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Research Article

Biphasic MRI Examination of Fecal Incontinence with External Coil: Technique and Clinical Applications

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Abstract

Purpose: To describe a standard MRI examination of the pelvis by which the radiologist can contribute to the diagnosis and therapy planning of patients with fecal incontinence

Method: Between April 2017 and May 2019, seventy-seven females (86%), mean age 57 ± 14.4 years, range 12 - 81 and thirteen males (14%), mean age 56 ± 14.3 years, range 30 - 79 with fecal incontinence underwent bi-phasic MR-defecography with external coil and 1.5 T Magnet, as follows: Phase I (static) to depict the anatomy of pelvic floor structures; and Phase II (dynamic) to document their changes under the effect of various maneuvers, including squeezing, straining, rectal emptying and interrupting the stream of contrast (stop test). Images were analyzed for evidence of (a) anal sphincter defect; (b) laxity of pelvic floor musculature and anorectal abnormalities; (c) low rectal compliance

Results: Patient's coaching during the preliminary interview helped obtaining a uniform performance of the protocol in less than 30 minutes and optimal image quality in all cases. Based on their prevalent etiology, subjects were classified to be incontinent as result of evacuation dysfunctions (53%), obstetric injury (48%), anorectal surgeries (34%) and chronic assumption of psychopharmaceuticals (13%). At imaging, an involuntary loss of rectal contrast (61%), anal sphincters defects (52%), pelvic floor laxity (46%), and low rectal compliance (37%), alone or in combination, were the most relevant changes. The results of the examination contributed to therapy planning in over half the cases.

Conclusion: MR-defecography can play a significant role to clarify the mechanism by which fecal incontinence develops in singular cases.

Keywords: *Fecal Incontinence; Anorectal Surgeries; Obstetric Trauma; MR Defecography; Imperforate Anus; Evacuation Dysfunctions*

Introduction

Fecal incontinence (FI), defined as recurrent failure to control the passage of stools and/or flatus in subjects over 4 years of age [1], is a condition of great economic and personal impact on both the affected people and the health care system. The disorder is usually classified as "functional" in case of normally innervated and structurally intact muscles or disordered bowel habits (fecal retention or diarrhea), and "organic" when it is associated to a number of disorders including diabetic or pudendal neuropathy, connective tissue diseases, surgical sequela, radiotherapy, inflammatory bowel diseases (IBD), malabsorption syndromes, and rectal prolapse. An explicit description of all causative anatomic abnormalities, pathophysiology and clinical variants of fecal incontinence is beyond the scope of this paper. Readers interested in a detailed discussion of these topics are referred to the excellent review article by Ahmad., *et al.* [2], the one by Wald [3] and to a recent monographic publication by Catto Smith [4]. As far as the issue of the diagnosis is concerned, after history taking and complete rectal examination, anorectal manometry and three- dimensional (3- D) endoanal ultrasonography (EAUS) are usually performed as part of an established diagnostic work-up [5]. Until recently, magnetic resonance imaging (MRI) has been limited to singular cases with use of endoanal coils [6-9], mainly to reinforce the diagnosis of atrophy and degeneration associated to anal sphincter defects. It can be argued, however, that endocoil MR imaging has even less availability than EAUS, while sharing the same limitation of not offering a global display of all other factors which normally ensure fecal continence, including rectal compliance and pelvic floor musculature, to name a few. Moreover, an important drawback of both techniques is that they do not provide a real time depiction of the involuntary passage of rectal content, thus failing to give objective evidence of the dysfunction.

The aim of the present article is to highlight the use of an external coil connected to a conventional 1.5 T MR magnet for the routine investigation of fecal incontinence, so as to develop a standardized diagnostic imaging protocol in less than 30 minutes. Thanks to the great ease of the method and its superior ability to offer an estimate of the multiple causative abnormalities of the disorder, the ultimate scope of the current paper is to encourage physicians to consider it for proper therapy planning in various common and less common clinical applications.

Methodology

Description of the Protocol

Patient interview

Careful history taking and preliminary interview with patients in the waiting room (average time 7 minutes) are of paramount importance to the radiologist so as to tailor the examination to singular cases. Besides obtaining direct information on symptom's onset and characteristics, medical records and details on treatments, if any, this step is crucial to inform patients of the need for insertion of a small catheter inside the anal canal for contrast administration and to obtain their cooperation during the performance of various maneuvers, such as squeezing, straining and emptying on the diagnostic table. In addition, patients are reassured on the use of a disposable paper apron to maintain dignity together with an absorbent pad positioned under the exposed buttocks to collect any material during the examination.

Imaging technique

After keeping a trolley equipped with all necessary instruments and supplies inside the area of the diagnostic room, patients are helped by a nurse of the staff to lie on the diagnostic table in the left lateral position (Sims position) so as to obtain a relaxed and comfortable attitude while adjusting an unlocked water proof pad beneath the buttocks; then, a lubricated three-mm-diameter soft rubber catheter is gently inserted into the anal canal to serve as anatomical marker and subsequent contrast administration. Thereafter, patients are turned supine and a high resolution, surface phased-array coil is wrapped around the pelvis to start the MR imaging study (Siemens Aera, 1.5 T magnet, Herlangen, Germany), as follows:

Phase I (static): A localizer scout scan is performed in the three planes using a half fourier single shot turbo spin-echo (HASTE) pulse sequence with imaging coverage from the sacral promontory (top) through the perianal skin (bottom) to mark the boundaries of the region of interest (ROI) and the anorectal junction centered in the midline. Shared parameters common to all planes include 3.83/1.92 ms TR/TE; 6 - 7 mm section thickness; 400-mm field of view (FOV); 54 - 70 flip angle (FA°); 256 x 156 matrix, two averages and 14 - 22 images. After this, the pelvic anatomy is depicted at rest with high resolution images obtained in the sagittal plane using turbo spin-echo (TSE) T2-weighted pulse sequence. Then, taking the intra anal marker as reference, the sequence is repeated in the axial and coronal oblique planes obtained perpendicular and parallel to the long axis of the anal canal, respectively (Figure 1A and 1B). Occasionally, in case of suspected pudendal nerve neuropathy, a T2 double inversion recovery dark blood (DB) pulse sequence is also obtained in the axial oblique and coronal oblique planes.

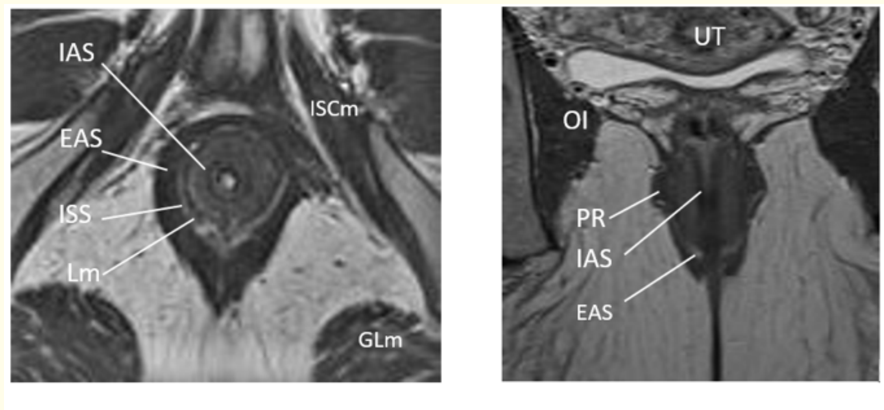

Figure 1: *Phase I MR defecography. (A) Axial T2-weighted turbo spin-echo (TSE) MR image. Section obtained through the middle part of the anal canal showing the intermediate signal intensity of the internal sphincter (IAS), compared to the low signal intensity of the external sphincter (EAS); the low signal intensity longitudinal muscle layer (Lm) is also well displayed, embedded into the high signal intensity of the intersphincteric space (ISS). In the coronal plane (B), the typical indentation of the outer margin (arrow) allows distinction between the puborectalis muscle and the deep portion of the external sphincter. IAS: Internal Sphincter; EAS: External Sphincter; ISS: Intersphincteric Space; Lm: Longitudinal Muscle; ISCm: Ischiocavernosus Muscle; GLm: Gluteus Maximus Muscle; OI: Obturator Internus Muscle; UT: Uterus; PR: Puborectalis Muscle.*

Phase II (dynamic): After patient withdrawing from the gantry opening and no need to alter his/her supine position relative to the diagnostic table, contrast administration (acoustic coupling gel) is started via the previously positioned catheter until a characteristic desire to evacuate is experienced by patients (normal rectal capacity, 200 - 250 mL). In case of anticipated filling sensation, urgency, discomfort or involuntary loss, the injection is interrupted and the total volume injected before leakage, as well as the volume leaked are registered. At this point, the residual volume of contrast is used to depict the dynamic behavior of the anorectal junction in the sagittal, coronal and axial planes during the performance of various maneuvers, as explained in advance. More particularly, patients are firstly instructed to contract forcefully their pelvic floor musculature and anal sphincters while a fast gradient echo (GRE) pulse sequence imaging is obtained in the midsagittal plane (Figure 2) so as to depict the upward displacement of the anorectal junction and register the endurance of contraction. Thereafter, he/she is asked to start rectal emptying and just give notice of it by pushing an acoustic device to allow simultaneous acquisition of images in the same plane over a complete time cycle of 60 seconds. The latter sequence is repeated in the coronal oblique plane centered over the anorectal junction using the maximum stream of contrast in the midsagittal plane as reference, while the patient is expelling the residual rectal content. Finally, three horizontal sections are selected in the axial plane relative to the pubic bone to image the levator ani hiatus while patients perform a "steady-state" Valsalva maneuver without interrupting it for nine seconds, as follows: upper section at the level of midsymphysis; middle section at the level of symphysis's inferior border; and bottom section at the point of maximum bulging of the anterior rectal wall. A complete summary of the imaging parameters used is presented in table 1.

Image analysis and diagnostic criteria

MR series are systematically analyzed for evidence of one of the following four categories of abnormalities, considered alone or in combination:

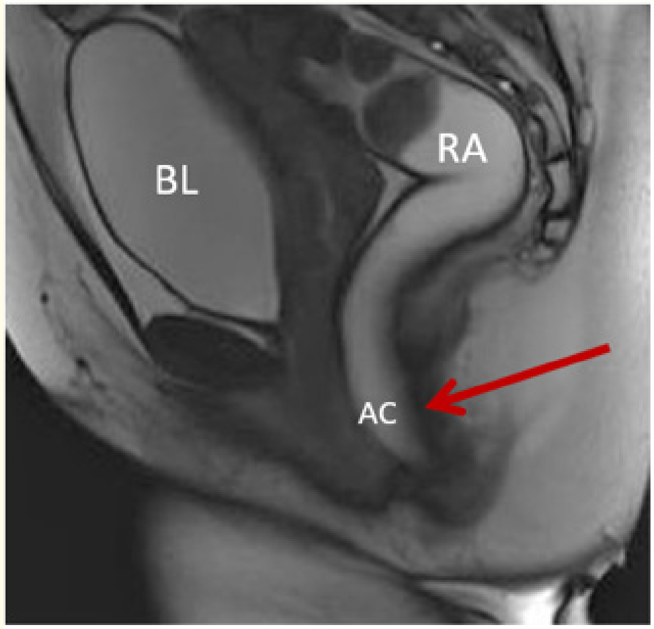

Figure 2: *Phase II MR defecography. GRE pulse sequence obtained in the midsagittal plane during patient's attempt to interrupt the stream of contrast (stop test) by active voluntary contraction of pelvic musculature (arrow). BL: Bladder; RA: Rectal Ampulla; AC: Anal Canal.*

Phase	**1st Static**			**2nd Dynamic**		
Type	Series 1	Series 2	Series 3	Series 4	Series 5	Series 6
Pulse Sequence	T2-W TSE	T2-W TSE	T2-W TSE	GRE	GRE	GRE
Plane	Sagittal	Coronal oblique	Axial oblique	Sagittal	Coronal oblique	Axial
TR (ms)	3880	4400	4810	3.80	3.77	3.77
TE (ms)	91	57	58	1.58	1.53	1.53
ETL	17	15	15			
NEX	1	1	1	60	60	60
FOV (mm)	260	340	350	380	380	380
Acq. Matrix	384x384	321x384	408x448	378x448	340x448	340x448
Slice thickness (mm)	4.0	3.0	4.0	10.0	8.0	8.0
Flip angle (°)	150	150	150	70	70	70
Scan time (min)	4.33	2.58	3.24	1.10 1 im/1.1 sec	1.03 1 im/1.1 sec	1.03 1 im/1.1 sec
Slices (n°)	36	46	45	1	1	1

Table 1: *Technical setting for biphasic MR defecography in patients with fecal incontinence by 1.5T horizontally oriented magnet and external coil.*

Loss of contrast

The involuntary loss of rectal contrast occurring during retrograde filling, combined with anal diameter >10 mm, posterior anorectal angle (ARA) at rest > 116.2° ± 23.6, and inability to interrupt the contrast stream (poor stop test), have been reported by us in previous reports [10-12] to play a key role for the diagnosis of fecal incontinence (diagnostic accuracy > 80%, specificity > 90%, false negate rate 14.2% limited to patients with minor episodes only). The amount of contrast leaked in the present population ranged between 20 and 70 mL, and the contrast injected at the time of first leak varied from 70 to 210 mL. The involuntary loss of contrast occurred in 61% of our population.

Anal Sphincter defect

Any discontinuity or disruption of the expected axial ring morphology or longitudinal extent occurring in the internal and the external anal sphincter is considered a defect of integrity (Figure 3). How much of the sphincter has to be lost to lose normal continence, however, is uncertain even though it has been maintained [13,14] that when more than two-thirds is divided, some degree of incontinence will result. Besides this, further characterization of sphincter damage, which is unique to MR imaging, is also made by noting the existence of focal changes in T 2- weighted signal intensity, which are consistent with presence of tear, granulation tissue, fibrosis or fat replacement [15]. Traditionally, the signal intensity of both sphincters is compared to that of the obturator internus muscle and described as being the same (external sphincter), or slightly higher (internal sphincter). Finally, a diagnosis of sphincter atrophy can be advanced in case of reduced muscle thickness.

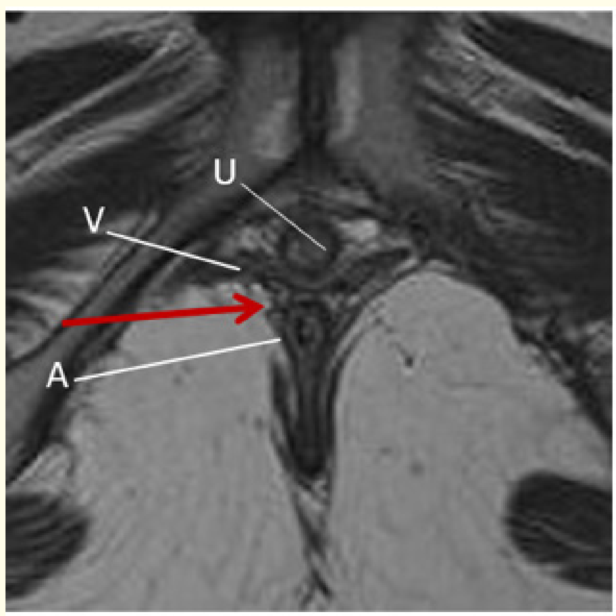

Figure 3: *Axial T2-weighted view of the levator ani hiatus of a 35-year-old woman with fourth-degree obstetric sphincter tear and avulsion of right pubococcygeal muscle. U: Urethra; V: Vagina; A: Anus.*

The use of an external coil and sections obtained parallel and transverse to the long axis of the anal canal make MRI perfectly suitable to depict the internal and external sphincters in exquisite details and detect any defect free from distortion due to foreign objects. Measurements of sphincter thickness on axial images are taken at the level of the upper (midway between the inferior border of the puborectalis muscle and the complete ring of the external sphincter), middle (where a complete ring of both sphincters is seen), and lower anal canal (caudal to the disappearance of the internal sphincter). The reported average values in subjects with intact external sphincter are 4.3 ± 0.85 mm, 4.0 ± 0.68 mm and 4.7 ± 0.93 mm from the high, middle and low anal canal, respectively; and 2.1 ± 0.61, 2.4 ± 0.54 mm from the high and middle anal canal in those with intact internal sphincter. Since the normal internal sphincter is reported to become thicker with age, a thin sphincter < 2 mm in patients older than 50 years and a loss of striated muscle bulk with fat replacement occurring in the external sphincter are central to the diagnosis of atrophy or degeneration, a common finding associated with passive fecal incontinence. Anal sphincter damage of various degree and extent was seen in 52% of our population.

Pelvic floor laxity

Much has been written on the unique ability of MRI to offer direct and global visualization of the abnormal descent of pelvic organs on straining with respect to their resting position [16-21]. In practice, any downward displacement greater than 3 cm relative to established anatomical landmarks and reference lines, including, the hymen plane (female), the line tangent to the inferior border of pelvic bone (male), or the pubococcygeal line (PCL) is virtually synonymous with pelvic floor laxity. This finding, in conjunction with evidence of an increased retrorectal space either at rest or on straining, will lead to a diagnosis of loosened gut posterior fixation (Figure 4). In addition, regardless of gender, a levator ani (LA) hiatus greater than 25 cm^2 on Valsalva axial images has been proven [22] to reflect the failure of the supporting structures to counteract the intermittent and repetitive load of intra-abdominal forces pushing from the above. On axial MR imaging, even small focal defects occurring in the supporting structures, including muscles, ligaments and fat recesses, can easily be detected and graded by comparing the size of the LA hiatus at rest and on straining, as follows: a hiatal ballooning with area of 30 - 34.9 cm^2 is associated with mild laxity, an area of 35 - 39.9 cm^2 with moderate laxity, and an area equal or greater than 40 cm^2 with severe laxity, respectively. In the proper clinical setting, the presence of an associated pudendal neuropathy can be anticipated when the typical increased signal intensity [23] is seen in the nerve along its course in the Alcock canal (Figure 5). Pelvic floor laxity was recognized in 46% of our population.

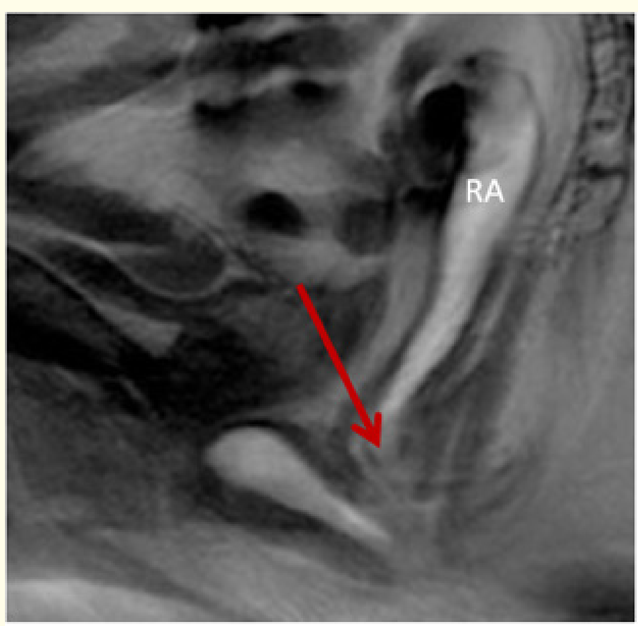

Figure 4: *Intra-anal intussusception (arrow) seen at the end of the emptying phase in a 58-year-old woman with chronic strain at stool and episodes of staining. RA: Rectal Ampulla.*

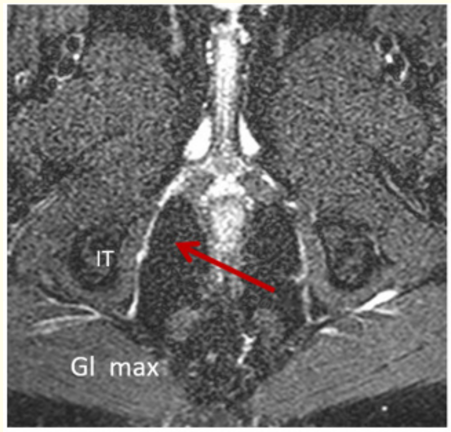

***Figure 5:** T2-weighted, double inversion recovery, fat suppressed, dark blood MR image obtained at the level of Alcock canal, showing typical signal hyperintensity of the pudendal nerve (arrow) consistent with pudendal nerve neuropathy. IT: Ischial Tuberosity; GL max: Gluteus Maximus Muscle.*

Abnormal rectal compliance

Adequate deferral of emptying during progressive rectal filling and ability to postpone an urgent desire to defecate, also known as rectal compliance, is another major factor contributing the maintenance of continence [24]. Various low rectal compliance conditions, including post-irradiated pelvis, proctocolitis and post-operative perirectal fibrosis (Figure 6) may give rise to increased frequency, urgency and incontinence, especially under the effect of powerful propelling contractions from the sigmoid colon. Retrograde injection of acoustic gel during phase II of our MRI imaging protocol provides a sort of artificial stool test which acts as an index of rectal sensitivity and perception to distention, as well as of its reservoir function. Normally, a functional subdivision of the distal hindgut is seen, as follows: a proximal, somewhat fixed sacral part, which follows the curvature of S1-to-S4 spine; a more mobile distal ampullary part, situated intraperitoneally which is endowed with greater distension and collapse capacity; an intermediate part, which is found in between the two, within transverse folds, having a diaphragm-like and telescopic property.

***Figure 6:** MR defecography performed in a 58-year-old man with urge incontinence after failed STARR procedure for obstructed defecation syndrome. Note the small rectal size (red arrow) just above the levator plate (white arrow) due to extensive perirectal fibrosis. PR: Puborectalis Muscle; EAS: External Sphincter.*

An anticipated sensation and urgency combined with rectal diameter smaller than 3 cm at capacity and involuntary loss of rectal contrast, is a common feature of low rectal compliance conditions. This pattern is usually seen at the opposite side of the wide spectrum of abnormal rectal capacitance culminating in conditions characterized by impaired sensitivity and perception associated with rectal size larger than 6 cm, anal gaping and passive loss of acoustic gel, all of which are consistent with idiopathic fecal incontinence. A condition of low rectal compliance was observed in 37% of cases of our population.

Results and Discussion

Clinical experience and results

Ninety consecutive patients (13 males and 77 females; 14% and 86%; mean age, 56 ± 14.3 and 57 ± 14.4 years; age range 30 - 79 and 12 - 81 years, respectively) have been referred to our Diagnostic Imaging Centre between April 2017 and May 2019 to undergo MR imaging examination with the above protocol for symptoms of impaired control of fecal material, whether solid, liquid or gas. Clinical information was obtained by medical chart review from the referring physicians and direct discussion with patients during the preliminary interview, just before starting the examination. Based on their history and major causative factors, the patient population was divided into the following groups, which can be used as a guideline for potential applications of MR imaging in case of known fecal incontinence and risk conditions:

Group 1: Evacuation dysfunctions

Chronic strain at stool as result of various evacuation disorders, leading to weakness of pelvic floor musculature, coexists quite commonly with fecal incontinence. Although more common in females, the symptom was recognized as the primary compliant in 20 cases of our population and the most important associated finding in additional 28 cases for a total figure of 48/90 (53%). While dynamic MRI has became a well established diagnostic tool since 1991 for the assessment of evacuation dysfunctions, its potential role in determining the various anatomical abnormalities responsible for the development of levator ani hiatus enlargement and defects in the endopelvic fascia, has been advanced only recently in the medical literature. Interestingly, as reported recently [22], regardless of gender and parity, levator ani hiatus ballooning, organ prolapse and pudendal neuropathy were common features in our incontinent subjects with long term history of chronic straining at defecation. Occasionally, in patients with intestinal motility disorders and recurrent episodes of diarrhea, the so-called "concertina-like" sigmoid colon is also seen (Figure 7), consistent with powerful propelling contractions which, if not counteracted by adequate rectal compliance, will expose subjects to staining of their underclothes and even episodes of overt incontinence.

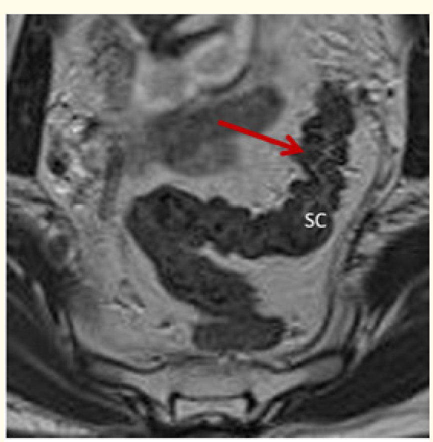

Figure 7: *MR defecography in a 61-year-old woman with urgency and incontinence associated to irritable bowel syndrome and soft motions: note the "concertina-like" shape of the sigmoid colon together with multiple small diverticula (arrow). SC: Sigmoid Colon.*

Group 2: Obstetric injury

Direct trauma to the anal sphincter during episiotomy, application of forceps and/or perineal lacerations are well recognized factors of fecal incontinence. After vaginal delivery, women have been reported to undergo anal sphincter tears in between 0.36% and 8.4% of cases and approximately one third of them will develop fecal incontinence, although only of minor degree, despite being treated with primary sphincter repair soon after delivery. In our population, a child birth related trauma emerged as the single major variable in 24 cases and as the most relevant concurrent factor in 13 additional cases (total, 37/77, 48%). While 3-D ultrasonography, whether by transperineal or endoanal technique, focused on the detection of sphincter disruption remains the first-line imaging choice from day 1 to 30 after childbirth, MR imaging is better suited after month 3 to obtain a global view and systematic quantification of all injuries occurring in the levator ani muscle (LA), ligaments and fascia. Besides depiction of anal sphincter defects of various degree, common findings include also LA muscle avulsion and tears, endopelvic fascia detachment, perineal body disruption and ligament discontinuity.

Group 3 Anorectal surgeries

Post-operative incontinence accounted for 31/90 (34%) in our patient population. This category included patients submitted to elective anorectal surgery and/or pelvic reconstruction for (a) common proctologic complaints such as rectocele and intussusception, prolapsed hemorrhoids and fistula-in-ano disease; (b) low rectal tumor removal, familial polyposis and ulcerative colitis; and (c) anal atresia, imperforate anus and other congenital anomalies [25-29]. Whatever the pathology and the procedure used, such patients are potential candidate to develop fecal urgency and become less continent to feces during the course of their life, particularly on physical exertion, heavy work activity or in case of pregnancy. As such, long-term results of surgery deserve careful assessment with regard to anorectal adequacy and continence. Pelvic MRI, with the above protocol is ideally suited for the scope (Figure 8A-8C), as it permits clear depiction of postoperative pelvic floor anatomy and contemporary detection of even subtle functional abnormalities which might interfere with future patient's activities.

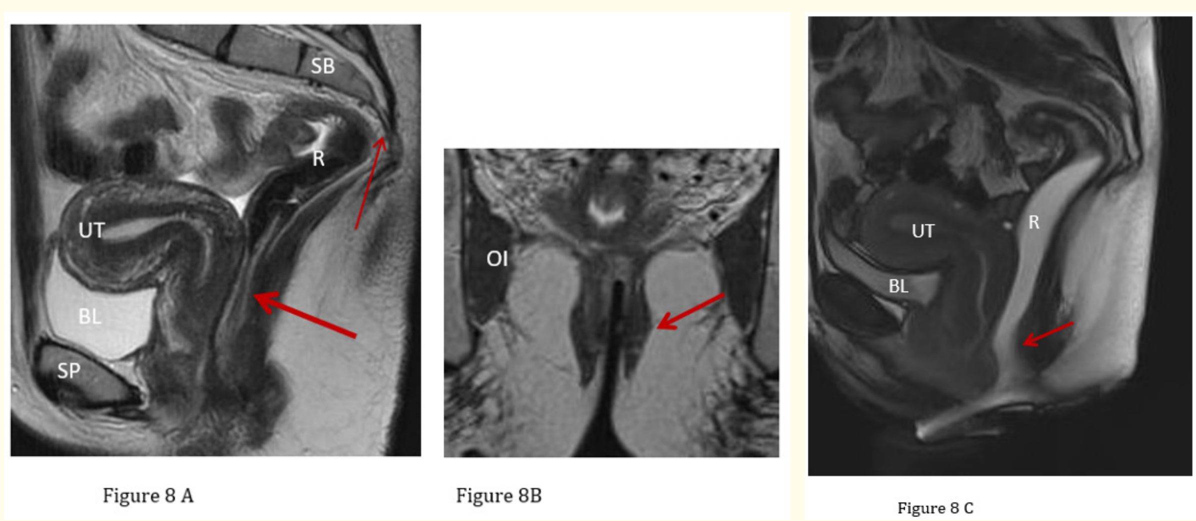

Figure 8: *Long term result of imperforate anus repair in the neonatal age. MR Defecography in a 38-year-old woman with episodes of fecal incontinence. Phase I examination (A) showing the pull-through procedure (thick arrow) and the congenital anomaly of the sacrococcygeal bones (thin arrow) and an underdeveloped left anal sphincter (arrow) (B). Phase II examination (C) showing partial emptying of rectal contrast through a gaping anal canal (arrow). SB: Sacrococcygeal Bone; R: Rectum; UT: Uterus; BL: Bladder; SP: Symphysis Pubis; OI: Obturator Internus Muscle.*

Group 4: Drug assumption

Chronic assumption of psychopharmaceutical agents has been recognized as the most relevant feature in 12/90 (13%) of the population examined in the face of a marginally normal anorectal and pelvic floor anatomy and/or minor, not specific changes at imaging.

Conclusions

Until recently, patients with fecal incontinence were treated either by pelvic floor rehabilitation and physiotherapy or surgery without access to MR imaging and only on the basis of results of anal endosonography. On the other hand, as radiologists, we are no longer asked to simply provide an imaging map of anal sphincter defects and must be prepared to offer a global display of the pelvic anatomy. Using this protocol, in our diagnostic centre MR imaging has undergone a fairly rigorous proving phase and is now diffusing into clinical practice, providing the needed information for better therapy planning. Doing so, we could alert the referring clinicians to the presence of one of the following factors which potentially caused the dysfunction: (a) sphincter damage; (b) pelvic floor laxity with or without pudendal nerve neuropathy; and (c) low rectal reservoir function. As a result, a new trend is under development in our medical community so that, at present, only rarely, if ever, a complete MR assessment of the pelvis will be denied to patients with fecal incontinence.

Conflict of Interest

Nothing to declare.

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