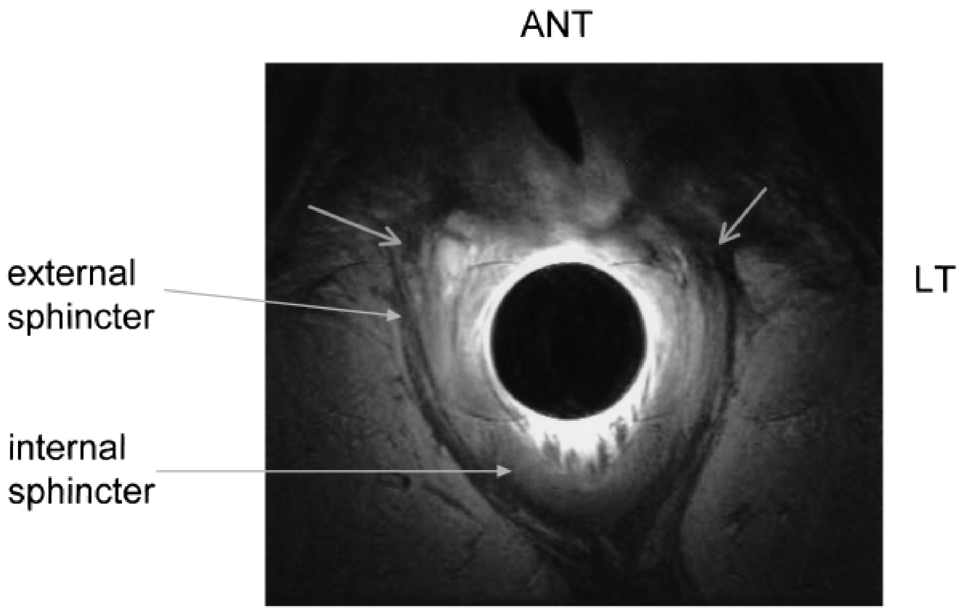


Fig. 11 Large anterior sphincter defect (*arrows*) of the internal and external sphincter in a 33-year-old female patient



nography and endoanal MRI to surgery, and found MRI to be the most accurate [28]. External sphincter defects were detected with sonography and endoanal MRI in, respectively, 16 (73%) and 20 (91%) patients, and internal sphincter defects in, respectively, 15 (68%) and 17 (77%). A prospective study in 52 consecutive patients with faecal incontinence suggested that endosonography and endoanal MRI are comparable for external sphincter defects and endosonography is superior for internal sphincter defects [29]. In this study comparison of imaging findings were made to a consensus of gastroenterologist and surgeon. The differences between the results of both studies are at least partly related to differences in patient populations, study design and experience with either technique. From a practical point of view, one may consider both techniques comparable for detecting sphincter disruption.

External sphincter atrophy is an important entity that has been somewhat neglected following the revelations of occult sphincter tears by endosonography and the difficulty of diagnosing atrophy other than by EMG studies; however, the accurate delineation of the external sphincter at endoanal MRI, especially of its borders and fat content facilitates the evaluation of atrophy. External

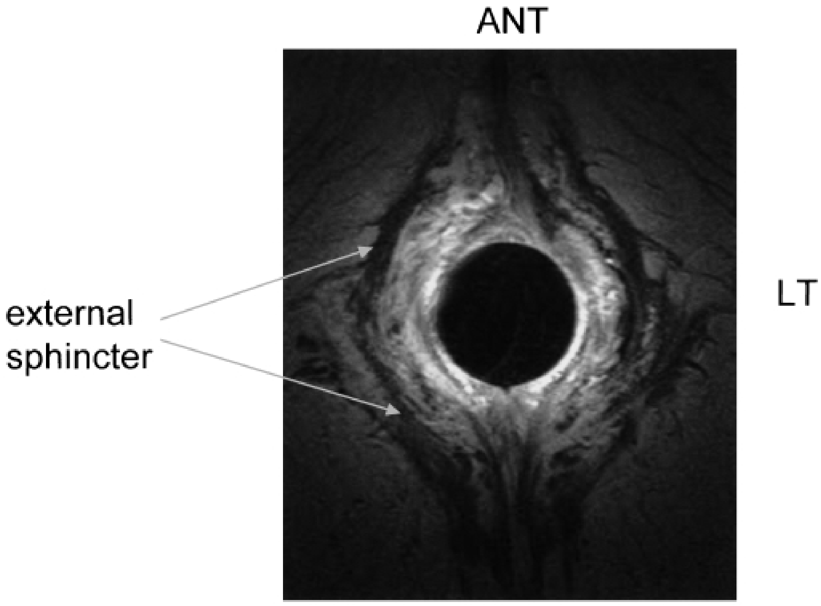


Fig. 12 Axial T2-weighted turbo spin echo demonstrates fragmentation of the external sphincter in a female patient with anal incontinence

Fig. 13 External sphincter atrophy at coronal T2-weighted TSE in a patient with anal incontinence and an anterior external sphincter defect (compare to Fig. 1)

sphincter atrophy is characterised by generalised sphincter thinning and fatty replacement (Fig. 13). Endoanal MRI has been demonstrated to be accurate in this evaluation, which has been validated both surgically and histologically [28, 30, 31, 32]. In a study with histological confirmation, endoanal MRI has been demonstrated to be accurate in determining the presence, as well as the absence, of external sphincter atrophy (14 of 15, 93%) [32]. In a comparative study of endosonography and endoanal MRI in 20 women with faecal incontinence due to obstetric trauma, external sphincter atrophy was not identified at endosonography, when it was present at endoanal MRI in eight women [31]. The problem with an endosonographic diagnosis of atrophy is that, although the outer border of the external sphincter is visible in normals, as the fat replacement increases and the muscle thins with atrophy the outer interface reflection is lost, and it becomes impossible to determine the outer border from adjacent ischio-anal fat. A poorly defined external sphincter and/or a thin internal sphincter have a 74% positive predictive value for atrophy [33]. External sphincter atrophy is a negative predictor of the outcome of sphincter repair [31], and however sphincter disruption has been diagnosed, MRI is strongly recommended prior to sphincter repair to exclude significant atrophy.

Conclusion

During the past two decades, imaging has become an integral part of the investigation of pelvic floor disorders. Evacuation proctography provides both structural and functional information for rectal voiding and prolapse. Dynamic MRI may be a valuable alternative as the pelvic floor muscles are visualised, and it is currently under evaluation. Endoluminal imaging is important in the management of anal incontinence. Both endosonography and endoanal MRI can be used for detection of anal sphincter defects. Endoanal MRI has the advantage of simultaneously evaluating external sphincter atrophy, which is an important predictive factor for the outcome of sphincter repair. Many aspects of constipation and prolapse remain incompletely understood and treatment is partly empirical; however, imaging has a central role in management to place patients into treatment-defined groups.

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