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Research Article

Advances in MR Defecography: Analysis of Rectal Clearance

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Abstract

Aim: To describe a technique, to be embedded into routine image processing, by which the quantitation of rectal area decrease is displayed synchronous with its graphic representation together with the image of rectal contrast emptying in a cinematic mode.

Method: The imaging series of two-hundred and twenty nine consecutive patients (191 females, 38 males, mean age and SD, 56.57 ± 14.4 yrs and 50.7 ± 16.6 yrs, respectively) with impaired defecation, fecal incontinence and prolapse syndromes who underwent MR defecography between April 2017 and July 2021, were retrospectively reviewed. The "clearance" of acoustic gel during rectal emptying is calculated planimetrically on MR sagittal images as the value of rectal area before evacuation minus the value after evacuation divided by value before evacuation × 100. In addition, the flow rate, is calculated as the change of rectal area by time (cm2/sec). Subsequently, values are displayed as a graph on the screen as the change of rectal area synchronous with the contrast emptying. The shape of the curve, numerical data and MR images are compared with clinical findings and presenting symptoms for characterization of pathologies.

Results: Average clearance values differed significantly (p, < 0.001) among the three groups i.e. 31.18 cm2 ± 23.34 in the obstructed group, 45.12 cm2 ± 22.53 in the prolapse group, and 58.27 cm2 ± 16.50 in the incontinent group. The same occurred for the flow rate i.e. 0.19 cm2/sec ± 0.15, 0.30 cm2/sec ± 0.16, and 0.83 cm2/sec ± 0.25, respectively. Rectocele accounted for the most frequent abnormality (68%) seen in the obstructed group, and the combination of rectal clearance, flow rate with graphic display and imaging feature allowed recognition of two different sub types.

Conclusion: The application of the above method indicates that a better discrimination of categories and subcategories of pathologies can be obtained in patients with functional disorders of defecation, with potential influence on therapy planning.

Keywords: *Magnetic Resonance Imaging; Defecography; Pelvic Floor Dysfunctions; Obstructed Defecation Syndrome; Pelvic Organ Prolapse; Chronic Constipation*

Introduction

Functional constipation (FC) and impaired evacuation are leading symptoms for office-based outpatient visits and are commonly associated with lower life quality, considerable health care utilization and spending for diagnostic work-up. This has emerged from a recent large-scale, multicenter study conducted in 33 countries all over the world on the epidemiology and impact of the functional gastrointestinal disorders (FGIDs), with a reported prevalence pooled rate of 11.7% for functional constipation, followed by functional diarrhea (4.7%), irritable bowel syndrome (IBS) (4.1%) and abdominal bloating/distention (3.5%) [1].

By definition, diagnostic criteria for FC [2] must include 2 or more of the following symptoms: straining during defecations, lumpy or hard stools, sensation of incomplete evacuation, anorectal obstruction/blockage, manual maneuvers to facilitate the expulsion of stools

(e.g. digital evacuation, support of the pelvic floor) and fewer than 3 spontaneous bowel movements per week. The above in more than one fourth (25%) of movements with symptom onset at least 3-to-6 months prior to physician consultation.

Traditionally, the diagnosis of FC relies on 5 key steps including clinical history, physical examination, minimal laboratory tests, colonoscopy and specific tests to evaluate constipation pathophysiology, such as transit time studies and rectal emptying imaging, i.e. defecography. The latter, combined with anorectal manometry and balloon expulsion testing, may help identifying anatomic etiologies, such as intussusception and rectocele with stool retention, as well as inability to relax the puborectalis muscle with straining, a feature considered typical of dyssynergia, so as to decide proper therapy accordingly, whether surgical or conservative.

With regard to Defecography, the original method in the early 80s [3], used fluoroscopic techniques after injection into the rectum of a semisolid barium sulphate suspension similar to the consistency of stool.

Since 1997 [4] magnetic resonance imaging using acustic jel as contrast, has almost completely replaced conventional (X-ray) techniques, mainly due to the absence of radiation hazard and its inherent superior diagnostic capabilities [5,6]. Currently, MR defecography is considered the method of choice in the diagnosis of impaired evacuation and pelvic floor dysfunctions. Despite recent refinements and valuable attempts to standardize the technique, however [7], the issue of rectal emptying quantification has received only little attention in the literature by clinicians and researchers [8,9].

Aim of the Study

The aim of the present article is to describe a technique, to be embedded into routine image processing of MR defecography, by which the quantitation of rectal area decrease is displayed synchronous with its graphic representation together with the image of rectal contrast emptying in a cinematic mode.

Materials and Methods

Study population

The clinical and imaging series of two hundred and twenty nine consecutive patients (191 females, 38 males, mean age and SD, 56.57 ± 14.4 yrs and 50.7 ± 16.6 yrs, respectively) referred to undergo MR defecography at our Diagnostic Imaging Centre between April 2017 and July 2021 were retrospectively reviewed. Most frequently, the referring doctors were coloproctogists (48.2%) rather than gastroenterologists (33.7%), followed at a considerable distance by urologists, gynecologists, physiatricians and neurophysiologists (cumulative percentage 16%). Based on their presenting symptoms, the patients were divided into three Groups as follows: Group A consisted of ninety-five patients (76 females, 19 males, mean age ± SD 55.47 ± 15.35 and 52.0 ± 17.73, respectively) with impaired defecation and chronic constipation; Group B consisted of twenty-three patients (19 females and 4 males, 56,89 ± 11,12 and 51,50 ± 12,92, respectively) with reduced control of their fecal material, whether solid, liquid or gas; Group C consisted of twenty-seven patients (23 females and 4 males, 59,0 ± 13,78 and 39,75 ± 3,40, respectively) with primary or recurrent pelvic organ prolapse and descending perineum syndromes. Presenting symptoms of group. A patients were more frequently associated with those of group C (68 cases, 59 females and 9 males) than those with group B patients (6 cases, 5 females and 1 male).

MRI examination

MR defecography was developed as described in previous reports [10], on a superconductive 1.5 T horizontal magnet (Siemens Magnetom AERA, Erlangen, Germany) equipped with high-speed gradients and surface phased-array coils wrapped around the patient's pelvis. Standard examination included static and dynamic image acquisition in the sagittal, coronal and axial planes, after injection of acustic gel into the rectum, as contrast. More specifically, the examination was conducted on the following points.

Patient interview and coaching

During this step (average time 15 minutes) the examiner evaluates all relevant documents brought by the patient including the request of the referring physician, the results of physical examination, treatments, instrumental examinations and prior surgery, if any. The various phases of the examination as well as the maneuvers to be performed-squeezing, straining, and evacuation– are thoroughly explained in details to the patient so as to make him/her aware of and participate in the success of the investigation.

Contrast preparation and administration

A well homogenized mixture of 70% coupling gel for ultrasonography and 30% tap water is prepared in the space adjacent to the diagnostic room; thereafter, with the patient in the Sims position on the diagnostic table, up to 240 milliliters of such contrast are slowly administered through an intra-anal, 3 millimeters wide rubber catheter connected to an 80 mL truncated cone syringe. During injection, the patient is asked to refer the perception of rectal filling and describe it as the first, characteristic and maximum tolerable volume. Similarly, in case of unvoluntary loss of contrast and/or urgency, the administration is interrupted and the first leakage volume as well as the volume injected at the time of loss are registered. After completing contrast administration and catheter withdrawal, the patient is turned supine and wrapped in a diaper adjusted under the undressed buttocks to collect any material.

Imaging technique

A localizer scout scan in the coronal, axial, and sagittal planes (HASTE T2 pulse sequence, Acq time 0.18 msec, FOV 400 mm, slice thick. 6.0 mm, TR 1200 ms, TE 83 ms, average 1, total n° of slices 15, SNR 1.00) is acquired first to mark the boundaries of the region of interest; then, one midsagittal fast imaging series of the pelvis is obtained at rest, during squeezing and on attempted evacuation of rectal contents using a T2 weighted TRUE FISP pulse sequence (Acq time 60 sec, FOV 260 mm, slice thick. 10 mm, TR 3.8 ms, TE 1.58 ms, average 1, total n° of slices 60, ETL 17, FA 45°, Matrix 475). The same series are repeated (no less than three attempts) in both the sagittal and coronal planes until obtaining an adequate stream of contrast. Thereafter, the patient is instructed to perform a steady-state Valsalva maneuver without interrupting the strain for 9 seconds during acquisition of three-to-four series in the axial plane, leaving the patient a 30s interval between two subsequent maneuvers. The entire emptying phase, as seen in the three scan planes, is directly videorecorded from the monitor at the time of the examination and subsequently revised in a real time or slow motion mode. Finally, static images using turbo spin-echo (TSE) T2-weighted pulse sequence (TR/TE 3880/91 msec, FA 150°, slice thickness 4 mm, FOV 260, two averages, matrix 384 x 384, FOV, 350 mm; scan time 4.33 min; total images 36) are acquired at rest in the axial, sagittal, and coronal planes to provide a complete evaluation of the pelvic anatomy.

Image analysis and interpretation

According to the basic principles described by Narayanan [8] a region of interest (ROI), is drawn around the gel-filled rectum on the MR sagittal images using a free-hand contour-tracing technique to calculate the change (%) in rectal area during no less than three emptying attempts. Unlike the original author's method, however, the upper edge of the body of the third sacral vertebra was not used as the uppermost boundary of the rectum when tracing the ROI (Figure 1A and 1B). This in view of the excessive variability of sacro coccygeal spine configuration which makes the third sacral vertebra an inconsistent reference relative to the gel filled rectal ampulla. Rather, the upper edge of the intermediate rectal compartment subdivision as described by Lesaffer [11] was preferred. The rectal clearance, defined as the proportion of contrast eliminated was estimated calculating the value of rectal area (cm^2) before evacuation minus the value after evacuation divided by the value before evacuation ×100. In addition, the flow rate, defined as the time employed for eliminating such amount of contrast, was calculated and given as cm^2 divided by t in seconds. Both parameters were considered expression of the speed and efficiency of rectal expulsion. Although beyond the scope of the present study, other well established abnormalities noted included (1) pelvic organ

prolapse, calculated as the vertical descent of bladder base, vaginal vault, prostate base and anorectal junction on straining according to the "HMO" MRI classification system; (2) levator ani hiatus enlargement on straining; (3) rectocele, defined as an outpouching of the anterior rectal wall measuring less than 2 cm in depth (small), 2-to-4 cm (moderate) or 4-to-6 (large); (4) rectoanal intussusception, defined as a circumferential in-folding of the rectal wall that descends toward the anal canal and disappears at the end of the evacuation, whether spontaneously or manually; (5) paradoxical contraction of the puborectalis muscle, defined as a persistent impression at the posterior aspect of the anorectal junction combined with lack of anorectal angle widening; and (6) enterocele defined as herniation of the pelvic peritoneum beyond the normal confines of the cul-de-sac which may contain fat, small bowel or sigmoid colon.

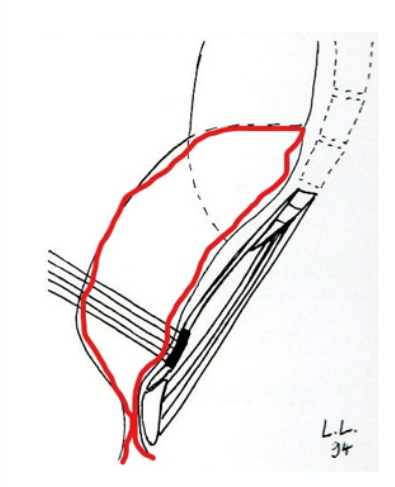

Figure 1A: *Scheme for tracing the region of interest (red contour) according to Lesaffer [11].*

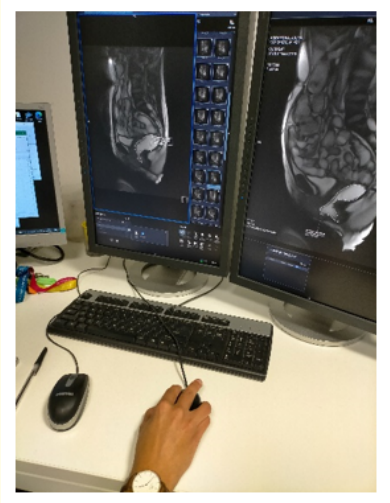

Figure 1B: *Freehand method during the post processing phase in a separate consol.*

Three radiologists (VP, M F and TM) blinded to clinical data performed the image analysis and calculated the rectal area separately. Once image analysis is over, clinical data and records collected at the time of patient's interview are re-examined to build up a combined clinical-imaging data and determine sign-to-symptom association. In this preliminary phase of the study, however, only the clearance values of acoustic gel, defined as the amount of contrast removed as result of rectal emptying, are presented in order to estimate their overall distribution in the entire population and discriminatory capacity in the three groups, if any.

In practice, on the MR sagittal images the decrease of rectal area is planimetrically calculated; subsequently the videotaped images are displayed on the screen synchronous with the graphic representation of rectal clearance. At the end, the shape and area under the curve of graphs representing the rectal emptying combined with the exact location of contrast trapping and change in morphology is used to better define the impaired evacuation in singular cases.

Statistics

Simple Descriptive statistics was used to summarise the data including measure of central tendency (mean) and spread (standard deviation and confidence interval).

Results and Discussion

The average time taken by the three examiners to draw the tracing around the jell filled ROI at 5-seconds interval during the entire cycle of the expulsive phase was 35 ± 3 seconds per image. Overall, at MR defecography the distribution of clearance of acustic gel in the entire population showed the classic bell shape (Figure 2) with cumulative means values of 39.71 ± 24.5 cm^2. When considered separately, however, average clearance values differed significantly (p, < 0.001) among the three groups as follows: 31.18 cm^2 ± 23.34 in the obstructed group, 45.12 cm^2 ± 22.53 in the prolapse group, and 58.27 cm^2 ± 16.50 in the incontinent group. The same occurred for the flow rate i.e. 0.19 cm^2/sec ± 0.15, 0.30 cm^2/sec ± 0.16, and 0.83 cm^2/sec ± 0.25, respectively (Figure 3). In the obstructed group, rectocele accounted for the most frequent abnormality (68%) seen; however, the combination of rectal clearance, flow rate with graphic display and imaging features allowed recognition of two distinct sub types, as follows: Type 1 characterized by a sand glass MR appearance and slow emptying pattern (maximal rectal area decrease -13.7% within 15 seconds) and; Type 2 characterized by a smoking-pipe MR appearance and faster emptying pattern (maximal rectal area decrease - 75.2% within 15 seconds) (Figure 4A-4C).

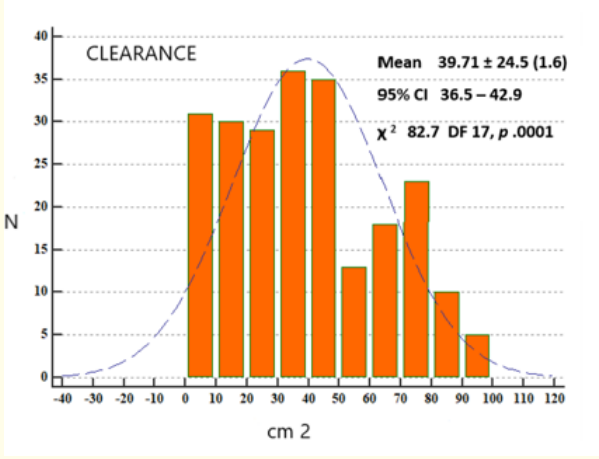

Figure 2: *Cumulative distribution of clearance values in the entire population.*

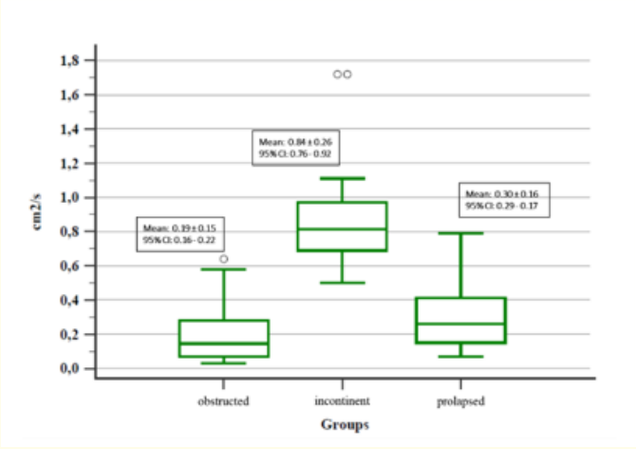

Figure 3: *Flow rate values in the three groups (see text).*

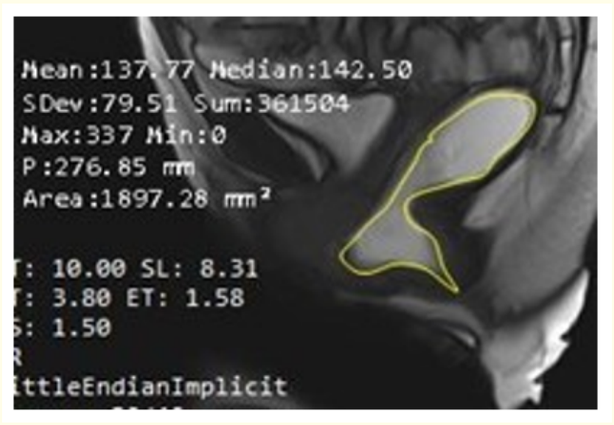

Figure 4A

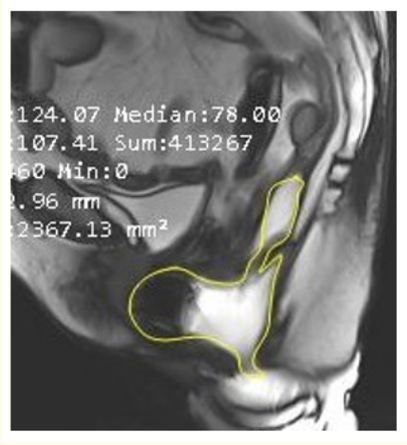

Figure 4B

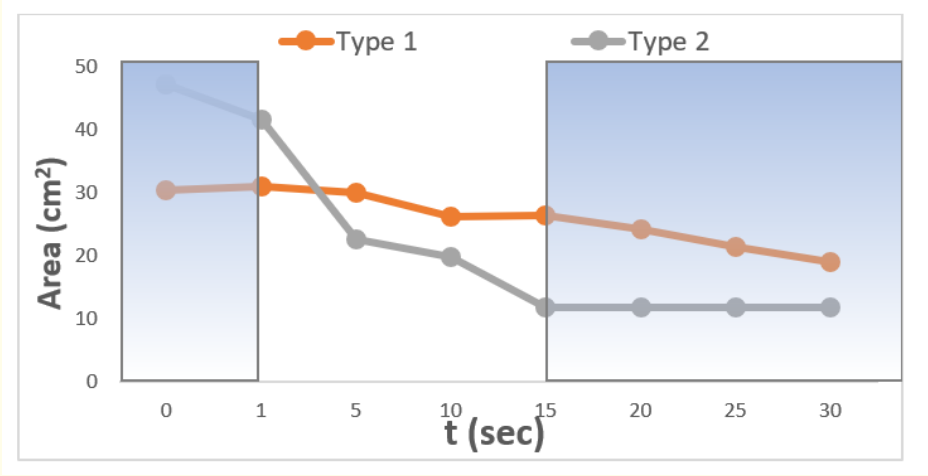

Figure 4C

Figure 4: *Type 1 and type 2 rectocele: note the different MR defecographic appearance (A and B), freehand ROI contour and tracing (C).*

Although only remotely comparable to the true evacuation phenomenon, imaging rectal contrast expulsion is the most resembling representation modern medicine can offer to date, whatever the diagnostic tool in use. It is no coincidence indeed that clinicians and researchers have so far employed various modalities, including scintigraphic [12], X-ray and, more recently MR techniques, in the belief that visualizing the expulsion of rectal content could help them distinguish various pathologies so as to decide on the treatment, whether surgical or conservative. Surprisingly however, the exact value and significance of rectal emptying quantification has not been established yet in the literature even in recent valuable contributions; as result, most of times nothing more than the contrast retained in the distal gut at the end of evacuation is reported by radiologists, and moreover in approximate terms only, such as one third, two thirds or more the amount injected. This, in overt contrast with the general trend of modern radiology which encourages to support clinical decisions by expressing as precisely as possible the various observations in quantitative terms and with precise measurements.

The results of the current study seem to indicate that including the calculation of the decrease of rectal area on sagittal MR images is worth the time spent to draw the free-hand contour tracing around the gel-filled ROI (average time 35 second per image). Regarding this drawback, however, considerable advantage can be anticipated by the implementation of computed assisted method for calculating the area by means of the so-called bit mat segmentation software for image processing [13] which, combined with algorithms developed by the aid of artificial intelligence, will contribute obtaining both superior performances and better characterization of pathological conditions. At present, it can be affirmed that calculating rectal clearance at MR defecography allows clear discrimination of cases with true obstruction from those with false one even in presence of similar changes, namely rectocele. This is particularly useful to the referring physician involved in the controversial question of whether or not planning its surgical repair. In light of what has been observed in the present study it is reasonable to affirm that type 1 rectocele, as opposed to type 2, will hardly if ever benefit from surgery, and that the conservative treatment should always be preferred.

Conclusion

Measuring the reduction of the gel-filled rectal area at MR defecography is a useful index of obstructed defecation syndrome. Its routine use can reasonably be included among the diagnostic criteria to adopt for therapy planning in functional constipation of distal gut.

Conflict of Interest

The authors declare that they have no conflict of interest.

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