



Anorectal Manometry in Defecatory Disorders: A Comparative Analysis of High-resolution Pressure Topography and Waveform Manometry

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Background/Aims

Whether high-resolution anorectal pressure topography (HRPT), having better fidelity and spatio-temporal resolution is comparable to waveform manometry (WM) in the diagnosis and characterization of defecatory disorders (DD) is not known.

Methods

Patients with chronic constipation (Rome III) were evaluated for DD with HRPT and WM during bearing-down “on-bed” without inflated rectal balloon and “on-commode (toilet)” with 60-mL inflated rectal balloon. Eleven healthy volunteers were also evaluated.

Results

Ninety-three of 117 screened participants (F/M = 77/16) were included. Balloon expulsion time was abnormal (> 60 seconds) in 56% (mean 214.4 seconds). A modest correlation between HRPT and WM was observed for sphincter length ($R = 0.4$) and likewise agreement between dyssynergic subtypes ($\kappa = 0.4$). During bearing down, 2 or more anal pressure-segments (distal and proximal) could be appreciated and their expansion measured with HRPT but not WM. In constipated vs healthy participants, the proximal segment was more expanded (2.0 cm vs 1.0 cm, $P = 0.003$) and of greater pressure (94.8 mmHg vs 54.0 mmHg, $P = 0.010$) during bearing down on-commode but not on-bed.

Conclusions

Because of its better resolution, HRPT may identify more structural and functional abnormalities including puborectal dysfunction (proximal expansion) than WM. Bearing down on-commode with an inflated rectal balloon may provide additional dimension in characterizing DD.

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Key Words

Anal canal; Constipation; Defecation; Gastrointestinal motility; Manometry

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Introduction

Defecatory disorders (DD), a prevalent condition associated with constipation, require anorectal testing to identify dyssynergic defecation and other rectal structural abnormalities.¹ Anorectal manometry is the preferable test for DD and conventional waveform manometry (WM) has been the gold standard until recently when high-resolution (HR) technology becomes available.² The greater fidelity and spatio-temporal topography of HR anorectal manometry allows better delineation of anatomy and physiological details that is not possible with WM, however, this has not been adequately studied or compared.

Four types (I-IV) of manometric patterns of DD have been described by Rao et al³ and Rao and Singh⁴ with WM. These 4 patterns can also be observed with HR topographic display.² Most recently, a study using complex principal components analysis of pressure data from HR anorectal manometry classified patients with DD into 3 distinct motor patterns^{5,6} which were similar to the Rao et al³ subtypes. Besides diagnosis and classifying dyssynergic patterns, HR pressure topography (HRPT) can reveal the differential involvement of anal sphincteric components that may explain the underlying pathophysiology of DD.⁷⁻⁹

The HR anorectal manometry system provides a dual display of anorectal pressure changes; a topographic plot and a manometric plot that can be viewed by toggling between the 2 modes. However, DD has been mainly characterized using WM. The aim of this study is to compare manometric assessment of DD and its subtypes using both HRPT and WM, and to determine the correlation between techniques and if there are other additional advantages of HRPT over WM.

Materials and Methods

Study Participants

Prospective patients referred to a tertiary center with chronic symptoms of constipation (for at least 6 months) were evaluated for participation. Besides anorectal manometry, all participants underwent colonoscopy, flexible sigmoidoscopy or barium enema, and blood tests to exclude any underlying mucosal or metabolic diseases that could cause constipation. For comparison, 11 healthy participants without chronic constipation as determined by the Rome III questionnaire underwent the same study protocol, including the above-mentioned investigations to exclude organic disorders. All

participants had informed consent on study entry. The protocol and informed consent form were approved by the Institutional Review Board of Georgia Regents University, Augusta, United States.

Participants with constipation were included into the study if they fulfilled the Rome III criteria for functional defecatory disorder. Briefly, participants fulfil the symptom criteria for functional constipation and 2 or more of the physiologic criteria including (1) presence of 1 of the 4 DD patterns (I-IV patterns) previously described by Rao et al³ and Rao and Singh,⁴ (2) inability to expel a balloon or stool-like device, (3) a prolonged colonic transit time, and (4) inability to expel barium or > 50% retention during defecography.

Participants were excluded if their predominant symptom was abdominal pain or bowel habit changes suggestive of irritable bowel syndrome or fecal incontinence other than that associated with fecal impaction, complicated pelvic floor surgery, spinal cord injury or stroke, previous abdominal surgery (except for cholecystectomy, hysterectomy, and appendectomy), and significant psychiatric or other co-morbid illnesses.

Anorectal Manometry

Anorectal manometry system

All participants underwent anorectal manometry using the same system (Given Imaging, Yoqneam, Israel) of which the technical details have been published previously.² Briefly, the 4.2 mm probe with 10 sensors at 6-mm interval was placed along the anal canal, and 2 other sensors housed in a 4-cm latex balloon were placed into the rectum. The sector pressures from these 12 sensors were averaged to obtain a single mean value at each location. Each sensing element records pressure transients excess of 6000 mmHg/sec and is accurate to within 1 mmHg of atmospheric pressure. The probe was connected to a proprietary recorder (Manoscan 360AR, Given Imaging) and the data recorded with the acquisition software at a frequency of 35 Hz. Due to the effect of "thermal drift," the probe was calibrated in a warm water-bath each week and thermal compensation applied to the data during analysis to compensate for the drift.¹⁰

Protocol of anorectal manometry

Approximately 3 minutes of familiarization was allowed lying on a bed in the left lateral position. This was followed by 1 minute of resting pressure assessment. Participants were then asked to squeeze the anal sphincter twice with 30-second interval of rest period and squeeze-hold for 30 seconds for assessment of endurance.

Abdomino-pelvic reflex was assessed by asking the participant to blow-up a party balloon twice separated by 30 seconds rest period. Subsequently, participants were asked to bear down “on-bed” without inflated rectal balloon as if to defecate for 2 or 3 occasions at 1-minute intervals. To simulate physiological defecation, participants were asked to attempt bearing down “on-commode or toilet.” The commode is a mobile unit, with soft seat cushion and has a removable dry collection pail. The procedure was carefully explained to the participant beforehand. The probe was secured in place with tapes and extreme care of the probe was taken when moving the participant from the bed to the commode. Once on the commode, the rectal balloon was inflated with 60-mL of water to simulate stool. The participant was then asked to perform the usual bearing down maneuver. After completion of the test, the participant was then moved back to the bed and the probe removed after deflation of the balloon.

Acquisition of anorectal pressure

Pressure parameters were derived from the proprietary software (Manoview AR v1.0; Given Imaging). Rectal pressure was measured by the proximal sensor within the rectal balloon. Anal pressures were measured by several sensors that straddled the anal

canal but the e-sleeve option allowed a single value at every time point. During resting and squeeze maneuvers, e-sleeve identified the maximum of all pressures recorded by anal sensors at any time point. On the other hand, for bearing down, the e-sleeve identified the most positive (or least negative) difference between rectal and anal pressures over 30 seconds of maneuver. For WM, 30 seconds e-sleeve values of the distal 2 cm of the anal canal was used to determine mean resting, squeeze, and bearing down pressures. For HRPT, 30 seconds e-sleeve values of all sensors straddling the anal canal was used to calculate the mean pressures of resting, squeeze, and bearing down pressures.

Anorectal pressure analysis during bearing down

The anal sphincter at rest and during bear down on-bed and on-commode were determined, with upper and lower baseline limits being the limits of anal sphincter length, measured in mean \pm SD. When there was anal sphincter lengthening during bearing down (Fig. 1), the proximal anal segment (p_1) was defined as the pressure segment above the upper baseline limit of the anal high-pressure zone, and the distal segment (p_2) was defined as the pressure segment between upper baseline limit and lower limit of the anal high-pressure zone. Mean pressure was derived using the software for

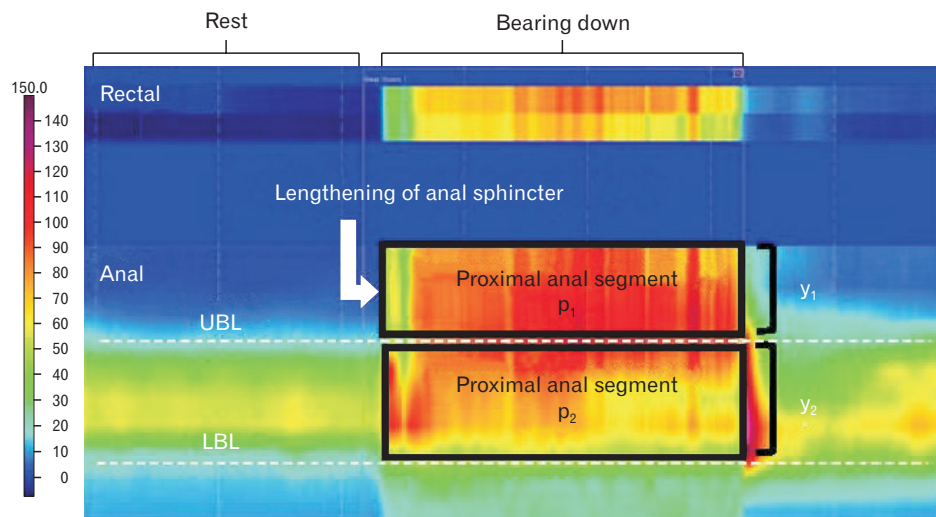


Figure 1. Color topography but not conventional lines is able to discern 2 or more different anal pressure segments (proximal and distal) during bearing down maneuvers. The proximal anal segment probably signifies the lengthening of anal sphincter during bearing down. The anal sphincter at rest and during bear down on-bed and on-commode were determined, with upper baseline limits (UBL) and lower baseline limits (LBL) being the limits of anal sphincter length, measured in mean \pm SD. The proximal anal segment was defined as the pressure segment above the upper baseline limit of anal high-pressure zone, and the distal segment defined as the pressure segment between upper baseline limit and lower limit of the anal high-pressure zone. Mean pressure was derived using software for both pressure segments (p_1 for proximal segment and p_2 for distal segment). Length of the proximal anal segment (y_1) was defined as distance between upper baseline limit of anal high-pressure zone to the uppermost limit measurable by sensor of the probe, and length of distal anal segment (y_2) as the distance between upper baseline limit and lower limit of the anal pressure zone.

both pressure segments. Length of proximal anal segment (y_1) was defined as the distance between the upper baseline limit of anal high-pressure zone to the uppermost limit measurable by the sensor of the probe, and length of distal segment (y_2) as the distance between the upper baseline limit and lower limit of the anal pressure zone.

In addition to DD patterns described by Rao et al³ and Rao and Singh,⁴ the 3 subtypes based on principal components analysis recently described by Ratuapli et al⁵ (high anal, hybrid, and low rectal) were also determined (Fig. 2). Type I was similar with high anal subtype, type II similar with hybrid subtype and type IV similar with low rectal subtype, but a similar description by Ratuapli et al⁵ for Rao's type III was not available. During bearing down, an intra-rectal pressure ≤ 45 mmHg was defined as inadequate and a percentage anal relaxation of $\leq 20\%$ was defined as abnormal.¹¹ Defecation index³ and rectoanal pressure gradient (RAPG),¹² both measures for coordinated effort of the rectum and anus, were also calculated.

Balloon Expulsion Test

After anorectal manometry, participants were asked to attempt

expulsion on-commode in their own privacy of a 50-mL water-filled 4-cm balloon in their rectum and the test was stopped if the balloon was not expelled by 5 minutes. A balloon expulsion time (BET) ≥ 60 seconds was considered as abnormal.

Statistical Methods

Both HRPT and WM were examined separately by 2 investigators (Yeong Yeh Lee and Askin Erdogan) independently using the proprietary software, Manoview Analysis Program (Given Imaging). Each HRPT and WM tracing was given a number and with simple randomization using a number table, and the investigators were randomly assigned to either tracing of HRPT or WM. To further reduce ascertainment bias, results were not disclosed to each investigator until data analyses. Both investigators had good agreement levels (κ coefficient = 0.8) before starting the study. Any disagreement on analysis of tracing was resolved individually with a third senior investigator (Satish Rao).

All data were presented as mean \pm SD unless otherwise stated. Correlations between HRPT and WM on manometric parameters were determined with correlation analysis (Pearson, R or Spearman, r coefficient). Comparison of lengths and pressures of anal sphinc-

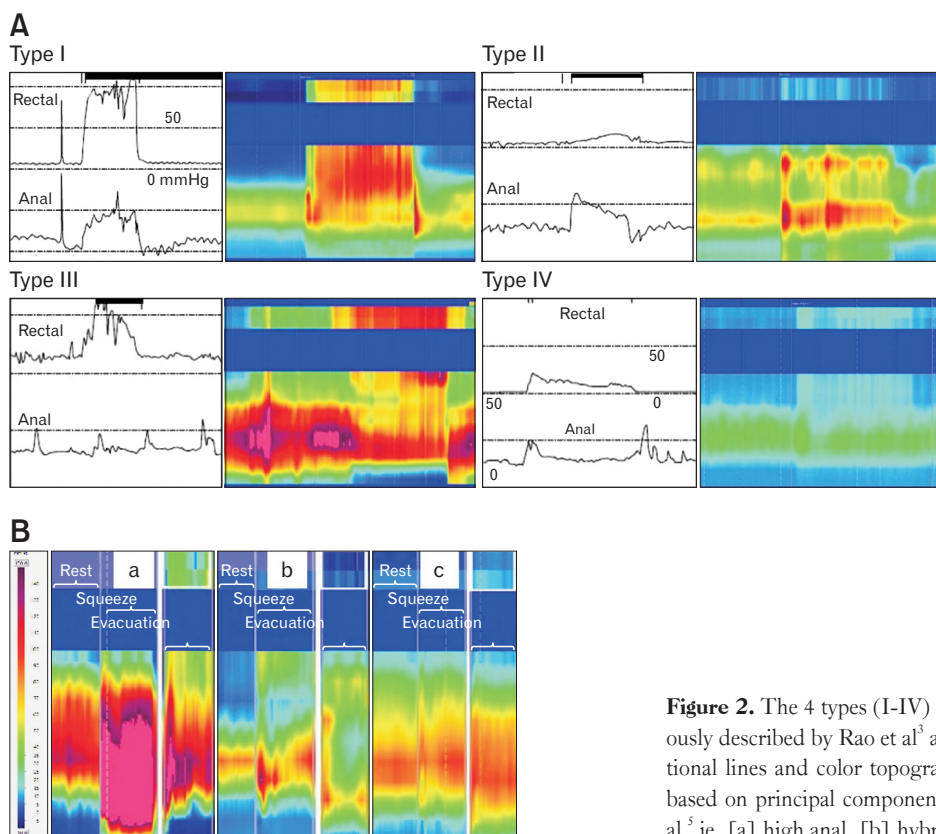


Figure 2. The 4 types (I-IV) of dyssynergic defecation patterns (A) previously described by Rao et al³ and Rao and Singh⁴ are illustrated in conventional lines and color topographic forms. (B) The 3 defecatory subtypes based on principal components analysis recently described by Ratuapli et al,⁵ ie, [a] high anal, [b] hybrid, and [c] low rectal.

ter between constipated and healthy subjects were made using *t* test. For all statistical tests, $P < 0.05$ was considered significant.

Results

Characteristics of Study Participants

A total of 117 consecutive participants with constipation were screened and eventually 93 participants were included into the study. Of those excluded participants, 9 were because of absence of defecatory disorder or failed BET, 7 were due to incomplete examination or technical issues with the anorectal manometry system, and the rest because of exclusion criteria.

Of the 93 participants with defecatory disorders (F/M, 77/16; mean age 48 ± 17 years), 77% had straining during defecation, 66% had hard stools, 83% with incomplete evacuation, and 57% reported fewer than 3 defecations/week. In addition, more than 80% of patients claimed the use of enemas. Slightly above half (56%) had abnormal BET > 60 seconds (F/M, 43/8; mean BET time of 214.4 ± 100.1 seconds). All healthy participants (M/F, 5/6; age range 22-55 years) had normal BET and without DD. There were no encounters of probe damage during the bearing down maneuver on-commode.

Correlation Between Pressure Parameters and Agreement of Dyssynergic Defecation Patterns

Pressure parameters measured by HRPT and WM and their correlations are presented in Table 1. There were significant correlations between HRPT and WM for resting anal pressures, maximum squeeze, and sustained/endurance squeeze (coefficient ranged 0.8 to 0.9, all $P < 0.001$), except for anal length ($R = 0.4$, $P < 0.001$). Between the 2 techniques of HRPT and WM, both rectal and anal pressures correlated for bearing down on-bed (both $r = 0.8$, $P < 0.001$), but not during bearing down on-commode (both $r = 0.1$ and $P = 0.300$). On the other hand, with HRPT, bearing down on-commode with an inflated rectal balloon, supposedly more physiological, correlated with bearing down on-bed for rectal pressure but modest correlation for anal pressures ($r = 0.7$ and $r = 0.5$ respectively, both $P < 0.001$). Both defecation index ($r = 0.6$, $P < 0.001$) and RAPG ($r = 0.7$, $P < 0.001$) correlated between the 2 techniques. Dyssynergic patterns determined by HRPT and WM and their κ coefficients are presented in Table 1. Between the 2 techniques of HRPT and WM, agreement between DD patterns was poor ($\kappa = 0.4$, $P < 0.001$), and likewise agreement between DD patterns described by Rao et al³ and Ratuapli et al⁵ ($\kappa = 0.4$, $P < 0.001$) (data not shown).

Table 1. Correlation Analysis of Pressure Metrics and Agreement Levels of Dyssynergic Patterns Between High-resolution Pressure Topography and Waveform Manometry

Parameters	HRPT	WM	Analysis ^{a,b}	P-value
Rest (mean [SD], mmHg)	77.2 (27.0)	72.1 (26.7)	0.8 ^a	< 0.001
Length (mean [SD], cm)	3.6 (0.8)	3.8 (0.8)	0.4 ^a	< 0.001
Maximum squeeze (median [IQR], mmHg)	156.2 (103.7)	148.9 (94.9)	0.9 ^a	< 0.001
Sustained squeeze (mean [SD], mmHg)	89.0 (33.1)	94.3 (34.6)	0.9 ^a	< 0.001
Bear down on-bed, rectal (median [IQR], mmHg)	42.3 (32.2)	42.7 (31.7)	0.8 ^a	< 0.001
Bear down on-bed, anal (median [IQR], mmHg)	61.2 (25.6)	62.2 (32.3)	0.8 ^a	< 0.001
Bear down on-commode, rectal (median [IQR], mmHg)	105.5 (155.4)	102.3 (162.0)	0.3	0.010
Bear down on-commode, anal (median [IQR], mmHg)	80.8 (157.0)	77.8 (171.1)	0.1	0.300
DI (median [IQR])	0.7 (0.4)	0.7 (0.5)	0.6 ^a	< 0.001
RAPG (median [IQR], mmHg)	-17.8 (-22.9)	-16.6 (-32.4)	0.7 ^a	< 0.001
DD patterns, type 1 (n [%])	21 (23.1)	30 (33.0)		
DD patterns, type 2 (n [%])	28 (30.8)	27 (29.7)	0.4 ^b	< 0.001
DD patterns, type 3 (n [%])	14 (15.4)	13 (14.3)		
DD patterns, type 4 (n [%])	28 (30.8)	21 (23.1)		

^aCorrelation analysis: Pearson's or Spearman rho correlation co-efficient, depending on normality of data. ^bAgreement analysis: kappa coefficient. HRPT, high-resolution pressure topography; WM, waveform manometry; IQR, interquartile range; DI, defecation index; RAPG, rectoanal pressure gradient; DD, dyssynergic defecation. $P < 0.05$ as significant.

Table 2. Characteristics of Anal Expansion Observed With High-resolution Pressure Topography During Bearing Down in Constipated Versus Healthy Individuals

Parameters	Healthy (n = 11)	Defecatory disorders (n = 93)	P-value
On-bed without rectal balloon			
Total anal length ($y_2 + y_1$)	4.5 (0.7)	4.5 (0.6)	0.900
Anal length (y_2), distal (mean [SD], cm)	3.3 (0.6)	2.4 (0.4)	0.004
Anal length (y_1), proximal (mean [SD], cm)	1.2 (0.7)	1.9 (0.3)	0.050
Anal pressure (p_2), distal (mean [SD], mmHg)	58.2 (12.6)	68.2 (24.0)	0.300
Anal pressure (p_1), proximal (mean [SD], mmHg)	41.5 (19.7)	48.5 (23.9)	0.600
On-commode with rectal balloon			
Total anal length ($y_2 + y_1$) (mean [SD], cm)	4.2 (0.6)	4.8 (0.4)	0.003
Anal length (y_2), distal (mean [SD], cm)	3.2 (0.9)	2.8 (0.4)	0.100
Anal length (y_1), proximal (mean [SD], cm)	1.0 (0.7)	2.0 (0.5)	0.003
Anal pressure (p_2), distal (mean [SD], mmHg)	60.4 (18.5)	87.1 (21.3)	0.004
Anal pressure (p_1), proximal (mean [SD], mmHg)	54.0 (6.8)	94.8 (35.1)	0.010

$P < 0.05$ as significant.

Expansion of Anal Sphincter During Bearing Down in Constipated Participants

HRPT but not WM was able to discern 2 or more different anal pressure segments (proximal, p_1 and distal, p_2) during bearing down on-bed and on-commode (Fig. 1). In addition, the anal sphincter was observed to expand in length during bearing down with HRPT but not with WM. Mean total length ($y_1 + y_2$) of the anal sphincter was greater during bearing down than at rest both on-bed ($4.4 \text{ cm} \pm 0.7 \text{ cm}$ vs $3.6 \text{ cm} \pm 0.8 \text{ cm}$, $P < 0.001$) and on-commode ($4.6 \text{ cm} \pm 0.7 \text{ cm}$ vs $3.6 \text{ cm} \pm 0.8 \text{ cm}$, $P < 0.001$). Distal segment (y_2) was longer than proximal segment (y_1) both during bearing down on-bed ($2.8 \text{ cm} \pm 0.7 \text{ cm}$ vs $1.7 \text{ cm} \pm 0.7 \text{ cm}$, $P < 0.001$) and on-commode ($2.7 \text{ cm} \pm 0.7 \text{ cm}$ vs $1.8 \text{ cm} \pm 0.8 \text{ cm}$, $P < 0.001$). The observed differences in length between segments also corresponded to differences in mean anal pressure between segments where the anal pressure was greater in the longer distal segment (y_2) vs the shorter proximal segment (y_1) ($62.9 \text{ mmHg} \pm 22.2 \text{ mmHg}$ vs $53.8 \text{ mmHg} \pm 23.9 \text{ mmHg}$, $P < 0.001$) during bearing down on-bed.

Anal Sphincter Expansion in Healthy Versus Constipated Individuals

Anal sphincter expansion observed with HRPT in constipated participants was also present in healthy individuals but different characteristics were observed (Table 2). Total anal length ($y_1 + y_2$) was significantly longer in the on-commode than on-bed in constipated ($P = 0.003$) but not healthy participants ($P = 0.900$). The proximal segment (y_1) was twice longer in constipated vs healthy

participants during bearing down on-commode ($2.0 \text{ cm} \pm 0.5 \text{ cm}$ vs $1.0 \text{ cm} \pm 0.7 \text{ cm}$, $P = 0.003$) but not on-bed ($P = 0.050$). On the other hand, a longer distal anal segment (y_2) was observed in healthy vs constipated participants during bearing down on-bed ($P = 0.004$) but not on-commode ($P = 0.100$). Anal pressures in the proximal (p_1) and distal (p_2) segments of bearing down on-commode were increased in constipated vs healthy participants ($P = 0.010$ and $P = 0.004$, respectively) but not during bearing down on-bed ($P = 0.6$ and $P = 0.3$, respectively).

Anal Expansion in Defecatory Disorders With Normal Versus Abnormal Balloon Expulsion Time

Table 3 shows the pressure metrics and anal expansion features in defecatory disorders with normal vs abnormal BETs. There were no differences in pressure metrics in those with normal vs abnormal BETs (all $P > 0.1$). During bearing down on-bed, there were also no differences observed in anal expansion between normal and abnormal BETs (all $P > 0.05$). Likewise, during bearing down on-commode, no differences were observed in normal vs abnormal BETs (all $P > 0.2$).

Discussion

The main findings from the current study include the following; (1) between HRPT and WM, significant correlations were observed of pressure metrics except for sphincter length and pressure metrics during bearing down on-commode, (2) during bearing down, HRPT but not WM can identify 2 or more anal pressure

Table 3. Characteristics of Pressure Metrics and Anal Expansion in Defecatory Disorders With Normal Versus Abnormal Balloon Expulsion Test

Parameters	Normal BET < 60 sec (n = 40)	Abnormal BET ≥ 60 sec (n = 51)	P-value
Pressure metrics			
Rest (mean [SD], mmHg)	72.0 (24.2)	81.3 (28.5)	0.100
Maximum squeeze (median [IQR], mmHg)	152.0 (131.8)	156.7 (105.4)	0.200
Sustained squeeze (mean [SD], mmHg)	88.4 (33.7)	89.5 (33.0)	0.900
DI (median [IQR])	0.8 (0.6)	0.7 (0.3)	0.100
RAPG (median [IQR], mmHg)	-13.4 (-23.4)	-21.5 (-24.6)	0.100
Anal sphincter expansion characteristics: on-bed			
Rectal (median [IQR], mmHg)	46.5 (35.2)	41.1 (29.9)	0.300
Anal (median [IQR], mmHg)	59.4 (22.4)	62.6 (25.2)	0.300
Anal pressure (P2), distal (mean [SD], mmHg)	60.3 (19.4)	65.2 (23.6)	0.300
Anal pressure (P1) proximal (mean [SD], mmHg)	51.3 (18.7)	52.6 (29.9)	0.400
Anal sphincter expansion characteristics: on-commode			
Rectal (median [IQR], mmHg)	106.0 (151.6)	102.5 (143.4)	0.300
Anal (median [IQR], mmHg)	76.7 (148.8)	82.8 (155.8)	0.900
Anal pressure (P2), distal (mean [SD], mmHg)	79.9 (35.3)	78.4 (25.1)	0.800
Anal pressure (P1), proximal (mean [SD], mmHg)	86.7 (29.6)	82.8 (34.1)	0.600

BET, balloon expulsion test; IQR, interquartile range; DI, defecation index; RAPG, rectoanal pressure gradient.
P < 0.05 as significant.

segments (distal and proximal), (3) there is a difference in characteristics of anal pressure segments during bearing down between healthy and constipated participants, especially with additional test of bearing down on-commode (toilet) with an inflated rectal balloon, however, and (4) there is no difference between abnormal vs normal BETs in pressure metrics and anal expansion characteristics regardless of bearing down on-bed or on-commode.

Pressures derived from solid state and water-perfused anorectal manometry were shown in studies to correlate well, although these studies found higher anal sphincter pressures and a shorter sphincter with solid state HR manometry.¹³⁻¹⁶ In these correlation studies, both techniques were performed on the same participants but on separate days, with intervals not clearly defined, and hence there is a potential for measurement bias due to changes in the anorectal physiology over time. Other factors to consider that might affect measurement include catheter design, number of sensors and diameter of the catheter, but these were eliminated with the current study design. In our study, to reduce bias, both HRPT and WM were performed in the same patients, at the same time with the same machine, but the tracings were analyzed by 2 experienced investigators at random. Our results indicate a good correlation in pressure metrics between the 2 techniques except for the length of sphincter and pressures during the bearing down on-commode. The agreement of DD types between the 2 techniques were poor, in keeping with a recently published data,¹⁶ and this is probably because of better

resolution of HRPT. Likewise, agreement between DD patterns described by Rao et al,³ Rao and Singh,⁴ and Ratuapli et al⁵ (Fig. 2) was poor and this suggests that they are not directly comparable.

Due to a better resolution of HRPT that captures data along the whole length of the sphincter, it can discriminate 2 or more anal pressure segments and their lengths that was not discernible with WM (Fig. 1). In both constipated and healthy participants, we observed a longitudinal expansion of anal high-pressure zone as evidenced by an increase in the length during bearing down when compared to its resting length. It may represent recruitment of more muscle during attempted defecation and or lengthening of anal sphincter muscles including puborectalis, external anal sphincter and longitudinal muscles that has been shown to occur during “normal” defecation.^{17,18} This process seems to be “exaggerated” in constipated compared to healthy participants by causing an expansion and increase in pressure of the proximal high-pressure zone. Whether this is unique to DD and a cause or effect of constipation merits further studies.

Interestingly, this lengthening may potentially increase the muscle mass and pose further resistance to the outlet causing functional obstruction to flow of stool. This expansion in the proximal segment is likely to be a result of recruitment and anterior pull of puborectalis muscle acting on the cranial part of the anal canal⁷ although longitudinal muscles may also be involved in a synergistic fashion. Recently 8 subtypes of dyssynergia have been described us-

ing HRPT and this includes 2 subtypes where puborectalis appears to be dyssynergic whereas external anal sphincter shows normal relaxation.¹⁹ This indicates that the puborectalis muscle rather than the longitudinal muscles may be more important in characterizing subtypes of DD. Indeed, abnormal contractions of the puborectalis muscle are often seen in obstructed defecation, and patients with these abnormal contractions seem to respond favorably to biofeedback treatment.^{20,21} Further studies are needed to ascertain the role of puborectalis muscle in different DD patterns, especially type I and III and their responses to biofeedback therapy.

Our study suggests that the HRPT provides assessment of function of the puborectalis and longitudinal muscles in constipated patients. In healthy subjects, the length of proximal segment (y_1) was similar during bearing down on-bed or on-commode but in constipated participants, the proximal segment (y_1) was significantly longer and of higher pressure on-commode than on-bed. The distal anal segment (y_2) was longer on-bed in healthy vs constipated patients because of lesser proximal segment recruitment among the healthy compared to constipated patients. The proximal segment recruitment was “enhanced” with bearing down on-commode, and this additional test on-commode seems to bring out abnormality in puborectalis function more than compared to bearing down on-bed. Furthermore, bearing down on-commode with inflated rectal balloon is probably more physiological compared to bearing down on-bed without inflated rectal balloon. Inflation of the rectal balloon during bearing down on-commode to simulate stool may therefore add another physiological dimension to this test. DD was found to persist when the test was performed in the more physiological condition of bearing down on-commode with an inflated rectal balloon. On the other hand, besides pressure metrics, the 2 methods of bearing down did not discriminate between normal and abnormal BETs. Similar to previous studies, although abnormal BETs may indicate a greater possibility of dyssynergia, this test does not define structural and physiological mechanisms of disordered defecation,²² which is the reason why pressure metrics were similar regardless of BET. Further studies are needed to confirm if bearing down on-commode with the rectal balloon inflated is a better diagnostic test than bearing down on-bed using HRPT.

There are limitations to the study. The results were produced by the same catheter and analyzed by the same software but presented to different investigators, and thus the numerical values could be similar but it is the qualitative interpretation of data that really matters. A larger sample of healthy participants matched for age and sex might be preferable. However, we acknowledged the limitation that the differences in age between healthy and constipated partici-

pants might affect pressure profiles. Likewise, the effect of possible sphincter injury on the manometric assessment of multiparous women. The description of expanded proximal anal segment might be seen by other investigators as pressure from the rectum or in case of a positive RAPG, as a normal simulated defecation maneuver. Unfortunately, our finding of expanded anal segment in constipation had not been validated using endo-anal ultrasound or other imaging techniques. Lastly, defecatory disorders are frequently seen in healthy and not just constipated subjects, but our study was not designed to compare defecatory abnormalities present in health and disease.

As a conclusion, we found a modest correlation between HRPT and WM for identifying sphincter length and dyssynergia. Because of its better resolution, HRPT may identify more structural and functional abnormalities including puborectal dysfunction than WM in patients with defecatory disorders that are associated with constipation. Bearing down on-commode with an inflated rectal balloon may provide additional dimension in characterizing constipation.

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Conflicts of interest: Satish S C Rao reports no conflict of interest in the context of this report but has served as a consultant for Forest Laboratories, Ironwood Pharmaceuticals, Takeda Pharmaceuticals, Salix Pharmaceuticals, and Given Imaging. Yeong Yeh Lee, Askin Erdogan, Siegfried Yu, and Annie Dewitt report no conflicts of interest.

Author contributions: Yeong Yeh Lee, Askin Erdogan, Siegfried Yu, Annie Dewitt, and Satish S C Rao contributed equally to the study design, data collection, statistical analysis, and writing of manuscript.

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