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Research Article

MR-Defecography: Which Protocol is Most Appropriate?

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Abstract

Aim: To highlight the advantages of one method for performing magnetic resonance defecography (MRD) over other three variants based on the total amount of information extracted from the examination.

Materials and Methods: The imaging series of sixty patients (39 females, 21 males, mean age 49 ± 5 yrs, range 18 - 83 yrs) referred for a variety of symptoms including obstructed defecation, fecal incontinence and pelvic organ prolapse, were randomly chosen from four different diagnostic centers (15 each). MRD studies were developed on a 1.5 T closed system imager in three centers and on a 0.3 T open system in one center. The image protocol varied over time in search for the best successful outcome of the examination, as follows: Protocol 1a = bladder half filled and static phase acquisition before rectal filling; Protocol 1b = bladder half filled and static phase acquisition after rectal filling; Protocol 2a = bladder empty and static phase acquisition before rectal filling; Protocol 2b = bladder empty and static phase after rectal filling. The null hypothesis under test was that each protocol would produce the same result in terms of diagnostic yield, defined as the total amount of information obtained from the combined analysis of both static and dynamic series. This was measured by calculating the frequency with which various abnormalities and normal structures were recognized (or missed). Differences among protocols were considered significant at a p-value of < 0.05.

Results: The highest diagnostic yield for depiction of pelvic anatomy was obtained by Protocol 2a and use of 1.5T magnets (28/45, 62.2%). Regardless of the overall image quality and conspicuity of changes, the detection rate of functional abnormalities by 0.3 T did not differ significantly from that of 1.5 T equipments (13/15, 80% vs 41/45, 91.1%). The amount and dilution of contrast administration were dictated by the specific clinical question, whether obstructive defecation, fecal incontinence or pelvic organ prolapse.

Conclusion: (1) The best MRD protocol is to visualize the undisturbed pelvic anatomy first, i.e. with the bladder and rectum empty and to adapt contrast administration to the specific complaint; (2) although preferable, using a 1.5 T MR equipment is mandatory only for optimal depiction of pelvic anatomy.

Keywords: *Magnetic Resonance Defecography; High Field-Strength Magnet; Pelvic Floor Dysfunctions; Obstructive Defecation Syndrome; Pelvic Floor Imaging; Fecal Incontinence; Pelvic Organ Prolapse*

Introduction

Following the advent of fast MR imaging in 1991 [1], with X-ray evacuation proctography (EP) in continuous decline [2-4] and in light of the inability of ultrasonography to assess the rectal emptying phase [5,6], magnetic resonance imaging (MRI) is currently considered the method of choice not only to evaluate the rate and completeness of evacuation, but also to depict the entire pelvic floor anatomy. As such, MR-defecography (MRD), first described in 1997 by Lienemann [7], has almost completely replaced EP all over the world in patients with pelvic floor dysfunctions. At the beginning of MRD application, most studies were focused on determining the agreement between measurements of the anorectal configuration made with dynamic MR imaging and EP or to compare detection and miss rates of pelvic floor abnormalities by MRD with patients in the horizontal position - either supine or left lateral - versus those obtained in the sitting position using a vertically oriented, open magnet [8-13]. This stage produced the vast majority of the widely accepted diagnostic criteria and grading systems currently in use for pelvic organ prolapse (POP) and other abnormalities [14-18]. Thereafter, a period followed in which the interest of clinicians and researchers seemed more attracted by the issue of MR/anatomic correlation, i.e. identification of the support system, including the endopelvic fascia, periurethral ligaments, levator ani muscle components, hiatus boundaries, perirectal and periprostatic tissues and surrounding structures [19-24]; more recently, the attention has definitely turned towards the production of a universal set of recommendations [25], with specific focus on the standardization of the technique, patient coaching of various maneuvers during MRD and redefinition of diagnostic criteria. All the above, in the effort of making the examination performance more uniform throughout the world, so as to improve communication between institutions and researchers.

In this article, the authors report their experience of over fourteen years with performing MRD across four different institutions in Italy. More precisely, the aim of the paper is to describe how and why the image protocol has been varied over time until reaching the current status, with continuous refinements and modifications of variables including bladder state of filling, rectal contrast composition relative to the clinical question, and timing for its administration, whether before or after the acquisition of the "anatomic" portion of the examination.

Purpose of the Study

The final purpose of the research is to highlight the advantages of one method for performing magnetic resonance defecography (MRD) over other three variants based on the total amount of information extracted from the examination.

Materials and Methods

The data base for the study consisted of the retrospective analysis of the imaging series and clinical findings of all the MRD examinations performed between March 2006 and Dicember 2000, in four different diagnostic centres in Italy (Figure 1). For the present study, fifteen examinations were chosen randomly from each institution (5 at the beginning, 5 in the middle, and 5 at the end of the activity period) for a total number of sixty patients (39 females, 21 males, mean age 49 ± 5 yrs, range 18 - 83 yrs), who were referred for one of the following three abnormal conditions alone or in combination, obstructive defecation syndrome (ODS), fecal incontinence (FI) and pelvic organ prolapse (POP). With the exception of Center 1, where a low field-strength, 0.3 T permanent field, horizontally oriented open-configuration magnet (Airis Vento; Hitachi Medical Systems,Genoa, Italy) was employed, a high field-strength 1.5 T closed system imager was used in the other three Centers (Philips, Achieva model, The Netherland in center 2 and 3; and Siemens, Aera model, Erlangen, Germany in center 4, respectively), all equipped with high-speed gradients and a surface phased-array coil for image acquisition (Table 1). An acoustic coupling gel was adopted as rectal contrast in all MRD examinations, which was mixed with 1.5 mL of gadopentetate dimeglumine per 200 mL of gel only when the examination was developed on the low field-strength magnet (centre 1), so as to obtain adequate signal intensity.

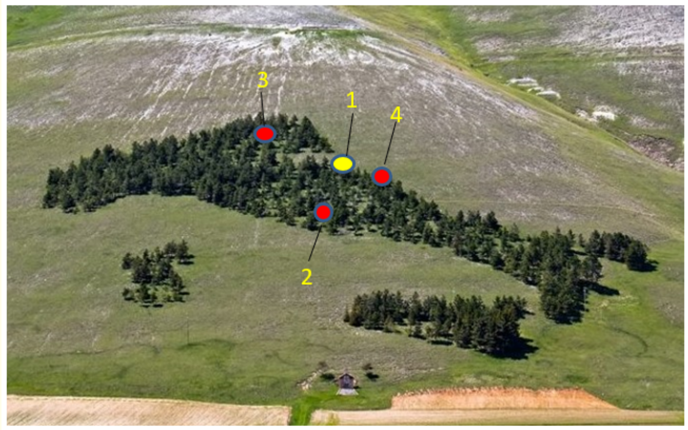


Figure 1: *Geographical location and activity period (years) of the four diagnostic centers in which MRD was developed using a 0.3 T open magnet (yellow dot) and a 1.5 T closed magnet (red dot). Center 1 (2012-2015); Center 2 (2006-2016); Center 3 (2012-2020); Center 4 (2017-2020).*

Diagnostic center	Manufacturer	Model	Field-strength (T)	Static series		Dynamic series (&)	
				Pulse sequence	Acquisition time (min)	Pulse sequence	Image update
1	Hitachi	Airis Vento	0.3	TSE T2-w	4.4	RSSG T1-w	1/3 sec
2	Philips	Achieva	1.5	TSE T2-w	3.4	BFFE T1-w	1/0.871 sec
3	Philips	Multiva	1.5	TSE T2-w	6.1	BTFE T1-w	1/0.871 sec
4	Siemens	Aera	1.5	TSE T2-w	4.3	GRE T1-w	1/1 sec

Table 1: *Differences and similarities of technical setting and equipments for MRD in the four centres.*

(&) = Acoustic gel as rectal contrast mixed with 1.5 mL of gadopentetade dimeglumine /200 mL when using the 0.3T magnet only. BFFE: Balance Fast Field Echo; BTFE: Balance Turbo Field Echo; RSSG: Radio Frequency Spoiled Steady State Gradient Echo; GRE: Gradient Echo; TSE: Turbo Spin Echo.

Although differing with regard to the geographical location, technical staff and equipments, MRD was conducted in the four institutions by the same radiologist (VP) who, during the entire course of the activity, alternatively adopted in each centre one of the following four imaging protocols in search for the best successful outcome of the examination: Protocol 1a = bladder half filled and static phase acquisition before rectal filling; Protocol 1b = bladder half filled and static phase acquisition after rectal filling; Protocol 2a = bladder empty and static phase acquisition before rectal filling; Protocol 2b = bladder empty and static phase after rectal filling. In practice, the four protocols differed from each other with regard to the state of pelvic organ repletion and the timing of the static phase acquisition, whether before or after administration of rectal contrast, the null hypothesis under test being that each protocol would produce the same result in terms of diagnostic yield. The latter was defined as the total amount of information obtained from the combined analysis of both static and dynamic series and was measured by calculating the frequency with which various changes and normal anatomical structures were recognized (or missed) as expected. For data collection, a framework of horizontal and vertical lines forming squares was developed to be filled with numbers indicating detection and missing rates. The overall quality of images developed by various magnet systems was judged by four observers (MV, VC, GG, TF) on the basis of sharpness vs haziness of contour, organ definition, contrast resolution and conspicuity of pathology and scored as poor (0), mild (1), good (2) and excellent (3). Disagreement in the judgements was resolved by consensus. Differences of results among protocols were considered significant at a p-value of < 0.05. What remained unchanged over time was (1) the patient interview (including coaching, history taking and evaluation of prior medical records); and (2) the position and orientation of the image sections in the three planes (axial, sagittal, coronal) during both portions of the examination as described in a previous report [26].

Results

The MRI examination was well tolerated by all patients who in no case denied their consent to the insertion of the catheter for contrast administration both inside the anal and vaginal canal (females), when necessary. The score of the image quality obtained during the dynamic portion of the examination was considered good in up to 66.6% of cases by the 0.3 T magnet (centre 1) and good-to-excellent in 68.8% of cases by the 1.5 T magnets (centre 2, 3 and 4), while a poor quality score was registered in no more than13.3% regardless of the field strength (See table 2). Unlike what occurred for the static phase, the detection rate of functional abnormalities by 0.3 T did not differ significantly from that of 1.5 T equipments (13/15, 80% vs 41/45, 91.1%). With regard to the diagnostic yield of MRD, the highest value for depiction of pelvic anatomy was obtained by the combination of Protocol 2 a (bladder empty and image acquisition before rectal filling) with use of the 1.5T magnet (28/45, 62.2%).

Item	**Protocol**								**Field-strength**		**p-value**
	1 a		**1 b**		**2a**		**2 b**		**(T)**		
	0.3	**1.5**	**0.3**	**1.5**	**0.3**	**1.5**	**0.3**	**1.5**	**0.3 (15)**	**1.5 (45)**	
Image quality (score) 0	1	2	/	3	/	1	1	/	2 (13.3)	6 (13.3)	n.s.
1	1	2	1	2	/	2	1	2	3 (20)	8 (17.7)	n.s.
2	2	4	2	6	3	8	3	5	10(66.6)	23 (51.1)	n.s.
3	/	3				4		1		8 (17.7)	< 0.05
Structure (n°)											
Fascia/ligmnt/nerve	/	3	/	4	/	28	/	3	/	38 (84.4)	< 0.05
Functional changes	5	14	4	3	2	7	2	15	13 (80)	41 (91.1)	< 0.05

Table 2: *Outcome of 60 MRD examinations by imaging protocol and field-strength magnet.*

MRD: Magnetic Resonance Defecography; Protocol 1 a: Bladder half filled + anatomic phase before rectal contrast injection; Protocol 1 b: Bladder half filled + anatomic phase after rectal contrast injection; Protocol 2 a: Bladder empty + anatomic phase before rectal contrast injection; Protocol 2 b: Bladder empty + anatomic phase after rectal contrast injection. Image quality score: 0=poor; 1=mild=2=good; 3= excellent. Number in parenthesis are percentages.

Discussion

It can be affirmed that much of current knowledge of the patophysiology of evacuation dysfunctions has followed suit and sometimes walked on the wheels of imaging studies when these began to include the depiction of rectal emptying by motion picture radiography. From that time on, technological advances in this area have occurred in a tumultuous fashion, passing in a relatively short period of time from the first EP imaging series obtained in a "double exposure" mode [27] to the current "real time" MRD (Figure 2a and 2b). At present, MRD has become the preferred modality in the clinical practice due to the absence of radiation hazard and the overtly superior information content so that, unless expressly refused by patients or unavailable, X-ray EP has been virtually abandoned. Alongside the well known pros, however, there are some cons associated with MRD to take into consideration as follow: first of all, apart from the claustrophobic problem, a significant proportion of patients may find it almost impossible to expel the contrast in a horizontal position; in addition, rectal emptying can be difficult to achieve on command. Whatever the diagnostic tool in use, indeed, key images for the diagnosis are those acquired during rectal emptying and failure to obtain an adequate stream of contrast is almost synonimous with an unsuccessful examination. Being aware of this, since 2017 we have begun to dilute the rectal contrast just before its administration by adding tap water to the acoustic gel in a proportion of 25 mL to 50 mL/syringe respectively, until obtaining a perfectly homogeneous mixture up to a total amount of contrast injected of no less than 250 mL. In addition, all patients were given the choice of starting the movement at will and just make notice of the first stream by intercom to allow for contemporary acquisition of images by the examiner. This strategy, which was routinely adopted in all patients with ODS, proved effective in reducing the rate of failed examinations down to current rate of one in fifteen cases. Conversely, in no case the acoustic gel was diluted before its administration to patients referred for FI, the goal of examination being to register different parameters such as the first leakage volume, total amount of contrast injected before leakge and the amount retained, as described by us in previous reports [28-30]. As regards to vaginal filling with 5 - 10 mL of ultrasound gel in case of known or suspected POP, although considered helpful for better demarcation, its application was always subjected to the informed consent obtained by the patient.

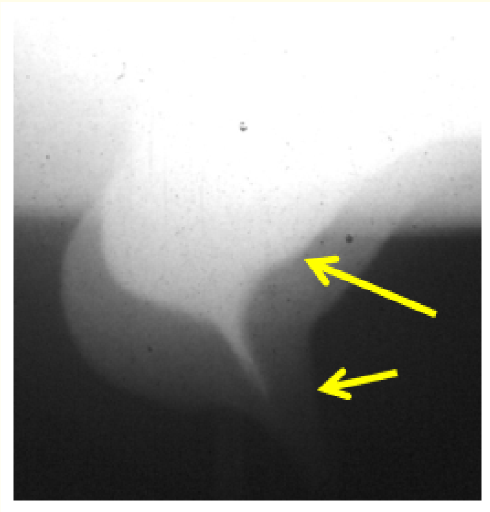


Figure 2a: *Evacuation proctography (EP) developed in the early 80's [27] by exposing the same radiographic film twice to the X-ray beam, i.e."Double Exposure" technique, showing the rectal ampulla at rest (long arrow) and during evacuation of semisolid radiopaque barium sulfate suspension (short arrow).*

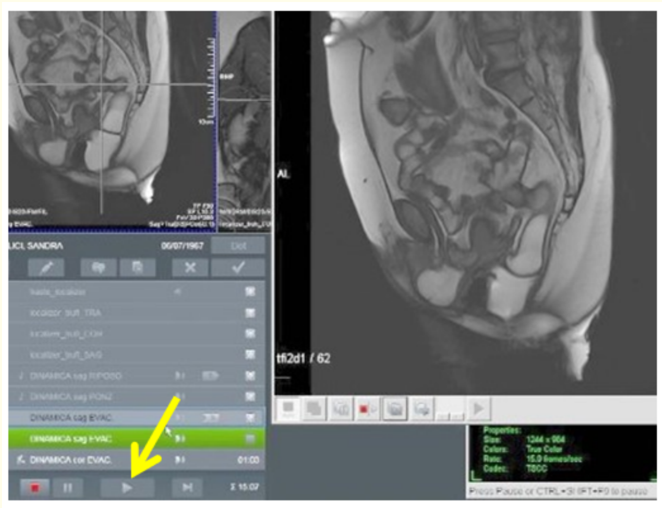
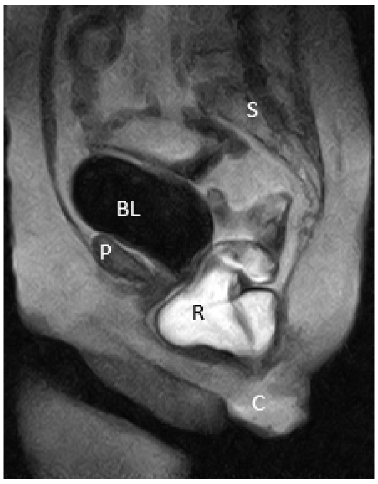


Figure 2b: *Current imaging of the dynamic series with magnetic resonance defecography (MRD) by simply clicking on the button of the videorecording facility (arrow).*

Now turning the attention to the issue of the equipment, contrary to what could have been expected, the use of a low field-strength magnet did not produce any significant decrease in the detection rate of functional abnormalities (Table 2). This observation seems to indicate that, despite the inevitable lower image quality (Figure 3a-3c), nor did the type, severity or site of various changes affect their diagnosis even by a 0.3T magnet. This observation has important implications in the field of feasibility of MRD in those patients who are claustrophobic due to the superior tolerability of the examination when performed in open magnet systems. On the other hand, as revealed by the overt difference of missing rates of various pelvic structures during the static phase, a threshold of 1.5 T magnet should be considered mandatory as the lowest acceptable level for adequate study of pelvic anatomy, namely ligaments and fascia (Figure 4), whose lack of integrity is a potential factor for the development of pelvic floor dysfunctions. In addition, with regard to the latter structures, it is interesting to note that the highest detection rate was scored in association with the protocol 2a, which combined an empty bladder with the image acquisition of static phase at the very beginning of the examination, before the administration of rectal contrast. This seems to indicate that the state of fullness of both bladder and rectum is a potential obstacle for the visualization of such delicate network.



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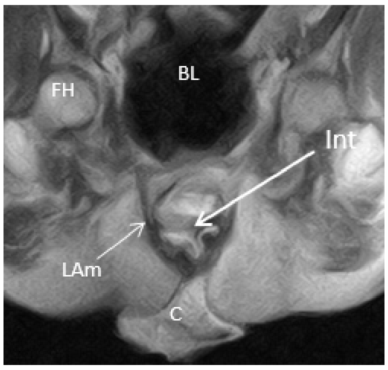

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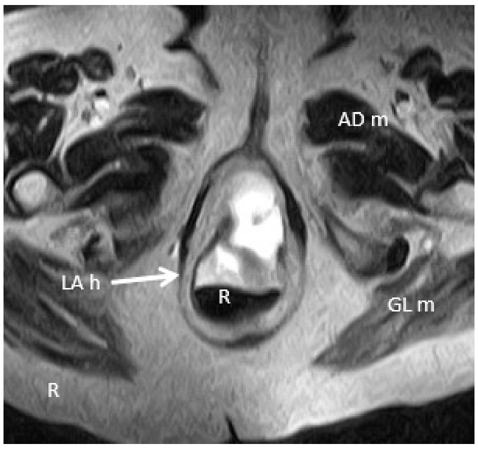

3c

Figure 3: *RSSG pulse sequence, MRD dynamic series developed on a 0.3T open system (diagnostic centre 1) as seen in the sagittal (a), coronal (b) and axial (c) plane. Despite the lower field strength and need to add gadopentetate dimeglumine to the acoustic gel to increase the signal intensity of rectal contrast, the dynamic series show sufficient image quality to depict the presence of rectocele, intussusception and levator ani hiatus ballooning. P: Pubic Bone; BL: Bladder; S: Sacrum; R: Rectocele; Int: Intussusception; C: Contrast; FH: Femoral Head; LAh: Levator Hiatus; LA m: Levator Ani Muscle: AD m: Adduttor Muscles; GL m: Gluteus Major Muscle.*

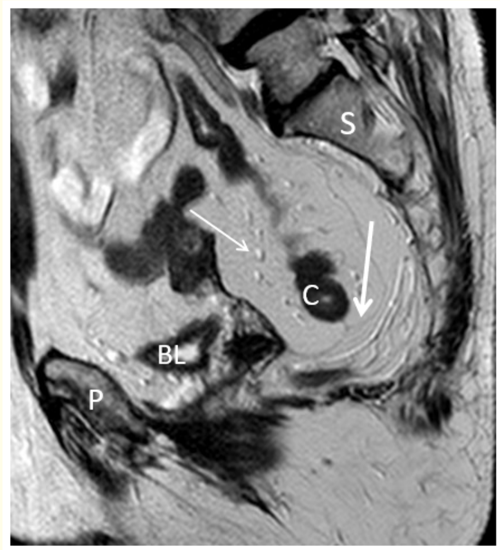

Figure 4: *TSE T2- w high resolution sagittal image of the pelvis obtained by a 1.5 T magnet (diagnostic center 3) with protocol 2 a: note the MR anatomy of the pelvis depicted in exquisite details, including the terminal nerve endings of the pericolic plexus (thin arrow) and the peritoneal reflections (thick arrow). P: Pubic Bone; S: Sacrum; BL: Empty Bladder; C: Sigmoid Colon.*

This article has various limitations including the low sample size and the retrospective nature of the study. As such, the statements expressed above deserve confirmation on a wider series of cases. Another important limitation lies in the fact that the topic of the preliminary interaction between the referring physician and the radiologist just before the performance of the examination has not been addressed. On the other hand, the common feeling suggests that this aspect might contribute strongly to determine the radiologist's conduct during image acquisition, as well as the diagnostic yield of the examination and subsequent therapy planning. This issue in the subject of a further study already underway in our Institute.

Conclusion

MR defecography, the most powerful diagnostic tool available to day in patients with evacuation disorders, is not in itself a guarantee of success. Rather, its outcome strictly depends on the rigorous application of certain criteria including a highly performing equipment and an optimal imaging protocol, to name a few. Despite a large set of recommendations on MRD has recently been published [25] and another important forthcoming document is currently under review in the process of printing [31], the issues of what is the best time to administer rectal contrast, whether before or after imaging the pelvic anatomy, and how to tailor the examination to the specific clinical question, have received little attention yet. The current study indicates that major factors contributing to the success of MRD include (1) accurate patient coaching during the preliminary interview; (2) an image protocol which depicts first the undisturbed pelvic anatomy with both the urinary bladder and anorectum empty using a 1.5 T magnet; (3) tailoring the amount and density of contrast administration to the specific clue.

Interestingly, unlike what occurs for the visualization of pelvic anatomy, namely fascia, ligaments and nerves, a low field-strength, open magnet can still be considered a valuable option for the diagnosis of most relevant functional changes.

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Conflict of Interest

The authors have no conflict of interest to declare.

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