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ORIGINAL ARTICLE

Relationships between the results of anorectal investigations and symptom severity in patients with faecal incontinence

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Abstract

Purpose Anorectal dysfunction is the focus of diagnostic investigations for faecal incontinence. However, severity of incontinence and anorectal investigation results can be discordant. The aim of this study was to define the relationships between anorectal investigation results and incontinence severity to determine which measures, if any, were predictive of incontinence severity.

Methods Patients presenting for investigation of faecal incontinence completed a symptom questionnaire, anorectal manometry, rectal sensation, pudendal nerve terminal motor latency, and endoanal ultrasound. Bivariate analyses were conducted between the Jorge-Wexner score and investigation results. Subgroup analyses were performed for gender and symptom subtypes (urge, passive, mixed). A multiple regression analysis was performed.

Results Five hundred and thirty-eight patients were included. There were weak correlations between the Jorge-Wexner score and maximal squeeze pressure [$r = -0.24$, 95%CI(-0.31, -0.16), $p < 0.001$], and resting pressure [$r = -0.18$, (95%CI(-0.26, -0.10), $p < 0.001$]. In men only, there were significant associations between the Jorge-Wexner score and endoanal sonography [IAS defects: $t(113) = -2.26$, $p = 0.03$, $d = 0.58$, 95%CI(-4.38, -0.29)] and rectal sensation (MTV: $r_s = -0.24$, 95%CI(-0.41, -0.06), $p = 0.01$). No substantial differences were observed in the urge/passive/mixed subgroup analyses. Multiple regression analysis included three variables: age ($\beta = 0.02$, $p = 0.17$), maximal resting pressure ($\beta = -0.01$, $p = 0.28$), and maximal squeeze pressure ($\beta = -0.01$, $p < 0.01$). The variance in the Jorge-Wexner score accounted for by this model was < 10%, ($R^2 = 0.07$, $p = < 0.01$, adjusted $R^2 = 0.06$).

Conclusion Anorectal investigations cannot predict the severity of faecal incontinence. This may be due to limitations of diagnostic modalities, the heterogeneity of anorectal dysfunction in these patients, or contributing factors which are extrinsic to the anorectum.

Keywords Faecal incontinence · Anal canal · Rectum · Manometry · Endosonography · Digestive system diseases

Introduction

Faecal incontinence is a common symptom with significant implications upon health, socialisation, and quality of life [1–4]. The estimated prevalence in the community is 8.3–12.4% [5], with symptoms likely to be under reported given their sensitive nature [3]. Faecal incontinence is a major contributor to aged care placement in the elderly [1] and incurs substantial healthcare costs with an estimated total annual expenditure exceeding AUD$1.5 billion [6] in Australia.

Anal sphincter injury and/or anorectal dysfunction are considered to be the predominant causes of faecal incontinence [7–9]. Diagnostic investigations include endoanal sonography, anorectal manometry, rectal sensation, and pudendal nerve terminal motor latency (PNTML). Collectively, these tests can determine the presence of a structural injury of the anal sphincter, neuromuscular dysfunction of the anal sphincter and pelvic floor, and the presence of pudendal nerve neuropathy. However, objective evidence of anorectal dysfunction in patients with severe incontinence is not always

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apparent, where as some patients with a demonstrable anorectal injury are asymptomatic or experience only mild incontinence. For example, anal sphincter injury is reported in 27% of primiparous women [10, 11], yet less than one-third of women with sphincter injuries report faecal incontinence postpartum [12]. Conversely, 40% of patients presenting with faecal incontinence have normal anal sphincter morphology on endoanal sonography [13]. Whilst lower anal canal resting and squeeze pressures have been associated with faecal incontinence when compared with healthy controls [14–16], there remains a considerable overlap in findings between these groups [17, 18]. One study found that 9% of women and 18% of men with faecal incontinence had normal results on all routine anorectal investigations [19].

Using the St. Mark's [15] and Jorge-Wexner [7] symptom scores as a measure of incontinence severity, Lam et al. demonstrated a significant association between abnormal findings on anorectal manometry and incontinence severity in a cohort of 218 patients [20]. However, that correlation was evident only in a subgroup of patients who reported soft stool consistency [20]. Studies with smaller sample sizes have failed to demonstrate any association between anorectal investigation results and incontinence severity using the Jorge-Wexner score [21], or the Faecal Incontinence Severity Index and Faecal Incontinence Quality of Life Scale [22]. The most important outcome pre- and post-intervention for faecal incontinence is whether the treatment can elicit a reduction in severity or resolution of symptoms. In order to achieve this, it is critical to be informed of which structural or physiological abnormalities are of most benefit to address.

In the anorectal clinic at Flinders Medical Centre, Australia, a clinical database of anorectal investigation results was established for patients with faecal incontinence. Using this database, our aim was to examine the relationships between anorectal investigations and the severity of incontinence to determine which measure or combination of measures, if any, were predictive of faecal incontinence severity.

Methods

Ethics approval was received from the Southern Adelaide Clinical Human Research Committee. All adult patients who presented to Flinders Medical Centre, South Australia, for investigation of faecal incontinence between 1998 and 2015 were considered for inclusion.

Symptom questionnaire

The patient questionnaire included past medical, surgical, and obstetric histories and the Jorge-Wexner faecal incontinence severity score [7]. The Jorge-Wexner score is a summative, five-category score, with categories including frequency of (1) incontinence of solids, (2) incontinence of liquids, (3) incontinence of flatus, (4) use of continence pads, and (5) lifestyle alteration. A frequency score from 0 to 4 is assigned for each category (0 = never, 1 = rarely or < 1/monthly, 2 = sometimes or < 1/weekly, 3 = usually or < 1/day, 4 = always or > 1/day), to produce a total score of 0–20. An additional question using the same five-category, summative score was used to elicit features suggestive of urge incontinence, with the question: how often do you have to rush to the toilet to open your bowels? Passive incontinence was determined with the question: do you know when you open your bowels (yes/no)?

Anorectal investigations

Anorectal manometry No bowel preparation was performed prior to investigations. A single clinical scientist (AS) performed all manometry procedures with the patients in a left lateral decubitus position. Manometry was performed using a water-perfused, three-channel, polyvinyl chloride or silicone, 3.0-mm external diameter catheter (Mui Scientific, Mississauga, Ontario, Canada). Each channel had a side hole, spaced at 5 mm, orientated circumferentially and at 120° to one another. Sequential pressure measurements were recorded using a station pull-through technique. The catheter was withdrawn 5 mm at 60 s intervals, with the patient instructed to squeeze maximally for 3 s at each station. The peak resting pressure and peak squeeze pressure from each of the three channels were recorded. Normal ranges (maximal resting pressure 54–104 cmH_2O, maximal squeeze pressure ≥ 179 cmH_2O) were based upon the results of two series of healthy patients studied with similar water-perfused systems [23, 24].

Rectal sensation Rectal sensation was recorded using a balloon which was incrementally inflated with air (10, 20, 40, 70, 100, 150, 200 mL). The volume at which sensation was first perceived by the patient and the maximum tolerable volume were recorded (normal ranges: first perceived volume 10–80 mL, maximum tolerable volume 200 mL).

Pudendal nerve terminal motor latency (PNTML) PNTML was measured using a disposable, glove-mounted St Mark's electrode (13L40 St Mark's Pudendal Electrode™; Medtronic Functional Diagnostics A/S, Skovlunde, Denmark). Square wave stimuli were delivered via transrectal stimulation at the level of the ischial spine (0.05 ms duration, 10 mA, 1 Hz). The time between the onset of the stimulus and depolarisation of the anal sphincter on electromyography was recorded as the PNTML. Normal latency was defined as < 2.2 ms [25].

Endoanal sonography A Bruel and Kjaer (Njaerum, Denmark) type 1846/1101 scanner was used with a 7/10 MHz rotating endosonic probe (model 1850). Axial 360°

views of the anal sphincter were obtained from the upper, mid, and lower anal canal as the probe was withdrawn. Images were interpreted by a consultant radiologist or a consultant colorectal surgeon. The internal anal sphincter (IAS) and external anal sphincter (EAS) were categorised as (a) intact or (b) abnormal if a defect was visualised. When present, a defect was further categorised into the circumferential extent; $< 90°$, $> 90°$, or $> 180°$.

Statistical analysis

Bivariate analyses were performed between the Jorge-Wexner score and anorectal investigation results including anorectal manometry (Pearson's correlation coefficient with bootstrapped 95% confidence intervals to accommodate outliers [26][i]), rectal sensation (Spearman's rho correlation coefficient with bootstrapped 95% confidence intervals[ii]), PNTML[i], and endoanal sonography (independent samples *t* test[iii], one-way ANOVA[iv]). Multiple regression analysis was then performed, using a model incorporating all variables identified from the bivariate analyses with a statistically significant relationship to the Jorge-Wexner score.

Secondly, subgroup analyses were performed with patients grouped by gender and symptom subtype (urge, passive, or mixed symptoms). Within these subgroups, the above bivariate analyses between the Jorge-Wexner score and each investigation result were repeated.

Thirdly, bivariate analyses were conducted between each anorectal investigation result to assess their associations (Pearson correlation coefficient[i], independent samples *t* test[iii], Pearson chi-square test of association[v]).

Statistical analysis was performed using IBM SPSS (Version 19.0, Released 2010; IBM Corp., Armonk, New York, USA), in addition to "Psychometric" R package [27] and Cohen's d online calculator [28]. A p value of ≤ 0.05 was considered statistically significant. Effect sizes and confidence intervals of 95% were reported.

Results

Sample demographics

Between 1998 and 2015, 847 patients presented to Flinders Medical Centre for investigation of faecal incontinence. Of those, 309 were excluded due to having an incomplete symptom questionnaire. The remaining 538 patients were included in the analysis. The study group included 423 women (78.6%) and 115 men (21.4%), with a median age of 67 years (range 18–90). The majority of the women were parous (92.3%, $n = 370$), with a median of two children (range 1–10). Fourteen women did not complete the obstetric history section of the questionnaire. Of the 538 patients, 30.3% ($n = 163$) had undergone previous anorectal surgery (anterior resection, rectopexy, haemorrhoidectomy, fistulotomy, sphincterotomy), and 2.6% ($n = 14$) had previously been treated with pelvic radiotherapy.

Mean (±SD) Jorge-Wexner score for the included patients was 11.1 ± 3.8. Those describing urge symptoms of having to rush to the toilet 'usually' or 'always' comprised 41.8% ($n = 225$) of the cohort. Those with passive symptoms, having no knowledge of when their bowels were opened, totaled $n = 30$ (5.6%). The remaining 52.6% ($n = 283$) reported mixed urge/passive symptoms.

Four patients (0.7%) had normal results on all anorectal investigations. All other patients in the database had at least one abnormal result. Frequencies of normal/abnormal findings on anorectal investigations are shown in Table 1, and associations between anorectal investigation results are shown in Table 2.

Faecal incontinence severity and anorectal investigation results

There were weak associations between the Jorge-Wexner score and maximal squeeze pressure [$r = -0.24$, 95%CI(-0.31, -0.16), $p < 0.001$[i]], resting pressure [$r = -0.18$, 95%CI(-0.26, -0.10), $p < 0.001$][i], and age [$r = 0.12$, 95%CI(0.03, 0.20), $p = < 0.01$][i]. A group of 161 patients (29.9%) had a Jorge-Wexner score ≥ 9 and a normal resting pressure, while 98 patients (18.2%) with a Jorge-Wexner score ≥ 9 had a normal maximal squeeze pressure (Fig. 1). Conversely, 77 patients (14.3%) and 80 patients (14.9%) had a Jorge-Wexner score (< 9), and resting pressure and maximal squeeze pressure below the normal ranges, respectively (Fig. 1).

There were no statistically significant associations between the Jorge-Wexner score and rectal sensation; [first perceived volume $r_s = 0.01$, 95%CI(-0.07, 0.09), $p = 0.81$[ii], maximum tolerable volume $r_s = -0.08$, 95%CI(-0.16, 0.00), $p = 0.06$[ii]], PNTML; left: $r = 0.01$, 95%CI(-0.09, 0.11), $p = 0.87$[i], right: $r = 0.05$, 95%CI(-0.05, 0.15), $p = 0.29$[i], endoanal sonography results [IAS $t(426) = -0.08$, $p = 0.93$, $d < 0.01$, 95%CI(-0.85, 0.78)[iii], EAS $t(514) = -1.3$, $p = 0.19$, $d = 0.13$, 95%CI(-1.21, 0.24)[iii]], or gender $t(161) = -1.5$, $p = 0.14$, $d = 0.16$, 95%CI(-1.54, 0.14)[iii].

Subgroup analyses

Gender

When separated by gender, the strength of the correlation between anorectal manometry and the Jorge-Wexner score was marginally stronger in the subgroup of men, and weaker in the subgroup in women (men; maximal squeeze pressure [$r = -0.33$, 95%CI(-0.48, -0.16), $p < 0.01$[i]], resting pressure [$r = -0.36$, 95%CI(-0.51, -0.19), $p < 0.01$][i]; women; maximal

Table 1 Frequencies of normal/abnormal anorectal investigation results

	Normal results Women Count, % of valid	Abnormal results Women Count, % of valid	Missing results Women Count, % of total	Normal results Men Count, % of valid	Abnormal results Men Count, % of valid	Missing results Men Count, % of total
Resting pressure	$n = 173$, 40.9%	$n = 250$, 59.1%	–	$n = 48$, 41.7%	$n = 67$, 58.3%	–
Maximal squeeze pressure	$n = 79$, 18.7%	$n = 344$, 81.3%	–	$n = 76$, 66.1%	$n = 39$, 33.9%	–
Rectal sensation						
Combined	$n = 205$, 49.2%	$n = 212$, 50.8%	$n = 6$, 1.4%	$n = 68$, 59.1%	$n = 47$, 40.9%	–
FPV	$n = 400$, 95.5%	$n = 19$, 4.5%	$n = 4$, 0.9%	$n = 105$, 91.3%	$n = 10$, 8.7%	–
MTV	$n = 223$, 53.5%	$n = 194$, 46.5%	$n = 6$, 1.4%	$n = 78$, 67.8%	$n = 37$, 32.2%	–
PNTML	$n = 123$, 32.7%	$n = 216$, 57.4%	$n = 84$, 19.9%	$n = 36$, 50.7%	$n = 35$, 49.3%	$n = 44$, 38.3%
Unable to obtain trace			$n = 37$, 8.7%			$n = 20$, 22.0%
Not performed			$n = 47$, 11.1%			$n = 24$, 20.9%
Endoanal sonography						
Combined	$n = 223$, 53.7%	$n = 192$, 46.3%	$n = 8$, 1.9%	$n = 82$, 75.9%	$n = 26$, 24.1%	$n = 7$, 6.1%
IAS	$n = 324$, 76.6%	$n = 99$, 23.4%	–	$n = 94$, 81.7%	$n = 21$, 18.3%	–
EAS	$n = 258$, 61%	$n = 151$, 35.7%	$n = 14$, 3.3%	$n = 98$, 90.7%	$n = 10$, 9.3%	$n = 7$, 6.1%

squeeze pressure [$r = -0.19$, 95%CI(-0.28, -0.09), $p < 0.01$[i]], resting pressure [$r = -0.10$, 95%CI(-0.20, -0.01), $p = 0.04$][i]).

In the subgroup of men, significant associations were also observed between the Jorge Wexner score and endoanal sonography [IAS only, $t(113) = -2.26$, $p = 0.03$, $d = 0.58$, 95%CI(-4.38, -0.29)[iii]], rectal sensation (tolerance only; $r_s = -0.24$, 95%CI(-0.41, -0.06), $p = 0.01$[ii]), and PNTML [left only; $r = 0.28$, 95%CI(0.04, 0.48), $p = 0.02$[i]]. No other statistically significant associations between the Jorge-Wexner score and investigation results were observed in either gender subgroup.

Symptom subtype: urge, passive, or mixed incontinence

In patients presenting with urge ($n = 225$) or passive ($n = 30$) symptoms, there were no significant associations between

Table 2 Associations between anorectal investigation results

	Anorectal manometry		Rectal sensation		PNTML		Endoanal sonography	
	Resting pressure	Maximal squeeze pressure	First perceived volume	Maximum tolerable volume	Left	Right	IAS	EAS
Anorectal manometry	Maximal squeeze pressure	$r = 0.52$ $p = <0.01$[i]						
Rectal sensation	FPV	$r = 0.10$ $p = 0.06$[i]	$r = 0.05$ $p = 0.31$[i]					
	MTV	$r = 0.03$ $p = 0.58$[i]	$r = -0.17$ $p = <0.01$[i]	$r = 0.42$, $p = <0.01$[ii]				
PNTML	Left	$r = -0.29$ $p = 0.64$[i]	$r = -0.07$ $p = 0.23$[i]	$r = -0.06$, $p = 0.32$[ii]	$r = 0.42$, $p = <0.01$[ii]			
	Right	$r = -0.20$ $p = 0.01$[i]	$r = -0.22$ $p = < 0.01$[i]	$r = 0.05$, $p = 0.44$[ii]	$r = 0.42$, $p = <0.01$[ii]	$r = 0.26$ $p = <0.01$[i]		
Endoanal sonography	IAS	$t(348) = 4.75$, $p = < 0.01$ $d = 0.59$[iii]	$t(348) = 1.9$ $p = 0.05$ $d = 0.30$[iii]	$t(347) = 0.27$ $p = 0.79$ $d = 0.04$[iii]	$t(346) = 1.98$ $p = 0.05$ $d = 0.28$[iii]	$t(265) = 0.25$ $p = 0.80$ $d = 0.04$[iii]	$t(255) = -2.04$, $p = 0.04$ $d = 0.34$[iii]	
	EAS	$t(203) = 3.2$ $p = <0.01$ $d = 0.37$[iii]	$t(217) = 3.77$ $p = <0.01$ $d = 0.43$[iii]	$t(338) = 1.19$ $p = 0.24$ $d = 0.16$ [iii]	$t(149) = 2.47$ $p = 0.02$ $d = 0.31$[iii]	$t(258) = 0.85$ $p = 0.40$ $d = 0.12$[iii]	$t(248) = 0.85$ $p = 0.40$ $d = 0.12$[iii]	$x^2(1) = 29.47$ $p = <0.01$ Phi = 0.3[v]

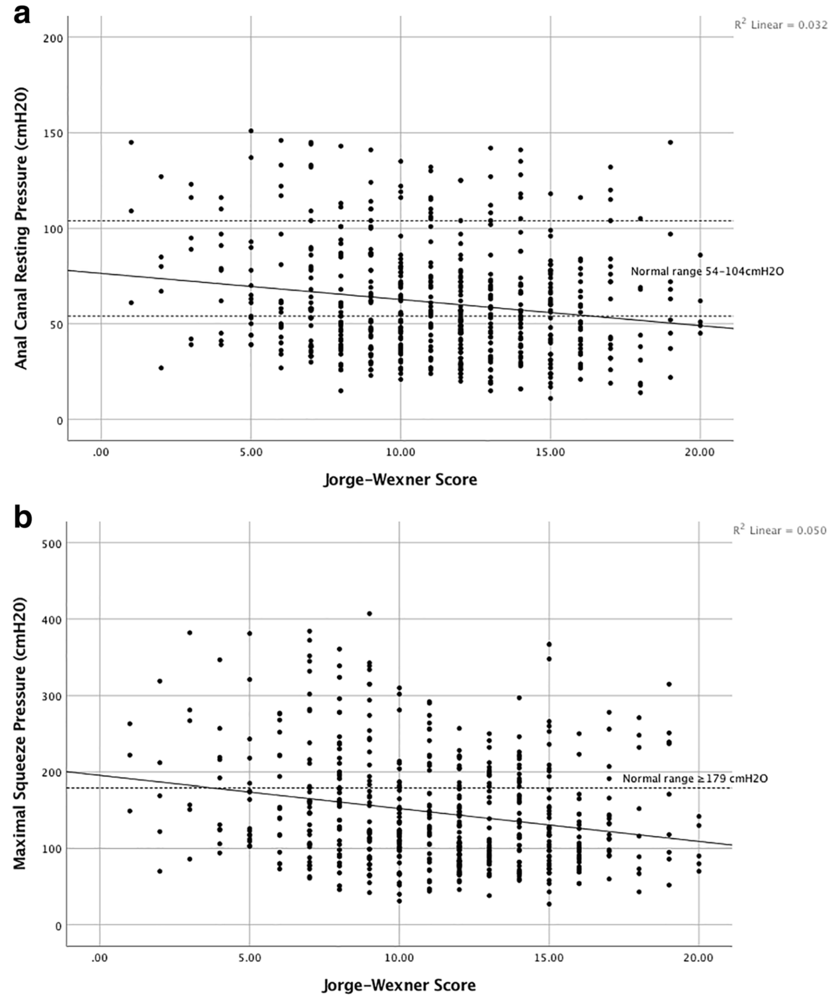

Fig. 1 Correlation between the Jorge-Wexner score and anal canal resting pressure and correlation between the Jorge-Wexner score and anal canal maximal squeeze pressure

Jorge-Wexner score and any individual anorectal investigation result (Table 3). In the remaining patients with mixed symptoms (n = 283), there were significant relationships between Jorge-Wexner score and anorectal manometry (resting pressure; $r = -0.34$, (− 0.45, − 0.22), $p = < 0.001^{\mathrm{i}}$, maximal squeeze pressure; $r = -0.29$, (− 0.41, − 0.16), $p = < 0.001^{\mathrm{i}}$) and rectal sensation (maximum tolerable volume; $r_s = -0.13$, 95%CI(− 0.24, 0.01), $p = 0.03^{\mathrm{ii}}$).

When comparing the three subgroups, there were statistically significant differences between mean age $F(2,535) = 13.14$, $p = < 0.001^{\mathrm{iv}}$, resting pressure $F(2,535) = 10.78$, $p = < 0.001^{\mathrm{iv}}$, maximal squeeze pressure $F(2,535) = 4.75$, $p = < 0.01^{\mathrm{iv}}$, rectal sensation (tolerance; $F(2,529) = 5.09$, $p = < 0.01^{\mathrm{iv}}$), and Jorge-Wexner score $F(2,535) = 33.05$, $p = < 0.001^{\mathrm{iv}}$. Those in the passive subgroup were more elderly (mean ages; passive subgroup = 74 ± 11 years, urge subgroup = 62 ± 14 years, mixed subgroup = 67 ± 14 years) and had the lowest pressures recorded on anorectal manometry (mean resting pressures; passive subgroup = 40.0 ± 23.5 cmH_2O, urge subgroup = 66.1 ± 30.7 cmH_2O, mixed subgroup = 60.0 ± 30.0 cmH_2O; mean maximal squeeze pressures; passive subgroup = 122.1 ± 60.2 cmH_2O, urge subgroup = 140.9 ± 63.6 cmH_2O, and mixed subgroup = 157.1 ± 86.1 cmH_2O). Those with urge incontinence reported the most severe Jorge-Wexner scores (mean score; urge subgroup = 12.6 ± 3.4, passive subgroup = 12.3 ± 3.6 years, and mixed subgroup = 10.0 ± 3.8). There were no significant differences between groups in endoanal sonography or PNTML results.

Multiple regression analysis

The multiple regression analysis included three variables: age ($\beta = 0.02$, $p = 0.17$), maximal resting pressure ($\beta = -0.01$, $p = 0.28$), and maximal squeeze pressure ($\beta = -0.01$, $p < 0.001$). The variance in the Jorge-Wexner score accounted for by this model was < 10%, ($R^2 = 0.07$, $p = < 0.001$, adjusted $R^2 = 0.06$) and therefore cannot explain the variability in the Jorge-Wexner score in > 90% of patients with faecal incontinence.

Table 3 Subgroup analyses: associations between the Jorge-Wexner score and anorectal investigation results in subgroups separated by gender, urge, passive, or mixed faecal incontinence symptoms

		Women $n = 423$	Men $n = 115$	Urge incontinence $n = 225$	Passive incontinence $n = 30$	Mixed symptoms $n = 283$
Anorectal manometry	Resting pressure	r = −0.10 95%CI(− 0.20, − 0.01) $p = 0.04$	$r = -0.36$ 95%CI(− 0.51, − 0.19) $p < 0.01$	$r = -0.05$ 95%CI(− 0.18, 0.08) $p = 0.45$	$r = -0.20$ 95%CI(− 0.52, 0.18) $p = 0.30$	$r = -0.34$ 95%CI(− 0.45, − 0.22) $p = < 0.01$
	Maximal squeeze pressure	$r = -0.19$ 95%CI(− 0.28, − 0.09) $p < 0.01$	$r = -0.33$ 95%CI(− 0.48, − 0.16) $p < 0.01$	$r = -0.08$ 95%CI(− 0.21, 0.05) $p = 0.24$	$r = -0.05$ 95%CI(− 0.40, 0.31) $p = 0.78$	$r = -0.29$ 95%CI(− 0.41, − 0.16) $p = < 0.01$
Rectal sensation	FPV	$r_s = 0.07$ 95%CI(− 0.03, − 0.05) $p = 0.15$	$r_s = -0.14$ 95%CI(− 0.32, 0.04) $p = 0.14$	$r_s = 0.09$ 95%CI(− 0.05, 0.21) $p = 0.21$	$r_s = -0.01$ 95%CI(− 0.38, 0.36) $p = 0.96$	$r_s = -0.39$ 95%CI(− 0.15, 0.08) $p = 0.51$
	MTV	$r_s = -0.03$ 95%CI(− 0.13, 0.06) $p = 0.59$	$r_s = -0.24$ 95%CI(− 0.40, − 0.06) $p = 0.01$	$r_s = 0.08$ 95%CI(− 0.05, 0.21) $p = 0.24$	$r_s = -0.01$ 95%CI(− 0.37, 0.37) $p = 0.99$	$r_s = -0.13$ 95%CI(− 0.24, 0.01) $p = 0.03$
PNTML	Left	$r = -0.04$ 95%CI(− 0.15, 0.07) $p = 0.46$	$r = 0.28$ 95%CI(0.04, 0.48) $p = 0.02$	$r = -0.05$ 95%CI(− 0.20, 0.10) $p = 0.53$	$r = 0.18$ 95%CI(− 0.32, 0.60) $p = 0.48$	$r = 0.04$ 95%CI(− 0.09, 0.17) $p = 0.56$
	Right	$r = 0.01$ 95%CI(− 0.11, 0.12) $p = 0.93$	$r = 0.11$ 95%CI(− 0.14, 0.34) $p = 0.40$	$r = 0.06$ 95%CI(− 0.10, 0.21) $p = 0.50$	$r = 0.42$ 95%CI(− 0.03, 0.72) $p = 0.07$	$r = 0.08$ 95%CI(−0.06, 0.21) $p = 0.27$
Endoanal Sonography	IAS	$t(421) = 1.04$ $d = 0.12$ 95%CI(− 0.39, 1.28) $p = 0.30$	$t(113) = -2.26$ $d = 0.58$ 95%CI(− 4.38, − 0.29) $p = 0.03$	$t(188) = 0.92$ $d = 0.16$ 95%CI(− 0.59, 1.62) $p = 0.36$	$t(27) = -1.25$ $d = 0.45$ 95%CI(− 4.68, 1.15) $p = 0.22$	$t(207) = -0.39$ $d = 0.06$ 95%CI(− 1.42, 0.95) $p = 0.70$
	EAS	$t(407) = -1.11$ $d = 0.11$ 95%CI(− 1.17, 0.33) $p = 0.27$	$t(15.36) = 0.14$ $d = 0.05$ 95%CI(− 1.83, 2.23) $p = 0.84$	$t(216) = -0.43$ $d = 0.06$ 95%CI(− 1.17, 0.76) $p = 0.67$	$t(27) = 0.50$ $d = 0.19$ 95%CI(− 2.14, 3.55) $p = 0.62$	$t(267) = -0.92$ $d = 0.13$ 95%CI(− 1.51, 0.55) $p = 0.63$

Discussion

These data demonstrate a weak correlation between anorectal manometry results and faecal incontinence severity, supporting the findings of previous smaller studies [18, 20]. However, there are a substantial proportion of patients with severe incontinence despite normal anorectal manometry results and, conversely, patients with mild incontinence yet significantly abnormal manometry results (Fig. 1). Significant relationships were also demonstrated between faecal incontinence severity and results of rectal sensation and endoanal sonography in men only. The strongest single predictor of severity was an IAS defect detected by sonography in men, with a moderate effect size. The findings from the multiple regression analysis suggest that the results of anorectal investigations do not predict faecal incontinence severity in the majority of patients. While these findings may cast doubt upon the usefulness of anorectal investigations, there are several factors that need to be considered in relation to the discord between test results and faecal incontinence severity.

Firstly, diagnostic modalities used in this study may simply have been inadequate to detect relevant features of anorectal dysfunction. The manometry data was derived from low resolution, water-perfused anorectal manometry. In many tertiary hospitals and research centres, this equipment has been superseded by high resolution, solid state anorectal manometry [29, 30], and it is possible that high-resolution manometry may improve diagnostic accuracy [31, 32]. However, low-resolution, water-perfused manometry is still in common use, with approximately half of institutions still using this technology in a recent international survey of > 100 specialist centres [30].

Our study also recorded anal sphincter integrity using two-dimensional endoanal sonography. As with anorectal manometry, this technology has been updated to three-dimensional endoanal ultrasound and/or high-frequency ultrasound [33] in a number of laboratories. In our study, using two-dimensional sonography, we identified anal sphincter defects in 41.7% of our cohort. In those patients, there were strong associations between an anal sphincter defect and reduced anal canal resting or squeeze pressures (Table 2). This would suggest that our findings from two-dimensional endoanal sonography correspond with functional impairment, demonstrated by reduced manometric pressures.

A previous study by Bharucha et al. [18], using the same sonography equipment, also reported anal sphincter defects in a similar proportion of patients with faecal incontinence (21/53 women; 39.6%). In that study, Bharucha et al. reported a significant association between IAS and EAS defects and the presence, but not severity, of faecal incontinence. In addition to sonography, Bharucha et al. [18] also assessed the musculature of the pelvic floor using dynamic magnetic resonance imaging (MRI), and found that puborectalis atrophy (present in 8/51 women) was the only anorectal investigation finding that had a significant association with faecal incontinence severity. Our two-dimensional probe did not allow for assessment of puborectalis integrity. Therefore, it is possible that a proportion of patients with severe incontinence may be explained by puborectalis injury or atrophy. However, there is no strong evidence for puborectalis injury being a primary cause of increased incontinence severity.

Assessment of neurological integrity via PNTML and rectal sensation is used to determine whether disruption to the motor innervation of the external anal sphincter and pelvic floor, or altered sensation, are contributing to symptoms [34–39]. Previous studies have demonstrated conflicting findings, with PNTML having no correlation with symptom severity scores in one study [40], but a significant relationship in another study [41]. PNTML has been demonstrated to correlate with the results of other anorectal investigations including manometry [13, 42], which is consistent with our findings. The utility of PNTML remains the subject of debate [43], with particular criticisms including (1) low sensitivity/specificity for detecting EAS weakness [44–46], (2) considerable variability in range seen in healthy controls [47], and, (3) operator-dependency [46]. Rectal hypersensitivity and reduced rectal compliance are considered to be associated with urge symptoms [18], whereas hyposensitivity is related to passive symptoms [37]. In our subgroup analysis, there were no significant associations between rectal sensation and symptom severity in either urge or passive subgroups.

In addition to these equipment considerations, there are also potential limitations in using a quantitative symptom score to determine faecal incontinence severity. The questionnaire used for this study incorporated the Jorge-Wexner score. While many other symptom severity scores are available [48–51], the Jorge-Wexner score remains the most widely used validated symptom score for faecal incontinence [52]. Criticisms regarding the use of the Jorge-Wexner score include (1) the equivalent weighting of the nature of the per rectal loss (gas, liquid, and/or solid), (2) not including symptoms of urgency [48, 53], (3) the inclusion of continence pad use, which is influenced by personal behaviour and concurrent urinary incontinence [48, 54], and (4) the day-to-day variability of symptoms in any individual patient [21]. While it is difficult to encapsulate the subjective nature of symptomatology in a quantitative score, the correlation of symptom scores to validated quality of life scores [2, 55–57] would suggest that such measures do bear a reflection of the holistic impact of symptoms upon the patient. Additionally, the correlation between symptom scores and quality of life scores has been replicated and cross-validated in multiple cultures and languages [56–58]. Whilst a quality of life score was not included in our symptom questionnaire, this would be beneficial as an additional outcome measure to assess the overall burden of symptoms on the patient pre- and post-intervention.

Relating symptom scores to investigation results may also be problematic given the heterogeneity of our sample population. The pathophysiology of faecal incontinence is complex, manifesting in varied symptom subsets and severity [7, 9, 59]. For example, some patients may report symptoms of predominantly urge or passive incontinence, or incontinence only to flatus but not solids, among other patterns of symptoms. Women are at considerable risk of incontinence following obstetric injury, which of course does not affect men. In an attempt to homogenise the sample and address these differences, we performed subgroup analyses with patients separated by gender and symptom subtype. In the gender subgroup analysis, stronger correlations were observed in the male subgroup between symptoms and anorectal manometry; however, the strength of the correlation remained weak to moderate. No anorectal investigation had any bearing on the severity of incontinence in those with predominantly urge or passive incontinence (Table 3). This would suggest that both gender and common symptom sub-types are unlikely to account for the discord that remains between our anorectal investigation results and the faecal incontinence severity.

A third possible explanation for the results of our study is to consider that some contributing factors to faecal incontinence severity are extrinsic to the anorectum, and therefore not recorded by routine anorectal investigations. Bowel continence and controlled defaecation require coordinated motility between the colon and anorectum [60–62]. Previous studies have demonstrated that rectal contents can be moved back to the sigmoid colon when defaecation is inappropriate [63] and that motor patterns in the sigmoid colon may assist in slowing or preventing premature rectal filling [64–68]. As a result, dysmotility in the distal colon may contribute to faecal incontinence. Examination of colonic motor patterns in patients with faecal incontinence is rarely performed. Two previous studies comparing colonic motility between patients with faecal incontinence and healthy controls in small cohorts report conflicting results; Herbst et al. [61] demonstrated no substantial change in colonic motility between patients and healthy adults, where as Rodger et al. demonstrated increased colonic motility in the patient group whilst fasting, but a similar meal response to healthy controls [69]. However, both of those studies used low-resolution colonic manometry which would overlook much of the propagating activity that may be of importance in the distal colon [65, 68, 70, 71].

Given the discord between symptom severity and anorectal investigation results, there has been much debate on the utility of anorectal investigations. Some authors suggest that history and examination alone are sufficient [72, 73], or that anorectal investigations should be used selectively rather than routinely in this patient group [20]. Other studies have demonstrated that anorectal investigations provide more diagnostic and prognostic information than clinical examination alone, which alters patient management [74–77]. At our anorectal clinic, we continue to use anorectal investigations in the diagnostic investigation of patients presenting with faecal incontinence. In our experience, the information provided by anorectal investigations complements our history and examination findings, and assists in both planning treatment and re-assessment post-intervention.

In conclusion, the presence or extent of anatomical and/or physiological anorectal dysfunction cannot predict the severity of faecal incontinence. Furthermore, no single diagnostic investigation, or combination of investigation results, can reliably identify or predict faecal incontinence severity. Further studies with a more detailed assessment of symptomatology and utilisation of three-dimensional, high resolution anorectal manometry and three-dimensional endoanal sonography are needed.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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