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ORIGINAL CONTRIBUTION

Systematic Characterization of Defecographic Abnormalities in a Consecutive Series of 827 Patients with Chronic Constipation

ARunning head: Defecographic abnormalities in constipation

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ABSTRACT

BACKGROUND: Barium defecography can assess structural and functional abnormalities in patients with chronic constipation.

OBJECTIVE: To determine the prevalence of individual and overlapping defecographic findings in this setting.

DESIGN: Cross-sectional.

SETTING: University Hospital: tertiary gastrointestinal physiology department.

PATIENTS: Consecutive examinations of 827 consecutive patients presenting over a 30-month period with well-defined symptom severity (≥12 points on the Cleveland Clinic Constipation score): systematic evaluation of images with results stratified by sex.

MAIN OUTCOME MEASURES: Six individual functional or anatomical (intussusception, rectocele, enterocele, megarectum, excessive dynamic perineal descent) defecographic observations were defined *a priori* thus permitting 2^6 possible combinations of findings (i.e. 63 abnormal types + 1 normal).

RESULTS: Patients with constipation (mean symptom score, 19) were predominantly female (88%) with median age 49 (17-98) years. All 6 individual radiological findings were identified with a total of 43 combinations found in the cohort; the 14 most prevalent of these accounted for >85% of patients. Only 136 (16.4%) patients had a normal defecography (34.3% males vs. 13.9% females; P<0.0001). Overall, 612 (74.0%) patients had structural (n=508 [61.4%]) or functional (n=104 [12.6%]) abnormalities in isolation, with 79 (9.6%) others exhibiting combinations of both. Functional abnormalities in isolation were more common in males compared to females (22.5% vs.11.2%,P=0.025) as opposed to structural abnormalities (57.8% vs. 85.7%, P<0.0001). Expulsion time was longer in females compared to males (110 [60-120] vs. 90 [60-120] sec; P=0.049).

LIMITATIONS: Lack of multiorgan opacification.

CONCLUSIONS: These results provide a contemporary atlas of defecographic findings in constipation. Several individual structural and functional features have been systematically classified, with overlap greater than previously acknowledged and profound differences among sexes that carry implications for tailoring management. See **Video Abstract** at http://links.lww.com/DCR/B552 .

CARACTERIZACIÓN SISTEMÁTICA DE ANOMALÍAS DEFECOGRÁFICAS EN UNA SERIE CONSECUTIVA DE 827 PACIENTES CON ESTREÑIMIENTO CRÓNICO

ANTECEDENTES: La defecografía con bario puede evaluar anomalías estructurales y funcionales en pacientes con estreñimiento crónico.

OBJETIVO: Determinar la prevalencia de hallazgos defecográficos individuales y superpuestos en este entorno.

DISEÑO: Transversal.

ENTORNO CLINICO: Hospital Universitario **de tercer nivel,** departamento de fisiología gastrointestinal.

PACIENTES: Exploraciones consecutivas de 827 pacientes consecutivos que se presentaron durante un período de 30 meses con una gravedad de los síntomas bien definida (≥12 puntos en la **escala** de estreñimiento de la *Cleveland Clinic*): evaluación sistemática de imágenes con resultados estratificados por sexo.

PRINCIPALES MEDIDAS DE VALORACION: Se definieron a priori seis observaciones defecográficas individuales**,** funcionales o anatómicas (**intususcepción**, rectocele, enterocele, megarecto, descenso perineal dinámico excesivo), lo que permitió 26 combinaciones posibles de hallazgos (es decir, 63 tipos anormales + 1 normal).

RESULTADOS: Los pacientes con estreñimiento (puntuación media de síntomas, 19) eran predominantemente mujeres (88%) con una edad **mediana de** 49 (17-98) años. **Se**

identificaron 6 hallazgos radiológicos individuales con un total de 43 combinaciones encontradas en la cohorte; los 14 más **predominantes** de éstos representaron >85% de los pacientes.Solo 136 (16,4%) pacientes **tuvieron** una defecografía normal (34,3% hombres **vs**. 13,9% mujeres; P <0,0001). En general, 612 (74,0%) pacientes tenían anomalías estructurales (n = 508 [61,4%]) o funcionales (n = 104 [12,6%]) de forma aislada, y **otros** 79 (9,6%) presentaban combinaciones de ambas. Las anomalías funcionales aisladas fueron más comunes en los hombres en comparación con las mujeres (22,5% **vs.** 11,2%, P = 0,025) en comparación con las anomalías estructurales (57,8 **vs.** 85,7%, P <0,0001). El tiempo de expulsión fue mayor en las mujeres en comparación con los hombres (110 [60-120] **vs**. 90 [60-120] segundos; P = 0,049).

LIMITACIONES: Falta de opacificación multiorgánica.

CONCLUSIONES: Estos resultados proporcionan un atlas contemporáneo de hallazgos defecográficos en estreñimiento. Varias características **individuales,** estructurales y funcionales**;** se han clasificado sistemáticamente, con una superposición mayor que la reconocida anteriormente y con **grandes** diferencias entre los sexos que tienen implicaciones para adaptar **su tratamiento**. Consulte **Video Resumen** en http://links.lww.com/DCR/B552 . *(Traducción— Dr. Francisco M. Abarca-Rendon)*

KEY WORDS: Barium defecography; Chronic constipation; Evacuation disorder; Functional abnormalities; Structural abnormalities.

INTRODUCTION

Symptoms of constipation affect about 14% of the general population in Western countries,[1] mostly resulting from a primary disturbance of bowel function due to dietary or lifestyle factors or from a disorder of colonic propulsion or rectal emptying.[2] The latter, known as evacuation disorder,[3] results from inability to expel stools due to structural (e.g., intussusception, rectocele, enterocele) and/or functional causes (e.g., impaired recto-anal coordination).[4] Patients with chronic and severe symptoms (unresponsive to basic measures) may undergo specialist tests to determine pathophysiology.

Compared to non-radiological tests of evacuation and anorectal coordination (e.g. balloon expulsion test; anorectal manometry), defecography is considered the reference standard for the assessment of both pelvic floor anatomy and function, given its capability to dynamically evaluate rectal morphology (and other pelvic organs) during simulated defecation.[4,5] However, a recurrent criticism of defecography is the acknowledged overlap between health and disease,[6] hampered by a paucity of normative data. Nevertheless, despite significant heterogeneity of protocols and technical variations in published studies, a recent systematic review and meta-analysis derived specific definitions and cut-offs to diagnose 'true abnormalities' (i.e. those rarely or never found in health).[4]

Coexistence of structural and functional abnormalities has certain important implications for management. Detection of a 'functional' obstruction may be amenable to management approaches such as biofeedback. In contrast, defecography is widely used to direct the surgical approach in patients with constipation / evacuation disorder allied to pelvic organ prolapse (e.g., rectocele, high-grade intussusception), where the operation is dependent on reversal of the demonstrated anatomical abnormality. As extensively demonstrated, surgical outcomes are often suboptimal given the frequent overlap between various organic, functional and psychological factors in the same patient.[7]

Although various pathophysiological abnormalities are acknowledged,[8–10] the frequency with which they occur is poorly defined. Further, the degree of overlap between various structural and functional abnormalities is unknown. The purpose of this study was to systematically analyze findings from barium defecography (BD) to catalogue radiological findings using contemporary diagnostic criteria in a large cohort of patients with chronic constipation and to compare findings between sexes.

MATERIALS AND METHODS

Setting and Participants

All patients attending a tertiary referral center for anorectal physiology testing had data entered in a prospectively collected database. Through retrospective database interrogation, those presenting with a primary complaint of constipation (difficult and/or infrequent defecation) with or without concomitant fecal incontinence, scoring ≥12 on the Cleveland Clinic Constipation score (CCCS),[11] and undergoing defecography over a 30-month period were identified for inclusion within this cross-sectional study. Patients presenting with a primary complaint of fecal incontinence and/or pelvic floor dysfunctions other than constipation, and those in whom defecography was not technically possible (e.g. weight exceeding 120 Kg; uncontrolled anorectal pain; major incontinence on transfer to the commode precluding any interpretation of radiological imaging) were excluded.

Clinical assessment

All patients were screened for coexistent gastrointestinal (GI) disease and other relevant comorbidities using a comprehensive, self-report questionnaire, which included validated scores for constipation,[11] fecal incontinence,[12] irritable bowel syndrome,[13] and joint hypermobility syndrome,[14] as well as structured surgical, medical and obstetric histories. The 7-point Bristol Stool Form scale was used to categorized stools into ‘hard’ (score 1–2), ‘normal’ (score 3–4), ‘loose’ (score 5–7), or variable (i.e. more than one category selected).[15]

GI physiology testing

In addition to defecography, patients typically underwent a battery of lower GI physiology tests including anorectal manometry, rectal sensation to balloon distension (hypersensitivity was defined as a maximum tolerated volume <75 mL, whereas hyposensitivity was diagnosed when ≥2 sensory thresholds were above normal limits),[16] and whole gut transit study using radio-opaque markers. This latter test was limited to patients reporting infrequent (<3 per week) defecation, and was performed by administration of a single set of markers (n=50), with delayed transit defined as >20% retention.[17]

Defecography

A detailed description of the technique is provided in Suppl. Table 1 http://links.lww.com/DCR/B553 . Specific measurements are described below.

Static measurements

Posterior anorectal angle

The posterior anorectal angle (PARA) was defined as the angle between a tangential line drawn along the posterior edge of the rectal ampulla just proximal to the impression of the puborectalis and a line drawn along the axis of the anal canal. The angle was measured during rest, squeeze and maximum evacuatory effort (Suppl. Figure 1 http://links.lww.com/DCR/B554).

Rectal diameter

The mid-rectal diameter was determined by measuring a line drawn between the anterior and posterior walls of the rectum at its widest point.[18] If >8.1 cm in males or >6.9 cm in females, a diagnosis of megarectum was made (Figure 1).[19] The volume of neostool instilled to reach a strong sustained desire to defecate was also recorded (Suppl. Table 1 http://links.lww.com/DCR/B553).

Dynamic measurements

Structural abnormalities

Rectocele was defined as an outpouching of the rectal wall during maximal evacuatory effort.[20] The height was measured as the length of a line running across the 'mouth' of the rectocele, and the depth as the length of a line running perpendicularly from the line across the mouth to the apex of the bulge.[19,21] Based on the latter measurement, rectocele size was determined (e.g. small [<2 cm]; medium [2-4 cm]; large [>4 cm]).[8] In addition, rectocele morphology was defined according to Marti types I (digitiform), II (with a lax rectovaginal septum, an anterior mucosal prolapse and a deep pouch of Douglas), or III (associated with intussusception or even rectal prolapse).[22] The presence of contrast retained within the pouch was also recorded. Large rectoceles (irrespective of symptoms) and medium rectoceles (if present, together with at least one of the following complaints: a) sense of pelvic organ prolapse; b) digital assistance to aid fecal expulsion) were considered as structurally significant. Small rectoceles were deemed as a variant of normality, as were isolated medium trapping and asymptomatic rectoceles (Suppl. Table 2 http://links.lww.com/DCR/B553).

Rectal intussusception was defined as an infolding of the rectal wall during straining and characterized using the Oxford Prolapse Grade system (Figure 1).[23] In addition, the presence of obstructive features were recorded. Any obstructing and Oxford grade 3-5 non-obstructing intussuscepta were considered as structurally significant, whereas non-obstructing Oxford 1-2 intussuscepta were not considered structurally relevant,[4] i.e. a normal variant (Suppl. Table 2 http://links.lww.com/DCR/B553).

Enterocele was defined as a herniation of the posterior cul-de-sac downward between the vagina and rectum,[24] or between the bladder and rectum in males, manifest as a broad invagination of the anterior rectal wall, and deemed as structurally significant in all cases (Figure 1).

Excessive dynamic perineal descent was defined as descent of the anorectal junction during straining more than 3.5 cm from its resting position at the inferior plane of the ischial tuberosities.[25]

Functional abnormalities

One or more of the following criteria deemed indicative of dyssynergic defecation defined a functional abnormality on expulsive attempts[19,26,27]: a) incomplete or absent opening of the PARA; b) incomplete or absent anal sphincter relaxation (maximal lower anal canal width <0.5 cm); c) ineffective propulsive forces (absent rectal mobility or dissipated force vectors during push efforts) (Figure 1).

Evacuatory inefficiency

Each procedure was timed from the commencement of evacuatory effort to completion. The percentage of contrast expelled at end evacuation was calculated from the area of contrast within the rectum at rest. Expulsion <65% of neostool and/or evacuation >150 seconds were considered as abnormal.[19]

Combinations of radiological findings

Six binary BD observations (presence or absence) were selected *a priori* by consensus of the study authors (surgeons, radiologists and GI physiologists with at least 10 years of experience in BD) to identify a finite number of defecographic types. These were: (1) functional abnormality; (2) structurally significant intussusception; (3) structurally significant rectocele; (4) excessive dynamic perineal descent; (5) enterocoele; and (6) megarectum. These variables in random combination could give rise to 2^6 (=64) possible defecographic types, including normal. Venn diagrams and UpSet tool were used for the quantitative analysis of sets, their intersections, and aggregates of intersections. UpSet is web-based and open source (https://vdl.sci.utah.edu/upset2/) focused on creating task-driven aggregates, communicating

the size and properties of aggregates and intersections, and a duality between the visualization of the elements in a dataset and their set membership.[28]

Operators and Assessors

Defecography was performed by 9 different clinical practitioners throughout the study period, all appropriately trained, with 5 to 23 years of experience in the procedure, and with the appropriate radiation protection certification. Measurements and morphologies were determined by two study coordinators (both with 5 years of experience in BD), with discrepancies resolved by the senior author. Reviewers were blinded to patients' history during radiological assessment.

Statistical analysis

Main results were reported descriptively as proportions of the cohort with each finding of interest. Categorical variables were compared using Fisher's exact test or Pearson's chi-square test with Bonferroni correction for multiple comparisons; continuous variables were reported as mean (standard deviation, SD) or median (interquartile range, IQR) as appropriate. All analyses were performed using proprietary software (Stata V15.0; Stata Corp., College Station, Texas, USA). To account for multiple testing, the Benjamini-Hochberg method was used to control the false discovery rate (FDR) set at 10%. Corrected *P* values were calculated and reported for the assessment of statistically significant sex differences.[29]

RESULTS

Participants

A total of 832 subjects initially fulfilled criteria for inclusion (Figure 2) of whom five (0.6%) were excluded due to major contrast loss on transfer to the commode precluding any reliable analysis. Of the remaining 827 patients (median age, 49 years; range, 17-98), 725 (87.7%) were female. Among these, 525 (72.4) were parous with a median of 2 (IQR, 2-4) childbirths.

Two-hundred-eight (28.7%) female patients had undergone hysterectomy. No statistically significant differences were found between sexes for all comparisons except for CCCS, with marginally higher mean symptom severity (~1 full point of the scale) demonstrated in females compared to males (18.6 [3.6] vs. 17.5 [3.1], respectively; P=0.002) (Table 1).

Defecographic findings

Static measurements

No differences were found in terms of rectal diameter at rest between sexes. The mean volume of rectal contrast used was 248 (SD, 103) mL with no significant variation between sexes (P=0.87) (Table 2).

Dynamic measurements

Volume of contrast expelled and prevalence of evacuatory inefficiency was similar between sexes (Table 2). However, expulsion time was shorter in males (90 [60-120] seconds) compared to females (110 [60-120] seconds) (P=0.049). Overall, defecography was classified as normal (i.e. normal parameters of evacuation, in the absence of any pathological obstructive structural or functional features) in 136 (16.4%) patients. A total of 612 (74.0%) patients had structural abnormalities in isolation (61.4%) with 9.6% in combination with a functional abnormality (Figure 3). Among structurally significant abnormalities (n=571 [69%]), 50% (n=283) occurred in isolation and 50% (n=288) in combination (Figure 4). Isolated rectocele and intussusception were the most prevalent radiological findings, accounting for 18% and 15%, respectively. When considering combined abnormalities, the association of intussusception and perineal descent was the most frequently encountered (10%).

Functional abnormalities were detected in a larger proportion of males compared to females (29.4% vs. 21.1%, respectively; P=0.078) (Table 2; Figure 5) whereas structural abnormalities were much more prevalent in females (85.7% vs. 57.8% in males; P<0.0001),

mainly due to the higher rate of significant rectoceles in these patients (52.1% vs. 2.0% in males; P<0.0001). Enterocele and excessive dynamic perineal descent were also more frequently found in females compared to males (22.3% vs. 12.7%, P=0.036 and 29.9% vs. 14.7%, P=0.001, respectively). Rectocele depth was greater in parous women compared to nulliparous (median, 2.7 [2.0-3.5] vs. 2.4 [2.0-2.9] cm, respectively; P=0.007). However, increasing parity was not associated with a greater number of abnormalities. Although the rate of intussusception did not differ between sexes, structurally insignificant intussuscepta were less frequently encountered in males compared to females (4.9% vs. 14.8%; P=0.016). Minor differences (not statistically significant) were noted in gender distribution of intussuscepta according to the Oxford Prolapse Grade system.[23]

Combinations of radiological findings and gender comparison

Of 64 possible combinations of radiological findings, a total of 43 (67%) were encountered in the cohort (Figure 6). However, the first 14 in descending order covered 86% of the total population (n=714), with each including at least 2% of the cohort (Table 3). Patients with a normal defecography (type I) and those with an isolated functional abnormality (type II) were the most prevalent, accounting together for about 30% (Table 3). Sex differences for the first five types were statistically significant (Benjamini-Hochberg corrected *P* values with FDR at 10%), with types I and II being more prevalent in males than females, as opposed to types III to V. Among females undergoing a whole gut transit study (n=360), those with an isolated functional abnormality (type II) were more likely to show delayed rather than normal transit time (25/149 [17%] vs. 19/211 [9%]: P=0.040).

DISCUSSION

This is the first study to systematically review defecographic findings in patients with chronic constipation using rigorous methodology and applying definitions derived from recent data in healthy subjects,[19] systematic review and meta-analysis.[4] Moreover, the study provides

defecographic characterization of the largest series ever reported of male patients with moderate to severe symptoms of constipation.

Our analysis shows that multiple structural and functional abnormalities may coexist in the same subject, with degree of overlap greater than previously recognized. Of 64 possible *a priori* defined structural and functional radiological combinations, a total of 43 (67%) were encountered in 827 patients, though the 14 most prevalent of these encompassed >85% of the patient cohort (Table 3). The most common finding was a functional abnormality in isolation (12.6%) and this was more frequently encountered in males than females (P<0.025). Significant, common structural abnormalities (rectocele and intussusception) were identified in 61.4% of patients and co-existed in 86%. A normal study was encountered in 16.4% patients and was much more prevalent in males than females (34% vs. 14%, respectively; P<0.0001).

The first systematic description of defecographic normality was published by Mahieu *et al.*[20] who studied 56 asymptomatic subjects. Normal recto-anal dynamics were based on characterization of 5 radiological features: (a) increase in the anorectal angle; (b) obliteration of the impression of the puborectalis muscle; (c) wide opening of the anal canal; (d) total evacuation of the rectal contents; (e) normal resistance of the pelvic floor. Ahlback and Broden reported the first large series of patients (n= 781).[30] Since that time, 7 large case series (>250 patients) have been published (Table 4). Only 3 of these exclusively focused on patients with constipation.[31–33] Others included a mixture of defecation disorders without providing stratified results on constipated patients. Emblematic is the paper by Mellgren *et al.*[8] on 2,816 patients (superseding Ahlback and Broden),[30] two thirds of whom were constipated (Table 4). Despite being the largest series ever reported, this study is limited by its very long duration of data collection (32 years c.f. < 3 years current study) and the high number (n=7) of assessors involved in the interpretation of defecographic data, with

methodological changes that may have influenced the outcomes throughout the study length. The low prevalence of functional abnormalities (4%) is certainly underestimated as it was not recorded during the first 20 years of experience.

The majority of existing series sought to determine the prevalence of structural and functional abnormalities as separate entities. The study by Grassi *et al.*[34] is the only one to provide details about the coexistence of both abnormalities. Despite reporting on patients with varied defecation disorders (with at least two thirds being constipation), 8% of 564 patients were diagnosed with combined structural and functional abnormalities, which is similar to the prevalence observed in our series (10%). Among structural abnormalities, our prevalence of significant intussusception (28%) is equivalent to that reported by Mahieu *et al.*[20] (23%) and Dvorkin *et al.*[33] (25%). Prevalence of rectocele in other studies varies from 22% to 89%, mainly secondary to heterogeneity in definitions and cut-offs adopted to diagnose significant rectoceles. The latter point is of critical importance given the high prevalence of rectocele in healthy women.[19] When considering small or isolated trapping/asymptomatic medium-sized rectoceles as a variant of normality (Suppl. Table 2 http://links.lww.com/DCR/B553), prevalence of rectoceles did not reach 50% in our series, with slightly less than one third (31%) being significant. Prevalence of enterocele (21%) was equivalent to that reported by Mellgren *et al.*[8] (19%) and Agachan *et al.*[35] (16%). Prevalence of excessive dynamic perineal descent was double in women compared to men (30% vs. 15%), with a greater ratio than that reported by Andrade *et al.*[36] using the same cut-off for diagnosis (22% vs. 17%).

Prevalence of functional abnormalities in previously published studies ranged between 8% and 29%, reflecting methodological variability between studies (e.g. using fixed or defecatory desire contrast volumes and heterogeneity in definitions). The overall prevalence observed in our series was slightly lower than that reported by Agachan *et al.*,[35] possibly due

to the higher number of males included in their compared to our study (24% vs. 12%, respectively). There is also large variation in the prevalence of normality among published studies, ranging from 8% to 38%. The 16% rate observed in our series resulted from the adoption of rigorous methodology derived from previous studies on healthy subjects,[4,19] and was 3 times more likely to occur in males compared to females. Yet, this prevalence is surprisingly high considering that all patients scored above 11 to CCCS. Hence, further causes of obstructive defecation may contribute to symptom severity, especially in males (e.g. hemorrhoidal disease; anal fissure; impaired rectal sensation).

Limitations

The main limitation of this study is the lack of administration of multiorgan contrast. Therefore, prevalence estimates are strictly linked to our protocol. While aimed to improve sensitivity, bowel, vaginal, and bladder opacification undoubtfully increase invasiveness of this test and, as such, make defecography less well accepted by patients. The lack of administration of oral contrast may have underestimated the prevalence of enteroceles, which was however identical to that resulting from a recent meta-analysis of studies reporting the use of small bowel opacification (i.e. 20.4%).[4] In the current study, although defecographies were conducted by nine experienced and consistently-trained clinical practitioners throughout the study period, measurements and morphologies were determined by 2 assessors upon good inter-observer agreement, similar to previous reports.[37,38] Further, whether structural (or indeed functional) abnormalities represent the cause of symptoms, or are the resultant effect of other underlying constipation mechanisms remains uncertain in some patients.

Interpretation

Do our findings have relevance to patient management? This is difficult to answer due to the absence of any prospective stratified studies in the field. It is thus impossible to judge whether the distinction of a radiologically significant finding from one observed in health

affects outcomes, at least based on the published literature. However, the surgical community increasingly depends on the distinction between a 'physiological' and 'pathological' entity, since litigation and intense media scrutiny force surgeons to rigidly objectify their motivation for offering surgery (especially mesh and stapling).[39] Accordingly, a multi-disciplinary position statement has been written.[40] It has to be emphasized that defecography was deemed abnormal in 84% of patients in this study, yet only 36% of these patients had abnormal parameters of emptying. This finding should not be neglected when determining the appropriateness of surgical repair of structurally significant abnormalities (e.g. high-grade recto-anal intussuscepta) that do not impede emptying. Ultimately, decision-making depends on correlation of patient history, symptoms, examination findings and the results of specialist radio-physiological testing (including defecography).

CONCLUSION

In conclusion, significant structural abnormalities (i.e., those not seen in health) and functional abnormalities are common in patients with chronic constipation. As the primary goal for any useful clinical test is to provide the correct diagnosis, our data will at the very least provide a useful atlas of findings to clinicians and thence understanding for patients. Ultimately they may aid design of future studies in which such findings are used to stratify management.

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FIGURE LEGENDS

Figure 1. Defecographic characterization of functional abnormalities (absent opening of the anorectal angle and ineffective propulsive forces on push maneuver up to 240 seconds since the start of the procedure), enterocele, megarectum, and intussusception according to the Oxford Prolapse Grade system.

Figure 2. Patient flow chart. CCCS: Cleveland Clinic Constipation score; CC: chronic constipation.

Figure 3. Outcomes of defecography in the patients' cohort. Venn's diagrams (left); UpSet graph (right).

Figure 4. Prevalence of structural abnormalities. Venn's diagrams (left). UpSet graph (right).

Figure 5. Outcomes of defecography in males and females.

Figure 6. Upset graph showing the prevalence of the 43 defecographic types encountered.

Suppl. Figure 1. Examples of (A) hyper-acute (males, <84°; females, <80°) and (B) hyper-obtuse (>132°) posterior anorectal angle at rest based on the results of a previous study on healthy subjects.[19]

TABLE 1. Patients' demographics and clinical characteristics.

Characteristics	**Total N=827**	**Females N=725**	**Males N=102**	***P***
Age, years	49.2 (15.2)	49.1 (15.0)	50.2 (16.5)	0.511
CCCS (max. 30)	18.5 (3.6)	18.6 (3.6)	17.5 (3.1)	**0.002**
St Marks Incontinence score (max. 24)	9.0 (6.4)	9.0 (6.4)	8.8 (6.6)	0.693
Bristol Stool Form scale				
Normal (3-4-5)	95 (11)	81 (11)	14 (14)	0.457
Hard (1-2)	211 (26)	187 (26)	24 (23)	0.534
Loose (6-7)	71 (9)	58 (8)	13 (13)	0.230
Variable	450 (54)	399 (55)	51 (50)	0.547
Irritable bowel syndrome (Rome IV criteria)†	278 (48)	248 (49)	30 (44)	0.463
Beighton score‡	1.8 (2.0)	1.8 (2.0)	1.6 (2.0)	0.532
Tight (0-3)	517 (84)	450 (84)	67 (86)	0.785
Hypermobile (4-6)	68 (11)	61 (11)	7 (9)	0.660
Distinctly hypermobile (7-9)	29 (5)	25 (5)	4 (5)	0.777
Use of medications				
Opioids	151 (18)	129 (18)	22 (22)	0.431
Antidepressants	220 (27)	191 (26)	29 (28)	0.744
Rectal sensitivity§				
Normal	597 (79)	525 (78)	72 (81)	0.680
Hyposensitivity	120 (16)	105 (16)	15 (17)	0.894
Hypersensitivity	42 (5)	40 (6)	2 (2)	0.215
Whole gut transit time¶				
Normal	235 (59)	211 (59)	24 (65)	0.575
Delayed	162 (41)	149 (41)	13 (35)	

†*Available for 575 (70%) of patients.*
‡*Available for 614 (74%) of patients.*
§*Available for 759 (92%) of patients.*
¶*Available for 397 (48%) of patients.*

TABLE 2. Defecographic parameters and findings.

Parameters	**Total N=827**	**Males N=102**	**Females N=725**	***P***
Volume of rectal contrast, ml	248 (103)	246 (109)	248.2 (103)	0.868
Rectal diameter at rest, cm	5.5 (4.2)	5.5 (1.5)	5.5 (4.4)	0.987
Volume of contrast expelled, %	70 (60-80)	70 (55-80)	70 (60-80)	0.589
Expulsion time, sec	107 (60-120)	90 (60-120)	110 (60-120)	**0.049**
Normal defecography	136 (16)	35 (34)	101 (14)	**<0.0001**
Evacuatory inefficiency	294 (36)	37 (36)	257 (35)	0.958
Functional abnormalities	183 (22)	30 (29)	153 (21)	0.078
Structural abnormalities	680 (82)	59 (58)	621 (86)	**<0.0001**
Significant	571 (69)	68 (67)	503 (69)	0.660
Insignificant	304 (37)	17 (17)	287 (40)	**<0.0001**
Intussusception	434 (52)	48 (47)	386 (53)	0.676
Significant	268 (32)	36 (35)	232 (32)	0.065
Obstructing Oxford 3-5	96 (12)	12 (12)	84 (12)	0.745
Non-obstructing Oxford 3-5	121 (15)	19 (19)	102 (14)	0.081
Obstructing Oxford 1-2	51 (6)	5 (5)	46 (6)	0.947
Insignificant	112 (14)	5 (5)	107 (15)	**0.016**
Oxford grade				
I	43 (10)	3 (6)	40 (11)	0.453
II	174 (40)	14 (29)	160 (42)	0.137
III	124 (28)	15 (31)	109 (28)	0.773
IV	77 (18)	13 (27)	64 (16)	0.106
V	16 (4)	3 (6)	13 (3)	0.402
Rectocele	380 (46)	2 (2)	378 (52)	
Significant	260 (31)	1 (1)	259 (36)	
>4 cm trapping	54 (7)	0 (0)	54 (7)	
>4 cm non trapping	5 (1)	0 (0)	5 (1)	
2-4 cm trapping & symptomatic	201 (24)	1 (1)	200 (28)	
Insignificant	88 (11)	1 (1)	87 (12)	
Depth, cm	2.8 (1.0)	<2	2.8 (1.0)	
Marti types				
I	112 (14)	0 (0)	112 (16)	
II	188 (23)	1 (1)	187 (26)	
III	80 (10)	1 (1)	79 (11)	
Enterocele	175 (21)	13 (13)	162 (22)	**0.036**
Megarectum	24 (3)	6 (6)	18 (3)	0.104
Excessive dynamic perineal descent	232 (28)	15 (15)	217 (30)	**0.001**

TABLE 3. Most prevalent defecographic types in descending order (i.e. including at least 2% of the total cohort = 14/43).

Radiological findings		Total N=714 (86%)	Males N=90 (88%)	Females N=624 (86%)	*Benjamini Hochberg P* value
I	Normal	136 (16)	23 (23)	101 (14)	**<.001**
II	Functional abnormality	104 (13)	23 (23)	81 (11)	**.025**
III	Rectocele + intussusception	76 (9)	1 (1)	75 (10)	**.003**
IV	Rectocele	74 (9)	1 (1)	73 (10)	**.003**
V	Rectocele + intussusception + EDPD	57 (7)	0 (0)	57 (8)	**.003**
VI	Intussusception + EDPD	53 (6)	11 (11)	42 (6)	.218
VII	Intussusception + enterocele	41 (5)	8 (8)	33 (5)	.488
VIII	Intussusception	36 (4)	8 (8)	28 (4)	.200
IX	Rectocele + EDPD	29 (4)	0 (0)	29 (4)	.139
X	Rectocele + intussusception + enterocele	29 (4)	0 (0)	29 (4)	.139
XI	Rectocele + functional abnormality	25 (3)	0 (0)	25 (3)	.191
XII	Intussusception + enterocele + EDPD	19 (2)	1 (1)	18 (3)	.533
XIII	Rectocele + intussusception + enterocele + EDPD	18 (2)	0 (0)	18 (3)	.343
XIV	Enterocele	17 (2)	2 (2)	15 (2)	.533

EDPD: excessive dynamic perineal descent.

TABLE 4. Defecographic findings in studies reporting on >250 patients after Mahieu *et al*. [20].

First author	Year	No. (F, %)	Mean age	Inclusion criteria	CC %	Vol. (ml)	Duration (years)	Assessors (No.)	Normal %	Abnormalities						
										Structural % (significant I and R, %)					Functional %	Combined %
										I	EP	R	E	EDPD		
Mahieu [20]	1984	132 (77)	46	CC	100	300	NR	NR	28	31 (23)	5	22 (22)	NR	1	NR	NR
Sunderland [31]	1992	288 (82)	47	CC	100	120	NR	NR	38	6 (NR)	1	23 (NR)	NR	21	26	NR
Mellgren† [8]	1994	2816 (84)	54	Mixed disorders	67	NR	32.0	7	23	31 (NR)	13	27 (NR)	19	9	4‡	NR
Grassi [36]	1994	564 (72)	53	Mixed disorders	~70	150	3.0	NR	NR	15 (NR)	2	60 (NR)	NR	10	15	8
Agachan [37]	1996	744 (76)	64	Mixed disorders	60	DDV	7.0	NR	12	30 (NR)	8	41 (10)	16	35	29	NR
Dvorkin [33]	2005	896 (81)	48	CC	100	DDV	7.5	2	12§	31 (25)	NR	89 (NR)	NR	NR	12§	NR
Andrade [38]	2014	290 (92)	58	Mixed disorders	NR	DDV	2.7	2	8	33 (NR)	4	60 (NR)	NR	22	12	NR
Bozkurt [32]	2014	630 (93)	46	Rome III CC	100	NR	3.5	NR	9	42 (NR)	NR	79 (NR)	NR	3	8	NR
Grossi	2020	827 (88)	49	CC with CCCS ≥12	100	DDV	2.8	2	16	49 (28)	4	46 (31)	21	28	22	10

F: females; CC: chronic constipation; CCCS: Cleveland Clinic Constipation score; I: intussusception; EP: external prolapse; R: rectocele; E: enterocele; EDPD: excessive dynamic perineal descent; NR: not recorded; DDV: defecatory desire volume.

†*Superseded Ahlback, Broden [30]*

‡*Underestimated as only recorded since 1980*

§*Combined normal or functional abnormalities*

Figure 1

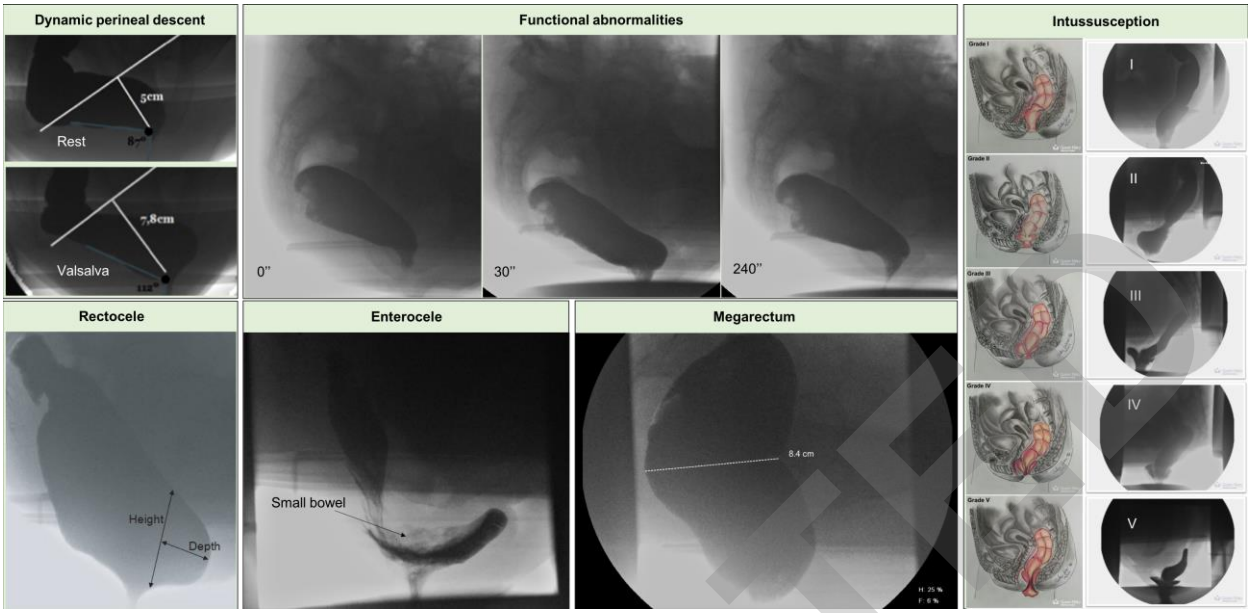

Figure 2

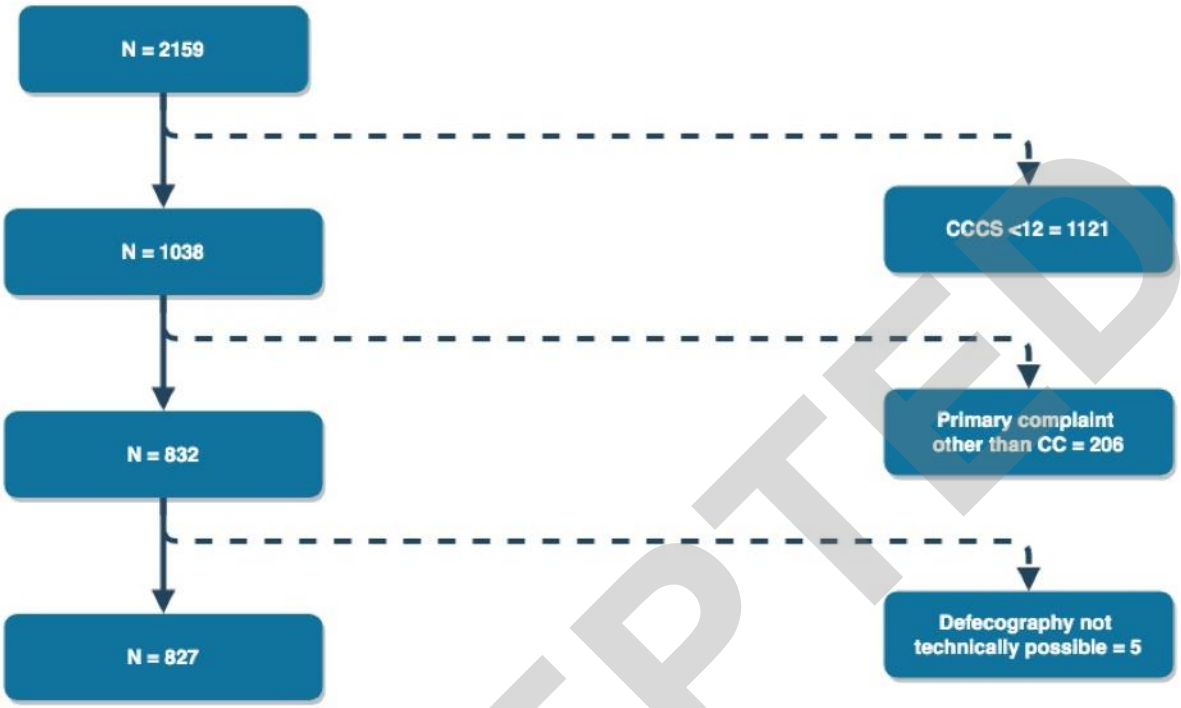

Figure 3

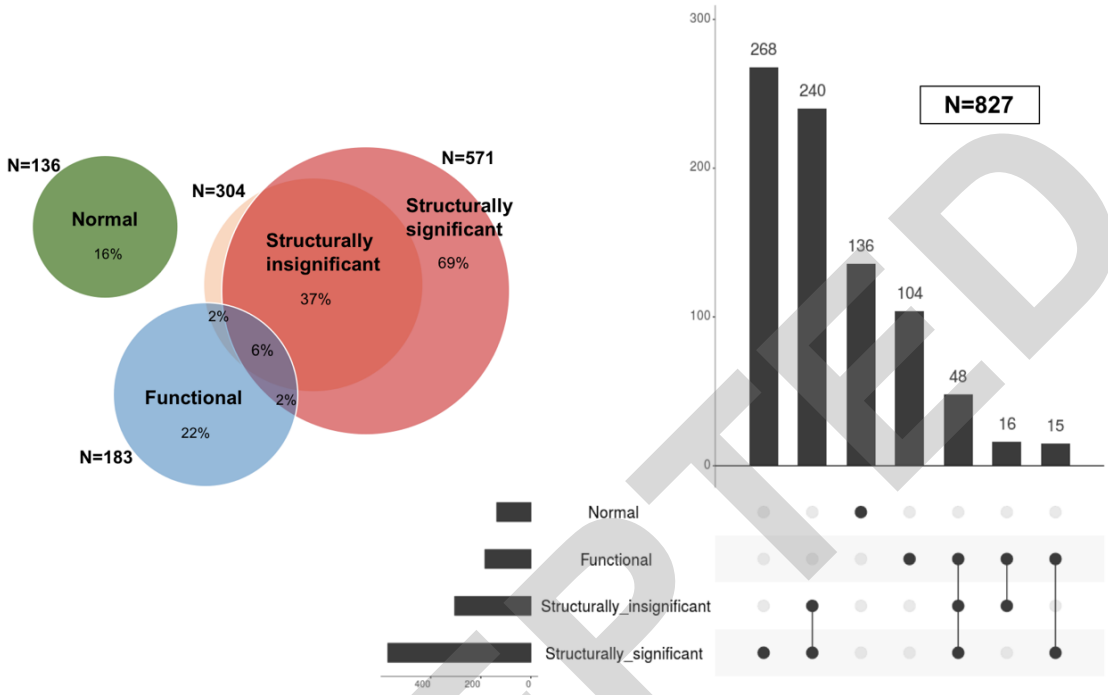

Figure 4

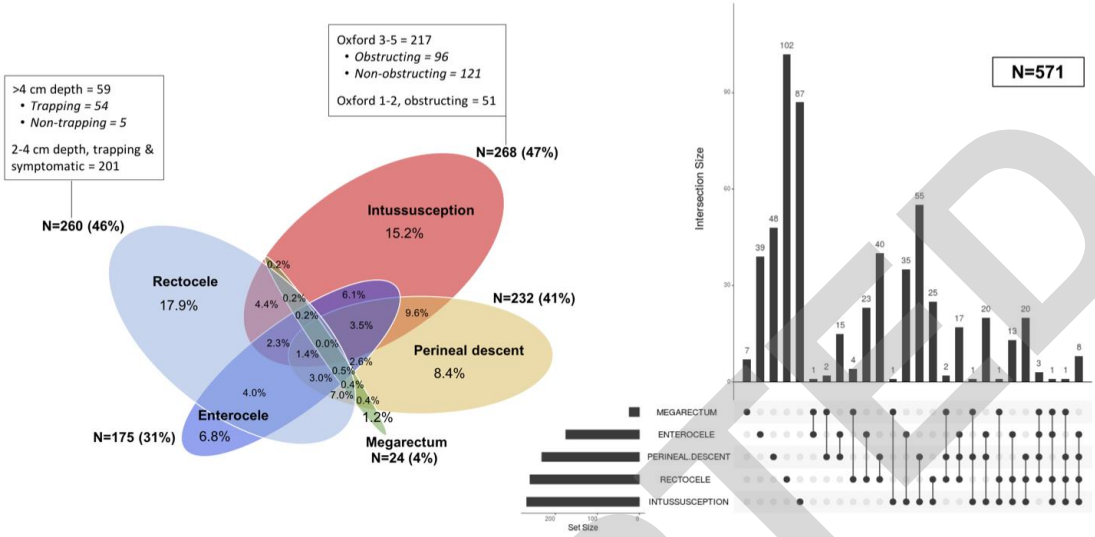

Figure 5

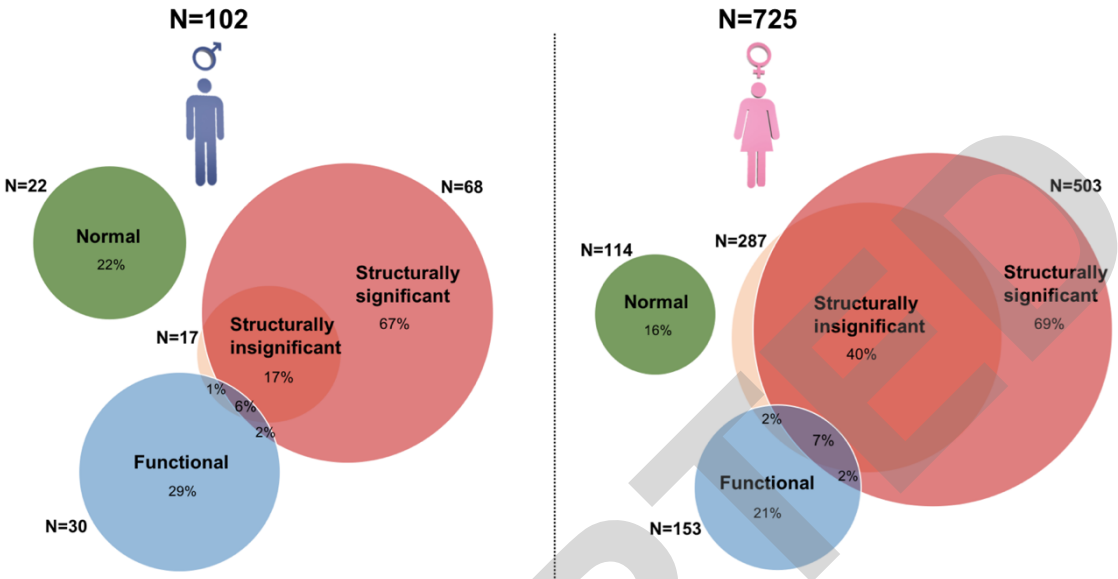

Figure 6