Prospective controlled trial of duplicated (J) versus quadruplicated (W) pelvic ileal reservoirs in restorative proctocolectomy for ulcerative colitis

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Abstract

Aims—A prospective randomised controlled trial was conducted to find out what influence the design of the pelvic reservoir had on the functional outcome.

Patients and Methods—Sixty patients received either a duplicated (J) or a quadruplicated (W) reservoir, constructed with either 30 or 40 cm of ileum. Each patient underwent laboratory tests of anorectal function before and one year after operation.

Results—One year after operation, 57 patients were available for assessment: each had good anal continence, though eight experienced minor leakage of mucus, and all were able to defer defecation for more than 15 minutes. Median bowel frequency in 24 hours (IQR) in patients with J reservoirs (5 (4–7)) did not differ significantly from that of patients with W reservoirs (5 (4–6)). Likewise, bowel frequency in patients with the smaller (30 cm) reservoirs did not differ significantly from bowel frequency in patients with the larger (40 cm) reservoirs. However, patients with large W40 reservoirs had the lowest bowel frequency of the four groups (median 4 per 24 hours, $p=NS$). The capacity and compliance of the W40 reservoirs were greater than those of the other types of reservoir, but the differences were not statistically significant.

Conclusions—These findings provide support for the use of a relatively small (30 cm), duplicated (J) ileal reservoir, which is simple to construct with linear stapling instruments.

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Figure 1: Duplicated (J) and quadruplicated (W) reservoirs.

Eighteen years after Parks and Nicholls first introduced the pelvic ileal reservoir into clinical practice,¹ there is still no consensus about the ideal design of the reservoir. Two designs – the duplicated (J) and the quadruplicated (W) reservoir (Fig 1) – have been found to possess advantages over the original triplicated (S) reservoir.^{2–3} In our own experience,^{4–6} the W reservoir constructed with 40 cm of ileum was associated with a lower bowel frequency (4 in 24 hours) than the J reservoir (6 in 24 hours). However, in the only prospective randomised trial that has been reported, no significant difference in clinical outcome was found when the J and W reservoirs were compared.⁷ Although no randomised trial of the use of different lengths of ileum for construction of the reservoir has been performed, reports that bowel frequency is inversely proportional to the capacity of the reservoir^{4,5} would tend to favour the construction of larger reservoirs.

The aim of this study was to find out if the functional outcome after restorative proctocolectomy is related to the design of the reservoir and the length of ileum used in its construction. Our hypothesis was that a quadruplicated (W) design would produce a more capacious reservoir than a duplicated (J) one, when the same length of ileum was used in their construction. Assuming that bowel frequency is inversely related to the capacity of the reservoir, we predicted that patients with a W reservoir would have a lower bowel frequency than patients with a J reservoir.

Methods

A consecutive series of 60 patients with ulcerative colitis was studied (the diagnosis was later revised in five patients, see later). They were randomised to receive one of four types of reservoir: (1) Duplicated reservoir made with 30 cm of ileum (J30). (2) Duplicated reservoir made with 40 cm of ileum (J40). (3) Quadruplicated reservoir,

TABLE 1 Details of the 60 patients

Reservoir design	J30	J40	W30	W40
Number	14	17	15	14
Age (y)	32 (24–62)	32 (25–43)	33 (24–50)	33* (10–59)
Sex m:f	5:9	7:10	7:8	7:7
Diagnosis†				
Ulcerative colitis	14	15	12	14
Indeterminate colitis	0	0	3	0
Crohn's disease	0	2	0	0
Previous colectomy	1	3	3	5
One stage RP	7	5	5	6
Eversion of anorectum	10	14	9	10

J30, J40, W30, and W40: see text. *Median (range). †Before operation, all patients had been diagnosed as having either ulcerative colitis or indeterminate colitis. One stage RP: no defunctioning ileostomy was used. Eversion of anorectum: temporary eversion of the anorectum through the anus in the course of the operation.

30 cm of ileum (W30). (4) Quadruplicated reservoir, 40 cm of ileum (W40). Table I shows details of the patients. Two patients proved to have Crohn's disease and three, indeterminate colitis, when the resected specimen was examined pathologically.

Operative technique

The J reservoirs were constructed with the aid of the GIA linear stapler (Autosuture, Ascot, UK): the staple lines were inverted with 3-0 Maxon.² The W reservoirs were constructed by hand suture in two layers,³ an all layer catgut suture being oversewn with a seromuscular layer of 3-0 Maxon (Cyanamed GB Ltd, Gosport, Hants). The rectum was removed by close perimuscular dissection in an attempt to avoid autonomic nerve damage. In each patient, a stapled, end to end pouch-anal anastomosis was constructed as we described previously,⁸ temporary eversion of the anorectum being used in most patients during the course of the operation in an attempt to site the pouch-anal anastomosis accurately 1 to 1.5 cm above the dentate line.⁹ A defunctioning ileostomy was not used if the surgeon was satisfied with the integrity of this anastomosis ('doughnuts' intact, airtight and watertight on testing), and if the patient was medically fit, well nourished and not receiving high dose corticosteroid therapy. Thirty seven patients received an ileostomy and 23 did not.

Laboratory studies

Each patient underwent tests of anorectal function in the laboratory before operation^{6–10} and these were repeated in 50 patients one year after restorative proctocolectomy or closure of the defunctioning ileostomy. Seven patients declined to have the anorectal physiological assessment repeated one year after operation. Three patients are not yet one year from the operation.

Resting anal sphincter pressure was measured at 1 cm intervals along the anal canal by means of a 5 mm diameter water filled balloon. The pressure at each station was measured for at least one minute or until the recording became stable. Pressure in the system was transmitted via a transducer and amplifier (3552 Ormed

Ltd, Welwyn Garden City, UK) to a chart recorder (5041 Ormed Ltd).⁸

Threshold electrosensitivity of the mucosa of the anal canal was measured in the upper, mid and lower anal canal (as determined by anal manometry) by means of a bipolar constant current stimulator probe lubricated with a solution of KY Jelly (Johnson and Johnson, Slough, UK) and normal saline in equal quantities.^{10 11}

Capacity and compliance of the reservoir were measured by means of a latex balloon 7.5 cm in length, which was attached to a 14 FG catheter, similar to that used for anal manometry. Pressures within the balloon were transmitted to a Gould Statham P-50 pressure transducer (Spectramed, UK) and recorded on a Lectromed chart recorder (Multitrace 4; Lectromed Ltd, Jersey UK). The balloon and catheter were inserted into the anal canal with the patient in the left lateral position. The catheter was advanced until the base of the balloon was at least 5 cm from the anal verge. The balloon was then inflated slowly with air at a constant rate of 1 ml per second to determine the functional capacity (first sensation) and the maximum tolerated volume (unequivocal desire to defecate). The ratio of change in volume to change in pressure was estimated from the baseline curve on the Lectromed chart and used as an index of compliance.

Rectoanal inhibitory reflex was assessed by measuring the response of the upper anal sphincter to distension with air of a balloon within the rectum or ileal reservoir at a rate of 1 ml per second. A 20 per cent decrease in pressure was taken to denote a positive reflex.¹²

Clinical assessment of outcome

The quality of anal continence was assessed one year after operation or closure of the defunctioning ileostomy in 57 patients, by one or other of three clinicians who had not been part of the surgical team (WGL, MERW, ASM) and who were not aware of the results of the laboratory tests. In two patients, the operation was a failure: each required a permanent ileostomy on account of pelvic sepsis. A third patient has been followed up for less than one year since reversal of the ileostomy. Each patient was questioned about faecal leakage, anal soreness, the ability to defer defecation, and whether he or she could not only discriminate between flatus and faeces, but actually release flatus safely while standing or sitting, without fear of even the most minor leakage.

Statistical analysis

Grouped data were expressed as median and interquartile range. Differences between groups were assessed by the Mann-Whitney U test. The correlation between different variables was determined by means of Spearman's rank correlation.¹³

Results

CLINICAL RESULTS

Morbidity and mortality (Table II)

There was no operative mortality. Morbidity was similar in the four groups of patients. The operation failed in two patients with a J reservoir

Figure 2: Capacity of the ileal reservoirs in the four groups of patients one year after restorative proctocolectomy ($p=NS$). Note the similar median values, but also the wide range that exists within each group.

Figure 3: Compliance of the ileal reservoirs in the four groups of patients one year after restorative proctocolectomy ($p=NS$).

Figure 4: Sensation (threshold mucosal electrosensitivity) in the upper, mid, and lower anal canal in the four groups of patients one year after restorative proctocolectomy ($p=NS$).

made from 40 cm of ileum: both developed pelvic sepsis after operation and both subsequently experienced poor function in terms of excessive bowel frequency and urgent defecation, which necessitated excision of the reservoir and construction of a permanent ileostomy.

LABORATORY TESTS

(a) Function of the pelvic reservoirs

Capacity and compliance of the reservoirs (Figs 2 and 3)

J reservoirs compared with W reservoirs – the capacity and compliance of the J reservoirs did not differ significantly from the capacity and compliance of the W reservoirs. The median (interquartile range) capacity of the J reservoirs was 250 (180–365) ml compared with 300 (170–398) ml for the W reservoirs ($p=NS$). The median compliance of the J reservoirs was 6.7 (5.2–8.9) ml/cm H_2O compared with 7.6 (6.2–10.2) ml/cm H_2O for the W reservoirs ($p=NS$).

Thirty centimetre reservoirs compared with 40 centimetre reservoirs – no significant differences were found between the two sizes of reservoir. The median (interquartile range) capacity of the 30 cm reservoirs was 250 (176–374) ml, compared with 300 (191–416) ml for the 40 cm reservoirs ($p=NS$). The median compliance of the 30 cm reservoirs was 6.7 (5.2–8.9) ml/cm H_2O compared with 7.5 (5.2–9.8) ml/cm H_2O for the W reservoirs ($p=NS$).

Comparison of all four designs of reservoir – both capacity and compliance of the quadruplicated W reservoir made with 40 cm of ileum were greater than the capacity and compliance of either type of J reservoir and of the W30 reservoir, but the differences were not statistically significant (Figs 2 and 3).

(b) Anal sphincter function

Motor function – median maximum resting anal pressures before and one year after operation were 105 (89–115) v 58 (50–90) cm H_2O ($p=NS$) after J30 construction, 112 (79–131) v 71 (53–88) cm H_2O ($p=0.008$, J40), 88 (54–94) v 57 (46–64) cm H_2O ($p=NS$, W30), and 76 (50–95) v 73 (42–81) cm H_2O ($p=NS$, W40). Resting anal pressures in the four groups of patients did not differ significantly,

TABLE II Morbidity after restorative proctocolectomy

Reservoir design	J30	J40	W30	W40
Pelvic sepsis	3	6	3	1
Wound infection	0	0	1	1
Bleed per anum	2	1	0	1
IAAS	0	0	2	1
SBO	1	2	0	3
Relaparotomy	3	4	1	2
E-C fistula	0	1	0	0
DVT	0	0	0	1
Pulmonary embolus	0	1	0	0
Urinary infection	0	0	1	1

The incidence of postoperative complications was similar in the four groups of patients. IAAS=stricture of the ileoanal anastomosis. E-C fistula=enterocutaneous fistula. SBO=small bowel obstruction. DVT=deep vein thrombosis.

TABLE III Clinical functional results according to design of reservoir and length of ileum used (one year after operation)

	Reservoir design		Length of ileum	
	J	W	30 cm	40 cm
Number	28	29	28	29
Bowel frequency:				
in 24 hours	5 (2–10)	5 (2–11)	5 (2–10)	5 (2–11)*
at night	0 (0–3)	0 (0–3)	0 (0–3)	0 (0–3)
Leakage of faeces	0	0	0	0
of mucus	4	5	5	3
(pad)	0	0	0	0
Ability to defer				
>30 min	27	25	26	26
>15 min	28	29	28	29
Ability to discriminate flatus from faeces				
No	3	3	4	2
Yes	25	26	24	27
Yes+safe release of flatus	14	16	14	16

*Median (range), p=NS. For definition of safe, see text.

TABLE IV Clinical results in the four groups one year after operation

Reservoir design	J30	J40	W30	W40
Patients (n)	13	15	15	14
Bowel frequency:				
in 24 hours	5 (2–8)	6 (2–10)	5 (2–10)	4 (2–11)*
at night	0 (0–1)	1 (0–3)	0 (0–3)	0 (0–2)
Leakage of faeces	0	0	0	0
of mucus	2	2	3	1
(pad)	0	0	0	0
Ability to defer				
>30 min	13	14	13	12
>15 min	13	15	15	14
Ability to discriminate flatus from faeces				
No	2	1	2	1
Yes	11	14	13	13
Yes+safe release of flatus	6	8	8	8

*Median (range), p=NS. For definition of discrimination, see Methods section.

either before or after operation. However, when all four groups were considered together, median resting anal pressure after operation was 67 (49–88) cm H₂O, significantly lower than median resting anal pressure before operation: 93 (76–116) cm H₂O ($p<0.001$).

Sensory function – thresholds for sensation in the four groups of patients did not differ significantly, either before or after operation (Fig 4).

Reflex function – the rectoanal inhibitory reflex was present in all patients before operation and in 39 of 50 patients who were tested one year after operation. Loss of the reflex in 11 patients did not correlate with the use of any particular type of reservoir.

Figure 5: Bowel frequency according to reservoir design. Differences are not significant. Note the wide range of bowel frequency within each group.

Clinical anorectal function (Tables III and IV)

All patients achieved a good degree of anal continence, though eight (17%) experienced minor leakage of mucus, especially at night. None had to wear a pad. Duplicated and quadruplicated reservoirs yielded similar results. Also, reservoirs constructed with 30 cm of ileum gave similar results to those produced by reservoirs made with 40 cm of ileum. Quadruplicated reservoirs constructed from 40 cm of ileum yielded slightly better results in terms of bowel frequency than the other three types of reservoir, but the differences were not statistically significant (Fig 5). Bowel frequency in 24 hours bore no relation to the capacity of the reservoir (Fig 6, $r=-0.181$, $p=0.244$).

Twenty four patients (40%) regularly used antidiarrhoeal medication, usually codeine phosphate, while a further two patients used it only occasionally. The number of patients requiring antidiarrhoeal medication was the same for each design of reservoir.

The two patients with Crohn's disease and the three patients with indeterminate colitis achieved clinical results that were similar to those of the patients with ulcerative colitis.

Discussion

This randomised trial is the largest prospective study of the design of the pelvic reservoir in the surgery of ulcerative colitis. Judging by our own previous experience of different types of reservoir^{5,6} and from the reports of other authors,^{2,3,14} we expected that the more capacious reservoirs made with 40 cm of ileum and constructed in a quadruplicated (W), 'spherical' configuration would yield better results than the more cylindrical, duplicated (J) reservoir made from 30 cm of ileum. To our surprise, we found in fact that the J reservoirs provided as good results as the W reservoirs and that reservoirs made with 30 cm of ileum produced as good results as those made with 40 cm of ileum.

Good anorectal function from the patient's point of view after restorative proctocolectomy results from a combination of several desirable end points, such as the ability to defecate spontaneously without needing to intubate the reservoir, the ability to defer defecation, perfect anal continence, and low stool frequency in 24 hours.¹⁵ Each of the patients in this study was able to defecate spontaneously, which confirms previous findings^{16–21} and shows that both the J and W types of reservoir have overcome the emptying problem that beset the early Parks' triplicated or S reservoirs.¹ Each of the 57 patients who were available for study one year after operation could defer defecation for longer than 15 minutes and 52 of them (91%) could defer defecation for longer than 30 minutes. The ability to defer defecation correlated strongly both with the capacity ($r=0.51$, $p<0.001$) and compliance ($r=0.42$, $p=0.004$) of the reservoir, irrespective of its design. Anal continence was also found to be satisfactory, because none of the patients experienced faecal leakage and only eight

Figure 6: The relation between bowel frequency per 24 hour and the capacity of the ileal reservoir ($r = -0.181$, $p = 0.244$).

experienced minor leakage of mucus. This finding confirms our previous experience with stapled end to end ileoanal anastomoses without stripping of the anal mucosa.^{6 8-10 22}

Frequency of defecation has been shown previously to correlate inversely both with the capacity and the compliance of the ileal reservoir.^{4 17} In theory, the volume of the reservoir should depend on the length of ileum used in its construction. Mathematical formulas have been devised to permit the volume of a given design of reservoir to be calculated.²³ According to such formulas, which assume that the circumference of the ileum is 5 cm, the calculated volumes of the J and W reservoirs constructed with either 30 or 40 cm of ileum are 96, 151, 168, and 251 ml for J30, J40, W30, and W40 reservoirs respectively. A quadruplicated reservoir constructed from the same length of ileum as a duplicated reservoir should produce a structure that more nearly resembles a sphere and should, in theory, provide the greatest volume for any given length of ileum. So much for theory: the actual measurements told a different story! One year after operation, we found that the capacities of the J30, J40, W30, and W40 reservoirs were, respectively, 220, 250, 260, and 310 ml. Clearly other factors, in addition to the length of ileum used and the shape of the reservoir, must influence reservoir capacity: one such factor is undoubtedly the passage of time, while another may be the strength of the anal sphincter obstructing the exit of the reservoir.

The capacity of the pelvic reservoir has been shown consistently to be the most important factor influencing stool frequency. In that respect, triplicated and quadruplicated reservoir designs have in the main yielded lower stool frequencies than either duplicated reservoirs or no reservoirs ('straight' ileum).^{16 24 25} The capacity of the reservoir increases with time and as it does so stool frequency diminishes, but exactly how the capacity of the reservoir influences stool frequency is not clear. Indeed, reservoir capacity may be less important than has been thought previously: in this study, for example, we found that one year after operation the length of ileum that had been used in the construction of the reservoir

bore no significant relation to the maximum tolerated volume of the reservoir. The beneficial effect of a pelvic reservoir on stool frequency may therefore reside as much in its ability to modify or 'damp' ileal motility as in the increased capacity that it provides. Interruption of normal ileal peristalsis as ileum enters the reservoir may delay the onset of propulsive wave activity within the reservoir.^{16 24-27} Capacious reservoirs also tend to be more compliant than less capacious ones,^{14 18 22} another finding that is supported by the results of this study, as we found that there was a significant correlation ($r = 0.365$, $p = 0.012$) between maximum tolerated volume and compliance.

Overall clinical anorectal function, therefore, reflects the interplay of many factors. Moreover, it is clear that patients who have morphologically and physiologically 'identical' pouches may report wide differences in clinical function. Thus, in this study, five patients had to defecate between nine and 11 times in 24 hours, whereas nine patients only had to defecate two or three times in 24 hours (Fig 5). These contrasting outcomes bore no relation to the design of the pelvic reservoir. Nevertheless, the construction of a pouch that has a certain minimum capacity seems advisable, though what that minimum is remains to be defined. The anal sphincter too, should be left strictly alone to preserve its full motor, sensory, and reflex functions.²⁸ Judging by the results of this prospective controlled trial, the extra time and effort invested in the construction of a capacious, quadruplicated (W) reservoir by laborious hand suturing have not been repaid by any significant advantage in terms of overall bowel function when the results are compared with those provided by a comparatively small, duplicated (J) reservoir, which is simple to construct with the aid of linear stapling instruments.

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