Reduction in Tissue Blood Flow in J-Shaped Pelvic Ileal Reservoirs

David N. Armstrong, M.D., Lelan F. Sillin, M.D., Raphael Chung, M.D.

From the Department of Surgery, Veterans Administration Medical Center, and State University of New York Health Science Center at Syracuse, Syracuse, New York

PURPOSE: This study sought to evaluate tissue blood flow during J-shaped ileal reservoir construction. METHODS: Using laser Doppler flowmetry, tissue blood flow was measured at various locations in J-shaped ileal reservoirs constructed in 10 dogs before pouch-anal anastomosis. For 12 weeks postoperatively, animals were assessed for clinical complications. In another five dogs, tissue blood flow was measured at various stages of J-pouch construction. RESULTS: Tissue blood flow in the reservoir was reduced and was lowest at the "apex" of the "J", the site of clinical stricture in one animal. During reservoir construction, longitudinal enterotomy was associated with the greatest reduction in tissue blood flow. Lowest blood flow in the reservoir was at the site of the intended pouch-anal anastomosis (11.5 ± 1.6 ml/100 g/min *vs.* 43.4 ± 3.4 ml/100 g/min (controls); $P < 0.05$). CONCLUSIONS: Operative maneuvers of J-shaped ileal reservoir construction, particularly longitudinal enterotomy, significantly reduce tissue perfusion in the involved bowel segment. Tissue blood flow in the pouch is lowest at the site of intended pouch-anal anastomosis, and this may contribute to development of complications seen clinically. [Key words: Pelvic reservoir; Capillary blood flow; Small bowel; Laser Doppler flowmetry; Ileal reservoir]

Armstrong DN, Sillin LF, Chung R. Reduction in tissue blood flow in J-shaped pelvic ileal reservoirs. Dis Colon Rectum 1995;38:526-529.

Pelvic ileal reservoir is a useful adjunct for sphincter-sparing colectomy and mucosal proctectomy for ulcerative colitis and multiple polyposis. However, a significant incidence of anastomotic leak, fistula formation, pouch ischemia, and anastomotic stricture is reported in many series.[1–5] In the J-shaped reservoir, the most frequently used design, stricture at the pouch-anal anastomosis is also a common complication.[6]

Operative construction of ileal reservoirs involves an extensive longitudinal enterotomy, which may compromise blood flow to the bowel wall. Mobilizing the mesentery by division of peritoneal attachments, positioning the pouch in the pelvis, and creating an anastomosis may further reduce blood flow. It is possible that reduced blood flow to the reservoir may result from these maneuvers.

Supported in part by grants from the Department of Veterans Affairs and the National Foundation for Ileitis and Colitis.

Address reprint requests to Dr. Sillin: Department of Surgery, University Hospital, 750 East Adams Street, Syracuse, New York 13210.

To test this hypothesis, we first studied acute changes in blood flow in pelvic ileal reservoirs in the dog. We next studied the effect of various operative maneuvers on the blood flow to identify the component in which the major reduction occurred.

MATERIALS AND METHODS

Chronic Study: Changes in Tissue Blood Flow in J-Shaped Pelvic Ileal Reservoirs

A chronic study was performed in which blood flow in J-shaped pelvic ileal reservoirs was measured at operation and correlated to development of anastomotic leak, fistula formation, and stricture at the pouch-anal anastomosis. Ten adult mongrel dogs (16–22 kg) underwent abdominal colectomy and mucosal proctectomy. Ten-cm J-shaped pelvic ileal reservoirs were constructed using the terminal 20 cm of ileum by making a longitudinal enterotomy 0.5 cm lateral to the mesentery and reconstruction performed using a two-layered anastomosis of continuous 3–0 Vicryl™ (Ethicon, Sommerville, NJ). The mesentery was mobilized by relaxing peritoneal incisions along the mesentery to reduce tension at the pouch-anal anastomosis. Ileal arcades were preserved. After reservoir construction, but before pouch-anal anastomosis, tissue blood flow was measured on the antimesenteric serosa of the ileum at 5-cm intervals, from the afferent terminal ileum (0 cm) to the site of ileal transection (25 cm).

Tissue blood flow was measured with a laser Doppler velocimeter (BPM 403, TSI, St. Paul, MN) with the operating room light turned off. A laser Doppler probe (1.8 mm in diameter) was applied to the tissue with minimal force (<20 gm/cm^2) but good optical coupling. Mean blood flow was calculated by integrating the area under the curve on the tracing, using a digitizer and microcomputer, and dividing by the time of the curve. Because the instrument measures blood flow in a volume of tissue approximately 1 mm in diameter and 1 mm deep and because the thickness of the bowel wall was 1.7 mm, the tissue blood flow

measured includes that of the serosa, muscularis, and part of the submucosa.[7] Postoperatively, animals were given broad spectrum antibiotics, were given intravenous total parenteral nutrition for one week, and were observed for three months for signs of sepsis, pouch necrosis, and development of anal stricture.

Acute Study: To Determine the Effect of Operative Maneuvers on Tissue Blood Flow During Reservoir Construction

To identify the stage in construction at which the fall in blood flow occurred, acute studies were performed in five adult mongrel dogs. Following colectomy and mucosal proctectomy, blood flow was recorded at each stage in construction of the reservoir at fixed locations in the bowel using the same technique as described for the chronic study.

Blood flow was recorded at 5-cm intervals: 1) from intact terminal ileum; 2) after folding the ileum; 3) after longitudinal enterotomy; 4) from the completed reservoir. Because of difficult access to the reservoir once positioned in the pelvis, all blood flow readings were taken before performing the pouch-anal anastomosis.

RESULTS

Chronic Study: Changes in Tissue Blood Flow in J-Shaped Pelvic Ileal Reservoirs

Table 1 summarizes blood flow at various points around the reservoir. As expected, highest blood flow was found in normal terminal ileum proximal to the entrance to the pouch. Significant reduction in blood flow was found in both limbs of the reservoirs compared with flow in the terminal ileum (Dunnett's comparison of means). Lowest blood flow occurred adjacent to the apex of the "J" (15 cm.), possibly as a result of the acute bend at this point and at the site of ileal transection (25 cm).

In the chronic phase of the study, there was no clinical episode of pouch necrosis, leak, or dehiscence. One dog developed a symptomatic stricture at the pouch-anal anastomosis, which was confirmed at examination under anesthesia at 12 weeks. No other dogs had evidence of stricture formation.

Table 1.
Blood Flow Around the Limbs of "J" Reservoirs

Site (cm)	Mean BF ± SE (ml/100 g/min)
0	45.0 ± 4.9
5	38.0 ± 5.1
10	22.4 ± 2.3*
15	19.0 ± 1.7*
17.5 (apex of "J")	
20	27.6 ± 4.6*
25	19.0 ± 2.5*

SE = standard error.

Blood flow (BF) was significantly lower in both limbs of the reservoir compared with flow in the intact ileum proximal to the reservoir. (n = 10).

* $P < 0.01$, Dunnett's test.

Acute Study: Effect of Operative Maneuvers on Tissue Blood Flow

Blood Flow in Intact Ileum. Control readings from intact terminal ileum failed to demonstrate a gradient in blood flow along the 25 cm of terminal ileum used in this study.

Effect of Folding Intact Terminal Ileum on Itself. Figure 1 shows the comparison between blood flow in normal terminal ileum and terminal ileum that was folded on itself to the "J" shape. There was no significant difference in blood flow before and after folding (paired *t*-test).

Effect of Longitudinal Enterotomy. Figure 2 shows the comparison between blood flow in intact ileum and ileal blood flow after longitudinal enterotomy. There was a significant fall in blood flow along the whole length of incised bowel compared with values from intact ileum (paired *t*-test).

Blood Flows in the Completed Reservoir (Effect of Side-to-Side Anastomosis of Reservoir Limbs). Figure 3 compares blood flow in normal ileum and after final construction of the reservoirs. Lowest blood flow in the reservoirs was found adjacent to the apex of the

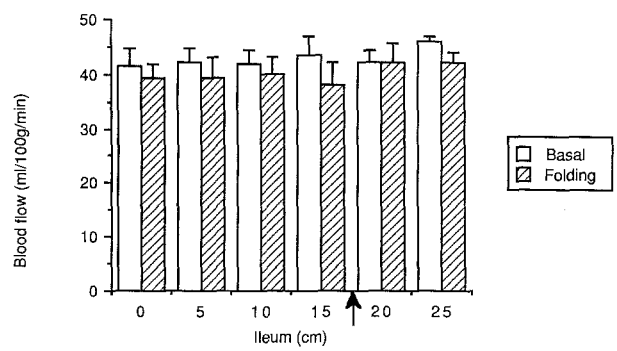

Figure 1. Blood flow in intact terminal ileum before (basal) and after folding on itself (folding). No significant differences were found in blood flows after folding the bowel.

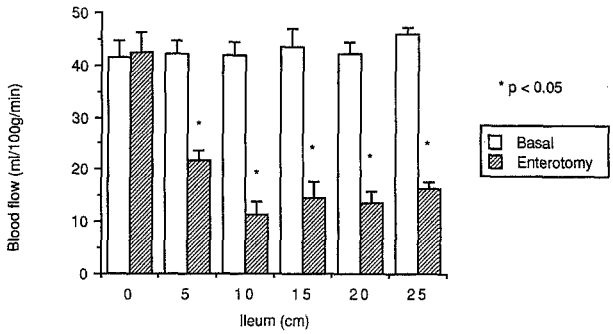

Figure 2. Blood flow in intact terminal ileum before (basal) and after longitudinal enterotomy (enterotomy). Lower flow was found along the whole length of incised ileum compared with basal flow (paired *t*-test).

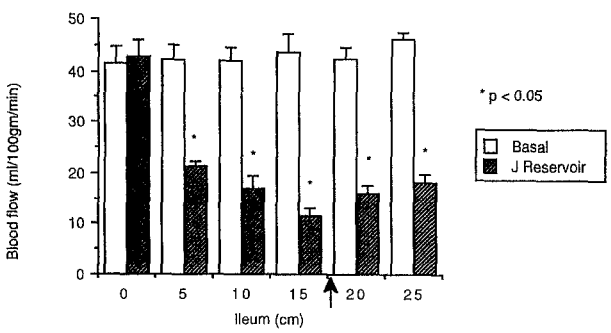

Figure 3. Blood flow in intact terminal ileum (basal) and after final construction of the reservoir ("J" reservoir). Again, flow was reduced in both limbs of the reservoir compared with basal flow (paired *t*-test). Blood flow was lowest adjacent to the apex of the "J" (15–20 cm).

"J" (15–20 cm), and this was significantly lower than values obtained from intact ileum ($P < 0.01$; paired *t*-test).

DISCUSSION

Laser Doppler flowmetry measures microvascular blood flow for a depth of approximately 1 mm.[8, 9] In the canine terminal ileum (1.7 mm thick), this represents serosa, muscularis externa, and part of the submucosa. In this experiment no attempt was made to identify the exact layer in which blood flow was measured. However, because the same technique of measurement and the same segment of bowel were used in each animal throughout the study, comparisons among readings are valid. Laser Doppler flowmetry has been validated using both krypton[85] washout[10] and electromagnetic flowmetry.[8, 9, 11] Calibration in our laboratory against H_2 gas clearance was previously done, which makes it possible to convert readings to units of ml/100 gm/min.[12]

Results of the chronic study demonstrated a significant reduction in tissue blood flow in the reservoir, lowest adjacent to the apex of the "J." One dog developed a stricture at the pouch-anal anastomosis requiring dilation. Tissue blood flow recorded in this animal was among the lowest in the series. These findings are consistent with a previous study on the pathogenesis of anastomotic stricture, in which we demonstrated that ischemia of the bowel, rather than ischemia at the suture line itself, leads to anastomotic stricture.[13]

The acute study showed that folding the bowel on itself caused no reduction in blood flow. However, longitudinal enterotomy produced a significant fall in blood flow along the entire length of incised ileum. The vascular supply to small bowel consists of obliquely perforating arteries, which enter the serosa at the lateral aspects of the bowel.[14] A watershed, therefore, exists along the antimesenteric surface. In this study, the enterotomy was made approximately 0.5 cm lateral to the mesentery; this interrupts the blood supply from one side of the bowel. The devascularized flap now derives its blood supply from circumferential flow from one side, across the watershed. If enterotomy were to be performed at the antimesenteric border, blood flow may not be compromised to such a degree; however, in these circumstances the mesentery would be stretched over the posterior circumference of the pouch, which may itself compromise blood flow.

Final construction of the pouch involved folding through 180 degrees, side-to-side anastomosis of the limbs of the reservoir, and mobilizing the small bowel mesentery to permit the pouch to reach the pelvic floor. The lowest blood flow in the completed pouch was at the apex of the "J," the site of the future pouch-anal anastomosis. These values were significantly lower than at adjacent sites. Although folding of the intact bowel *per se* caused no fall in blood flow, folding after enterotomy resulted in a further reduction in blood flow at the apex of the "J."

The findings of this study indicate that construction of a pelvic ileal reservoir reduces tissue blood flow in ileum used in reservoir construction and may contribute to clinical complications of dehiscence, anastomotic leak, pouch ischemia, and anastomotic stricture. Although we did not look at blood flow in the reservoir after positioning it in the pelvis, it is a common experience that tension in the pouch is a frequent occurrence. Furthermore, tissue blood flow in an intestinal anastomosis is reduced compared with

the bowel wall before suturing.[7, 13, 15] Because the apex of the reservoir already has the lowest blood flow, these maneuvers at this site may have a cumulative effect sufficient to bring about the complications seen clinically.

Demonstration of a significant blood flow reduction by an enterotomy, which is not on the antimesenteric border on the ileum, suggests that an antimesenteric location may be more desirable, although technically not achievable. Separating the mesentery posteriorly, as much as possible, may minimize the drop in circumferential blood flow. Data we present are clinically pertinent to attempts at reducing potential complications caused by tissue ischemia.

REFERENCES

1. Smith LE. Current status of sphincter-saving operations for chronic ulcerative colitis. South Med J 1985;78: 1304–8.
2. Schoetz DJ Jr, Coller JA, Veidenheimer MC. Proctocolectomy with ileoanal reservoir: an alternative to permanent ileostomy. Proctocolectomy 1984;75:123–38.
3. Fonkalsrud EW. Endorectal ileoanal anastomosis with isoperistaltic ileal reservoir after colectomy and mucosal proctectomy. Ann Surg 1984;199:151–7.
4. Cohen Z, McLeod RS, Stern H, Grant D, Nordgren S. The pelvic pouch and ileoanal anastomosis procedure: surgical technique and initial results. Am J Surg 1985;150: 601–7.
5. Bubrick MP, Jacobs DM, Levy M. Experience with the endorectal pull-through and S pouch for ulcerative colitis and familial polyposis in adults. Surgery 1985;98: 689–99.
6. Williams NS, Johnston D. The current status of mucosal proctectomy and ileoanal anastomosis in the surgical treatment of ulcerative colitis and adenomatous polyposis. Br J Surg 1985;72:159–68.
7. Chung RS. Blood flow in colonic anastomoses: effect of stapling and suturing. Ann Surg 1987;206:335–9.
8. Shepherd AP, Riedel C-L. Continuous measurement of intestinal mucosal blood flow by laser doppler velocimetry. Am J Physiol 1982;242:G668–772.
9. Granger DM. Recent advances in measurement of gastrointestinal blood flow. Gastroenterology 1985;88: 1073–6.
10. Ahn H, Lindhagen J, Nilsson GE, Salerud EG, Jodal M, Lundqren 0. Evaluation of laser doppler flowmetry in the assessment of intestinal blood flow in the cat. Gastroenterology 1985;88:951–7.
11. Haumschild DJ. Microvascular blood flow measurement by laser doppler flowmetry [TSI Application Note], 1986.
12. Chung RS, Bruch D, Dearlove J. Endoscopic measurement of gastric mucosal blood flow by laser doppler velocimetry: effect of chronic esophageal variceal sclerosis. Am Surg 1988;54:116–20.
13. Chung RS, Hitch DC, Armstrong DN. The role of tissue ischemia in the pathogenesis of anastomotic stricture. Surgery 1988;104:824–9.
14. Bruce J, Walmsley R, Ross JA. Manual of surgical anatomy. Baltimore: Williams & Wilkins, 1964:365.
15. Shikata JI, Shida T. Effects of tension on local blood flow in experimental intestinal anastomoses. J Surg Res 1986;40:105–11.