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Research Article

MR Imaging of Fecal Incontinence: A Pilot Study

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Abstract

Background: With the exception of anal endosonography, imaging of fecal incontinence (FI), has had a limited role in the clinical practice until recently.

Aim: (a) To describe an MR imaging protocol tailored to patients with FI and (b) to validate an MR 1-5point confidence rating scale useful for the diagnosis and therapy planning.

Method: Bi-phasic MR-defecography has been performed in two groups of patients with similar demographic characteristics regarding their age (55.3 ± 10.7 yr vs 57.9 ± 14.6 yr, p 0.4489) who differ only for presence/absence of fecal incontinence. Image interpretation is performed twice by the same observer blind to patient's clinical features with a 1-week interval between readings. The examiner reports his diagnosis taking into account the following two categories of changes: A = involuntary loss of rectal contrast, anal gaping at rest, poor squeezing and inability to interrupt the stream of contrast on command (main changes); B = pelvic organ prolapse, levator ani hiatus ballooning, uncompliant rectal ampulla, hasty emptying, anal sphincter defect, hyperactive sigmoid colon and pudendal nerve neuropathy (additional changes). Based on the combination of various changes, a 1-5 rating confidence rating scale for FI is developed with 1 indicating certainly present, 3 equivocal, and 5 certainly absent for the purpose of ROC curve and accuracy rates according to the various thresholds. In addition, intraobserver agreement between first and second readings and its statistical significance is calculated.

Results: At MR defecography, the unvoluntary loss of contrast, anal gaping at rest and poor squeeze test were the best discriminants between the two groups of patients (optimal cutoff ≤ 2, sensitivity 0.5652, specificity 0.8947, accuracy 0.7705) with good agreement between the first and second reading (weighted K value 0.6834, SE 0.054, CI 0.5775 - 0.7893).

Conclusion: MR defecography is suitable for application in patients with FI due to its diagnostic accuracy and promise for robust diagnostic criteria.

Keywords: *Fecal Incontinence; Quality of Life; Diagnosis; Endoanal Ultrasonography; Magnetic Resonance Imaging; MR-Defecography*

Introduction

Faecal incontinence (FI), defined as the failure to control the passage of solid, liquid and gas through the anus recurring for > 3 months [1], is a very distressing symptom which severely compromises the emotional, social and working life quality of affected people. Most frequently, a general reluctance by patients and relatives to admit episodes of fecal loss combined with scarcity of adequate referral

centers and lack of shared guidelines, are all factors which contribute to delay in seeking medical attention and reaching a possible remedy. While a substantial agreement does exist in Italy between clinicians and researchers [2] over the fact that, after history taking and physical examination, the initial assessment of FI will start with the assessment of patient's cognitive function, a considerable debate still remains as to whether or not an instrumental diagnosis should always be used before therapy planning. Moreover, given the multifactorial genesis of the disturbance and lack of a single diagnostic tool capable to assess FI in its entirety, the physician is faced with the difficult choice among currently available tools including ano-proctoscopy, anorectal manometry, electroneurophysiological tests and imaging [3-6]. With regard to the latter, endoanal ultrasonography (EAUS) has traditionally been given the highest priority as the gold standard [7] for detection of any defect occurring in the internal and external anal sphincter. It can be argued however that factors other than anal sphincter defects are not explored by EAUS. As an alternative, magnetic resonance imaging (MRI) has recently been proposed [8,9] due to its non-invasiveness, superior overview and capabilities to provide both, direct evidence of leakage in objective way and depiction of anatomic changes.

This article brings the reader's attention to the use of MRI in the diagnostic workup of FI. More particularly, the aim is two-fold as follows: (1) to describe how to develop and conduct a successful MR examination in patients with FI and (2) to validate the diagnostic value of MR based on a 1 - 5 scale confidence system.

Material and Methods

The clinical records and imaging files of sixty-two consecutive patients referred to our diagnostic unit between April 2017 and May 2021 to undergo MR defecography have been retrieved from the database and retrospectively examined (MF and TM). Out of them, twenty-three patients (Group A), were incontinent to fecal material whether solid, liquid or gas, (nineteen females, 82.6% and four males, 17.4%; mean age 55.3 ± 10.7 years, range 33 - 70 yrs). For comparison, thirty-nine patients (Group B) with no evidence of fecal incontinence, (thirty-two females, 82.1%, and seven males, 17.9%; mean age 57.9 ± 14.6 years, range 18 - 81 years) and a combination of disorders including pelvic organ prolapse, diverticular disease, spastic colopathy, irritable bowel syndrome, chronic diarrhea with fecal urgency and left lower quadrant pain were also included into the study. Regardless of the severity of faecal incontinence, which is outside the scope of the present article, exclusion criteria were as follows: known or suspected ulcerative colitis (UC), Crohn disease, cancer of distal gut and active ano-perianal sepsis.

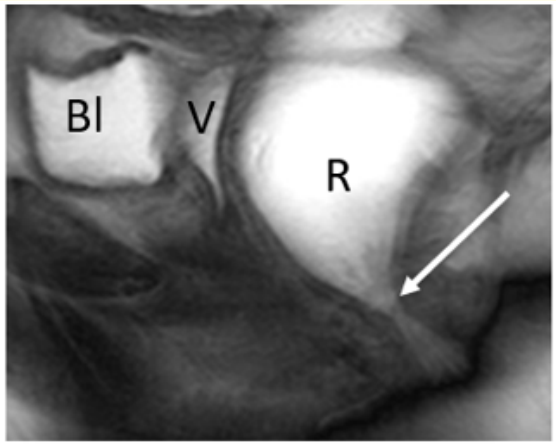
Imaging technique

Bi-phasic MR-defecography, as reported by us in a prior article [9], was developed on a 1.5 T superconductive, horizontally oriented magnet, (Siemens, AERA model, Herlangen, Germany) equipped with a phased array coil wrapped around the patients' pelvis. In practice, after preliminary interview and coaching, patients are positioned horizontally on their left side on the diagnostic table, and the examination starts with slow intrarectal injection of up to 240 mL of acoustic gel as contrast medium, under continuous monitoring of rectal adaptation to distension and filling perception. Image acquisition in the three planes consists of a static phase, intended to depict the anatomy of pelvic floor structures and a dynamic phase which assesses the presence of various changes under the effect of specific maneuvers such as squeezing, straining, rectal emptying and attempt to interrupt the stream of contrast on command (stop test). In addition, the so called "black blood" MR pulse sequence for evidence of pudendal nerve damage is included into the protocol which selectively suppresses the signal of fat and moving fluids, i.e. blood, while enhancing that of static fluid contained into the endoneural compartment [10].

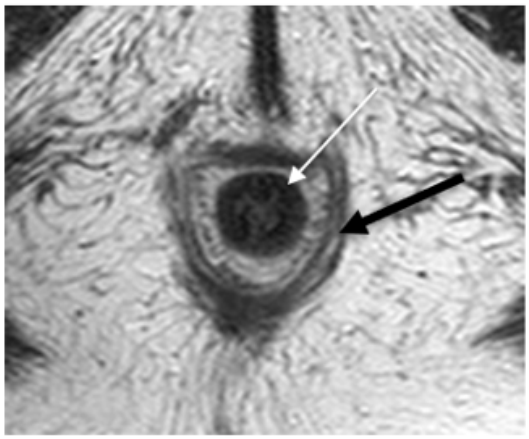
Image interpretation

Diagnostic criteria for FI are subdivided into two categories, as follows: A) Specific changes including (1) the inability to retain the total volume of contrast injected without leakage. In case of unvoluntary loss, the first leakage volume and the total leaked volume are registered; (2) anal gaping at rest, defined as lack of apposition of anal walls together with passage of a certain amount of contrast into

the lumen of the anal canal; (3) poor squeeze, defined as an upward elevation of the anorectal junction (ARJ) less than 1 cm combined with inability to lock the anal neck on voluntary contraction (Figure 1A-1C) and B) Non-specific changes, including (1) disruption of the anal sphincter integrity involving more than 50% the axial or the longitudinal extent; (2) rectal size < 3 cm or > 6 cm in its anteroposterior diameter, as an expression of abnormally decreased and increased rectal compliance, respectively; (3) posterior anorectal angle (ARA) greater than 116.2° at rest; (4) increased signal intensity of the pudendal nerve in the Alcock's canal indicating nerve damage (Figure 2); (5) "concertina like" feature of the sigmoid colon consistent with hyper propulsive gut activity (Figure 3); (6) ballooning of levator ani hiatus on straining and (7) hasty emptying of rectal content.



A



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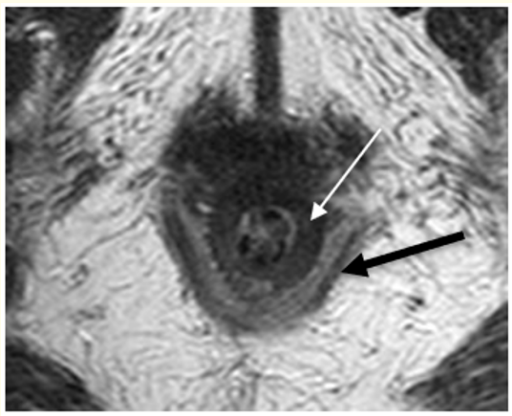


Figure 1: *(A) Midsagittal MR image at rest in a 62 year old woman with fecal incontinence showing the loss of contrast through the anal gaping (white arrow) at the end of rectal filling; (B) Axial T2 w TSE MR image of the same patient showing the normal feature of the internal anal sphincter (thin white arrow) as opposed to the increased signal intensity consistent with atrophy of the external anal sphincter (black arrow) and that of (C) The puborectalis muscle (black arrow). Bl = Bladder; V = Vaginal canal outlined by contrast; R = Rectal ampulla.*

Figure 2: *Axial MR image of the pelvis using DP SPAIR BB pulse sequence: Increased signal intensity of the pudendal nerve in the Alcock canal (arrow) indicating pudendal nerve neuropathy in a 58 yr old woman with staining episodes associated to pelvic floor descent and straining at stools.*

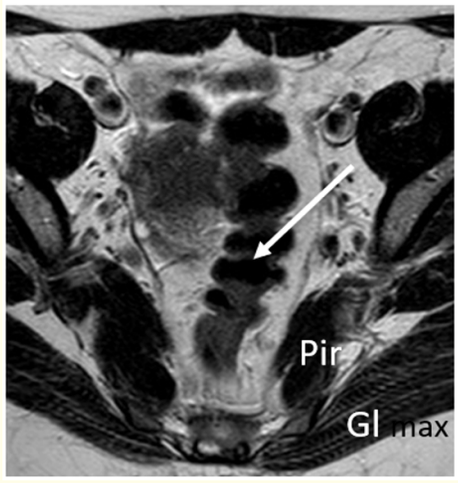


Figure 3: *Axial T2 w MR image of the pelvis in a 42 yr old woman with episodes of fecal urgency, left lower quadrant pain and no evidence of fecal incontinence: note the increased number of haustra in the sigmoid colon ("concertina" sign) consistent with spastic colopathy and irritable bowel syndrome 1). PIR = piriformis muscle and 2) Gl max = gluteus maximum muscle.*

Interpretation of the imaging series was performed twice with a minimum elapsing time of one week between the two readings by the same observer (VP) who, blind to the clinical features of the two Groups, reported his diagnosis, taking into account the findings mentioned above in combination and completing a 1 - 5 confidence rating scale for FI, where 1 = almost certainly present, 3 = equivocal and 5 = almost certainly absent (Table 1).

Score	Disease	MR findings
1	Present	1. Loss of contrast during retrograde injection occurring at one third, half filling or at full capacity 2. Anal gaping at rest (lack of anal wall apposition) 3. Poor squeezing (upward elevation of ARJ < 1 cm and failure to lock the anal neck on maximal voluntary contraction) 4. Disruption of integrity > 50% the axial and/or the longitudinal extent of the anal sphincters
2	Probably present	1. Leakage of contrast at rest and on effort 2. ARA > 116.2±23.6° at rest 3. Rectal size < 3 cm or > 7 cm with fecaloma at capacity indicating abnormal rectal compliance 4. Disruption of integrity < 50% the axial and/or the longitudinal extent of the anal sphincters 5. Ultra Fast emptying, i.e. < 30 seconds
3	Equivocal	1. Penetration of minimal amount of contrast in the proximal half of the anal canal on effort only 2. Ballooning of the levator ani hiatus with area > 40 cm^2 on straining 3. "Concertina-like" sigmoid colon with(out) diverticula 4. Pudendal nerve neuropathy 5. Focal defects of anal sphincter integrity involving < 20% the extent
4	Probably absent	1. No contrast loss even on maximal effort despite evidence of rectal floor descent > 4 cm relative to rest, rectoanal intussusception on evacuation and external rectal prolapse 2. Ballooning of the levator ani hiatus < 40 cm^2 3. Difficulty in expulsion of rectal contrast
5	Absent	1. No contrast loss at all 2. Anal wall apposition even on maximal effort 3. ARA 90° at rest and up to 80° on voluntary contraction 4. Good squeezing (upward elevation of the ARJ ≥ 1.5 cm)

Table 1: *1-5 point confidence rating scale for the diagnosis of faecal incontinence at MR defecography. Criteria used when selecting the threshold for construction of the receiver operating characteristic curve (ROC) for the diagnosis of Fecal Incontinence by MR defecography.*

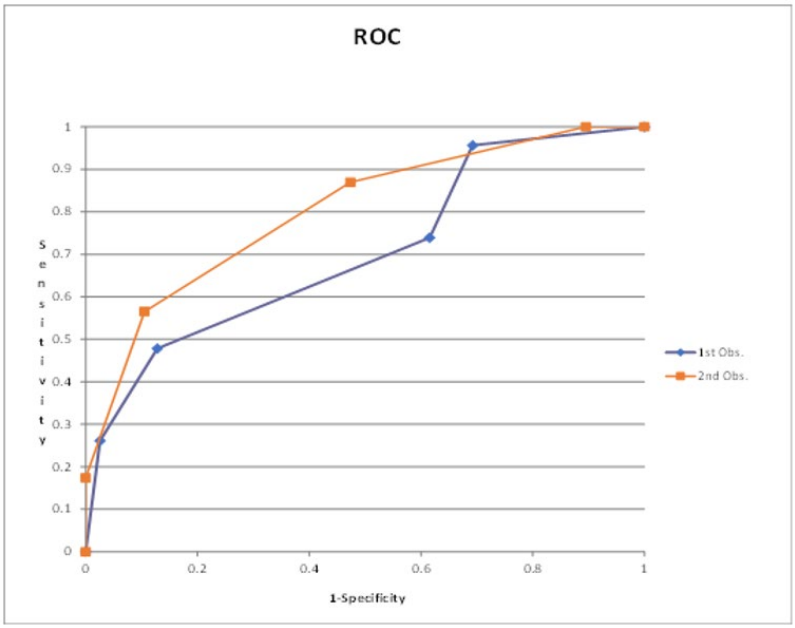
Statistics: A receiver operating characteristic curve (ROC) analysis was determined (CS) at MR defecography for the diagnosis of FI by selecting the optimal cutoff with J of Yauden statistics to calculate the accuracy rates of various thresholds and distinguish incontinent subjects from those without disease. In addition, the intraobserver agreement between the first and second reading in expressing the judgment is calculated by the weighted K index. Quantitative data are means and standard deviations, categorical data are number of patients. Analyses were performed using Student's t-test and the Fisher's exact test when appropriate for quantitative and categorical data, respectively. For the statistical analysis, the SAS 9.4 software was employed.

Results

Despite the 1:4.6 male- to- female ratio (11 males vs 51 females) seen in the entire population examined, the two patients groups were not significantly different with regard to their age and gender distribution (55.3 ± 10.7 yr vs 57.9 ± 14.6 yr, p 0.4489; 17.4% vs 17.9% males and 82.6% vs 82.1% females, *p* 1.0000, in group A and B respectively). Overall at MR defecography, unlike what obtained for the involuntary loss of rectal contrast, poor squeezing and anal gaping at rest which consistently characterized those patients with FI, considerable overlap has been noted between the two patients groups with regard to all other changes, including anal sphincters defects, laxity of pelvic floor musculature and pelvic organ prolapse, fast emptying clearance, excessive propulsive activity of sigmoid colon and reduced rectal compliance (Table 2). On the other hand, at the ROC analysis (Figure 4A-4C) an effective differential diagnosis of FI is achieved when using the 1 - 5 point scale, the optimal cutoff being seen with threshold point ≤ 2 (sensitivity 0.56522, specificity 0.10526, accuracy 0.45995, area under the curve 0.8071, SE 0.0546, 95% CI 0.700 - 0.9142 at J of Youden) with a false positive rate of just 4 cases. In addition, the intraobserver agreement between the first and second reading (Table 3) was high enough (weighted K value 0.6834, SE 0.054, CI 0.5775 - 0.7893) to indicate an acceptable reproducibility and reliability of the specific diagnostic criteria adopted. Finally, the additional changes, alone or in combination, allowed better characterization of the disease in singular cases.

Changes	Group A (23)	Group B (39)
Contrast Loss	21	4
Anal gaping at rest	18	3
Poor squeezing	18	9
Anal sphincter atrophy/defect	12	16
Hiatus ballooning	7	15
Pelvic Organ Prolapse/ARA ≥116°	6	15
Pudendal nerve neuropathy	4	12
Concertina sign of sigmoid colon	3	11
Fast/ultrafast emptying	8	9
Abnormal rectal size	5	8

Table 2: *List of abnormalities seen at MR defecography in the patient population (n = 62). With the exception of the contrast loss and anal gaping at rest signs, considerable overlap of changes is registered between the two groups of patients (multiple findings for each patient)*



A

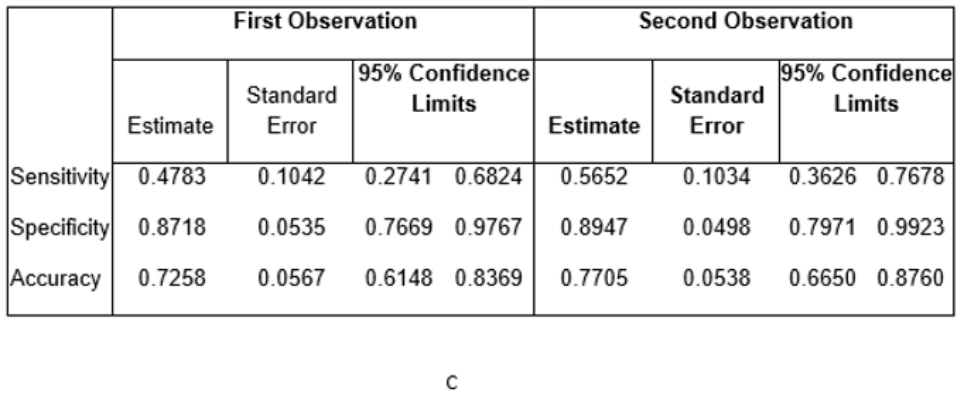
1st Observation

Cutoff	TP	TN	FP	FN	Sensitivity	Specificity	Accuracy
1	6	38	1	17	0.261	0.974	0.710
2	11	34	5	12	0.478	0.872	0.726
3	17	15	24	6	0.739	0.385	0.516
4	22	12	27	1	0.957	0.308	0.548
5	23	0	39	0	1.000	0.000	0.371

2nd Observation

Cutoff	TP	TN	FP	FN	Sensitivity	Specificity	Accuracy
1	4	38	0	19	0.174	1.000	0.689
2	13	34	4	10	0.565	0.895	0.770
3	20	20	18	3	0.870	0.526	0.656
4	23	4	34	0	1.000	0.105	0.443
5	23	0	38	0	1.000	0.000	0.377

B



	First Observation				Second Observation			
	Estimate	Standard Error	95% Confidence Limits		Estimate	Standard Error	95% Confidence Limits	
Sensitivity	0.4783	0.1042	0.2741	0.6824	0.5652	0.1034	0.3626	0.7678
Specificity	0.8718	0.0535	0.7669	0.9767	0.8947	0.0498	0.7971	0.9923
Accuracy	0.7258	0.0567	0.6148	0.8369	0.7705	0.0538	0.6650	0.8760

Figure 4: *(A) Receiver operating characteristic (ROC) curve in two subsequent readings for the diagnosis of fecal incontinence by MR defecography. (B) Distribution of sensitivity, specificity and accuracy values by threshold at J of Youden analysis. (C) Estimate, Standard Error and 95% Confidence Limits for the sensitivity, specificity and accuracy values of the optimal threshold (score ≤ 2, J index 0.45995), TP= true positive; TN= true negative; FP = false positive; FN= false negative.*

1st Obs	2nd Obs					Total
	1	2	3	4	5	
1	4	3	0	0	0	7
2	0	7	2	0	0	9
3	0	3	16	6	0	25
4	0	0	3	5	0	8
5	0	0	0	8	5	13
Total	4	13	21	19	4	62

Table 3: *Calculation of weighted K index for intra observer agreement in the diagnosis of fecal incontinence at MR defecography with no less than 1-week interval between two subsequent readings. 1st Obs = First reading; 2nd Obs = Second reading. K index: Estimate 0.6834, SE 0.054, 95% CI 0.5775 - 0.7893.*

OBs = Observation.

Discussion

In contemporary society, dominated by the myth of self-control, the loss of one's own excretions constitutes a stigma that irreparably compromises the life quality of affected persons [11]. Anything must be attempted by the medical community in aid of people with this devastating condition, starting with promoting research for better understanding of the mechanisms that determine FI.

Under normal conditions, an adequate control of fecal material in humans is made possible by a complex integrated system of sophisticated mechanisms which are not present at birth, being usually accomplished during the first two years of life. While the entire maturation process of continence is far from being known, it eventually seems to be the result of a balance between the propulsive activity of the sigmoid colon, the reservoir function of the rectal ampulla [12] and the closing mechanism of anal sphincters. Other important

contributing factors include the inherent rheological properties of fecal material, the perception and discriminatory capacity of rectal contents, the sustainment of pelvic floor muscles and fascial cohesion between pelvic organs. Each of these factors can be compromised but continence can still be guaranteed by a sort of "compensation" from the others. When more than one is impaired, the risk of incontinence becomes higher. Established risk factors are aging, multiparity, anorectal and pelvic reconstructive surgery [13,14], neurologic disease, and recurrent use of antidepressants. Chronic diarrhoea, irritable bowel syndrome and obstructed defecation should also be considered as additional independent risk factors for FI. From the clinical point of view, it is usual to distinguish FI into stress incontinence, urge (active) incontinence, passive (unaware) incontinence, faecal soiling, and overflow incontinence due to faecal impaction. Scoring systems have also been devised to assess the severity of FI, the most widely used being that of Wexner, also known as the Cleveland Clinic system. The dysfunction is frequently associated with a large variety of conditions, including long term sequela of ano-rectal surgery for congenital anomalies repair, common proctologic disease, accidental and obstetric injuries, and aging, to name a few [15,16]. Whatever the cause, sooner or later the need for a diagnosis as exact as possible is highly desirable for rational therapy planning.

Traditionally, the diagnostic work up starts with a preliminary patient interview followed by careful rectal examination. This includes inspection of the anus and perineum at rest, during straining and squeezing, in search of possible descending perineum, rectal and vaginal prolapse, scars from prior surgery. Examination of external genitalia, perineum, and vagina with a speculum, as well as bimanual pelvic examination, is also mandatory. Ano-proctoscopy is also warranted to rule out colorectal cancer. A recent review [17] on the use of instrumental diagnostics clearly indicates anorectal manometry as the first necessary step for assessing anorectal sensation using balloon dilation in the rectum, as well as anal sphincter resting and squeeze pressures so as to obtain crucial information about the anal sphincter functions and rectal capacity. Thereafter, with regard to imaging, endoanal ultrasonography (EAUS) is recommended by the authors as the gold standard to assess anal sphincter morphology and to detect any defect in sphincter integrity. This technique [18] adopts a 10-to-16 MHz, 360° rotating transducer with three-dimensional (3-D) reconstruction, near-field focusing in the range of 5 - 45 mm, transverse resolution of less than 0.05 mm, and lateral resolution of 0.5 - 1.0 mm. More precisely, EAUS can indicate whether the internal or external anal sphincter, or the puborectalis muscle, is damaged and give the exact extent of circumference and length of the defect in relation to anal canal levels, as well as the presentation of sphincter remnants. When compared with intraoperative results, the accuracy of the technique for locating the defect in incontinent subjects is 100% for the external anal sphincter and 95.5% for the internal anal sphincter. As an alternative, endoanal MR imaging has been credited with obtaining even better results [19] to document external anal sphincter atrophy as opposed to those occurring in the internal anal sphincter for which US remains preferable. Moreover, in experienced hands, MRI with external phased arrays [20] are used more and more frequently with confidence so as to avoid discomfort to patients. It can be argued, however, that both examinations fail to get an objective view of the loss of rectal content in a real time, an evidence considered essential for the diagnosis, given the common difficulty during patient interview to ascertain whether or not true episodes of incontinence do exist. This, in turn, is precisely the rationale behind the current study: in other words, in patients referred for known or presumed FI, the goal has been to depict by a single diagnostic tool the entire pelvic floor anatomy together with the loss of contrast as a reliable index of the severity of the disease. Compared to prior studies conducted by others [19] that have considered the use of MRI limited to demonstrating external anal sphincter atrophy, the results of the current investigation show that the unvoluntary loss of rectal contrast at MR defecography (Figure 2), should be given highest priority. The contrast loss sign occurred in all but two cases of our population, and its diagnostic value seems reinforced by the fact that its presence was seen in up to 40% of cases in which both anal endosonography (EAUS) and/or anorectal manometry, the two most frequently methods used, had failed to elucidate the true existence of leaks episodes. The effectiveness of this diagnostic test in giving an objective evidence of FI is proven in the current study at the receiver operating curve (ROC) analysis which has shown a sensitivity of 0.5652, specificity of 0.8947, accuracy of 0.7705, SE 0.1042, 0.0535 and 0.0567, respectively and a false-positive rate of 4 cases and false negative rate of 10 cases only. Besides this unique criterion which is beyond the diagnostic capabilities of ultrasonography, a clear advantage of MR defecography consists in the ability to show in exquisite details also the presence of a hyperactive sigmoid colon and even that of pudendal nerve damage in the Alcock canal (see figure 2 and 3). Despite their

lack of specificity and absence of discriminatory capacity between the two groups of patients, as seen in the current study, these changes undoubtedly added value in the characterization of FI in singular cases potentially useful for the therapeutic choice, whether surgical or conservative. In addition, at MR defecography both the anatomy of anal sphincters and that of the levator hiatal ballooning on straining as an expression of pelvic floor laxity were depicted in a similar way to that of EAUS (Figure 5).

Figure 5: *Midcoronal T2 w TSE MR image of the anal canal showing the normal feature of the internal anal sphincter (thin arrow) and that of the external anal sphincter (thick arrow) in exquisite detail.*

A common cliché to debunk, is that of excessive cost associated with the examination and lack of availability. Apart from exam time of MR defecography (average 30 - 40 minutes), very similar to that of all other MR examination of the pelvis, the only adjunctive cost to be faced is that of acoustic gel as contrast (range 100 - 250 mL), one disposable catheter, two-to-three syringes and a diaper to collect the materials; all the above in face of the overtly superior diagnostic yield, including information on anal sphincter damage, rectal reservoir, propulsive activity of sigmoid colon, pelvic floor musculature laxity and pudendal nerve neuropathy. As far as the lack of availability issue, given the diffusion of MR equipment all over the world, it can no longer be considered a sustainable justification today against the use of MR defecography. As such, it seems reasonable to us to recommend this exam as the first imaging step immediately after anorectal manometry in patients with FI.

Now turning attention to the limitations of the current study, the small sample size of patients with FI and its unbalance relative to those without the disease cannot be ignored, as well as the fact that, rather than true controls, patients of the latter group actually suffered from pelvic floor dysfunctions. To obviate this, the validity of the criteria expressed by the 1 - 5 point scale will be tested by us in an ongoing study of a much larger number of cases. On the other hand, as far as the second point is concerned, it might be noted that the inherent value of such criteria could even be highlighted and receive greater relevance from the large overlapping of disorders in the two groups. Further limitation of the study is that it fails to analyze the relationship between the diagnostic yield at MR defecography and the severity of FI symptoms. Again, we deliberately avoided to determine it in the current pilot study deferring this analysis to a forthcoming investigation which is intended to address all possible correlation of diagnostic criteria with symptoms severity, risk factors and therapeutical choices.

Conclusion

Until recently, MRI has played a role of simple adjunct to EAUS, limited to a better characterization of external anal sphincter atrophy. Today instead we learn that, well beyond the capabilities of EAUS, MRI's unique value consists in giving direct objective evidence of the loss of rectal content, a sign with sufficient diagnostic accuracy which helps distinguishing ambiguous cases from those with symptoms overlap where there is doubt on whether incontinence really exists or not. Moreover, thanks to the superior panoramic capabilities and inherent characteristics of MRI, a number of additional information can be achieved, such as that of pudendal nerve neuropathy, with potential implications for therapeutic choice, whether surgical or medical. Ongoing future research will demonstrate the validity of the current pilot study.

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