Meta-analysis

Meta-analysis of colonic reservoirs *versus* straight coloanal anastomosis after anterior resection

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Background and methods: **The comparative benefits and drawbacks of straight coloanal anastomosis (CAA), colonic J-pouch and coloplasty anastomosis after anterior resection are uncertain. Studies published between 1986 and 2005 of colonic J-pouch *versus* transverse coloplasty or straight CAA were analysed. Endpoints included postoperative complications, and functional and physiological outcomes measured within 6 months, 1 year and 2 years or more after the procedure. A random-effect model was used to aggregate the study endpoints and assess heterogeneity.**

Results: **Thirty-five studies containing 2240 patients (1066 straight CAA, 1050 J-pouch and 124 coloplasty) were included. There was no significant difference in postoperative complications between the three groups. There was a significant reduction in the frequency of defaecation per day by 1·88, 1·35 and 0·74 motions at the three time intervals in the J-pouch group compared with the straight CAA group. Faecal urgency was less prevalent in patients with a J-pouch than those with a straight CAA (odds ratio 0·27 at 6 months or less and 0·21 at 1 year). There was no difference in functional outcome between J-pouch and coloplasty anastomosis.**

Conclusions: **The colonic J-pouch provided functional benefits over straight anastomosis with no increase in postoperative complications. Coloplasty appeared to have similar benefits but further studies are required for validation.**

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Introduction

The application of sphincter-preserving procedures for mid and low rectal cancers has become increasingly common[1]. Acceptance of good oncological outcome with reduced distal resection margins[2–5], in combination with technical developments in stapling devices, have increased the availability of low anastomosis, resulting in abdominoperineal resection rates of less than 10 per cent[6]. A number of studies have described significant impairment in a spectrum of functional outcomes after straight coloanal anastomosis (CAA)[7–9]. Paty *et al.*[10] assessed function in 81 patients after straight CAA and reported overall function as excellent in 28 per cent, good in 28 per cent, fair in 32 per cent and poor in 12 per cent, with frequency and evacuation problems as the major complaints. The combination of frequency, urgency and soiling has been termed 'anterior resection syndrome'[11]. Frequency and urgency have been attributed to loss of the rectal reservoir[12,13], although there is some improvement over time that may result from progressive dilatation of the neorectum[8,14,15].

This functional limitation was first addressed by Lazorthes *et al.*[16] and Parc *et al.*[17] in 1986 with the use of a coloanal J-pouch reconstruction. A number of studies have assessed the functional and physiological outcome of the colonic J-pouch, which appears to be superior to straight CAA, at least for the first year after surgery[18–20], and which may result in a possible reduction in anastomotic leak rate[21,22]. An alternative reconstruction using a coloplasty has also been applied[23–26], particularly where use of a colonic J-pouch is not possible for technical reasons, such as a narrow pelvis, long narrow anal canal

or bulky sphincters[27]. It remains uncertain which of these reconstructive techniques is superior. The present meta-analysis evaluated the differences in short-term complications, and functional and physiological outcomes, between straight coloanal, colonic J-pouch–anal and coloplasty–anal anastomosis after anterior resection.

Methods

Study selection

The literature was searched using Medline, Embase, Ovid, Pubmed and Cochrane databases for studies between 1986 and 2005 comparing straight CAA with colonic J-pouch or transverse coloplasty in patients undergoing low anterior resection. The Mesh search headings 'J-pouch and rectum' were used. The following text searches and search headings and their combinations were used: 'colonic pouch', 'J-pouch', 'coloplasty', 'transverse coloplasty', 'coloanal anastomosis', 'rectum' and 'colonic'. The related articles function was used to broaden the search, and all abstracts, studies and citations scanned were reviewed. No language restrictions were made. The references from articles were also used. The date of the most recent search was March 2005.

Data extraction

Three reviewers (A.G.H., P.P.T. and V.C.) independently performed the search as well as reviewing and extracting the following data from each study according to a prespecified protocol: first author, year of publication, study population characteristics, study design, inclusion and exclusion criteria, number of subjects and length of follow-up.

Inclusion criteria

The following requirements had to be met. (1) Studies had to compare J-pouch with transverse coloplasty or J-pouch with straight CAA without a colonic reservoir. (2) They had to report on at least one of the outcome measures noted below. (3) When two studies were reported by the same institution, either the one of better quality or the most recent publication was included, unless the study outcomes were mutually exclusive or measured at different time intervals.

Exclusion criteria

Non-comparative studies were excluded. Within the studies evaluated, those with endpoints that were not comparable, or from which it was impossible to calculate these endpoints from the published results, were excluded. Studies that displayed a 'zero cell' for the outcomes of interest in both groups were excluded.

Outcomes of interest and definitions

The following outcomes of interest were used to compare the three operative techniques. Early outcomes considered were: postoperative mortality, defined as death occurring within 30 days of the operation; anastomotic leak, defined as the presence of contrast medium or faecal matter at the level of the anastomosis or colonic pouch during radiological examination or reoperation; wound infection, defined as the presence of inflammation and/or purulent discharge and/or positive wound swab for bacterial growth. Additional adverse events studied included anastomotic stricture, rectovaginal fistula, perianal excoriation and other complications comprising small bowel obstruction, pelvic abscess and ureteric injury. Length of hospital stay and operating time were also assessed.

Functional outcomes were evaluated at three time intervals: within 6 months of the original procedure or reversal of the proximal diversion, at 1 year and at 2 or more years. These included frequency of defaecation per 24 h, faecal urgency, defined as the inability to defer defaecation for more than 15 min, inability to discriminate between faeces and flatus, seepage at night, incomplete evacuation and the need for antidiarrhoeal medication.

Physiological outcomes were compared at two time intervals, within 6 months and at 1 year or more after the original procedure. They included resting and maximum squeeze pressure of the sphincter complex, and neorectal threshold volume and maximum neorectal volume. Compliance was not included because only a limited number of studies assessed this variable. Quality of life was not included as the method of assessment within the few studies that did record this variable was not comparable.

Statistical analysis

Meta-analysis was performed in line with recommendations from the Cochrane Collaboration and the Quality of Reporting of Meta-analyses (QUORUM) guidelines[28,29]. The effect measures estimated were odds ratio (OR) for dichotomous data and weighted mean difference (WMD) for continuous data, both reported with 95 per cent confidence intervals (c.i.). The OR represents the odds of an adverse event occurring in the J-pouch group compared with the straight CAA or coloplasty group. An

OR of less than 1·00 favours the J-pouch group, and the point estimate of the OR is considered statistically significant at the $P < 0{\cdot}050$ level if the 95 per cent confidence interval does not include the value 1·00. Studies that contained a zero in one cell for the number of events of interest in one of the two groups resulted in problems with the computation of the OR and a value of 0·50 was added in both groups from one particular study.

For categorical variables the ORs were combined with the Mantel–Haenszel χ^2 method using a random-effect meta-analytical technique[30]. In a fixed-effect model it is assumed that there is no heterogeneity in treatment effect between studies, whereas in a random-effect model it is assumed that there is variation between studies and the calculated ORs therefore have a more conservative value[31–33]. Use of the random-effect model is preferable and advisable when meta-analysis is used to analyse data in surgical research. For each surgical technique each centre has its own selection criteria for patients and these patients have different risk profiles. For continuous variables statistical analysis was carried out using the WMD as the summary statistic[33]. For studies that presented continuous data as mean (range), the standard deviation was

Table 1 Characteristics of included studies

Reference	Year	Study type	Operations			Mean age (years)			Matching	Inclusion criteria	Exclusion criteria	Study quality (star rating)
			J	C	S	J	C	S				
24	2001	PNR	16	20	17	52	60	58	1,9,10	2	2	*****
25	2002	RCT	44	44	—	68	65	—	1–10	1,2,3	1,2,3	*********
40	2002	PNR	61	25	—		62 (overall)		2,5,9	1,2,3	1,2	****
26	2003	RCT	20	20	—	56	59	—	1–9	1,2,3,4	1,2,3	********
41	2003	RCT	15	15	—	62	60	—	1–9	1,2	1,2	********
42	1999	R	15	—	30	64	—	62	1,2,3,4,5	1,2	1,2	****
44	1999	R	12	—	25	58	—	57	1–4,6,9,10	2,3	2,4	*****
45	1997	R	15	—	37		62 (overall)		1,6,9	1,2,4	1,2	****
46	2004	R	12	—	21		57 (overall)		6,10	1,2,3	1,2,3	****
47	1995	PNR	7	—	22		59 (overall)		1,2,10	1,2	1,2	*****
48	1997	R	17	—	10	60	—	63	1,2,4,9,10	1,2,3	1,2	***
49	2003	PNR	4	—	18	—	—	—	1,2,5	1,2	1,2	***
19	1998	R	122	—	136	62	—	64	1,2,4,5,7	1,2,3	1,2	*****
50	1998	PNR	47	—	34	60	—	60	1,2,4,8,9	1,2,3	1,2,3,4	*****
36	2002	RCT	37	—	37	61	—	60	1,3,4,6,8,10	1,2,3,4	1,2,3	*********
52	2001	PNR	20	—	25	62	—	64	1–6,9,10	1,2,3	1,2	******
22	1996	RCT	45	—	52	67	—	69	1–7,9,10	1,2,3	1,2,3	*********
56	2001	R	62	—	57	59	—	60	1,2,5	1,2,3	1,2	***
58	2004	PNR	46	—	48	62	—	60	1,2,4,5,8,10	1,2,3	1,2,3,4	*****
37	1996	RCT	17	—	16	61	—	61	1,4–6,8–10	1,2,3	1,2	******
38	2000	RCT	21	—	26	62	—	61	1–7,9,10	1,2	1,2,3	*********
73*	1999	RCT	29	—	30	62	—	62	1–5,9, 10	1,2,4	1,2	*******
59	1997	PNR	34	—	22	57	—	60	1–4,6,9	1,2	1,2	****
20	1998	R	44	—	39	65	—	66	1,5	2	2	***
61	1996	PNR	24	—	39	60	—	58	1–3,5,6,10	2,4	2	*****
16	1986	PNR	20	—	45	57	—	57	1,2,3,5,9	1,2,3	1,2,4	***
18	1997	RCT	18	—	19	56	—	59	1,2,3,6,8–10	1,2	1,2	******
63	2002	PNR	40	—	41	60	—	62	1–7,9	1,2,3	1,2,3	******
74	2003	RCT	50	—	50	67	—	67	1–7,9,10	1,3	1,3,4	*********
65	1988	PNR	13	—	15	58	—	63	1–6,10	2	2	*****
66	1995	RCT	19	—	19	60	—	67	1,2,3,5,6,10	1,2,3	1,2,4	******
67	2002	RCT	21	—	21	61	—	59	1–5,7–10	1,2	1,2,3	********
68	2002	RCT	32	—	32	64	—	67	1–4,6,8,9,10	1,2,4	1,2,3	*******
69	1995	RCT	20	—	20	65	—	63	1,2,3,5,6,8,9,10	1,2,3	1,2,3,4	*******
72	2001	PNR	31	—	63	52	—	59	1,4,6	1,2,3	1,2,3,4	***

PNR, prospective non-randomized trial; RCT, randomized controlled trial; R, retrospective study; J, J-pouch; C, coloplasty; S, straight coloanal anastomosis. Matching: 1, age; 2, sex; 3, tumour height; 4, tumour stage; 5, height of anastomosis; 6, proximal stoma; 7, preoperative chemo/radiotherapy; 8, postoperative chemo/radiotherapy; 9, duration of follow-up; 10, type of anastomosis. Inclusion criteria: 1, carcinoma; 2, mid or low rectal disease; 3, curative intent; 4, normal preoperative continence. Exclusion criteria: 1, inflammatory bowel disease; 2, proximal rectal disease; 3, extensive local disease; 4, local/distal recurrence (cancer). *Includes patients with side-to-end anastomosis.

calculated using statistical algorithms and checked using bootstrap resampling techniques. Thus all continuous data were standardized for the analysis.

The quality of the randomized and non-randomized studies was assessed using the Newcastle–Ottawa scale with some modifications to match the needs of the present study[34]. The quality of the studies was evaluated by examining three items: patient selection, comparability of the three study groups and assessment of outcome. Studies achieving six or more stars were considered as being of highest quality.

Two strategies were employed to assess heterogeneity quantitatively. First, graphical exploration with funnel plots was used to evaluate publication bias[33,35]. Second, sensitivity analysis was undertaken for the following subgroups: study size more than 50 patients, year of publication later than 1999, and higher-quality studies with six or more stars. All analysis was conducted using Review Manager version 4.2 (Update Software, Oxford, UK).

Results

A total of 48 comparative studies published between 1986 and 2005 matched the selection criteria[16,18–20,22,24–26,36–76]. Eleven were excluded because there was temporal overlap with respect

Table 2 Outcomes measured by each study

	Outcomes																		
Reference	OT	LOS	MOR	AL	WI	CI	F	FC	AS	SF	U	IE	RP	SP	NTV	MNV	NI	FS	PE	M
24				√					√	√			√	√		√				√
25	√	√	√	√	√	√	√	√		√		√	√	√	√	√	√	√	√	√
40										√		√					√			
26								√		√			√	√	√	√				
41				√			√	√	√	√			√	√		√	√			√
42				√	√				√	√			√	√		√		√		
44				√					√	√	√						√	√		√
45										√	√						√			√
46													√	√	√	√				
47										√							√			
48		√	√	√	√						√									√
49													√	√						
19			√	√			√													
50										√		√					√			√
36			√	√	√	√		√	√	√			√	√	√	√				
52	√	√		√	√					√	√		√	√				√		
22			√	√		√		√	√	√	√	√						√		√
56										√	√	√								√
58											√	√			√	√		√	√	√
37										√	√	√	√	√	√	√				√
38			√							√		√	√	√			√	√	√	√
73	√			√			√			√	√	√	√	√	√	√				√
59										√	√	√			√	√	√	√		√
20			√	√	√		√		√	√	√		√	√	√	√				
61			√	√					√	√			√	√						
16							√			√	√		√	√	√	√				
18										√	√									
63				√	√				√	√	√	√	√	√	√	√				√
74	√	√	√	√	√	√		√	√	√	√	√							√	√
65		√		√	√				√	√	√		√	√	√	√			√	√
66			√	√							√	√	√	√		√				
67					√			√		√	√	√	√	√	√	√				
68	√		√	√	√								√	√						
69	√				√	√				√	√						√			√
72			√	√					√	√	√	√	√	√	√	√				

OT, operating time; LOS, length of hospital stay; MOR, mortality; AL, anastomotic leakage; WI, wound infection; CI, chest infection; F, rectovaginal fistula; FC, failure to construct pouch; AS, anastomotic stricture; SF, stool frequency per 24 h; U, urgency; IE, incomplete evacuation; RP, postoperative resting pressure; SP, postoperative squeeze pressure; NTV, neorectal threshold volume; MNV, maximum neorectal volume; NI, night incontinence; FS, soiling on passing flatus; PE, perineal excoriation; M, antidiarrhoeal medication.

to patient recruitment with other published studies by the same authors that were included in the analysis[39,43,51,53–55,57,70,75–77]. Data were not extractable in one comparative study as it compared patients with and without evacuation difficulties after J-pouch construction and straight CAA[64]. Three further studies were unobtainable and so were also excluded[60,62,71]. No study was found that compared transverse coloplasty solely with straight CAA.

There were, therefore, 35 studies that fulfilled the inclusion criteria with a combined total of 2240 subjects[16,18–20,22,24–26,36–38,40–42,44–50,52,56,58,59,61,63,65–69,72–74]. One prospective non-randomized study[24] provided data on all three groups (J-pouch, coloplasty and straight CAA) and the remaining 34 studies reported outcomes on two groups of patients. In total, five studies[24–26,40,41] compared J-pouch ($n = 156$) with coloplasty ($n = 124$) and 31 studies compared J-pouch ($n = 910$) with straight CAA ($n = 1066$). There were 14 randomized controlled trials (RCTs)[22,25,26,36–38,41,66–69,73,74,77], 13 prospective non-randomized trials[16,24,40,47,49,50,52,58,59,61,63,65,72] and eight retrospective comparative studies. Review of the data extraction showed 100 per cent agreement between the three reviewers. The demographic characteristics, inclusion criteria, exclusion criteria and matching of the groups in terms of patient and procedural factors are shown in *Table 1*. Sixteen studies[22,25,26,36–38,41,52,63,66–69,73,74,77] scored six or more stars on the modified Newcastle–Ottawa scale, of which 14 were RCTs and two were prospective non-randomized trials.

Table 2 summarizes the outcomes measured for each study. Failure to construct a J-pouch reservoir was only reported by seven studies[22,25,26,36,41,67,74] with an incidence of 12 failures out of 249 patients (4·8 per cent). The outcomes of interest for the five studies[24–26,40,41] comparing J-pouch with transverse coloplasty are shown in *Table 3*. There was no significant difference in any of the adverse postoperative events or functional outcomes between the two groups. Only one study reported length of hospital stay and operating time[25]. A significant reduction of 1·40 days was reported in favour of the J-pouch ($P < 0·001$) and a decrease in operating time of 33·60 (95 per cent c.i. 24·55 to 42·65) min in the coloplasty group ($P < 0·001$). Four studies[24–26,41] compared postoperative resting pressure and, although not clinically relevant, values in the J-pouch group were higher by 3·32 (95 per cent c.i. 0·89 to 5·74) mmHg ($P < 0·001$). Two studies[25,26] compared neorectal threshold volume; there was an overall 18·98 (95 per cent c.i. 2·24 to 35·72) ml increase in the J-pouch group ($P = 0·034$).

The outcomes of interest for the 31 studies comparing J-pouch with straight CAA are shown in *Table 4*. Seventeen studies[20,22,24,36,42,44,48,50,52,61,63,65,66,68,72–74] reported on anastomotic leak with an overall reduction from 13·8

Table 3 Summary statistics for outcomes after J-pouch *versus* coloplasty

	No. of patients	No. of studies	OR or WMD	*P*	Test for heterogeneity	
					χ^2	*P*
Early postoperative adverse events						
Anastomotic leak	154	3	0·33 (0·06, 2·01)	0·232	2·58	0·275
Anastomotic stricture	66	2	0·81 (0·17, 3·87)	0·790	0·24	0·624
Rectovaginal fistula	118	2	0·32 (0·03, 3·18)	0·331	–	–
Other complications	124	2	0·83 (0·29, 2·40)	0·728	0·41	0·52
Overall mortality	118	1	0·33 (0·01, 8·22)	0·501	–	–
Functional outcomes						
Stool frequency (per 24 h)*	276	5	−0·14 (−1·00, 0·73)	0·763	71·66	<0·001
Incomplete evacuation	142	2	1·26 (0·54, 2·95)	0·657	0·96	0·327
Seepage (night)	172	3	0·96 (0·37, 2·46)	0·923	2·12	0·346
Discrimination for faeces/flatus	118	2	1·20 (0·37, 3·93)	0·760	0·71	0·399
Antidiarrhoeal medication	154	3	1·87 (0·66, 5·31)	0·241	1·16	0·560
Anorectal physiology						
Resting pressure (mmHg)*	190	4	3·32 (0·89, 5·74)	0·007	3·26	0·353
Squeeze pressure (mmHg)*	170	4	−0·66 (−5·63, 4·31)	0·793	3·14	0·371
Neorectal threshold volume (ml)*	108	2	18·98 (2·24, 35·72)	0·034	3·63	0·057
Maximum neorectal volume (ml)*	174	4	8·37 (−12·27, 29·01)	0·433	14·87	<0·001
Hospital stay (days)**	88	1	−1·40 (−1·86, −0·94)	<0·001	–	–
Operating time (min)*	88	1	33·60 (24·55, 42·65)	<0·001	–	–

Values in parentheses are 95 per cent confidence intervals. An odds ratio (OR) of less than 1·00 favours treatment with a J-pouch. *A positive weighted mean difference (WMD) denotes higher overall values for the J-pouch group and a negative value denotes lower values in the coloplasty group. **A negative WMD denotes lower hospital stay for the J-pouch group.

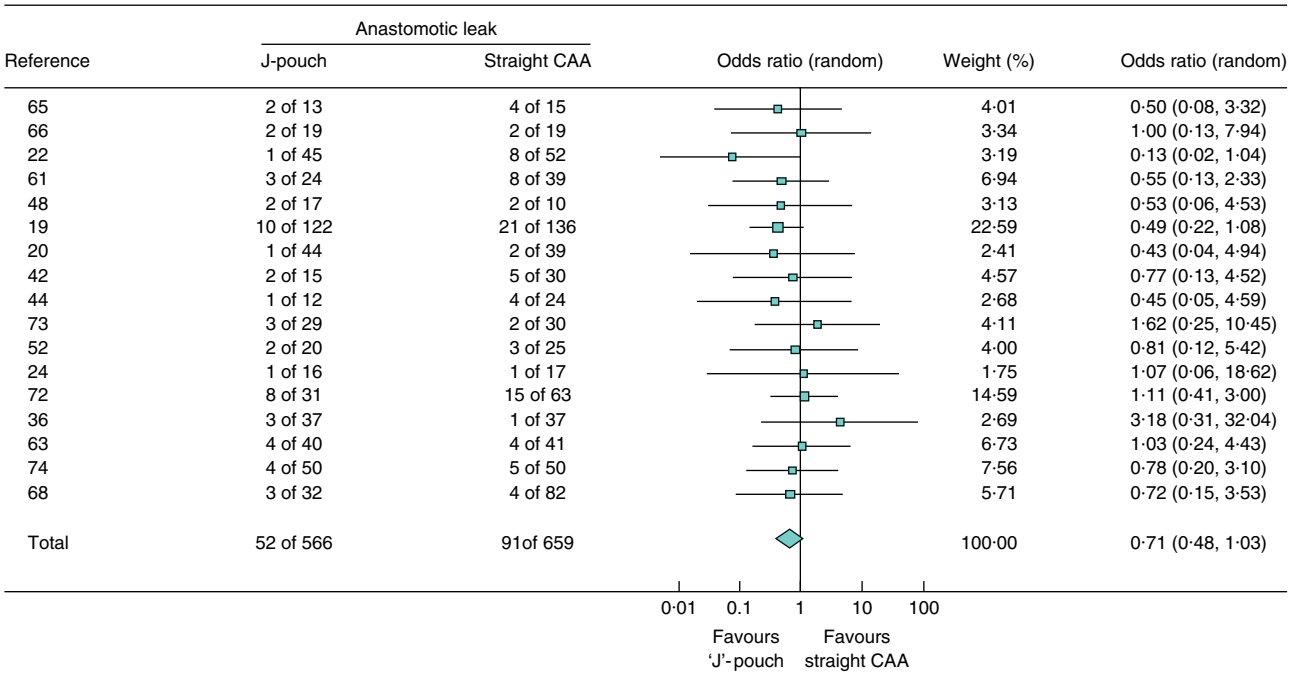

Fig. 1 Forrest plot of anastomotic leak rates in studies of J-pouch *versus* straight coloanal anastomosis (CAA) (random-effect model). Odds ratios are shown with 95 per cent confidence intervals. Test for heterogeneity: $\chi^2 = 7{\cdot}69$, 16 d.f., $P = 0{\cdot}957$, $I^2 = 0$ per cent; test for overall effect: $Z = 1{\cdot}79$, $P = 0{\cdot}069$

to 9·2 per cent in favour of the J-pouch group, a difference that did not reach statistical significance (OR 0·71 (95 per cent c.i. 0·48 to 1·03); $P = 0{\cdot}069$) (*Fig. 1*). There was no significant difference in any of the other adverse postoperative events between the J-pouch and straight CAA groups: anastomotic stricture 7·1 *versus* 6·7 per cent, rectovaginal fistula 2·3 *versus* 2·8 per cent, wound infection 7·8 *versus* 5·0 per cent, respiratory tract infection 4·6 *versus* 4·4 per cent, perianal excoriation 20·2 *versus* 22·6 per cent, postoperative mortality 1·8 *versus* 3·1 per cent. Operating time, length of hospital stay and seepage at night, and anal manometric resting and squeeze pressure were not significantly different between the two groups.

Fig. 2 is a Forrest plot comparing stool frequency per 24 h after J-pouch reconstruction *versus* straight CAA. Within 6 months of the original procedure patients with a J-pouch had a reduction in the frequency of defaecation by 1·88 stools per day compared with patients with a straight CAA ($P = 0{\cdot}011$). This apparent difference diminished to 1·35 stools per day at 1 year ($P < 0{\cdot}001$) and 0·74 stools per day at 2 or more years ($P = 0{\cdot}010$).

Fig. 3 is a Forrest plot comparing faecal urgency after J-pouch reconstruction *versus* straight CAA. Within 6 months of the procedure 44 (21·0 per cent) of 210 patients with a J-pouch had urgency compared with 126 (51·4 per cent) of 245 in the straight CAA group ($P = 0{\cdot}001$), a difference that retained statistical significance at 1 year after surgery (8·7 *versus* 30·3 per cent; $P < 0{\cdot}001$). At 2 or more years the difference in faecal urgency between the two groups was not statistically significant ($P = 0{\cdot}250$). Significant differences between the two groups were also reported at 1 or more years for neorectal threshold and maximum neorectal volume in favour of the J-pouch group (*Table 4*).

A funnel plot of the studies used in the meta-analysis of postoperative anastomotic leak between J-pouch reconstruction and straight CAA is shown in *Fig. 4*. This is a scatter plot of the treatment effects estimated from individual studies plotted on the horizontal axis (OR), against a measure of mortality shown on the vertical axis (SE[logOR]). The overall effect estimate is indicated by the vertical dotted line and the 95 per cent c.i. for the overall effect is shown by the diagonal dotted lines, forming an inverted funnel shape around the overall estimate. The effect of each study is marked by a circle on the graph. Studies should be evenly distributed within the inverse funnel shape around the total line (as indicated by the 95 per cent c.i. lines); otherwise publication bias is indicated. None of the studies lay outside the limits of the

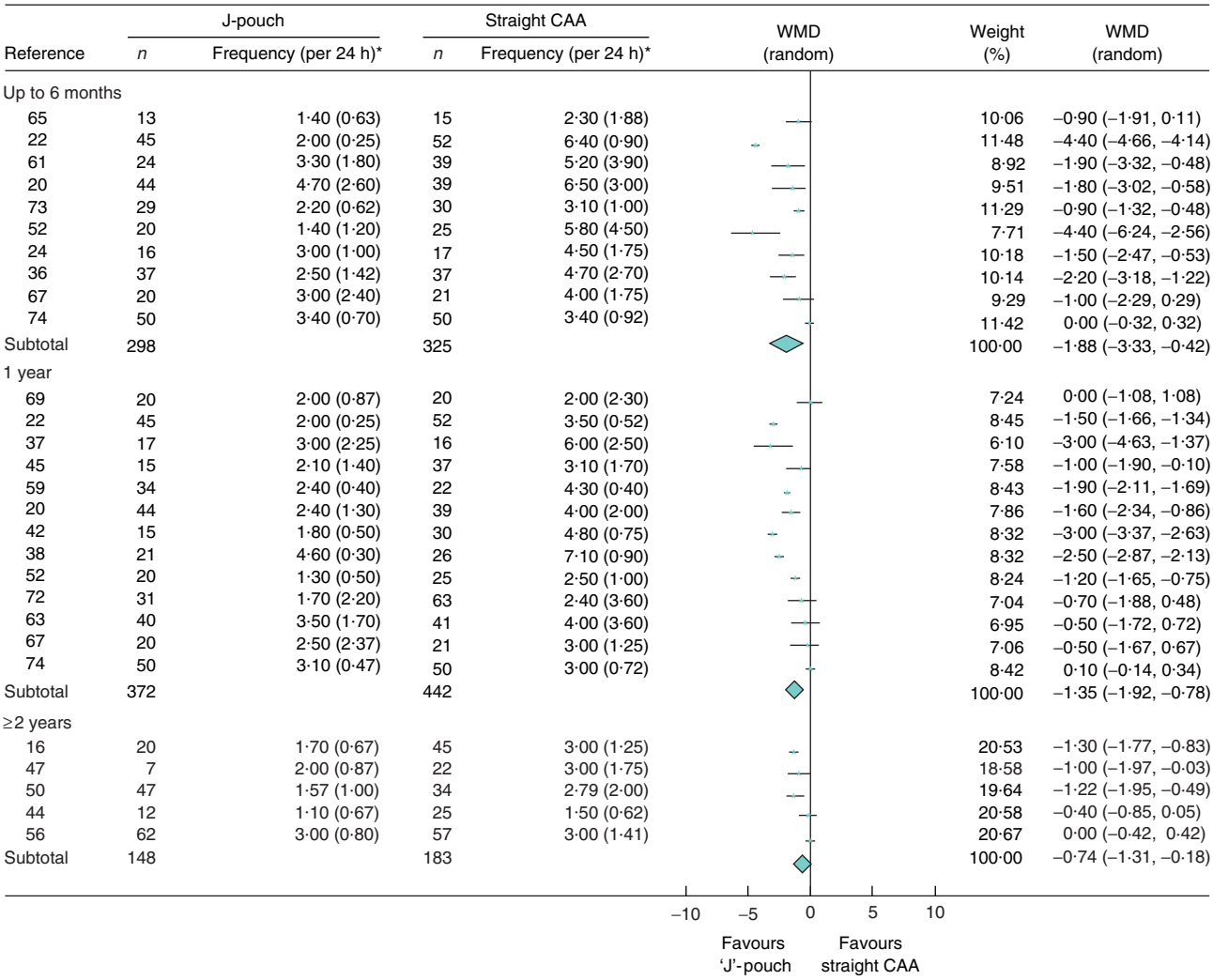

Fig. 2 Forrest plot of stool frequency per 24 h after J-pouch *versus* straight coloanal anastomosis (CAA). *Values are mean(s.d.). Weighted mean differences (WMDs) are shown with 95 per cent confidence intervals. The outcomes are shown at three time intervals: within 6 months of the original procedure or reversal of the proximal diversion (test for heterogeneity: $\chi^2 = 519{\cdot}70$, 9 d.f., $P < 0{\cdot}001$, $I^2 = 98{\cdot}3$ per cent; test for overall effect: $Z = 2{\cdot}53$, $P = 0{\cdot}011$), at 1 year (test for heterogeneity: $\chi^2 = 297{\cdot}89$, 12 d.f., $P < 0{\cdot}001$, $I^2 = 96{\cdot}0$ per cent; test for overall effect: $Z = 4{\cdot}68$, $P < 0{\cdot}001$), and at 2 years or more (test for heterogeneity: $\chi^2 = 20{\cdot}68$, 4 d.f., $P < 0{\cdot}001$, $I^2 = 80{\cdot}7$ per cent; test for overall effect: $Z = 2{\cdot}58$, $P = 0{\cdot}010$)

95 per cent c.i.; there was no evidence of publication bias (all studies were equally distributed around the vertical axis) or heterogeneity among the studies with regard to anastomotic leak ($P = 0{\cdot}960$). Heterogeneity between studies was significant for stool frequency and maximum neorectal volume for all studies (*Tables 3* and *4*). There was also significant heterogeneity when comparing need for antidiarrhoeal medication and the four physiological outcomes in studies of J-pouch *versus* straight CAA.

Table 5 shows the results of the sensitivity analysis of studies comparing J-pouch and straight CAA for all high-quality trials with six or more stars, for studies published after 1999, and for studies with a sample size of more than 50 patients. The results of the sensitivity analysis mirror the estimates shown in *Table 4*. Although the heterogeneity between studies was reduced for all three endpoints, it remained significant for stool frequency. There was no significant heterogeneity for faecal urgency in studies containing more than 50 patients but heterogeneity remained significant in the high-quality studies and in studies published after 1999.

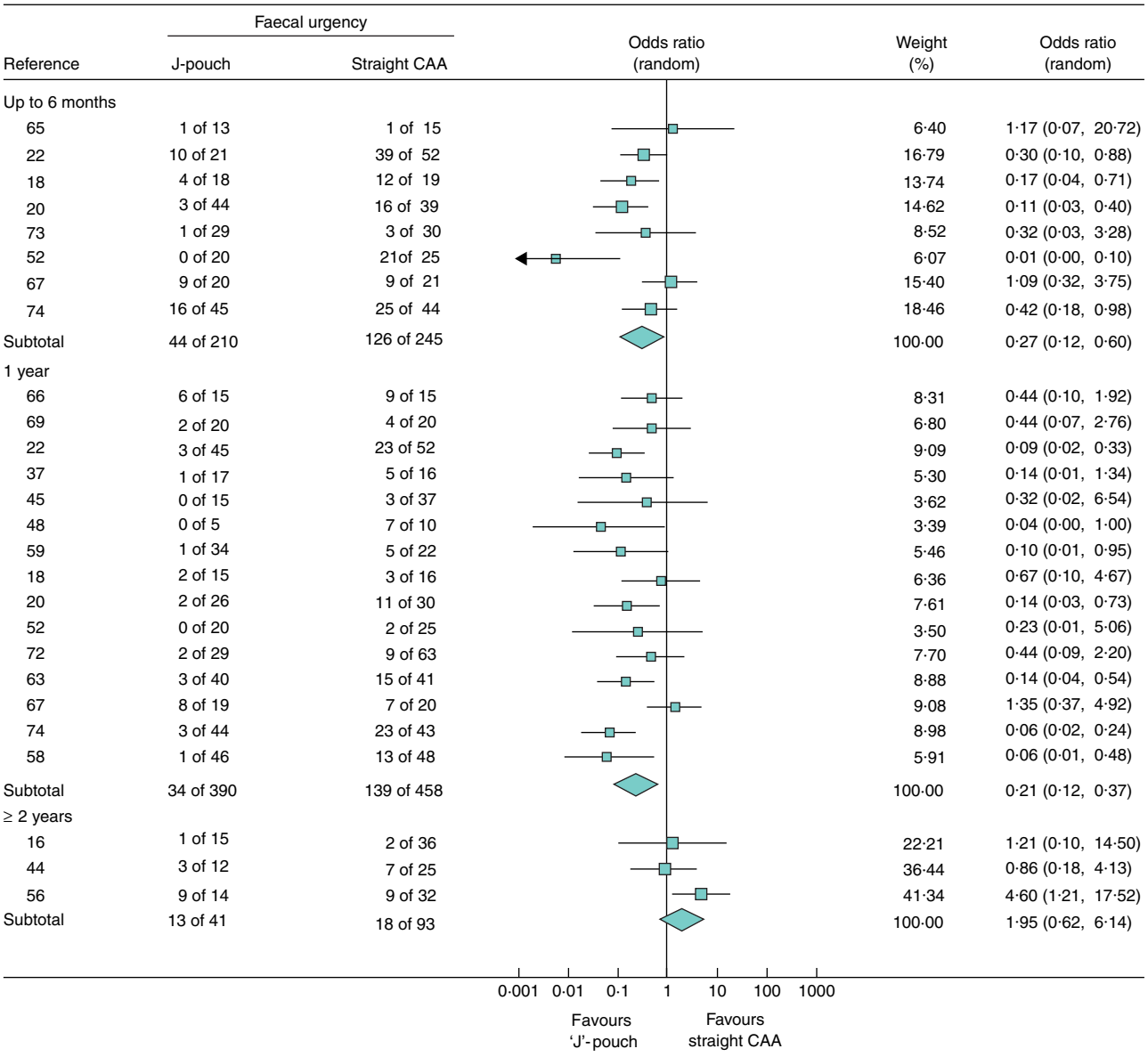

Fig. 3 Forrest plot of faecal urgency after J-pouch *versus* straight coloanal anastomosis (CAA). Odds ratios are shown with 95 per cent confidence intervals. The outcomes are shown at three times intervals: within 6 months of the original procedure or reversal of the proximal diversion (test for heterogeneity: $\chi^2 = 16{\cdot}35$, 7 d.f., $P = 0{\cdot}022$, $I^2 = 57{\cdot}2$ per cent; test for overall effect: $Z = 3{\cdot}19$, $P = 0{\cdot}001$), at 1 year (test for heterogeneity: $\chi^2 = 20{\cdot}28$, 14 d.f., $P = 0{\cdot}121$, $I^2 = 31{\cdot}0$ per cent; test for overall effect: $Z = 5{\cdot}50$, $P < 0{\cdot}001$), and at 2 years or more (test for heterogeneity: $\chi^2 = 2{\cdot}76$, 2 d.f., $P = 0{\cdot}251$, $I^2 = 27{\cdot}4$ per cent; test for overall effect: $Z = 1{\cdot}14$, $P = 0{\cdot}250$)

A power calculation was performed for the outcome anastomotic leak. The overall incidence of postoperative anastomotic leak was 52 (9·2 per cent) of 566 after J-pouch reconstruction compared with 91 (13·8 per cent) of 659 after straight CAA. To rule out a 4·6 per cent absolute risk reduction (from 13·8 per cent to 9·2 per cent) with a 5 per cent significance level and 80 per cent power, a traditional RCT would require 797 patients in each arm.

Discussion

It is now almost 20 years since Lazorthes *et al.*[16] and Parc *et al.*[17] suggested forming a colonic reservoir after low anterior resection and many studies, both randomized and non-randomized, have addressed this issue. It has been demonstrated that the more distal the anastomosis the greater the impact on functional outcome. Matzel

Table 4 Summary statistics for short- and long-term outcomes after J-pouch *versus* straight coloanal anastomosis

	No. of patients	No. of studies	OR or WMD	*P*	Test for heterogeneity χ^2	Test for heterogeneity *P*
Early postoperative adverse events						
Anastomotic leak	1225	17	0·71 (0·48, 1·03)	0·069	7·69	0·957
Anastomotic stricture	771	12	1·04 (0·52, 2·06)	0·910	12·69	0·314
Rectovaginal fistula	465	4	0·99 (0·31, 3·18)	0·991	1·55	0·670
Wound infection	628	11	1·51 (0·78, 2·94)	0·222	3·09	0·979
Respiratory tract infection	311	4	0·89 (0·29, 2·71)	0·843	0·85	0·837
Perineal excoriation	248	4	0·90 (0·47, 1·70)	0·742	2·67	0·445
Other complications	570	11	1·26 (0·68, 2·32)	0·731	7·30	0·697
Overall deaths	1280	11	0·66 (0·29, 1·47)	0·310	8·57	0·573
Functional outcomes						
Stool frequency (per 24 h)*						
≤ 6 months	623	10	− 1·88 (− 3·33, − 0·42)	0·011	519·70	< 0·001
1 year	814	13	− 1·35 (− 1·92, − 0·78)	< 0·001	297·89	< 0·001
≥ 2 years	331	5	− 0·74 (− 1·31, − 0·18)	0·010	20·68	< 0·001
Faecal urgency						
≤ 6 months	455	8	0·27 (0·12, 0·60)	0·001	16·35	0·022
1 year	848	15	0·21 (0·12, 0·37)	< 0·001	20·28	0·121
≥ 2 years	134	3	1·95 (0·62, 6·14)	0·250	2·76	0·251
Incomplete evacuation						
≤ 6 months	286	4	0·83 (0·28, 2·41)	0·730	9·56	0·022
1 year	646	10	0·70 (0·44, 1·13)	0·150	12·60	0·181
≥ 2 years	127	2	0·31 (0·14, 0·68)	0·004	0·69	0·406
Seepage (night)						
≤ 6 months	130	2	0·51 (0·15, 1·75)	0·292	1·43	0·232
1 year	525	9	0·64 (0·40, 1·02)	0·061	7·62	0·471
≥ 2 years	112	3	0·31 (0·08, 1·18)	0·090	3·63	0·162
Discrimination for faeces/flatus						
≤ 6 months	138	2	0·35 (0·07, 1·86)	0·220	2·94	0·086
≥ 1 year	403	7	0·30 (0·15, 0·60)	< 0·001	7·00	0·321
Antidiarrhoeal medication						
≤ 6 months	282	5	0·93 (0·14, 6·36)	0·940	20·72	< 0·001
1 year	584	10	0·42 (0·18, 0·97)	0·040	28·88	< 0·001
≥ 2 years	164	3	0·21 (0·07, 0·63)	0·005	1·70	0·427
Anorectal physiology						
Resting pressure (mmHg)*						
≤ 6 months	502	10	0·57 (− 5·35, 6·50)	0·851	31·26	< 0·001
≥ 1 year	591	10	− 3·40 (− 9·71, 2·90)	0·292	127·08	< 0·001
Squeeze pressure (mmHg)*						
≤ 6 months	502	10	− 6·90 (− 17·00, 3·20)	0·178	6·44	0·695
≥ 1 year	591	10	− 6·90 (− 19·02, 6·85)	0·362	59·94	< 0·001
Neorectal threshold volume (ml)*						
≤ 6 months	275	5	12·49 (0·08, 24·90)	0·052	26·17	< 0·001
≥ 1 year	547	8	19·93 (2·13, 37·73)	0·031	588·96	< 0·001
Maximum neorectal volume (ml)*						
≤ 6 months	308	6	34·75 (0·64, 68·86)	0·048	35·81	< 0·001
≥ 1 year	630	10	44·56 (20·79, 68·33)	< 0·001	379·28	< 0·001
Hospital stay (days)**	200	4	− 1·14 (− 3·29, 1·00)	0·300	0·31	0·958
Operating time (min)*	308	5	0·26 (− 14·73, 15·24)	0·970	3·11	0·540

Values in parentheses are 95 per cent confidence intervals. An odds ratio (OR) of less than 1·00 favours treatment with a J-pouch. *A positive weighted mean difference (WMD) denotes higher overall values for the J-pouch group and a negative value denotes lower values in the straight coloanal group. **A negative WMD denotes lower hospital stay for the J-pouch group.

et al.[78] assessed function with respect to the level of the anastomosis and reported that daily stool frequency ranged from 5·2 to 2·8 to 2·1 when the residual rectum ranged from 0·5 to 5·1 to 8·9 cm respectively. Guidelines for the management of colorectal cancer issued by the Association of Coloproctology of Great Britain and Ireland in 2001[79] suggested that the formation of a colonic pouch should be considered after low anterior resection. Defining the

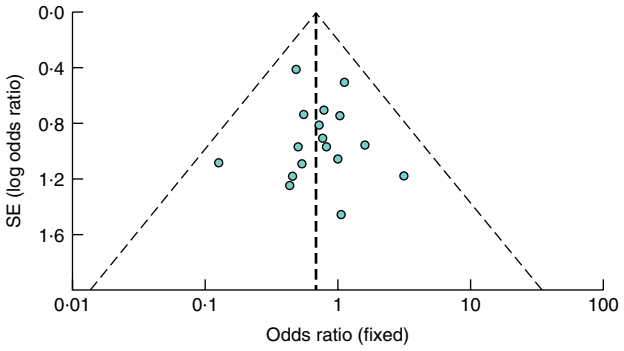

Fig. 4 Funnel plot for comparison of anastomotic leak for all studies of J-pouch *versus* straight coloanal anastomosis. Each study is marked by a dot around the overall effect estimate (vertical dotted line). The diagonal dotted lines represent the 95 per cent confidence interval around the overall effect estimate. SE, standard error

role of a colonic reservoir is important for guiding future practice.

The present meta-analysis assessed 35 trials containing a total of 2240 patients. The value of meta-analyses is that the sample size and statistical power of the analysis are greatly increased, allowing assessment of a total number of patients that is unlikely to be attained in a single study. Such an analysis is, in effect, a 'study of studies'[80] and its accuracy depends on the quality of the available studies in the literature; 14 of the studies included in this analysis were RCTs. The literature on J-pouch anastomosis was considerable but only five studies assessed coloplasty, although three of these were RCTs.

There was no difference in postoperative complications between either straight CAA *versus* J-pouch reconstruction or between J-pouch and coloplasty anastomoses. A number of individual studies have suggested that the anastomotic leak rate may be lower after J-pouch anastomosis than straight CAA. Hallbook *et al.*[22] reported, in a RCT of straight CAA *versus* colonic pouch, a symptomatic leak rate of 15 per cent in the straight group and only 2 per cent in the pouch group. Interestingly, over 50 years ago it was reported that a colorectal end-to-side anastomosis had a slightly lower leak rate than a colorectal end-to-end anastomosis[81]. As the present meta-analysis showed no difference in anastomotic leak rate between straight and J-pouch anastomoses, this should not impact on the decision whether to form a colonic reservoir or

Table 5 Sensitivity analysis for studies comparing J-pouch *versus* straight coloanal anastomosis

	No. of patients	No. of studies	OR or WMD	*P*	Test for heterogeneity χ^2	Test for heterogeneity *P*
High-quality studies (≥ 6 stars)						
Anastomotic leak	558	8	0·85 (0·46, 1·59)	0·620	5·06	0·650
Stool frequency (per 24 h)*						
≤ 6 months	416	6	−2·12 (−4·13, −0·10)	0·040	508·51	< 0·001
1 year	784	8	−1·11 (−1·88, −0·34)	< 0·001	187·33	< 0·001
Faecal urgency						
≤ 6 months	344	6	0·28 (0·11, 0·71)	0·008	12·84	0·020
1 year	483	9	0·25 (0·12, 0·54)	< 0·001	16·08	0·040
Studies published after 1999						
Anastomotic leak	739	9	0·82 (0·49, 1·39)	0·470	5·21	0·740
Stool frequency (per 24 h)*						
≤ 6 months	293	5	−1·67 (−3·01, −0·34)	0·010	42·68	< 0·001
1 year	441	7	−1·15 (−1·15, −0·09)	0·003	146·79	< 0·001
Faecal urgency						
≤ 6 months	175	3	0·22 (0·03, 1·68)	0·150	11·83	0·003
1 year	471	7	0·21 (0·08, 0·55)	0·002	13·09	0·030
Studies with sample size > 50						
Anastomotic leak	1029	10	0·71 (0·46, 1·10)	0·130	7·15	0·620
Stool frequency (per 24 h)*						
≤ 6 months	517	7	−1·75 (−3·56, −0·06)	0·006	504·78	< 0·001
1 year	563	7	−1·05 (−1·76, −0·34)	0·004	171·46	< 0·001
Faecal urgency						
≤ 6 months	304	4	0·29 (0·16, 0·52)	< 0·001	2·97	0·400
1 year	615	8	0·12 (0·07, 0·22)	< 0·001	4·60	0·710

Values in parentheses are 95 per cent confidence intervals. An odds ratio (OR) of less than 1·00 favours treatment with a J-pouch. *A positive weighted mean difference (WMD) denotes higher overall values for the J-pouch group and a negative value denotes lower values in the straight coloanal group.

not. Insufficient studies commented on the anastomotic technique used for this variable to be assessed. It is well established that the risk of complications related to pouch construction and functional outcomes is affected by the use of chemoradiation[82,83]. Too few studies commented on chemoradiation and so statistical analysis of this variable was not feasible. Similarly, statistical comparison of patients with and without a defunctioning loop stoma was not feasible as only a small number of studies mentioned this variable. It is probably prudent, however, owing to the nature of ultralow resection and reservoir formation, that a temporary defunctioning stoma is formed at the time of surgery.

Functional assessment of outcome showed a significant reduction in stool frequency after J-pouch reconstruction compared with straight CAA. At 6 months there was a difference of 1·88 motions per 24 h, reducing to 1·35 at 1 year, and 0·74 at 2 years or more. A number of randomized trials comparing straight *versus* colonic pouch anastomosis consistently demonstrated reduced frequency at 1 year in patients with a colonic pouch[22,37]. Dehni *et al.*[19] and Lazorthes *et al.*[18] both showed persisting superiority in bowel frequency in patients with a colonic pouch at follow-up of 60 and 24 months respectively. Joo *et al.*[20], however, reported that by 24 months there was no difference between a straight CAA and a pouch–anal anastomosis in terms of bowel frequency. It appears that, although the superiority of J-pouch reconstruction in terms of frequency does persist over time, by 2 years the difference is empirical rather than clinical. What it is not possible to determine is how many patients with a straight CAA continue to have significant impairment from frequency after 2 years in whom this may have been prevented by use of a J-pouch anastomosis.

In contrast to frequency of defaecation, no individual study has shown a persistent reduction in faecal urgency with use of a J-pouch[18–20], although a number of RCTs did show a benefit up to 1 year[22,74,77]. These findings are also mirrored by the present meta-analysis. Urgency was significantly reduced by use of a J-pouch up to 1 year, but this difference did not persist. There was a difference in both threshold volume and maximum tolerated neorectal volume, which persisted after 1 year, and both were greater in patients with a J-pouch rather than a straight anastomosis, with no difference in resting or squeeze pressure. However, this did not appear to be reflected by any difference in faecal urgency. The incidence of provoked evacuation was not recorded in the studies, although this may be an important factor to consider.

The comparison of function between J-pouch and coloplasty anastomoses showed that there was no difference between the two procedures in terms of postoperative complications, functional outcome or anorectal physiology other than threshold volume and anorectal resting pressure. Although the analysis contained only five studies, it is encouraging that there was no identifiable difference as it justifies the decision between the two options being made purely on technical grounds. Furst *et al.*[26] reported that in five of 20 patients randomized to the J-pouch group, formation of a pouch was not attempted owing to the presence of extensive colonic adipose tissue or a narrow male pelvis. Harris *et al.*[27] reviewed reasons for failure to construct a colonic J-pouch. Of 107 patients, it was impossible to construct a colonic J-pouch in 28 (26·2 per cent). Seven reasons were identified for failure, either technical in most patients (narrow pelvis, bulky anal sphincters or need for mucosectomy, diverticulosis, insufficient colon length, or pregnancy) or non-technical (complex surgery or distant metastases present). The coloplasty pouch–anal anastomosis was introduced towards the end of the study, and reduced the incidence of failure to form a reservoir from 27 (31 per cent) of 88 to one (5 per cent) of 19.

There are potential sources of error in meta-analysis and care was taken to minimize these. A comprehensive literature search was made of all comparative studies of straight coloanal, J-pouch and coloplasty anastomoses. Overlapping studies were excluded to minimize bias. It was impossible to eliminate publication bias as studies with statistically significant results were more likely to be published than those without and so there is potential for under-representation of negative studies. This publication bias was formally tested using a funnel plot and did not appear excessive. Heterogeneity was shown to be an issue for variables that are dependent on patient reporting (stool frequency, faecal urgency, antidiarrhoeal medication) or human measurement (anorectal physiological variables). Inconsistencies arising from these two important factors, in addition to heterogeneous patient populations (in terms of sex, age and pathology) and surgeon-specific preferences, account for the significant heterogeneity observed. These biases are inherent to the individual studies and so it was not possible to account for them by means of sensitivity analysis. Furthermore, Gavaghan *et al.*[84] have cast doubt on the validity and power of heterogeneity testing by showing that significant heterogeneity was observed in homogeneous groups of patients. Their suggestion of clearly defined inclusion criteria and outcome measures as a way of defining 'clinical homogeneity' was followed in this study.

Use of a colonic J-pouch after anterior resection appeared to have significant functional advantages over

straight CAA and this persisted over time. There was no increase in postoperative complications and J-pouch construction, if technically feasible, seems to be the procedure of choice after anterior resection. J-pouch and coloplasty reconstruction appeared to be equivalent, but evidence is limited to a small number of studies. High-quality randomized trials are required for this issue to be addressed definitively.

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