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Practical Imaging of Faecal Incontinence: The Eyes of Science

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<http://dx.doi.org/10.5772/57591>

1. Introduction

Faecal continence is achieved by equilibrium of several forces and a combination of factors related to stool consistency, colonic propulsion, rectal compliance and filling awareness, pelvic floor muscle reflex activity and outlet resistance. Any of these factors may be damaged and other factors can compensate for this impairment in function so that continence is ensured. Incontinence can result from the breakdown of any one or more of the mechanisms that normally ensure continence. Consequently, accurate diagnosis of all factors that interplay to cause incontinence is required in order for the condition to be treated effectively, alone or in combination, by medical or surgical management.

Until recently, diagnosis of fecal incontinence**** has relied on history taking, physical examination and anoproctoscopy. With the exception of endoanal ultrasonography (EAUS) [1-3], imaging studies have not been extensively considered as a valuable diagnostic tool for evaluating the disease, a possible explanation being that it is not easy for diagnostic imaging of the distal gut to reach the level of quality expected and achieved in most other fields of diagnosis; indeed, it demands a sufficient level of interest and commitment by the radiologist and an understanding of the inherent problems of physiology and technique. Not by chance, EAUS is traditionally performed and interpreted by the coloproctologist, who considers such an investigation the natural extension of the physical examination. Despite much controversy still in existence regarding this issue [4], recent reports have emphasized the potential role of imaging studies, including evacuation proctography, also called defecography (D) [5-7] and more recently, MR imaging of anal sphincters and the pelvic floor [8-13] in health and disease states. In particular, the development of fast-sequence MRI has renewed hope that a singular imaging study could be used to differentiate those patients requiring conservative treatment from those necessitating surgery.

The purpose of this paper is to revitalize interest for imaging studies in patients with faecal incontinence. Specifically, the paper will address aspects of technique, performance of examination and diagnostic criteria of the three modalities that are currently in use, and will select areas of their clinical application. Finally, a standard one-hour, integrated (EAUS- MR-D) imaging protocol is presented, to be applied at best in a cost-effective manner so as to have a positive impact on clinical outcomes.

2. Imaging techniques

2.1. Ultrasonography

2.1.1. Equipment

Ultrasound examination of the anal canal can be performed today by either endocavitary or external probes aided by 3D reconstruction, which provide detailed analysis of the pertinent anatomy. For the endocavitary investigation of the anal canal, called EAUS, following a digital rectal examination performed for ruling out any stenosis, a 6-16 MHz, 360° rotational transducer (type 2050, B-K medical, Herlev, Denmark) protected by a gel-containing condom and a soluble lubricant placed on the tip is gently inserted into the anus. The probe has a shaft of 270 mm, a focal length of 2-5 cm and a built-in 3D automatic motorized system allowing acquisition of up to 300 axial images over a distance of 60 mm in 60 seconds. The data from a series of 2D images are then combined to create a 3D volume displayed as a cube (Figure 1). Alternatively, the probe can be inserted into the vagina [14] to depict the anatomy of the pelvic floor and the anal canal free from distortion due to potential foreign objects (Figure 2), thus appearing similar to the image obtained during a conventional external intralabial approach. For the latter examination, a conventional 3.5-6 MHz curved array transducer is used, enabling B mode 2-D analysis or, more recently, a 3-D probe that combines an electronic curved array with mechanical sector technology, which allows fast motorized sweeps through a field of view sufficient to include the entire levator hiatus [15]. Volume data sets are then stored and displayed in the three orthogonal planes to enhance the visibility of the anatomical structure of interest.

2.1.2. Image analysis

In the axial plane, the anal sphincter complex is seen as a series of five concentric layers of different echogenicity, from inner to outer, as follows: the first hyperechoic layer corresponds to the interface of the transducer with the mucosal surface; the second layer shows an intermediate echogenicity, which results from a combination of the subepithelial tissues with the muscularis submucosa; the third hypoechoic layer corresponds to the internal anal sphincter (IAS), which is seen to extend from the anorectal junction down to 1 cm below the dentate line; the fourth layer appears as a moderately echogenic space containing a hypoechoic, thin linear structure, representing the longitudinal muscle embedded into the intersphincteric space; the fifth layer corresponds to the external anal sphincter (EAS), which shows a moderate echoge-

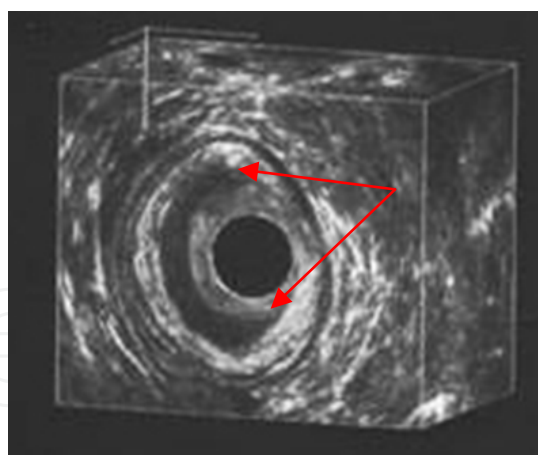


Figure 1. 3-D built-in EAUS of the anal canal with automatic image acquisition, allowing a volume of digital data to be examined: a 12-to-5 o'clock wide defect (space between the two arrows) is seen in the internal anal sphincter together with hypertrophy of the remaining portion.

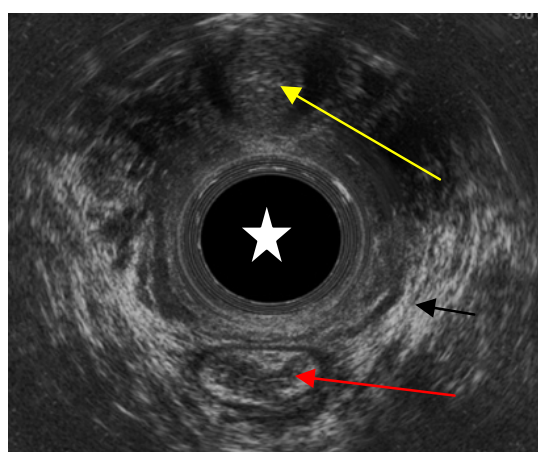


Figure 2. Endovaginal sonography performed with a 2050 B-K probe (white star) at the level of the bladder neck: the intramural portion of the urethra (yellow arrow), the anal canal (red arrow) and the pubovisceral muscle (short black arrow) are depicted.

nicity and a subdivision into a deep portion, continuous with the puborectalis muscle, a superficial portion in contact with the superficial transverse perineal muscle and a subcutaneous portion which extends below the IAS. Via the transvaginal or the transperineal route, the undisturbed virtual lumen of the anal canal is also seen at the centre as a “X-shaped” hypoechoic structure representing the mucosa (Figure 3a and b). Each couple of contiguous branches in this X image delimits three to four triangular hyperechoic structures representing the submucosa. On the longitudinal planes, the anal canal shows a railroad-like appearance of different echogenic structures, which exactly reproduces that described in the axial planes. The normal IAS is between 2 to 3 mm thick and the normal EAS in between 4 to 5 mm thick. The IAS becomes thicker and more hyperechoic with age, probably reflecting collagen replacement. Conversely, the EAS tends to become thinner with age. For female patients being evaluated for faecal incontinence, the examination is occasionally performed with the patient

in the prone position to more clearly delineate the anterior aspect of the EAS and improve visualization of the perineum.

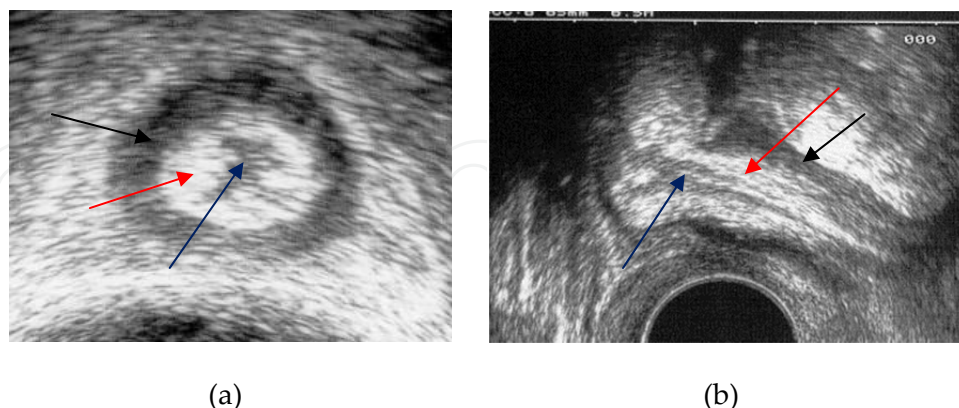


Figure 3. Two-dimensional (2-D) translabial imaging of the anal canal obtained with a 3.5 MHz convex probe showing the continuous hypoechoic ring of internal anal sphincter (black arrow), the hyperechoic submucosa (red arrow) and the “X-shaped” hypoechoic mucosa (blue arrow) in the axial view (a) and in the sagittal view (b)

2.1.2.1. Diagnostic criteria

The role of EAUS in faecal incontinence is specifically related to the detection of anal sphincter lesions including tear, scarring, thinning and atrophy. More particularly, the term 'tear' is used to indicate any discontinuity in the sphincter layer, which is seen as a break of the normal echotexture and geometrical configuration. On the other hand, the term 'scarring' relates to the presence of focal changes in echogenicity, which alter the expected normal pattern. 'Thinning' and 'atrophy' are virtually synonymous at sonography, which has no other criteria than a reduction in the thickness of the muscle bulk to make the diagnosis. At EAUS, defects in the IAS appear as hyperechoic breaks [16] in the normally hypoechoic ring, as opposed to defects in the EAS, which appear as relatively hypoechoic areas in the normally hyperechoic ring (Figure 4a and b). According to Starck [17, 18], a discontinuity involving less than half the thickness of the EAS and/or the IAS **should not** be classified as a defect. The term “partial defect” is used to indicate discontinuities engaging at least half sphincter thickness, while “total defect” is assigned when the whole sphincter thickness is involved. In order to define the severity of the lesion, sphincter defects are measured and classified taking into account their location as well as the longitudinal and circumferential extension. Traditionally, the site of the defect is described by referring to the “anal clock”, which is the view of the anal sphincter complex with the patient in the lithotomy position, where 12 o'clock is the anterior perineum, six o'clock is the natal cleft, three o'clock is the left lateral aspect and nine o'clock is the right of the anal canal. The starting point of the defect and quantification of how many hours (or degrees) it extends clockwise are registered together with annotation of its longitudinal extension, i.e., whether involving half the sphincter length, more than half, or the whole length.

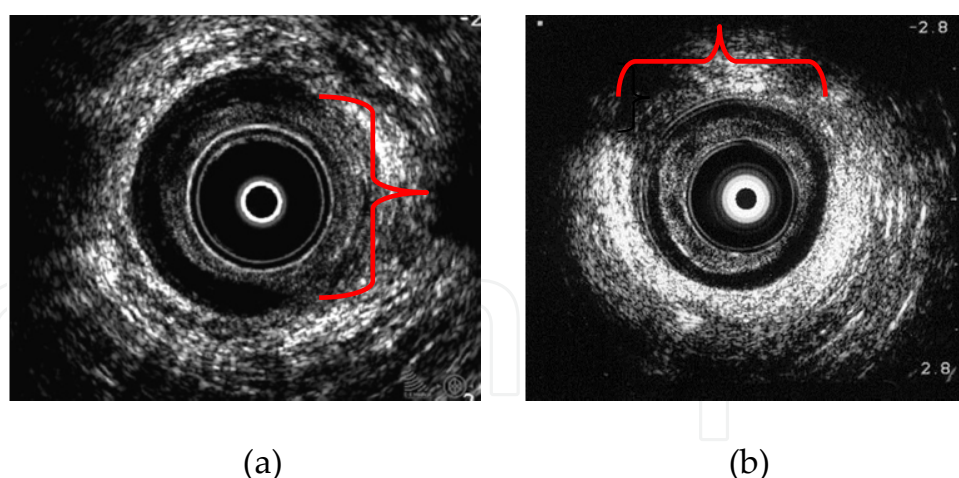


Figure 4. Close-up view of the anal sphincters at EAUS in the axial plane from two different patients: typical sonographic feature of the internal (a) and the external (b) anal sphincter defect which are seen as wide gaps (parenthesis) filled by fibrotic tissue showing moderate echogenicity and inhomogeneous hypoechogenicity, respectively. (Courtesy of dr. Favetta U.)

2.1.2.2. Diagnostic accuracy

Thanks to its superior axial resolution of less than 0.1 mm and lateral resolution of 0.8 mm in the focus zone, together with a slice thickness for reconstruction of 0.2 mm allowing a voxel size of 0.2 mm³, 3-D EAUS gives the most accurate assessment of anal sphincter anatomy and may significantly improve the diagnostic confidence of detecting damage to the anal sphincter complex [19]. The examination, performed immediately after vaginal delivery, allows diagnosis of clinically undetected anal sphincter tears that might be associated with subsequent faecal incontinence with a reported positive predict value of 37% [20]. When compared to other modern imaging techniques, the diagnostic accuracy between EAUS and endoanal MRI performed on the same day has been evaluated in 52 patients with faecal incontinence in comparison with clinical examination and anorectal physiological testing [21]. Complete agreement between the two techniques was found in 32 and disagreement in 20, with incorrect interpretation (arbitration) in six on anal ultrasound and in 15 on endoanal MR, and only one error made on sonography vs. 12 errors on MR when evaluating the IAS, as opposed to five errors vs. six, respectively, when evaluating the EAS. The authors concluded that anal endoanal sonography is a better imaging modality for evaluating IAS injury, while sonography and MRI have equivalent results in the evaluation of EAS injury.

3. Defecography

Despite the recent advent of high-technology modalities and the drawback of somatic and genetic risks associated with radiation exposure, conventional (X-ray) defecography (D) still has enduring value as a diagnostic test in FI. Contrary to the general view that the examination is difficult to perform in these patients, because they are unable to hold the injected rectal

contrast, D can be performed in virtually any patient who can have his/her ampulla filled with barium paste, be placed on a sitting chair and instructed to pass and stop the barium stream on command. The procedure is not time-consuming, requires intermittent and infrequent fluoroscopy or film taking and its diagnostic yield maintains a prominent role with great clinical and therapeutic implications. Several aspects of the technique, which has been described previously [6], help to obtain a uniformly satisfactory outcome of the examination as follows:

Imaging Technique: examinations are carried out on an all-purpose gastrointestinal tract remote controlled X-ray unit (Opera T90e model, General Medical Merate, Bergamo, Italy), using the video outlet from the monitor to record the fluoroscopic images onto a digital imaging system. Technical parameters include the following: voltage, 120 kV; mA, 2; field of view, 170 cm² (continuous fluoroscopy) and voltage, 75kV; mA, 400; number of images, 1Fps; number of series, 5 (digital radiography). For the examination, a radiopaque ruler is attached to the table to enable subsequent calculation of distances and angles from the images. A suspension of 400 grams of powder containing barium sulphate (Pronto Bario Colon, Bracco Laboratories, Milan, Italy) is gradually diluted in 160 mL of water heated at body temperature, resulting in a mixture that has the consistency of semisolid faeces. With the patient lying in the left lateral decubitus position on the radiological table and a pad positioned under the exposed buttocks to collect any material, the unprepared rectum is filled with up to 180 mL of this mixture, unless anticipated leakage occurs. The barium paste is introduced slowly through the anal canal via a 3 mm wide catheter connected to a 60 mL syringe. In case of barium loss, the injection is discontinued and the first image series is started immediately with the patient still lying on his/her left side; the first leakage volume and the total amount of contrast retained are registered; fluoroscopy is also continued while tilting the table upright (Figure 5a and b) during the patient's attempt to interrupt the barium stream (stop test). At this point, the patient is seated on a water-filled commode placed on the table's footrest after having adjusted a single use, removable plastic bag located directly within the commode. Four standard series of images are then taken at rest, squeeze, strain and emptying in sequential order. Permanent records and measurements of established parameters are obtained, including the anorectal angle (ARA°), the rectal and anal maximum diameters and the position of the anorectal junction (ARJ), with respect to the lower margin of the ischial tuberosities taken as reference. At the end of the examination, the review of defecographic series is performed by the examiner from the same console for assessment and reporting.

Image Analysis: the following observations are made from defecograms:

- Rectal size, i.e., measurement of maximum anteroposterior diameter from lateral view at capacity as an index of rectal compliance.
- Anal width, i.e., maximal distance between the two inner margins of the anal canal measured at rest in the total absence of efforts to void as an index of the closing mechanism of the anal sphincter.

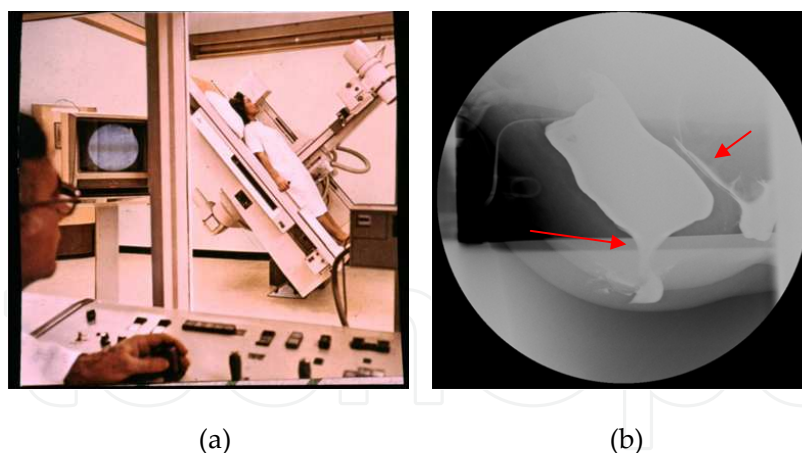


Figure 5. Continuous fluoroscopic monitoring at defecography while tilting the patient upright (a) for evidence of incontinence: a wider than normal 115° resting anorectal angle (long arrow) is seen (b) together with barium leak and failure of anal wall apposition. The short arrow points at the contrast within the vaginal canal injected as anatomical landmark.

- ARA° , defined as the angle between the longitudinal axis of the anal canal and a line drawn tangent to the posterior margin of the rectal ampulla close to the ARJ as an index of the activity of the puborectalis muscle.
- The position of the pelvic floor, defined as the perpendicular distance of the ARJ from the lower margin of the ischial tuberosities; ARJ upward/downward mobility during squeezing, coughing and straining, respectively, is taken as an index of tonic and reflex activity of the levator ani muscle as a whole.
- Barium loss, defined as any incompetence to the average 180 mL amount of the injected rectal contrast. The first leakage volume and the total amount injected before leakage are registered.
- The presence of associated pathologies, including mucosal prolapse, rectocele, rectoanal intussusception and excessive descent of the ARJ are also registered.

Diagnostic Criteria: most common findings associated with faecal incontinence include (a) **inability to retain the contrast material**, also called *barium loss* signs, with or without awareness of it. This is graded as minor (+) when it occurs only with the patient seated during coughing and/or straining forcefully, moderate (++) when it occurs during tilting the table upright or sitting at rest and straining minimally, and severe (+++) when it occurs with the patient still lying during retrograde injection; (b) **lack of apposition of anal walls** at rest, also called *anal gaping*, leading the contrast medium to fill the anal canal, which shows a mean transverse diameter ≥ 10 mm as a sign of incompetence; (c) **abnormal rectal size**, i.e., > 7.5 cm in case of rectal inertia and faecaloma or < 4 cm in case of overactive hyper-reflective ampulla; (d) **poor squeezing and stop test**, seen as inability or fatiguing when asked to actively contract the pelvic floor musculature and anal sphincter ; (e) **obtuse ARA°** at rest $> 116^\circ$; (f) **associated abnormalities** such as (1) descent of the ARJ > 4 cm below the ischial tuberosities; (2) full-thickness rectoanal intussusception (Figure 6a and b), defined as an intraluminal filling defect

> 1 cm in diameter, showing distal progression on evacuation; (3) rectocele, defined as any bulging of the anterior rectal wall greater than 2 cm beyond the expected line extending upward through the anterior margin of the anal canal.

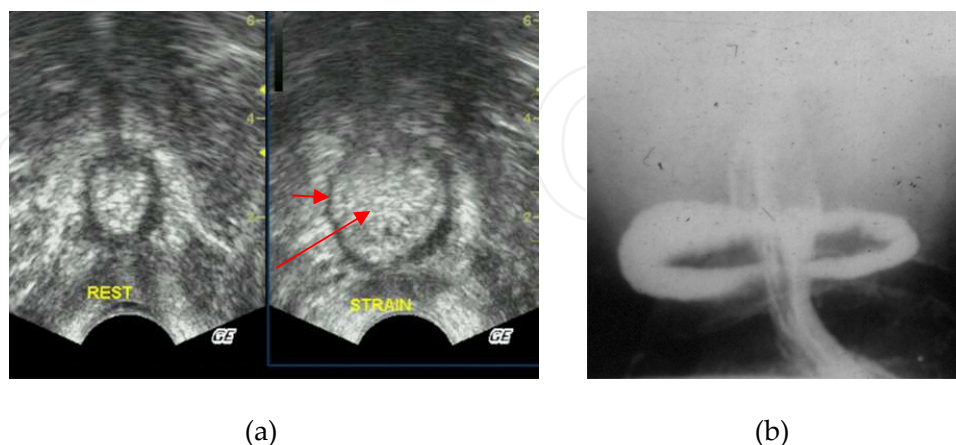


Figure 6. Sixty-two year-old woman under pharmacological treatment for psychological depression, with history of obstetric trauma, chronic constipation and episodes of passive fecal incontinence of recent onset. Integrated diagnostic work-up including perineal sonography (a) and defecography (b) within the same session: at sonography, thinning of the internal anal sphincter (short arrow) on straining and significant increase of the submucosal space (long arrow) suggestive of full-thickness intussusception. At defecography, involuntary barium loss during retrograde injection (not shown) and evidence of rectoanal intussusception with typical “Saturn’s ring” sign due to entrapment of contrast on emptying within the double layer mucosa infolding.

Diagnostic Accuracy: the “barium loss” sign occurring at rest has been found [22] to be at the receiver operating curve (ROC) analysis a highly reliable index of faecal incontinence (specificity 93-100%, intraobserver agreement K value 0.82, Z 21.58, $p < 0.001$) with a false-negative rate of 14.2% limited to patients with minor episodes of incontinence only. Useful adjunctive criteria include an anal diameter > 10 mm at rest and a poor stop test. Additionally, irrespective of age, gender and associated abnormalities, namely rectal prolapse, the resting ARA° measurement could reliably be reinterpreted and allowed for good differentiation between continent and incontinent subjects [23]. More precisely, it was found to be the most discriminating index at ANOVA by Fisher’s test ($104.5^\circ \pm 10.3$ vs $116.2^\circ \pm 23.6$, F 9.4, $p < 0.01$), with an accuracy of 79%, false-positive rate of 15.3% and false-negative rate of 26.5%. Abnormal rectal size and filling sensation (altered compliance) and rectoanal intussusception (obstructed defecation syndrome) helped the clinician in the search for an aetiologic diagnosis.

4. Magnetic resonance

Several studies have used static and dynamic high-resolution MR imaging to assess pelvic organ prolapse and anal sphincter derangements [24-30]. Without the hazard of ionizing radiation, this technique provides excellent depiction of the anal sphincter complex and all perianal spaces, including a multiplanar global evaluation of fat recesses, ligaments, fascial attachments and the pelvic floor musculature. As such, MR imaging is preferable in young

persons who are in their reproductive age. In addition, the development of fast sequence imaging since the early 90s has allowed for also including the assessment of voiding and evacuation phenomenon, leading to the so called MR-defecography as an alternative to the conventional (X-ray) examination. A potential disadvantage of MR, when compared to D, is its less physiologic nature, because the examination is usually performed with the patient supine. On the other hand, it provides superior reproducibility when measuring the parameters of anorectal configuration [31, 32].

Imaging Technique: in our centre, MR imaging is routinely performed in subjects with faecal incontinence with a conventional 1.5 T horizontally-oriented magnet system (Philips, Achieva model, The Netherlands), using an external body SENSE and a four-channel phased array coil wrapped around the patient's pelvis. In order to depict the morphology and quantify the thickness of the sphincter complex free from distortion, a flexible rubber catheter 3 mm in diameter is inserted at the beginning through the anus to act as a luminal marker and for subsequent contrast administration (acoustic gel). Static T2-weighted images of the pelvic region are acquired first in the sagittal plane using fast spin echo (FSE) pulse sequence (TR/TE, 3704/90 ms; FOV, 32 cm; slice thickness, 4 mm; interslice gap, 0.6 mm; ETL, 18; matrix size, 444x310 ; BW, 125.24 kHz; NEX, 4; FA°, 90) so as to define the field of view and put into focus the intra-anal marker. Subsequent axial and coronal images of the anal sphincter complex and pertinent perianal anatomy are acquired with the same pulse sequence and sections obtained parallel and transverse to the long axis of the anal canal. Thereafter, without interruption during scanning or patient movement, up to 160 mL of acoustic gel is slowly injected via the catheter by the examiner unless early leakage of contrast occurs. After probe withdrawal and proper patient coaching, dynamic images are obtained at rest, on squeezing, maximal straining and emptying in the midsagittal plane using a T1-weighted, balance fast field echo (BFFE) pulse sequence (TR/TE, 2.8/1.39 ms; FOV 300x300; section thickness, 30 mm; BW, 125.0 kHz; matrix size, 160x 160; acquisition time, one image/0.891sec over 48 sec; NEX, 2). The same sequence is then repeated during evacuation in the coronal plane centred over the anorectal junction. Finally, three parallel, contiguous 1-cm-thick sections, using the same pulse sequence (TR/TE, 3/1.51 ms; NEX, two acquisition time, nine sec) are obtained in the axial plane starting at the upper margin of the pubic symphysis down to the level of the anal margin to image the levator hiatus during the Valsalva manoeuvre in a steady state.

Image Analysis: key images for interpretation of the anal sphincter complex anatomy are those obtained in the midcoronal plane (Figure 7), which allows for good distinction between the innermost muscle layer of the internal anal sphincter showing intermediate signal intensity and the outer low signal intensity layer of the external sphincter. The latter also shows a characteristic shape, i.e., at its lower end it is seen to fold inward and upward to form a double layer leaving space to the terminal fibres of the longitudinal muscle, while at its upper and outer margin a cleft is clearly visible, which separates it from the puborectalis muscle. Coronal sections obtained slightly anterior and posterior to the midplane offer good depiction of the urogenital diaphragm, superficial and deep perineal muscles, ischiocavernosus muscle and levator ani muscle, respectively. In the axial plane, the internal sphincter is a ring-like hyperintense structure surrounded by the hypointense external sphincter with the interposition of

the relatively hyperintense intersphincteric space; key images for interpretation are those taken at the midportion of the anal canal where the two halves of the external anal sphincters become connected to each other. In the midsagittal plane, the anococcygeal ligament connects the external sphincter to the coccygeal bone and separates the superficial from the deep post-anal plane. Anteriorly, the puborectalis muscle and the bulbocavernosus muscle are seen to support the external sphincter. Overall, the anal canal shows a cylindrical appearance, averaging 5.7 cm in length with a mean thickness of 2.3 mm for the internal sphincter, 1.3 mm for the longitudinal muscle and 3.4 mm for the external sphincter. The anal sphincter's MR *signal intensity* is also given great relevance and compared to that of the obturator internus muscle, being described as the same (normal), higher (fibro-fatty degeneration) or lower (scarring). MR image analysis of the whole pelvis also includes (a) measurement of the width of the levator hiatus in the axial plane on straining at the point of its maximum extension at the level of the bladder neck and proximal urethra. For this, a contour tracking technique, allowing for anatomically adapted and automatically placed region of interest (ROI) is employed. A hiatal area of less than 25 cm² on Valsalva is reported to be consistent with normal pelvic support; (b) evaluation of pelvic organs' mobility in the midsagittal plane on Valsalva, by calculating the vertical distance of the bladder base, the cervix or vaginal cuff and the rectal floor from the pubococcygeal line (PCL) drawn from the lower border of the symphysis pubis to the last joint of the coccyx. According to Fielding, [28] pelvic organ descent beyond this line should not exceed 1 cm; (c) measurement of the levator plate angle (LPA) relative to a horizontal reference line; average values of 44.3° are reported [29] in women with normal support.

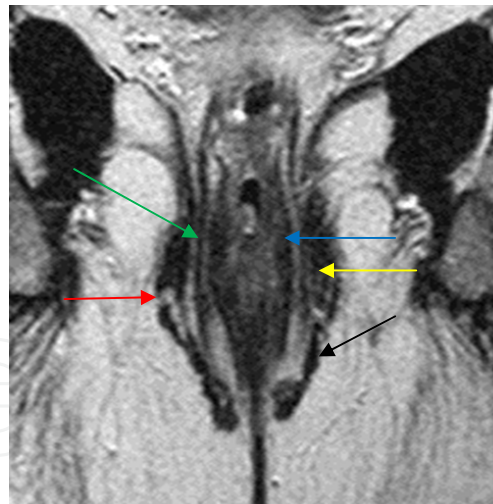


Figure 7. Forty-eight-year-old man with prior fistulotomy (red arrow) and no evidence of fecal incontinence. Postoperative mid coronal T 2-weighted MRI with external coil showing preserved integrity of the sphincter complex including the internal sphincter (sky-blue arrow), the external sphincter (black arrow), and the longitudinal muscle (green arrow). Incidentally, focal areas of increased signal intensity are observed within the puborectalis muscle (yellow arrow) consistent with fibrofatty degeneration.

Diagnostic Criteria: the MR diagnosis of anal sphincter derangement in faecal incontinence is two-fold and relies on: 1) a < 2 mm thinning of the internal anal sphincter for age > 50 years, which is considered consistent with **degeneration** of the muscle and responsible for passive

faecal incontinence; 2) disruption of the sphincteric ring with or without loss of striated muscle bulk and fat replacement, which are typical findings of external sphincter **tears and atrophy** most often associated with childbirth trauma, incisional surgery and dilatation procedures. Occasionally, degeneration and atrophy concur to maintain faecal incontinence even after surgical implant of bulking agents (Figure 8a and b). In symptomatic patients, pelvic organs descent greater than 2 cm below the PCL (Figure 9) is considered an indication of **pelvic floor laxity**, requiring surgical intervention. More precisely, quantification of **pelvic organ prolapse** by MR imaging has been classified [25] as mild if the vertical distance from the PCL on maximum straining extends for less than 3 cm (grades 1-2 of the Baden-Walker classification), moderate if it is between 3 and 6 cm (Baden-Walker grade 3) and severe if it exceeds 6 cm (Baden-Walker grade 3-4). Further characterization of the dysfunction and evidence of pelvic organ impingement (Figure 10) can be derived from a levator **hiatus area** of 30-34.9 cm² (mild), 35-39.9 cm² (moderate) and ≥ 40 cm² (marked ballooning), respectively [15]. Furthermore, with respect to controls, women with prolapse have been reported [11] to exhibit a significant + 21% **more vertical levator plate** with average LPA° of 53.4° vs 44.3°. Most common associated abnormalities seen during the expulsion of rectal contrast include **rectocele**, which is classified as mild when its protrusion from the expected anterior rectal wall is less than 2 cm, moderate if 2-4 cm and severe if greater than 4 cm, as well as **intussusception**, which is termed intrarectal (grade 1) when it remains within the rectum, intra-anal (grade 2) if its apex penetrates the proximal half of the anal canal, intra-anal (grade 3), if the apex is seen to impinge on the distal half of the anal canal and external (grade 4) if it is extruded outward.

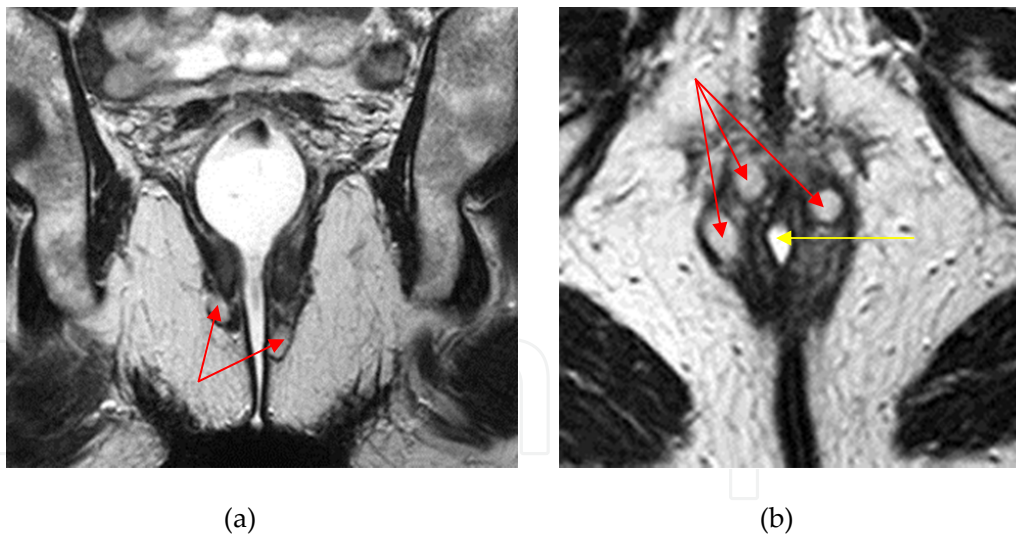


Figure 8. MR- defecographic images obtained in the coronal (a) and axial(b) plane in a sixty-one-year-old woman with persistent fecal incontinence after multiple gate keeper implants (red arrows) for degeneration of the internal sphincter and atrophy/disruption of the external sphincter: involuntary loss of contrast and lack of anal wall apposition (yellow arrow).

Diagnostic Accuracy: despite their limited availability, endoanal MR coils have been used as an alternative to EAUS with comparable results for detection of anal sphincter defects and a clear superiority of MRI for EAS atrophy [33, 34]. However, high-resolution MRI using external

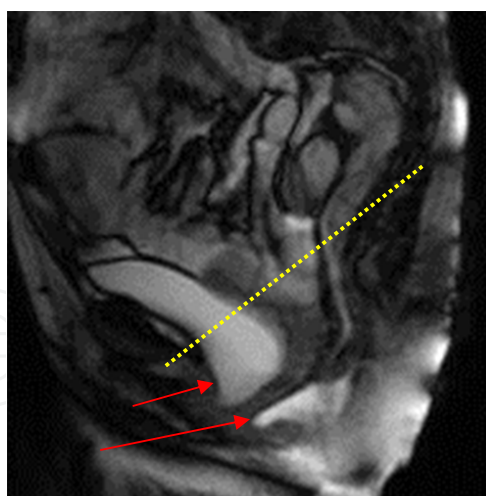


Figure 9. Mid- sagittal MR-defecographic series with BFFE T 1-weighted pulse sequence: excessive descent of the bladder base (short red arrow) and rectal floor (long red arrow) on straining below the pubococcygeal line (yellow dotted line) due to pelvic floor laxity in a thirty-one year-old woman with chronic strain at stool and staining episodes.

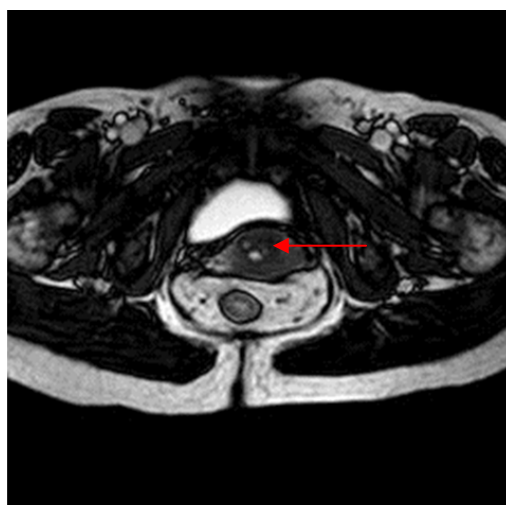


Figure 10. Dynamic MR- defecography in the axial plane at the level of the lower margin of the symphysis pubis: ballooning of the levator hiatus with impingement of the uterine cervix (red arrow) between the prolapsed bladder base, anteriorly and the anorectum, posteriorly.

phased-array coils in patients with faecal incontinence has the advantage of simultaneously providing both structural and functional information on the pelvic floor structures and anal sphincter complex. In our experience, the potential advantage of this technique is highlighted by its ability to be as accurate as EAUS in detecting structural changes of the sphincteric such as tears, atrophy and areas of focal degeneration and disruption, together with offering contemporary evidence of functional derangements including an inefficient anal closing mechanism with involuntary loss of rectal contrast and pelvic floor laxity. Until now, however there has been no mention of comparative studies of external coil MRI with EAUS and endoanal MRI in faecal incontinence published in the literature.

5. Clinical application of diagnostic imaging in faecal incontinence

From a practical point of view, one may consider the application of imaging studies to be worth pursuing in at least three situations as follows:

- a. Following surgical pelvic floor reconstruction in the neonatal period for congenital anomalies such as anal atresia, imperforate anus, bicornuate uterus, persistent vaginal septum and associated urologic or sacrococcygeal anomalies, male and female subjects are at increased risk for developing faecal incontinence in adult life [35], particularly on physical exertion, heavy work activity or in case of pregnancy. Usually, because such patients are infants when operated on, it often takes many years before full evaluation of results for a given anomaly can be given. Today, when considering long-term results of surgery with regard to anorectal adequacy and continence, we are looking for more than operative survival or a complication-free postoperative course. In an attempt to assess the patient's function or adjustment to his/her disability, a complete imaging investigation [36] is highly recommended, including EAUS and pelvic MRI: these two noninvasive diagnostic tools permit clear depiction of postoperative pelvic floor anatomy and detection of even subtle sphincter derangements that might interfere with future activities.
- b. Damage to the anal sphincter from vaginal delivery is a common cause of faecal incontinence in middle-aged women. The muscle tears, which may involve one or both parts of the sphincter, are situated consistently in the anterior quadrant. After vaginal delivery, women have typically been reported to undergo anal sphincter tears in between 0.36% and 8.4% of cases [17], even though small anal sphincter defects and minor gas incontinence are also occasionally found in nulliparous women without known sphincter trauma. However, only one third of these women will develop faecal incontinence and only of a minor degree, despite being treated with primary sphincter repair soon after delivery. Flatus incontinence after vaginal delivery is also described to be more common in women with sphincter disruption compared to those who received an episiotomy or a caesarean section (58.6%, 30.3% and 15.2%, respectively). While the use of EAUS from one day to six months after childbirth is mainly focused on the detection of sphincter disruption, MR imaging is better suited to quantify systematic changes occurring in the levator ani muscle (LA), including focal areas of increased signal intensity (i.e., fibrofatty degeneration), reduced thickness, LA muscle avulsion and tears, detachment from the endopelvic fascia and perineal body disruption and descent. All of these are considered to be highly correlated with the development of pelvic organ prolapse (POP) and double incontinence after the fifth decade.
- c. Patients who are about to undergo *elective anorectal surgery* with major procedures such as total colectomy and ileo-anal anastomosis (ulcerative colitis, familial polyposis), low coloanal anastomosis (rectal tumour), or more common procedures such as haemorrhoidectomy, fistulectomy, rectopexy and rectocele repair (prolapsed haemorrhoids, anal-perianal sepsis, intussusceptions and rectal prolapse) are potential candidates for developing faecal urgency and becoming more or less incontinent to faeces after surgery. This can occur for two reasons: mainly a reduced rectal reservoir function and/or anal

sphincter injury. In particular it should be noted that the internal sphincter muscle fibres, which contribute about 80% of the resting anal tone, are usually adhered to and easily dragged up with haemorrhoidal tissues during haemorrhoidectomy, leading to frequent episodes of post-operative mucous discharge and passive incontinence unless a substantial amount of vascular cushions and bridges of anoderm are preserved [37]. With regard to perianal sepsis, the overall incidence of major faecal incontinence after surgical management of complex fistulas is estimated at approximately 7%. While no effect is generally noted on continence in patients treated for low fistulae, minor incontinence can occur in up to 33% in patients in whom the sphincter muscle is divided after two-stage fistulotomy or cutting using the seton technique. Regardless of the pathology and the procedure being used, the patient's sphincter adequacy should be carefully assessed before and after surgery. A combination of EAUS, D and pelvic MRI study is needed to rule out a number of abnormalities such as anal sphincter defects, dehiscences, sinus tracts and abscesses, granulomas, strictures of the anastomotic ring, small uncompliant (neo) rectum and anal gaping.

6. Algorithm and integrated diagnostic work-up

EAUS is the most important imaging test to start with and to provide information about the morphology of a potentially disrupted sphincter. As a second step, in order to select patients for sphincteroplasty, an MRI with an external coil will help to identify focal areas of atrophy and fat replacement of the anal sphincter complex, which US tests does not identify. MR defecography is also an unsurpassed modality for depicting associated abnormalities such as pelvic organ prolapse, intra-anal intussusception, rectocele, pelvic floor weakness and pudendal nerve neuropathy. Finally, D is occasionally useful for sorting out overflow faecal incontinence and/or hyperactive, uncompliant rectal ampulla. For better patient compliance and quicker diagnostic algorithm, in the presence of adequate expertise and instruments, it is technically possible to perform a complete and integrated imaging investigation, i.e., EAUS + MR \pm D, within the same session in less than one-hour, as follows:

1. 2D or 3D EAUS is performed first for proper detection and staging of any anal sphincter damage. For the examination, the patient lies on his/her left side. The lubricated probe is gently inserted into the rectal ampulla for acquisition of the images from the volume of interest. Average time to complete the examination is between 10 and 15 minutes, which includes patient preparation and positioning, image acquisition, interpretation and reporting.
2. The patient is then moved into the MR imaging diagnostic room to undergo both static and dynamic pelvic floor examination with external coil. Usually, after coaching the patient and full explanation of the finality of the examination, a standard dose of contrast (acoustic gel) is administered. Average time for the examination, image interpretation and measurements of recognized parameters is between 25 and 30 minutes.

3. If necessary, the patient is then positioned horizontally on the X-ray table of a remote controlled diagnostic unit to undergo D, which includes (a) radiopaque contrast administration and tilting upright after probe withdrawal under continuous fluoroscopic control; (b) positioning seated on a specially designed commode; (c) image acquisition and recording in the lateral and anteroposterior plane. The required average time is 10 minutes.

7. Reporting

All reports on imaging techniques should specify the position of the patient during image acquisition as well as the performance of specific manoeuvres according to the examiner's demand. When using ultrasonography, detailed information is given concerning the transducer type, orientation and route of scanning; for magnetic resonance imaging, specifics of the technique include the equipment used, plane of imaging, pulse sequences, scan time, use and type of contrast, measurements and parameters during image analysis. Static and dynamic contrast radiography should include a description of the type, timing and amount of contrast administration and sequence of organ opacification, projections and exposures. Finally, a short and concise list of the abnormalities observed is included, followed by the most likely hypothesis of the (possible) mechanism responsible for the disease and suggestions regarding further investigation.

8. Combined non-imaging studies

Traditionally, anorectal manometry [38], i.e., calculation of the longitudinal pressure profile of the anal canal and, more recently, anal vector volume analysis [39] have received great consideration in the diagnostic work-up of faecal incontinence, being simple and relatively cheap procedures that help to indicate the exact location of any focal reduction in pressure along the course of a disrupted anal sphincter. More particularly, the validity of anal pressure vectography [40] should be emphasized in combination with EAUS or endoanal magnetic resonance [41], since it allows for evaluation of the radial pressure in the anal canal from which a symmetry index can be obtained that more closely reflects the functional relevance of any proven defect in anatomical integrity. However, factors other than anal sphincter muscles contributing to the pressure generated within the anal canal, such as the puborectalis muscle, should also be considered as a possible cause of incorrect vectorgram. Besides providing data on the responsibility of the internal and external anal sphincter in causing faecal incontinence, anorectal manometry is useful for demonstrating a reduced capacity and compliance of the rectum, as well as a reduced sensation and reflex activity of the anorectum, by correlating findings of the pressure profile with those from defecographic series. On assessing patients with possible neurogenic aetiology of their incontinence, electrodiagnostic tests should be considered [42], including electromyography (EMG) and a pudendal nerve terminal motor latency (PNTML) test. By EMG, the electrical activity arising in the external anal sphincter and

puborectalis muscle at rest, straining and during voluntary contraction is recorded and measurements are performed of the amplitude, duration and number of phases of motor unit action potentials, with inference on the innervations and functional state within the muscle. PNTML, on the other hand, evaluates conduction time in the motor nerve fibres of the pelvic floor musculature by recording the time interval from nerve stimulation to the onset of the electrical response in the muscle. Most common changes in EMG activity include denervation, which leads to loss of responsiveness and atrophy of the affected fibres and reinnervation occurring either by regrowth of the damaged axons or by sprouting of nearby unaffected axons, with a tendency for fibres to be clustered together in small groups; this change in spatial distribution will lead to a variation in the amplitude and duration of motor unit action potentials recorded by EMG. While denervated muscle fibres may show spontaneous activity at rest, evidence of reinnervation is offered by an increase in motor unit potential parameters. At PNTML, a prolonged latency has been reported in faecal incontinence, obstetric trauma and perineal descent; this parameter was also proposed as a predictive factor for the clinical outcome of biofeedback therapy or surgical repair, despite it being less sensitive for showing anal sphincter denervation when compared to needle EMG and a lack of correlation with manometric pressure studies. Finally, somatosensory evoked potentials (SEPs) and mucosal sensitivity (MS) to thermal or electrical stimulation of the anal canal have been proposed to reveal a lesion affecting the large-diameter nerve fibres in patients with suspected sensory deficit in the perineum and measuring anal sensation, respectively. Magnetic resonance imaging of pudendal nerve [43] is the only diagnostic tool that has been described as potentially useful in patients with positive electrodiagnostic test results.

9. Conclusions

Until some decades ago, the major examination method for patients with faecal incontinence has relied on history taking, physical inspection and digital examination. Most commonly, questioning about the nature of incontinence (passive vs. urgency) is the initial diagnostic step that helps to further delineate various causes. Passive incontinence usually indicates a defect in sphincter muscle integrity, loss of sphincter innervation with pelvic floor laxity, or decreased rectal sensation. On the other hand, urgency followed by incontinence is most frequently associated with a problem concerning rectal compliance due to colitis, prior surgery or radiation. Today, Diagnostic imaging is more and more frequently considered in subsequent evaluation, with important therapeutic implications.. A firm understanding of factors contributing to the image is helpful in the performance of the examination, but is also essential for accurate interpretation. EAUS is mandatory for detection of anal sphincter defects. Thereafter, static and dynamic pelvic MRI with external coil is an integral part of the investigation for assessment of associated pelvic floor disorders and better characterization of sphincter atrophy. D is occasionally useful to offer objective documentation of the inability to retain rectal content. Although many aspects of faecal incontinence remain obscure, imaging studies may contribute to patient management and clinical decision-making.

Acknowledgements

The authors are especially indebted to Mrs A. Donzelli, English language teacher, for her assistance in reviewing the manuscript and to Dr U. Favetta, surgeon, for providing some of the illustrations.

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