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Characterization of Distal Colonic Motility in Early Postoperative Period and Effect of Colonic Anastomosis

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Under standardized conditions, the manometric motility of the distal colon following rectosigmoid anastomosis ($N = 11$, median age 70 years, range 47–80), was compared to that following laparotomies not involving colonic anastomosis ($N = 9$, 56 years, 32–65). Microtransducer probes were inserted peroperatively and colonic activity recorded continuously (median 96 hr, range 48–109 anastomotic and 75 hr, range 46–107 control group) employing an ambulatory system. Quantitative indices of motility were calculated with an automated analysis program. Total postoperative analgesic doses and duration of surgery were similar in both groups. The first return in the anastomotic group of isolated waveforms [median 1.8 hr, interquartile range (IQR) 1–3] and propagated waves (92 hr, 79–100), was comparable to the control group (4 hr, 1.8–7, and 73 hr, 72–101, respectively). Motor complexes, characterized by bursts of regular contractile activity at 3–5 cpm, returned faster in the control group (3 hr, 2–24 vs 24 hr, 19–30, $P < 0.05$). Motility index was significantly depressed during the first 72 hr following surgery in the anastomotic group compared to controls ($P < 0.001$). Flatus was passed at a median of 72 hr (IQR 45–79) in the control and 94 hr (81–105) in the anastomotic group ($P = 0.05$). The presence of a left-sided colonic anastomosis has a major inhibitory effect on distal colonic motility, compared to nonanastomotic surgery of similar severity, in the early postoperative period.

KEY WORDS: colon; manometry; postoperative ileus; colonic anastomosis.

Postoperative ileus (POI) is an inevitable consequence of intraabdominal surgery. It causes discomfort and distress to patients in addition to delaying their recovery. The condition is associated with inadequate peristaltic activity, dilatation of the colon, abdominal distension, nausea, vomiting, and delayed defecation (1). Colonic dilatation results from gas, most of which is swallowed, and secretions accumulating in the lumen (2). Loss of secretions into the lumen from the extracellular compartment may lead to potassium depletion and prolonged ileus (2). There is evidence that postoperative ileus is in reality most pronounced and prolonged in the colon and not the small bowel (3–6).

Following laparotomy, the extent of dissection, handling of the bowel, or duration of procedure appear to make no difference to the duration of POI (1, 6, 7). Despite these findings, it is a clinical impression that the period of ileus is longer follow-

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ing colonic anastomosis than other comparative intraperitoneal procedures. This study compared the distal colonic motility following colonic anastomosis with that following intraabdominal procedures not involving colonic anastomosis, while other factors known to affect POI were standardized.

MATERIALS AND METHODS

Eleven patients (age 64 years, range 48–78, six male) undergoing sigmoid colectomy or high anterior resection for localized malignancy (9), localized diverticular disease (1) or intussusception (1) were studied. No patient was taking medication that was known to influence colonic motility. A further nine patients undergoing an abdominal procedure not involving a colonic anastomosis (age 56 years, range 32–65, six male) served as a control group. This group comprised cholecystectomy (3, one with common bile duct exploration), partial gastrectomy (3), abdominal rectopexy and postanal repair (3), and vagotomy and pyloroplasty (1).

Preoperative. All patients having colectomy or gastrectomy received bowel preparation with one sachet of Picolax (active ingredients sodium picosulfate 10 mg, magnesium oxide 3.5 g) taken twice on the day preceding surgery. In addition, anastomotic patients were on a fluid only diet for two days preoperatively and received rectal washouts on the evening before and the day of surgery. Cholecystectomy patients received a single sachet of Picolax on the evening prior to surgery.

Peroperative. A standard anesthetic protocol was used for all patients with a premedication of temazepam 20–30 mg and induction with thiopentone (4–7 mg/kg) and fentanyl (1–4 μg/kg). Anesthesia was maintained with enflurane (1–1.5%) and nitrous oxide, with atracurium (0.5 mg/kg) muscle relaxation. Relaxation was reversed with neostigmine and glycopyrrolate (50 μg/kg).

Flexible 1000-mm manometric probes (external diameter 2.3 mm) incorporating three strain gauge transducers at 10-cm intervals (Gaeltec CTO-3, Gaeltec Ltd., Isle of Skye), were inserted peranus and manipulated into position across an anastomosis [with one transducer (p1) proximal and one (p3) distal to the anastomosis] or into the sigmoid/descending colon in control patients. Transducers were placed under direct vision during a handsewn anastomosis, or by measurement and palpation through the bowel wall during stapled anastomoses and in control patients. The probes were fixed to the anal margin and the anterior abdominal wall by strapping.

Postoperative. Colonic manometric activity was recorded continuously following transfer to the recovery room until the first passage of flatus, which was taken as the end point of the study.

For postoperative analgesia in all cases, a loading dose of pethidine 0.5–1 mg/kg was given, followed by a subcutaneous infusion of pethidine starting at 1 mg/kg/3 hr. The infusion rate was then adjusted according clinical need to a maximum of 1.5 mg/kg/3 hr.

Probe position was verified immediately after surgery by radiography and again before probe removal at the end of study.

Patients were monitored at 4-hr intervals for the presence of bowel sounds and passage of flatus. Pain scores were assessed using a simple 10-cm linear analog scale and pethidine dosages obtained from nursing records.

Manometric System. Pressure activity acquired by the manometric probes was sampled at 8 Hz and stored on a digital solid-state portable recorder (Gaeltec 7MPR, Gaeltec Ltd.). Data were downloaded at 24-hr intervals and stored on disk for later analysis.

Data Analysis. Recordings were analyzed qualitatively by visual inspection of analog traces. The timing of the return, type, frequency, and duration of activity was recorded for each transducer. Quantitative indices of motility were analyzed using a software program incorporating a simultaneous wave filter to exclude artifactual activity (Gaeltec Ltd.). A wave amplitude threshold of 13 cm H_2O, (equivalent to 10 mm Hg) was utilized throughout.

The following quantitative parameters were calculated for each 2-hr period: motility index (MI) [sum (amplitude × duration of waveforms)/time × 10], activity index (AI) (total area beneath waveforms/time)[8], mean amplitude of waveforms (MA), percentage duration of activity (percentage of period with activity >13 cm H_2O), number of waves >13 cm H_2O and >50 cm H_2O.

Statistical Methods. Differences in the timing of return of manometric activity and the physical symptoms of post-operative ileus were compared by the Mann-Whitney U test.

Quantitative parameters of analysis were compared by repeated measures analysis of variance using BMDP 5V software program (Statistical Software Inc., Los Angeles, California). The distribution of both median and quartiles of each variable were considered in order to assess trends in both the average and the variation of the activity. The parameters were analyzed on a shifted log scale in order to reduce the positive skew inherent to these measurements and achieve the normal distribution of random error required for analysis of variance techniques.

The model investigated the effect of group (anastomotic vs control), time (condensed into 24-hr periods, day 1 to day 3), and channel (proximal p1-distal p3) for each of the quantitative indices. The significance of the differences are reported with *P* values. Presentation of the median and interquartile range allow an assessment of the size and direction of the effects (as the data are analyzed on a shifted log scale the parameters from the model are not directly interpretable). Where analysis of the quartile values mirrored changes in the median, the results from the median values are reported. In cases where there were changes in variation, the changes in the quartile values are reported in addition to the changes in the median.

The study was approved by the Tower Hamlets District Health Authority Ethical committee (EC 90/51).

RESULTS

The duration of surgery in the anastomotic group [median 160 min, interquartile range (IQR) 120–225, range 110–240 min], was similar to that in the control group (150 min, IQR 116–175, range 110–270).

Dosages of pethidine over each 24-hr period were

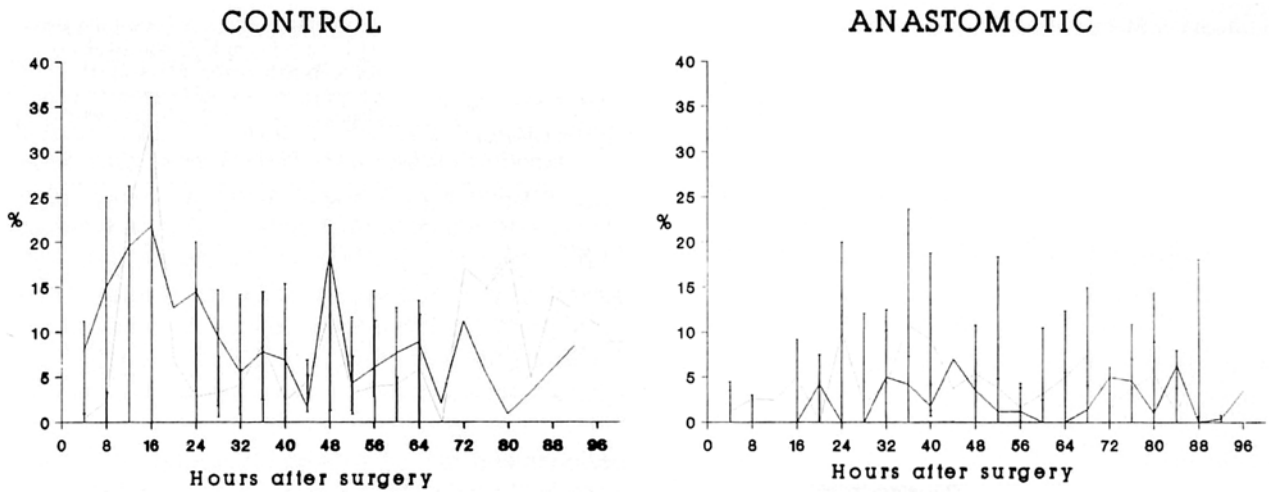

Fig 1. Percentage of duration of motor complex activity in proximal (p1, solid line) and distal (p3, dashed line) transducers in control and anastomotic groups.

comparable in both groups [day 1: control mean 10.2 ± 3.9 (SD), anastomotic 10.1 ± 3.3 mg/kg/24 hr) and declined with increasing time after surgery (day 5: control 5.0 ± 3.8, anastomotic 5.2 ± 3.2 mg/kg/24 hr). There were no significant differences in the pain scores between the two groups at any time during the study period.

Return of Manometric Activity. The earliest activity >13 cm H_2O to return were simple isolated waveforms of low amplitude. These returned in a median of 1.8 hr (IQR 1–3, range 1–5) in the anastomotic group and 4 hr (IQR 1.8–7, range 1–8) in the control group. Motor complexes (predominantly a series of simple waves occurring at a regular frequency of 3–5/min) returned significantly sooner in the control than the anastomotic groups (3 hr, IQR 2–24, range 2–25 vs 24 hr, IQR 19–30, range 7–98; $P < 0.05$). The percentage of time occupied by motor complexes was higher in the first 24-hr period in the control group (Figure 1).

Due to late transducer failure, analysis of propagated waves was only possible in six control and nine anastomotic patients. In three control and two anastomotic patients propagated waves were not detected before probe withdrawal. In the remainder, the onset of propagated waves was similar in both groups (control median 73 hr, range 72–101, anastomotic 92 hr, range 51–101).

Quantitative Indices of Motility: Motility Index (MI). The median and upper quartile range of MI recorded from all channels in the control and anastomotic groups are shown in Figure 2. An indication

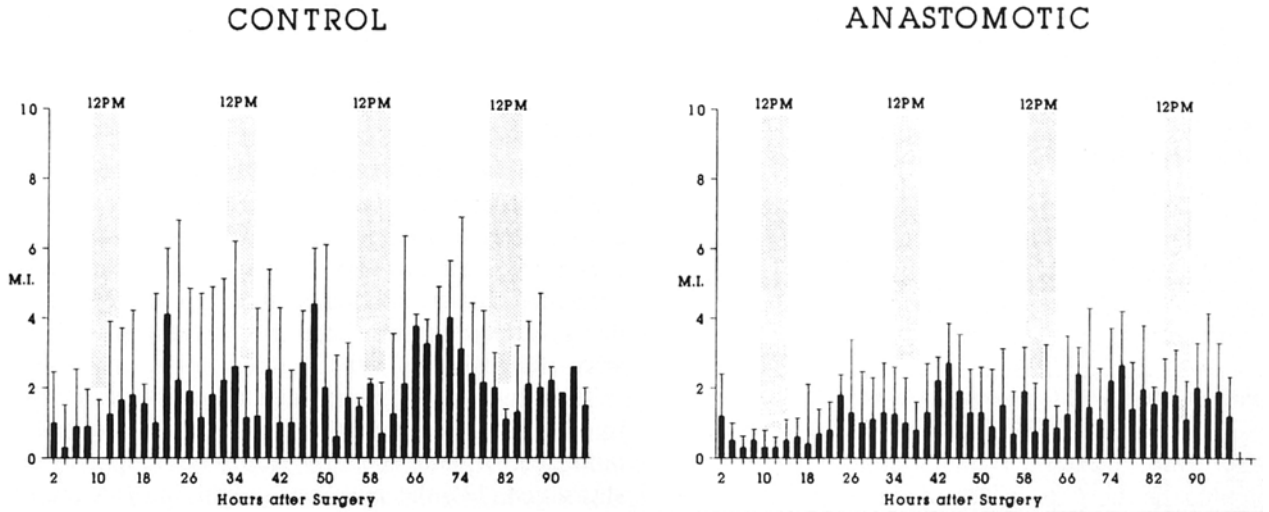

Fig 2. Median and upper quartile range motility index (MI) of all transducers in control and anastomotic patient groups.

TABLE 1. MEDIAN, INTERQUARTILE RANGE, AND RANGE PERCENTAGE DURATION OF ACTIVITY FOR 24-HOUR PERIODS IN CONTROL AND ANASTOMOTIC GROUPS

	Control			*Anastomotic*		
Hours	*Median*	*IQR*	*Range*	*Median*	*IQR*	*Range*
1–24	11.2	3.2–20	0.1–71	3.3	1.1–8.8	0.1–5.3
25–48	11.7	4.8–23	0.01–65	2.1	1.1–15	0.1–64
49–72	11.8	4.0–24	0.1–62	2.5	1.5–14.2	0.1–60
73–96	8	4.6–14	0.3–39	4.5	2.5–19	0.2–63

of the daily cycle is represented in Figure 2 by the range of 12 midnight (shaded band) for the studies.

The motility index was significantly depressed in all channels during the first 72 hr following surgery in the anastomotic group compared to the control group ($P < 0.001$). Both groups showed a low level of MI throughout the recording periods, the median not rising above 5 (with a maximum upper range of 11.8). There was a significant increase in the median and quartile values of motility index over time in the groups ($P = 0.002$).

The motility index was similar between transducers proximal and distal to anastomoses ($P = 0.1$).

Percentage of Duration of Activity. There was a significant change in the duration of activity with time following surgery ($P = 0.003$) and levels were significantly lower in the anastomotic group ($P = 0.002$), (Table 1). The duration of activity did not differ between channels in each group ($P = 0.5$).

Mean Amplitude. The mean amplitude of colonic waves persisted at a low level in both anastomotic and control groups throughout the recording period (Table 2). Mean amplitude was lower in the anastomotic than control group ($P = 0.04$). This difference was more marked in the proximal channels than the distal channels of the anastomotic group (group/channel interaction, $P = 0.01$). Mean amplitude did not increase with time after surgery ($P = 0.2$), or vary between channels ($P = 0.6$).

Wave Number. The number of waves of >13 cm H_2O and >50 cm H_2O occurring within the 2-hr period in control and anastomotic groups is summarized in Table 3. There was no significant difference between the number of waves >13 cm H_2O in the control and anastomotic groups ($P = 0.26$), but an increase in median and quartile numbers of these waves with time was seen [baseline day 1 = 19.8 (12.1–33), day 3 = 40.0 (22.8–71), $P = 0.003$].

TABLE 2. MEDIAN, INTERQUARTILE RANGE, AND RANGE MEAN AMPLITUDE OF WAVEFORMS (cm H_2O) FOR 24-HOUR PERIODS IN CONTROL AND ANASTOMOTIC GROUPS

	Control			*Anastomotic*		
Hours	*Median*	*IQR*	*Range*	*Median*	*IQR*	*Range*
1–24	17	14–23	10–53	14	12–17	7–53
25–48	16	14–21	11–55	15	12–18	10–64
49–72	18	15–22	11–64	15	13–19	10–58
73–96	17	15–20	12–35	16	14–21	10–110

TABLE 3. MEDIAN, INTERQUARTILE RANGE AND RANGE NUMBER OF WAVES OF >13 cm H_2O OR >50 cm H_2O FOR 24-HOUR PERIODS IN CONTROL AND ANASTOMOTIC GROUPS

	Amplitude	*Control*			*Anastomotic*		
Hours	*(cm H_2O)*	*Median*	*IQR*	*Range*	*Median*	*IQR*	*Range*
1–24	>13	28.5	7–68	1–323	20	6–60	1–297
	>50	5	2–13	1–74	3	1–8	1–58
25–48	>13	37	14–93	1–334	42	14–106	1–316
	>50	8	2–15	1–54	4	2–9	1–67
49–72	>13	49	16–98	1–393	49	22–88	1–391
	>50	9.5	4–17	1–70	6	3–12	1–54
73–96	>13	49	19–105	1–350	51	33–131	3–321
	>50	7	5–11	1–42	9	4–18	1–65

In comparison, the total number of waves >50 cm H_2O was significantly greater in the control than the anastomotic group in the first 72 hr ($P = 0.001$), and increased significantly with time in the anastomotic group [baseline day 1 4.76 (3.3–7.1), day 3 = 8.86 (5.8–14), $P = 0.001$]. There was no difference in detected waves between channels (>12 cm H_2O, $P = 0.3$; >50 cm H_2O, $P = 0.3$).

Clinical Signs of Ileus. Bowel sounds returned in the control group at a median of 26 hr (IQR 21–42, range 18–72) and at a median of 65 hr (IQR 29–69, range 27–94 hr) in the anastomotic group, but this difference did not reach significance ($P = 0.1$). Flatus was passed at 72 hr (IQR 45–79, range 36–101) in the control and 94 hr (IQR 81–105, range 71–113 hr) in the anastomotic group ($P = 0.05$).

DISCUSSION

This study represents the first attempt to continuously record postoperative manometric activity of the distal colon in humans under standardized conditions. Previous investigations of motor activity in POI had the disadvantage of intermittent short-term recording, diverse or unspecified operative procedures, and nonstandardized anesthetic or postoperative analgesia (6, 7, 9, 10).

The effects of anesthetic agents on colonic motility have been well reviewed (11, 12). Although the influence of many modern agents is thought to be shortlived (13), the anesthetic regime in this study was standardized throughout.

Pethidine, administered by continuous subcutaneous infusion, was used as postoperative analgesia in all patients. Epidural analgesia (using local anesthetics or opiates) has been shown to be associated with less severe POI (14), presumably by having fewer effects on bowel motility than by systemic administration. The routine use of epidurals was not possible here and was inappropriate in some of the control cases. Pethidine is associated with fewer effects on bowel wall contraction than is morphine (12, 15) and was therefore chosen as the standard analgesic. It was given as a continuous infusion to maintain stable blood levels and prevent well-recognized contractile effects on the colon of the peak levels of opiate following intramuscular injection (6, 9). The subcutaneous infusion also permitted more adequate and continuous pain relief to be achieved. Pain levels as assessed by linear analog scales did not differ significantly between the groups during this study. Any effect of pain on POI was thus minimized.

Most recordings demonstrated a period of complete quiescence of manometric activity in the postoperative period. This period was shorter than has been previously reported after noncolonic surgery and colectomy, detected by radiotelemetry and perfused tube techniques (6, 10, 16). This discrepancy probably resulted from the intermittent recording procedures used in other studies leading to failure to detect the initial infrequent manometric activity.

Serosal EMG monitoring following surgery in monkeys and man showed that spike activity (corresponding to contractions of the wall) was present after all types of surgery, but was severely depressed and gradually returned to preoperative levels over 50–72 hr in the distal colon (1, 4, 9). These findings only partly concur with the present study where the percentage duration of motor complex activity or overall activity did not significantly increase over a four-day period after noncolonic procedures. These differences may be a reflection of the incompletely understood relationship between the two modalities. EMG activity reflects the electrical activity producing colonic wall contraction but does not necessarily relate to the pressure generated within the lumen of the colon, which also depends on the tone and degree of distension of the colonic wall muscle. Distension of the colon during the period of stasis is common in the postoperative period. It may be that this distension accounts for low-pressure activity (and hence low activity indices) despite normal electrical activity in the colonic wall.

Postoperatively, motor complexes were found frequently in all leads and almost invariably at a frequency of 3–4 waves/min. The percentage of time occupied by motor complexes was depressed from that expected (17), presumably due to the unstimulated state of the colon in the postoperative period. No difference in percentage duration of complexes between proximal and distal recording sites was found in either the control or anastomotic groups, although it might be expected overall to be higher in distal transducers (17). The proximal and distal differences in duration of complexes may only become recognizable when the colon is stimulated by food and activity is increased.

Motor complexes detected by the distal transducers did not, as has been previously reported in the rectum (18), show any evidence of periodicity.

The motility index was greatly reduced from normal levels in the descending and sigmoid colons in the first four days postoperatively following both control and anastomotic operations. This reduction was significantly more marked in the anastomotic group and mainly resulted from reduced daytime levels of MI.

Pethidine has been reported to reduce colonic activity when administered intramuscularly (19). Postoperative doses of pethidine were not significantly different between the groups in this study, although MI differed substantially. This suggests that analgesia is not the only factor influencing MI in the postoperative period.

The pattern of sleep, for example, is disturbed by anesthesia, analgesia, and nursing procedures, with a tendency to increased sleep during the day, particularly in the first few days after surgery. Several components of bowel activity such as motor complexes in the small bowel and high-amplitude propagating contractions in the colon, are reduced during sleep (17, 20).

Inactivity in the postoperative period is unlikely to be a major factor, as the established levels of MI in normal distal human colon were obtained with subjects in a semirecumbent position with minimal activity similar to the situation in postoperative patients (21).

The diurnal rhythm and peaks of MI after food and waking (21) were absent in the early postoperative period. These findings emphasize the well-recognized stimulatory effect of food on colonic activity (22–25). All patients were prevented from

eating normally during the study period. Several were permitted fluids but as the colonic response is related to the caloric and fat content of a meal (25–27), little increase in colonic activity would be expected from ingestion of clear fluids or even small amounts of food.

In a previous study of colonic motility during the postoperative period using perfused tubes and an intermittent recording technique, the duration of activity on day 1 depended on the operative procedure, varying from 25% after herniorrhaphy, 10% after cholecystectomy, and to 0% following left colonic anastomosis (10). By the fourth postoperative day, mean percentage activity had risen to 38% in the control group and 2% in the anastomotic group (10). In the present study, percentage duration was lower in the control group but higher in the anastomotic group.

The control group in the present study included three cholecystectomies (one with bile duct exploration) and three gastrectomies. Gastrectomy was associated with longer time to passage of first flatus than cholecystectomy (67–101 hr vs 36–72 hr). This was despite the fact that vagotomy should have no effect on ileus.

Following laparotomy, the extent of bowel handling, dissection, and duration of operation have been reported not to influence postoperative bowel activity (1, 5–7). The comparable levels of MI within the control group (despite the heterogenicity of the control group arising from availability and suitability of patients for the study) appear to support this. The median MI following gastrectomy, for example, was 2.3 (range 0–11.9) compared to 2.1 (0.1–16) for the overall group, over the first 24 hr. Correspondingly, for the second 24-hr period median MI in the gastrectomy cases was 3.1 (range 0–15.7) and for the control group overall 2.35 (0.1–25). All control cases involved substantial handling of the colon in order to manipulate the transducer probes into position. Rectopexy was associated with short duration of ileus and high motility levels following surgery in the two patients studied. Although this procedure involves mobilization of the rectum and presumably nerve damage, the extent of dissection is less than that during colonic resection.

By contrast, there was a significant reduction in levels of MI in the anastomotic compared to the control group, despite attempts to standardize other factors known to influence colonic motility. Although the rectum appears more active in health (28), no gradient of MI or percentage duration of activity was found between recording sites distal (in the rectum) and proximal (descending colon) to a colonic anastomosis, implying that colonic anastomosis had a major inhibitory effect on motility, particularly distal to the anastomosis. This effect could arise from the physical presence of the anastomosis splinting colonic contraction, or it could be due to interference with the innervation of the perianastomotic region.

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