



Preoperative anorectal manometry as a predictor of function after ileal pouch anal anastomosis: a systematic review and meta-analysis

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Abstract

Background Since the ileal pouch anal anastomosis (IPAA) was first described, anorectal manometry (ARM) has been used to study its physiology and function. Few studies have investigated if preoperative ARM can predict pouch function.

Methods Pubmed, EMBASE, and the Cochrane Library databases were systematically searched. Papers detailing preoperative ARM results and postoperative functional outcomes of patients with IPAA were included. Meta-analysis with meta-regression was performed, assessing the relationship between preoperative manometric results and objective postoperative functional outcomes including frequency, seepage, pad usage and medications, and functional scoring systems including Wexner Incontinence and Oresland Scores.

Results Results from 31 studies were analysed. Mean resting pressure (MRP) decreased significantly (-23.16 mmHg, 95% CI -27.98 to -18.35 , $p < 0.01$) after pouch formation but before ileostomy reversal, with subsequent minor increase (3.51 mmHg, 95% CI 0.93 to 6.09 , $p = 0.01$) by 6 months after reversal of ileostomy. Pooled bowel frequency was 5.4 per 24 h (4.90 – 5.91), day and night-time soiling, incontinence, and pad usage rates were 16% (9–24%), 26% (19–33%), 12% (4–20%), and 21% (13–30%) respectively. Pooled Oresland and Wexner Scores were 3.81 (2.92–4.70) and 3.45 (2.71–4.19). A significant association between preoperative MRP and Wexner Score was observed ($p < 0.001$). As a result of risk of bias, study heterogeneity, and variation in manometry systems, certainty of evidence was low or very low.

Conclusion Preoperative predictors of function inform patient and clinician decision-making. Further investigations into the association between preoperative MRP and Wexner Score using modern ARM techniques are warranted.

Keywords Ileoanal pouch · Anorectal manometry · Functional outcomes · Meta-analysis

Introduction

Since the first descriptions of ileal pouch anal anastomosis (IPAA) surgery in the 1970s [1], it has become the procedure of choice for patients with ulcerative colitis (UC) and familial adenomatous polyposis (FAP) wishing to avoid a permanent stoma after proctocolectomy. The technique continues

to be refined in the pursuit of reduced surgical risk and improved patient outcomes. Early clinical studies focused on pouch design and anastomosis type, with an interest on increasing reservoir volume and reducing sphincter trauma based on the belief that physiological principles governing capacity and continence would translate to better function [2, 3].

Anorectal manometry (ARM) was performed as part of the pre- and postoperative clinical assessment in much of the early pouch literature, as it allows for objective physiological evaluation of the anal sphincter complex and intrarectal and intrapouch volume, pressure, and capacity, which facilitated the comparison of different pouch designs and anastomoses [4]. While different pouch designs have demonstrated unique postoperative manometric and functional profiles [2, 5], the utility of preoperative manometry in predicting postoperative function independent of pouch design is not well

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characterised. As the rectum is removed and replaced by the ileal reservoir, preoperative measurements of intrarectal volume, pressure, and capacity have no potential predictive values. Similarly, these variables for the new reservoir postoperatively are a product of pouch design, surgical technique, and perioperative complications as opposed to inherent patient anorectal physiology. Hence, the potential value of preoperative ARM in patient counselling needs to focus on sphincter function.

Since the first descriptions of IPAA surgery, ARM has evolved significantly. High-resolution and 3D high-resolution solid-state and water-perfusion systems, as well as portable air-charged ARM systems have emerged. These have increased spatial resolution and pressure topography fidelity compared to ARM and have also improved clinical accessibility of the technique [6]. Efforts to standardise ARM technique such as the London Classification and International Anorectal Physiology Working Group protocol aim to improve generalisability of results and communication of research findings [7].

This study aims to systematically review the literature on the association between preoperative ARM and postoperative pouch function, and to perform a meta-analysis with meta-regression assessing the relationship between preoperative manometric results and objective postoperative functional outcomes including bowel frequency, seepage, pad and medication usage, and composite functional scoring systems.

Methods

Search strategy and data extraction

Systematic review and meta-analysis of the literature was performed in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 statement [8] to identify relevant studies. On July 28, 2023, a search of EMBASE, Pubmed, and Cochrane Library databases was performed. This was updated on March 12, 2024. The search term “manometry” was used in combination with “ileal pouch anal anastomosis”, “restorative proctocolectomy”, or “IPAA” using “AND” and “OR” Boolean operators (see Appendix). Papers from database inception to search date were eligible for inclusion. References of included articles were screened for further eligible articles. Searches were imported to Covidence Systematic Review Software (Veritas Health Innovation, Australia) [9] for screening and full text review and automated removal of duplicates. A Royal College of Surgeons Ireland librarian assisted in article retrieval. Articles had to be published in English language in peer-reviewed publications. All indications for IPAA were eligible for inclusion. Articles had to

report preoperative ARM measurements and postoperative functional outcomes to be eligible for inclusion. Published abstracts, case reports, and studies reporting exclusively paediatric cohorts were excluded, as were papers publishing results for operations other than IPAA or anorectal manometry data in healthy controls. All papers were screened independently by two reviewers and disagreements were resolved by the senior author. Data was accrued and stored in a password protected Microsoft Excel® Data Sheet, using a pre-defined template. Author name, country, year of publication, journal, study design, and patient number were extracted for each article. Where available patient demographics including age, gender, and diagnosis were collected. Operative details including pouch design, number of stages, mucosectomy, and anastomosis type were extracted. Manometry data including type of system used, units of measurement, timing of investigations, and reported outcomes including mean resting pressure (MRP), maximal resting pressure (MxRP), mean squeeze pressure (MSP), maximal squeeze pressure (MxSP), recto-anal inhibitory reflex (RAIR), and length of high-pressure zone (HPZ) were catalogued. Timings of manometry measurements were standardised as “preoperative” defined as any time prior to pouch formation, “pre-ileostomy closure” defined as any time after pouch formation but prior to reversal of defunctioning loop ileostomy, “0–6 months”, “6–12 months”, and “12+ months” defined as measurements taken between the stated time-periods, after restoration of continuity. The “preoperative” timeframe included both patients within an intact colon and rectum (one- and two-stage procedures) as well as those that had a total abdominal colectomy with end ileostomy (three-stage procedure) prior to IPAA formation. If a study reported measurements at multiple timepoints within a bracket, the mean value was calculated and reported. Finally, postoperative functional data including functional scores, bowel frequency, soiling, pad usage, medication use, and incontinence were extracted, and the timing of measurements recorded. If relevant data was not available from the text, it was manually extracted from figures using Plot Digitizer as described by Jelacic Kadic et al. [10, 11]. Risk of bias was assessed using the Cochrane Risk of Bias Tool 2.0 (RoB2) [12] for randomised controlled trials (RCT) and the Newcastle–Ottawa Scale (NOS) [13] for observational studies. The study protocol was published on Open Science Foundation Registry (<https://doi.org/10.17605/OSF.IO/UDQZK>) and registered on the PROSPERO database (CRD42024547315) [14].

Statistical analysis

Continuous variables were standardised to mean \pm standard deviation using Hozo and Luo and Wan methods [15–17]. Pooled outcome measures are reported with their 95% confidence intervals in parenthesis. For ARM

data, measurements in cmH_2O were converted to mmHg ($1 \text{ cmH}_2\text{O} = 0.736 \text{ mmHg}$). If articles reported only subgroup ARM data, the values for the overall cohort were estimated with the Cochrane formulae [18].

Meta-analysis was performed using StataSE®18 Statistical Software [19]. For binary outcomes, proportional meta-analysis was performed using a random-effects restricted maximum likelihood model (REML) [20]. Similarly, a random-effects REML model was used for meta-analysis of means for continuous outcome measures. For comparative meta-analysis between pre- and postoperative ARM measures, mean difference (MD) was used to calculate pooled effect size. Heterogeneity between studies was calculated using the inconsistency test (I^2). Random effects meta-regression was used to assess the relationship between preoperative ARM and postoperative functional outcomes. GRADEpro GDT was used to calculate certainty of evidence for each pooled outcome [21]. Publication bias was assessed by funnel plot symmetry and Egger's regression test [22].

Results

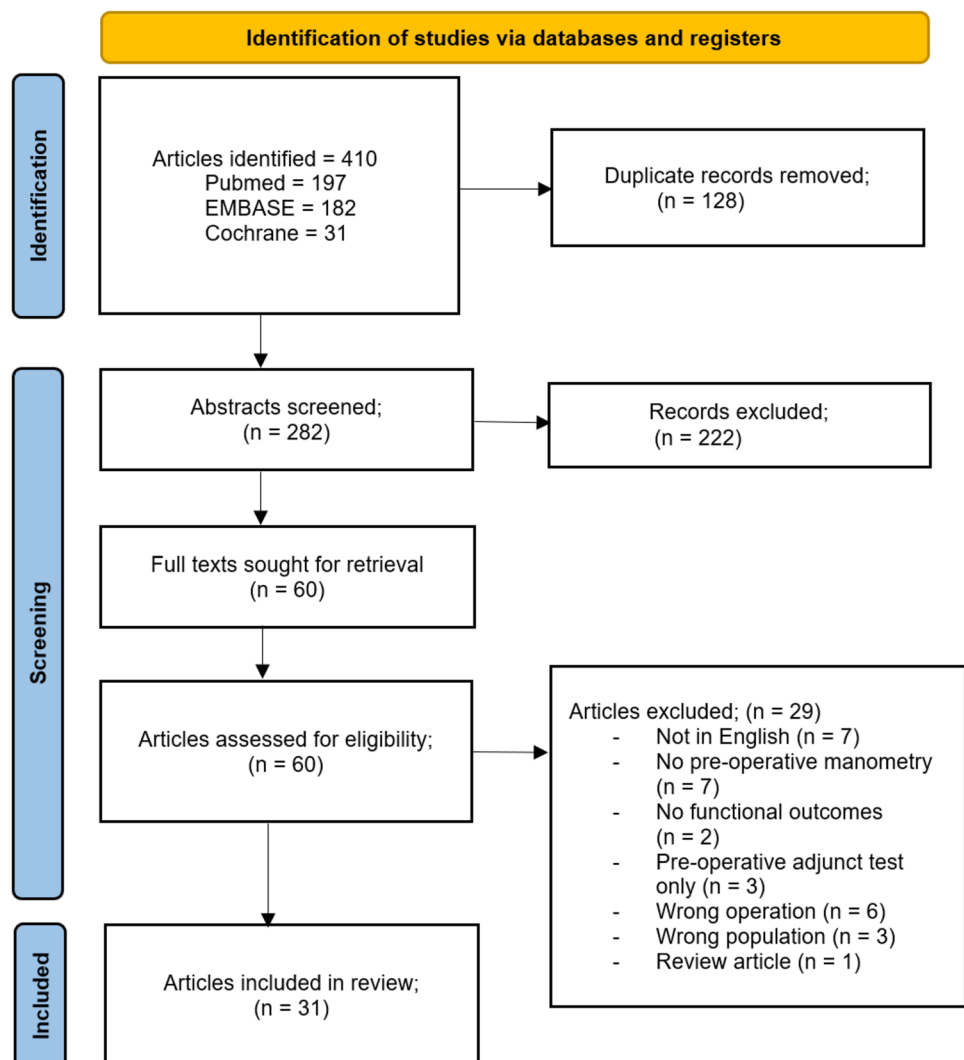
Search results

A total of 410 articles were identified for consideration. Of these, 197 were from Pubmed, 182 from EMBASE, and 31 from Cochrane library. There were 128 duplicates removed, and 282 abstracts were screened. A total of 60 papers were taken forward for full text review, and after which 29 were excluded, leaving a total of 31 for inclusion (Fig. 1).

Study characteristics

Of the studies identified, six were RCTs, and the remainder were either single-centre retrospective or prospective cohorts. Only three articles were published in the last decade, and 24 were published in the 1980s or 1990s with many papers published by the same institutions. Though all papers

Fig. 1 PRISMA flowchart of search strategy



performed preoperative ARM and postoperative functional assessments, only seven [23–29] specifically aimed to assess the relationship between preoperative sphincter function and postoperative functional outcome, and of these only two compared functional outcomes between subgroups based on preoperative ARM thresholds [23, 25]. In the observational studies Newcastle–Ottawa Scale was rated as “good to high” quality for 22 studies, and risk of bias was of “some concern” and “high” for three of the RCTs respectively (Table 1) [23–53].

There was a total of 3346 patients captured across the included studies, with ulcerative colitis (84.2%) being the most common indication for IPAA. Mean age ranged from

33 to 49 years. Staging of surgery was reported in 16 studies, for 896 patients. Single-stage surgery was performed in 3.3%, two-stage in 76.6%, and three-stage in 20.1%. Pouch design was reported for 25 studies (1529 patients), anastomosis type in 27 (1885 patients), and mucosectomy in 30 (1907 patients). In these patients, J-pouches were most common (88.7%), and S- (4.7%), W- (3.3%), and K-pouches (3.3%) were almost equally represented. Handsewn anastomosis was performed in 43.7%, and the remainder had a stapled anastomosis. Broadly, there were five different types of manometry systems used for ARM, and only one study used a high-resolution solid-state system [49] (Table 2).

Table 1 Included articles with study design and risk of bias

Author	Journal	Country	Year	Study design	NOS score ^a /RoB-2 score ^b
Pescatori [30]	Surg Gynecol Obstet	UK	1984	Retrospective single centre	*****
Luukkonen [29]	Int J Colorect Dis	Finland	1988	Prospective single centre	*****
Oresland [31]	Int J Colorect Dis	Sweden	1988	RCT	Some concerns
Hallgren [32]	Int J Colorect Dis	Sweden	1989	Prospective single centre	*****
Williams [33]	Br J Surg	UK	1989	Retrospective single centre	*****
Lindquist [24]	Dis Colon Rectum	Sweden	1990	Prospective single centre	*****
Oresland [50]	Scand J Gastroenterol	Sweden	1990	RCT	Some concerns
Becker [34]	Surgery	USA	1991	Prospective single centre	*****
Braun [26]	Dis Colon Rectum	Germany	1991	Prospective single centre	*****
Tuckson [35]	Am J Surg	USA	1991	Retrospective single centre	*****
Wexner [36]	Dis Colon Rectum	USA	1991	Prospective single centre	*****
Annibali [37]	Dis Colon Rectum	Sweden	1994	Retrospective single centre	*****
Farouk [27]	BJS	UK	1994	Prospective single centre	*****
Jorge [28]	Dis Colon Rectum	USA	1994	RCT	High
Jorge [38]	Dis Colon Rectum	USA	1994	Prospective single centre	*****
Morgado [25]	Dis Colon Rectum	USA	1994	Retrospective single centre	*****
Deen [39]	Dis Colon Rectum	UK	1995	RCT	High
Reissman [52]	J Am Coll Surg	USA	1995	Prospective single centre	*****
Staniunas [51]	Dis Colon Rectum	USA	1995	Retrospective comparative	***
Reissman [40]	Am Surg	USA	1996	Prospective single centre	*****
Orsoni [53]	Int J Colorect Dis	France	1997	Prospective single centre	*****
Reilly [41]	Ann Surg	USA	1997	RCT	Some concerns
Takao [42]	Ann Surg	USA	1998	Prospective single centre	*****
Kroesen [43]	Int J Colorect Dis	Germany	1999	Retrospective single centre	*****
Saigusa [44]	Surg Today	Japan	2000	Retrospective single centre	*****
Selvaggi [45]	Dis Colon Rectum	Italy	2000	RCT	High
Halverson [23]	J Gastrointest Surg	USA	2002	Prospective single centre	*****
Saigusa [46]	Dis Colon Rectum	USA	2003	Retrospective single centre	*****
Heon Oh [47]	World J Gastroenterol	South Korea	2017	Retrospective single centre	*****
Fukui [48]	Colorectal Dis	Japan	2023	Retrospective single centre	*****
Viazis [49]	Eur J Gastroenterol Hepatol	Greece	2024	Prospective single centre	*****

RCT randomised controlled trial

^aNewcastle-Ottawa Scale. Studies are rated from 0 to 9 stars: 0–2, poor quality; 3–5, fair quality; 6–9, good/high quality

^bCochrane Risk of Bias Tool 2.0. Overall study risk of bias rating is low, some concerns, or high

Table 2 Patient demographics, mucosectomy data, and anorectal manometry setup

Article	Total patients	Male/female (%)	Age (mean \pm SD)	UC (%)	Indication FAP (%)	Other (%)	Anorectal manometry features	
							Manometry system	Measurement unit
Pescatori 1984	50	58/42	34 (12)	76	24	–	Water-filled micro-balloon	cmH ₂ O
Luukkonen 1988	20	50/50	35 (8)	100	–	–	Perfusion catheter	cmH ₂ O
Oresland 1988	38	53/47	37 (10)	100	–	–	Air-filled balloon, water-filled transducer	mmHg
Hallgren 1989	33	–	–	–	–	–	Air-filled balloon, water-filled transducer	cmH ₂ O
Williams 1989	11	55/45	33 (11)	100	–	–	Water-filled micro-balloon	cmH ₂ O
Lindquist 1990	55	60/40	–	94	–	6	Microtransducer catheter	cmH ₂ O
Oresland 1990	55	60/40	33 (10)	100	–	–	Air-filled balloon, water-filled transducer	mmHg
Becker 1991	250	61/39	35 (10)	84	16	–	Perfusion catheter	mmHg
Braun 1991	33	67/33	38 (7)	73	27	–	Perfusion catheter	mmHg
Tuckson 1991	153	59/41	35 (–)	85	10	4	Perfusion catheter	mmHg
Wexner 1991	15	60/40	36 (11)	80	20	–	Perfusion catheter	mmHg
Annibali 1994	18	61/39	44 (15)	100	–	–	Air-filled balloon, water-filled transducer	mmHg
Faruok 1994	66	73/27	40 (12)	100	–	–	Perfusion catheter	cmH ₂ O
JorgeRCT 1994	26	62/38	38 (13)	100	–	–	Perfusion catheter	mmHg
Jorge 1994	72	63/37	39 (14)	88	12	–	Perfusion catheter	mmHg
Morgado 1994	73	–	–	–	–	–	Perfusion catheter	mmHg
Deen 1995	47	62/38	34 (17)	89	11	–	Water-filled micro-balloon	cmH ₂ O
Reissman 1995	140	64/36	41 (11)	76	15	9	Perfusion catheter	mmHg
Staniunas 1995	38	47/53	38 (12)	87	13	–	Perfusion catheter	mmHg
Reissman 1996	140	64/36	40 (12)	76	15	9	Perfusion catheter	mmHg
Orsoni 1997	10	60/40	42 (14)	100	–	–	Perfusion catheter	mmHg
Reilly 1997	32	56/44	38 (–)	100	–	–	Perfusion catheter	mmHg
Takao 1998	122	43/57	–	100	–	–	Perfusion catheter	mmHg
Kroesen 1999	75	47/53	35 (12)	83	17	–	Perfusion catheter	mmHg
Saigusa 2000	32	69/31	33 (10)	44	56	–	Perfusion catheter	mmHg
Selvaggi 2000	24	42/58	34 (8)	100	–	–	Water-filled micro-balloon	mmHg
Halverson 2002	1439	–	38 (10)	79	7	14	Perfusion catheter	mmHg
Saigusa 2003	100	53/47	46 (12)	100	–	–	Perfusion catheter	mmHg
Heon Oh 2017	127	–	40 (12)	100	–	–	Perfusion catheter	mmHg
Fukui 2023	32	75/25	49 (12)	88	12	–	Perfusion catheter	mmHg
Viazis 2024	20	60/40	39 (12)	100	–	–	Solid-state	mmHg

UC ulcerative colitis, FAP familial adenomatous polyposis, Other includes Crohn's disease (86), Indeterminate colitis (151), and Hirschsprung disease (1)

“–” denotes missing data

Anorectal manometry results

ARM results were captured preoperatively in all papers, 16 reported pre-ileostomy closure, 11 reported 0–6 months postoperative, 19 reported 6–12 months postoperative, and 12 reported 1 year or greater postoperative ARM results. There was a falloff in patient numbers completing pre- and postoperative ARM timepoints in eight studies, and only two articles reported ARM data for all five timepoints. MRP was most reported (21 papers), followed by MSP and MxSP (20 papers), and then MxRP (15 papers). HPZ (9 papers) and RAIR (8 papers) were reported in less than half of all articles. The definition of “squeeze pressure” varied between papers. The maximum was considered the highest measurement reached during sustained voluntary contraction, and the mean as the average across the period of sustained effort. However, the pressure measurement reported could be either (a) the absolute pressure or (b) the increase in pressure compared to resting pressure. In nine papers it was unclear which definition they used, whereas in five it was the

absolute pressure, and in six it was the pressure differential compared to baseline. As a result of these disparities, only MRP was used for meta-analysis.

Pooled preoperative MRP across all studies was 69.60 mmHg (63.92 to 75.27). Subgroup analysis of the two most common methods of manometry, air-filled balloon with water filled transducer or perfusion catheter, showed no significant difference ($p=0.75$) between the two techniques with a MRP of 70.41 mmHg (67.96 to 72.86) and 69.04 mmHg (60.91 to 77.16) respectively, but overall study heterogeneity was significant ($I^2=96.9\%$, $p<0.01$). There was a significant mean difference in MRP between preoperative and pre-ileostomy closure readings of -23.16 mmHg (-27.98 to -18.35 , $p<0.01$), with subgroup analysis by anastomosis type demonstrating a drop of -28.49 mmHg (-37.76 to -19.23) for handsewn and -19.72 mmHg (-23.39 to -16.05) for stapled, the difference between the two was not statistically significant ($p=0.08$) and heterogeneity was significant ($I^2=80.5\%$, $p<0.01$) (Fig. 2). There was a minor improvement in MRP between pre-ileostomy

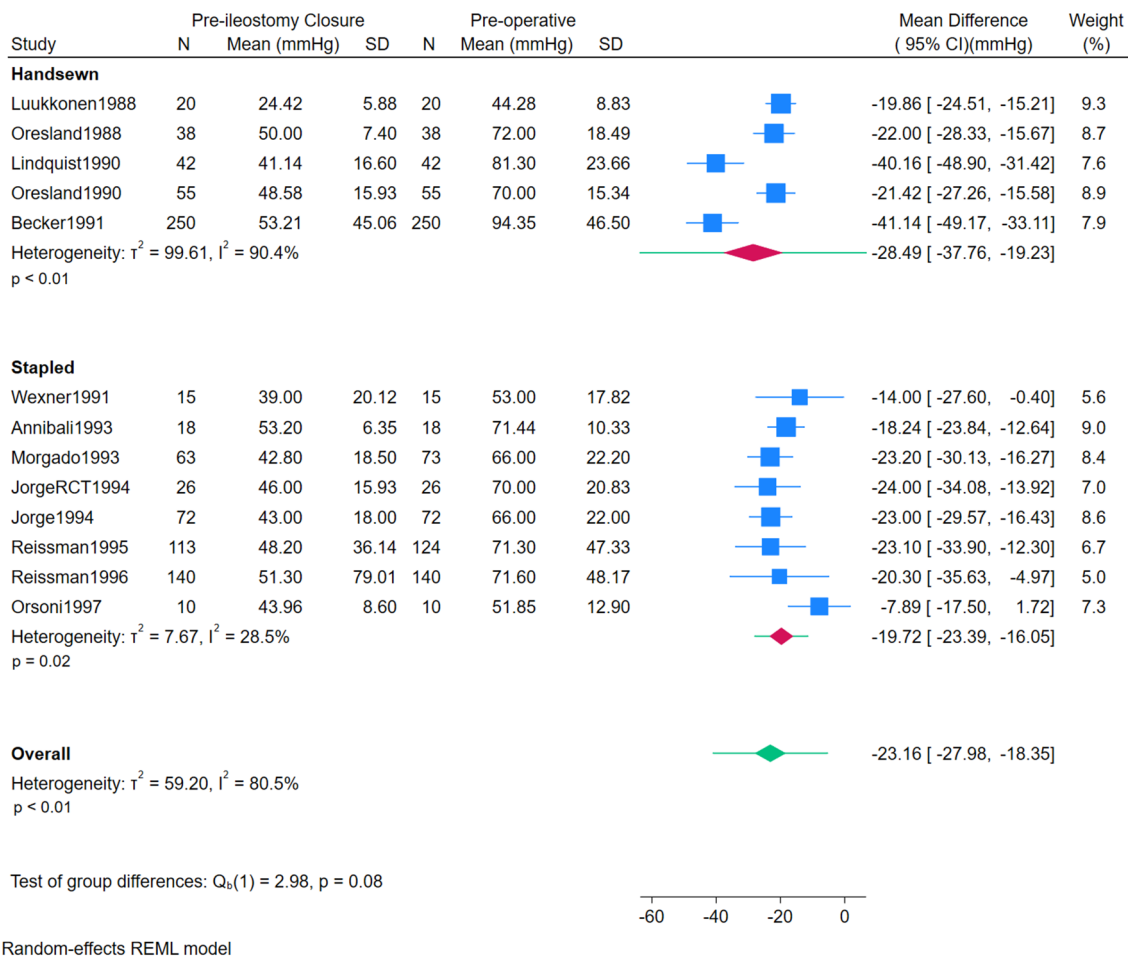


Fig. 2 Forest plot showing mean difference between preoperative and pre-ileostomy closure MRP (mmHg), with subgroup analysis by anastomosis type

closure and 0–6 months postoperatively (3.51 mmHg, 95% CI 0.93–6.09, $p=0.01$). The differences between 6 and 12 months compared to 0–6 months (2.30 mmHg, 95% CI -1.50 to 6.09, $p=0.24$) and 12 months or more compared 6–12 months (3.69 mmHg, 95% CI -1.22 to 8.6, $p=0.14$) were not significant.

Functional outcomes

Overall pooled daily frequency was 5.4 bowel movements per 24 h (4.90–5.91, $I^2=98.9\%$), and subgroup analysis showed a significant difference ($p<0.01$) between hand-sewn (4.68, CI 4.02–5.35, $I^2=96.9\%$) and stapled anastomoses (5.66, 4.94–6.38, $I^2=98.5\%$) when papers with mixed anastomotic methods were excluded. Nocturnal frequency was 0.99 bowel movements per night (0.6–1.38, $I^2=93\%$). Medication use was reported by eight papers, and proportional meta-analysis demonstrated a pooled frequency of 55% (41–69%, $I^2=84.6\%$). Similarly, eight papers reported inability to discriminate between gas and faeces, with pooled analysis demonstrating an overall rate of 20% (8–31%, $I^2=86.6\%$). Pooled analysis of pad usage (21%, 95% CI 13–30%, $I^2=90.6\%$), daytime soiling (16%, 95% CI 9–24%, $I^2=92\%$), night-time soiling (26%, 95% CI 19–33%, $I^2=90.4\%$), and incontinence (12%, 95% CI 4–20%, $I^2=98.3\%$) was performed using 12, 13, 18, and 13 papers respectively.

Oresland Score, Wexner Score, Keighley and Kelly-Holschneider incontinence scores, and Cleveland Clinic Global Quality of Life Score (CGQL) were used to assess function. Oresland Score was used in four articles, Wexner Score in seven, and Keighley, Kelly-Holschneider scores, and CGQL in one paper each. The Oresland Score is a composite of day and night-time bowel frequency, pad usage, and soiling, as well as urgency, evacuation difficulty, perianal soreness, dietary restriction, medication use, and social handicap giving a total score of 1–15 [54]. Wexner Incontinence Score grades frequency of solid,

liquid, and gas incontinence, as well as pad usage and lifestyle alteration with up to 4 points awarded to each, for a total score of 0 (perfect continence) to 20 (complete incontinence) [55]. Results across all papers were considered “good” based on their relative scoring system. Overall pooled Oresland Score was 3.81 (2.92–4.70, $I^2=74.1\%$) and pooled Wexner Score was 3.45 (2.71–4.19, $I^2=82.6\%$).

Preoperative anorectal manometry as a predictor of pouch function

Meta-regression was performed to assess the relationship between preoperative MRP and functional outcomes. No association was found between preoperative MRP and night-time soiling ($p=0.343$), daytime soiling ($p=0.973$), pad use ($p=0.387$), incontinence ($p=0.957$), inability to discriminate gas and faeces ($p=0.867$), and Oresland Score ($p=0.657$). There was a significant association with Wexner Score (effect size coefficient = -0.434 , $p<0.001$, $I^2=47.5\%$) whereby lower preoperative MRP resulted in worse scores. However, only four studies reported both preop MRP and Wexner Score (Fig. 3).

Certainty of evidence

GRADE quality of evidence assessment was low certainty or very low certainty for all pooled outcomes. Marking down of quality was due to significant heterogeneity across all outcomes, imprecision introduced by different ARM systems between studies, inconsistency appreciable as wide confidence intervals, risk of bias identified in several studies, publication bias, and indirectness owing to many studies aiming to investigate questions other than the predictor value of ARM for function (Table 3).

Fig. 3 Bubble plot of meta-regression assessing relationship between preoperative MRP as a predictor variable and Wexner Score. Study bubble size denotes weight, trend line with 95% confidence intervals

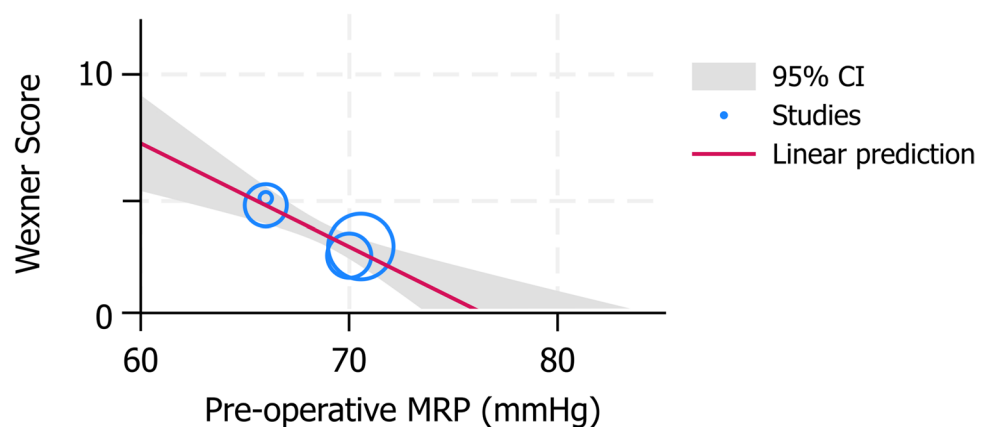


Table 3 Summary of findings

Meta-analysis of anorectal manometry outcomes	Timepoint 1	Timepoint 2	Mean difference (95% CI)	<i>p</i> value	No. of participants (studies)	Quality of the evidence (GRADE)	Comments
Mean resting pressure	Preoperative	Prior to ileostomy closure	-23.16 (-27.98 to -18.35) mmHg	<0.001*	862 (13)	⊕⊕○○	Subgroup analysis—Handsewn -28.49 (-37.76 to -19.23), stapled -19.72 (-23.39 to -16.05) (<i>p</i> =0.08)
	Prior to ileostomy closure	0–6 months postoperative	3.15 (0.93 to 6.09) mmHg	0.010*	325 (5)	⊕⊕○○	Too few for subgroup analysis
	0–6 months postoperative	6–12 months postoperative	2.3 (-1.50 to 6.09) mmHg	0.240	106 (3)	⊕⊕○○	Too few for subgroup analysis
	6–12 months postoperative	12+ months postoperative	3.69 (-1.22 to 8.60) mmHg	0.140	154 (3)	⊕⊕○○	Too few for subgroup analysis
Mean squeeze pressure	–	–	–	–	–	–	No meta-analysis performed due to disparity in measurement methods
Maximal squeeze pressure	–	–	–	–	–	–	No meta-analysis performed due to disparity in measurement methods
High-pressure zone	Preoperative	Prior to ileostomy closure	-0.44 (-0.67 to -0.21) cm	<0.001*	338 (6)	⊕⊕○○	No significant difference between handsewn and stapled (<i>p</i> =0.94)
Meta-analysis and meta-regression of functional outcomes	Meta-analysis of means/proportion (95% CI)	Meta-regression predictor variable	Coefficient (standard error)	<i>p</i> value	No. of participants (studies)	Quality of the evidence (GRADE)	Comments
Bowel frequency per 24 h	5.4 (4.90 to 5.91)	Preoperative MRP	0.0153 (0.0220)	0.488	775 (18)	⊕⊕○○	Subgroup meta-analysis—Handsewn 4.68 (4.02 to 5.35), stapled 5.66 (4.94 to 6.38) (<i>p</i> =0.05)
Night-time bowel frequency	0.99 (0.6–1.38)	Preoperative MRP	0.002 (0.002)	0.334	316 (7)	⊕○○○	Only 1 article with handsewn anastomosis
Daytime soiling	16% (9–24%)	Preoperative MRP	-0.0002 (0.005)	0.973	996 (13)	⊕○○○	No significant difference between handsewn and stapled (<i>p</i> =0.51)

Table 3 (continued)

Meta-analysis and meta-regression of functional outcomes	Meta-analysis of means/proportion (95% CI)	Meta-regression predictor variable	Coefficient (standard error)	<i>p</i> value	No. of participants (studies)	Quality of the evidence (GRADE)	Comments
Night-time soiling	26% (19–33%)	Preoperative MRP	−0.004 (0.004)	0.343	1335 (18)	⊕○○○	No significant difference between handsewn and stapled (<i>p</i> = 0.73)
Incontinence	12% (4–20%)	Preoperative MRP	−0.0001 (0.002)	0.957	1039 (13)	⊕○○○	Only 2 articles with handsewn anastomosis
Pad use	21% (13–30%)	Preoperative MRP	−0.005 (0.006)	0.387	677 (12)	⊕○○○	No significant difference between handsewn and stapled (<i>p</i> = 0.76)
Unable to discriminate between gas and faeces	20% (8–31%)	Preoperative MRP	0.002 (0.14)	0.867	226 (8)	⊕○○○	Only 1 article with handsewn anastomosis
Wexner score	3.45 (2.71–4.19)	Preoperative MRP	−0.434 (0.112)	<0.001*	353 (7)	⊕○○○	4 articles used for meta-regression
Oresland score	3.81 (2.92–4.70)	Preoperative MRP	0.168 (0.380)	0.657	144 (4)	⊕○○○	Too few for subgroup analysis

CI confidence intervals, *MRP* mean resting pressure

Grade certainty of evidence scores: ⊕○○○ = very low certainty, ⊕⊕○○ = low certainty, ⊕⊕⊕○ = moderate certainty, ⊕⊕⊕⊕ = high certainty

*Indicates a significant difference

Discussion

This systematic review and meta-analysis demonstrates that despite significant use of and interest in ARM in the assessment of pouch physiology, particularly in the early years of adoption, the predictive value of preoperative ARM has not been well assessed to date. Of 31 papers, only two directly investigated the relationship between preoperative cut-off ARM thresholds and postoperative function, with conflicting results. Through meta-analysis with meta-regression, we have identified a potential relationship between preoperative MRP and postoperative Wexner Incontinence Score. However, there are significant limitations to this analysis due to the paucity of dedicated RCTs and limited case–control studies which introduces risk of bias, and the heterogeneity related to the variation in manometry systems used, pouch indications, pouch design, and anastomosis types. Reporting of perioperative complications such as pelvic sepsis and short- and long-term outcomes like pouchitis which can influence function was limited.

Only two papers specifically addressed the question of whether postoperative function could be predicted on the basis of preoperative ARM measurement thresholds. The first of these, published by Morgado et al. in 1994, investigated the relationship between preoperative MRP above or below 50 mmHg, and mean squeeze pressure above or below 70 mmHg and functional outcomes. A total of 73 consecutive patients with IPAA between 1988 and 1990 had ARM performed preoperatively, prior to reversal of defunctioning loop ileostomy, and at 1 and 2 years postoperatively. All had a J-pouch with a double stapled anastomosis. Though they demonstrated a significant drop between pre- and postoperative ARM values, with an improvement after ileostomy reversal, there was no correlation between ARM findings and function, as measured by the Wexner Score. Morgado et al. concluded that the value of ARM as a predictor of clinical outcome remained unproven [25].

A similar study by Halverson et al. in 2002 looked at perioperative ARM data for 1439 patients that had an IPAA constructed between 1986 and 2002 with postoperative functional data available at any one or more of five postoperative

timepoints (6 months $n=621$, 1 year $n=699$, 1.5–2.5 years $n=801$, 2.5–5 years $n=963$, and 5–8 years $n=710$). They compared functional outcomes between patients with MRP above and below 40 mmHg, or maximum squeeze pressure (MxSP) above or below 100 mmHg at ARM performed either preoperatively or prior to ileostomy reversal. They demonstrated significantly worse incontinence (30.4% vs 23.6% at 1 year, $p=0.003$), and daytime (33% vs 16.2% at 1 year, $p=0.001$) and night-time (46.6% vs 28.5% at 1 year, $p=0.001$) seepage in patients with perioperative MRP < 40 mmHg at all follow-up timepoints. The relationship between MxSP and these functional outcomes was inconsistent across timepoints. It is important to note that patients were classified according to ARM values measured either preoperative or prior to ileostomy closure, collectively referred to as “perioperative” ARM data. As demonstrated above, there is a significant drop in ARM values between these two timepoints [23]. The authors did not give a breakdown based on preoperative values alone, and pouch design, anastomosis type, and staging are not described.

In our analysis, despite the differences in manometry systems, preoperative pooled MRP values did not differ significantly between the two most common methods employed (air-filled balloon with water-filled transducer vs perfusion catheter), which is supported by empirical studies of the comparability of different measurement systems [56]. Furthermore, the well-characterised drop in MRP after IPAA formation was demonstrated in our analysis, as was the more substantial drop seen with a handsewn anastomosis when compared to stapled [3]. Unfortunately, as a result of differences in definitions of squeeze pressure and ambiguity in its reporting, it was not possible to meaningfully include it in this meta-analysis. The variability in ARM methods and reporting are well characterised and remain an ongoing challenge [57]. The pelvic floor community has been working towards consensus and standardisation of definitions and methodologies to address this issue and improve the generalisability of ARM research between centres [58, 59]. Some components of manometric testing, such as capacity, compliance, and volume, while useful in the assessment of anorectal or indeed IPAA dysfunction are of limited relevance in the preoperative assessment of patients awaiting IPAA surgery as the rectum is replaced by the new ileal reservoir. Our pooled functional outcome data is comparable to prior meta-analyses of postoperative functional ranges which suggested a mean defecation frequency of 5.9 (95% CI 4.9–6.7) per 24 h, night-time frequency of 1.5 (1.0–2.1), and incontinence rate of 20.4% (10.2–38.2%) [60]. The wide confidence intervals for incontinence rates are likely a consequence of variation in reporting, as many papers fail to specify the definition used.

There has been renewed interest in defining “normal” or “optimal” pouch function. Quinn et al. performed anorectal

testing including high-resolution ano-pouch manometry, balloon expulsion test, pouch barostat, and magnetic resonance defecography on 20 patients with IPAA with self-reported healthy pouch function. Of note, six of these patients were excluded from analysis because of symptoms suggestive of pouch dysfunction, structural abnormalities, or both. The remaining 14 patients had a mean anal resting pressure of 72 ± 16 mmHg and mean anal absolute squeeze pressure of 247 ± 69 mmHg, with a mean daytime frequency of 6.2, and daytime incontinence and night-time incontinence rates of 7.1% and 28.6% respectively. Almost 30% of patient were unable to differentiate between stool and gas [61]. Sunde et al. invited 108 patients to interview using Oresland Score to determine pouch function. The best and worst functioning quartiles were invited to undergo ARM and endoscopy. The authors identified that pouch volume at first sensation, urge, and discomfort volumes best differentiated the poorest and highest Oresland Scores [62]. Similarly, Melvin et al. investigated the relationship between postoperative ARM, function, and quality of life using the Rockwood Fecal Incontinence Quality of Life Scale in 125 patients with IPAA. The authors found that compliance and pouch–anal pressure gradient (PAPG) correlated with 24 h and night-time stool frequency, and that daytime continence related to compliance, PAPG, and resting anal pressure, but no relationship between ARM outcomes and quality of life [63].

An IPAA is a physiologically and anatomically abnormal state, and hence defining “normal” function is challenging. Furthermore, what one patient determines to be acceptable function may differ significantly from another. It is important to differentiate between functional outcomes and quality of life measures. The former can be objectively measured and quantified, whereas the latter is a composite of the patient’s function and their perception of it informed by their personal life experiences. The importance of patient education and informed consent cannot be overstated for a functional procedure such as an IPAA; inadequate explanation or understanding of the expected functional outcomes can lead to unrealistic expectations [64]. Patient-reported outcome measures (PROMs) have been poorly reported in the IPAA literature, and assessment of preoperative baseline function with validated questionnaires should be an integral part of informing postoperative function [65]. Appropriate preoperative work-up with consideration of comorbidity, disease characteristics, endoscopic evaluation, assessment of the small intestine, and review of prior histology and operative notes is essential to ensure patient suitability, and failure to do this can result in poor patient outcomes due to inappropriate patient selection [66]. Despite the challenges in defining normal function, dysfunction is clearly a significant clinical issue as it accounts for 8.8–30% of pouch failure [5, 67, 68]. New scoring systems, such as the Ileoanal Pouch

Syndrome Severity Score, have incorporated patients in their development to identify symptoms and consequences that clinicians may undervalue such as time spent toileting, fragmentation, and discomfort, and sleep and intimacy challenges [69–71].

The limitations of this meta-analysis are significant. The heterogeneity of the literature, and its susceptibility to bias due to the lack of RCTs and case–control observational studies resulted in low to very low certainty of evidence. The variability of pouch indication, staging, design, and anastomosis between studies is important to highlight, as these factors all influence function. Furthermore, as a result of limitations of the primary literature, it was not possible to perform subgroup analysis of preoperative ARM in patients that had a prior total abdominal colectomy with end ileostomy (three-stage procedure) and those that did not. A small study of 38 patients with IPAA has demonstrated significantly lower preoperative MRP and MSP in patients with a defunctioned rectum and those without an existing stoma [51]. The differences in manometric methodologies and reporting introduce substantial imprecision, as does the variation in reporting of functional outcomes and composite scores used. ARM and functional assessment have evolved significantly over the last 40 years, with high-resolution water-perfusion and solid-state systems, as well as portable bedside ARM systems now providing additional physiological information but also providing more accessible and less cumbersome options than traditional multichannel water-perfusion based methods. Similarly, the surgical approach to IPAA, as well as appropriate indications have become more homogenised internationally [72].

Predictors and determinants of function have significant value, as they can inform patient and surgeons expectations both preoperatively and in the long term. Many of these are perioperative such as pouch design, anastomosis type, pelvic sepsis, anastomotic leak, or disease related such as pouchitis and cuffitis [64, 73]. As such, the extent to which they can inform preoperative patient decision-making is limited. The relationship between MRP and Wexner Score, a composite scoring system for incontinence, identified in this analysis warrants further exploration, as it may provide a useful adjunct to informed consent and in setting patient expectations. The complexity of ARM and the impact of surgical approach to the anastomosis (handsewn or stapled), mucosectomy, and access (transanal vs transabdominal) and perioperative complications such as anastomotic leak and fistula formation on postoperative anal sphincter function and hence ARM results need to be accounted for in the design of future of studies. By applying modern ARM techniques to a demographically homogenous IPAA population and following consensus guidelines on ARM reporting with robust follow-up of perioperative complications and short- and long-term outcomes it may be possible to

robustly assess the value of preoperative ARM in predicting postoperative pouch function.

Conclusion

This systematic review and meta-analysis highlights the limitations of the current literature investigating the relationship between preoperative ARM and postoperative IPAA function. It has identified a possible association between preoperative MRP and Wexner Incontinence Score that warrants further investigation with modern ARM techniques.

Appendix

Search strategy terms

Pudmed; (manometry) AND ((ileal pouch anal anastomosis) OR (IPAA) OR (restorative proctocolectomy)). EMBASE: #1('manometry'/exp OR manometry); #2 (ileal AND pouch AND anal AND anastomosis); #3 (ipaa); #4 (restorative AND proctocolectomy); #5 (#2 OR #3 OR #4), #6 (#1 AND #5). Cochrane Library: (manometry) AND ((ileal pouch anal anastomosis) OR (IPAA) OR (restorative proctocolectomy)).

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Data availability Data will be provided by authors upon reasonable request.

Declarations

Conflict of interest The authors declare that they have no competing interests.

Ethical approval As a systematic review and meta-analysis, no ethics approval or consent to participate was required.

Informed consent Informed consent was not required as this is a systematic review and meta-analysis of existing literature.

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