Gastrointestinal Myoelectric and Clinical Patterns of Recovery After Laparotomy

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The objective of this study was to define the patterns of myoelectric activity that occur throughout the gastrointestinal tract during normal recovery from laparotomy. Electrodes were placed on the stomach, jejunum, and transverse colon of 44 patients undergoing laparotomy. Basal electric rhythms in all areas showed no changes in frequency after operation (up to 1 month). Gastric spike wave activity showed a gradient of increasing activity from fundus to antrum. Antral spike activity was unchanged during the study. Jejunal spike activity was present in the earliest recordings and occurred in 45.9% ± 3.5% to 59.9% ± 5.5% of slow waves. Recovery of normal colon discrete and continuous electric response activity occurred on postoperative day 5.9 ± 1.5. Bowel sounds returned on day 2.4 ± 0.5 and passage of flatus and stool occurred on day 5.1 ± 0.2. The myoelectric parameters measured are not absolutely predictive of uneventful recovery from postoperative ileus but they are, as a group, more informative than any currently available clinical criteria.

POSTOPERATIVE ILEUS IS a poorly understood transient phenomenon occurring almost uniformly after all abdominal laparotomies. Clinically it is characterized by abdominal distention, loss of peristaltic bowel sounds, and lack of passage of flatus or stools. Symptoms of distention, vomiting, and cramping pain may be experienced by the patient during its onset and reversal. Postoperative ileus remains an area in which improved treatment could result in a further decrease in hospitalization after laparotomy. Unfortunately the physiologic controlling mechanisms of this process are incompletely understood.

Despite the magnitude and frequency of the problem of postoperative ileus, only a few investigators have done studies involving measurement of human recovery from postoperative ileus using physiologic parameters. Early studies of postoperative motility using radiologic parameters showed differences in recovery of postoperative motility between various segments of the gastrointestinal tract.[1,2] Other investigators[3,4] attempted to correlate the presence and type of bowel sounds to postoperative recovery of motility. They showed bowel sound activity very early after operation, which does not correlate with clinical recovery.

The gastrointestinal tract's smooth muscle produces patterns of coordinated electric activity that represent the summarized depolarizations and repolarizations of the mass of smooth muscle cells functioning jointly. Recording electrodes placed on or within the bowel wall can record such activity. Electric activity of two types is present: slow wave and spike wave activity.

In each alimentary tract organ there is a 'slow wave' pattern of slowly conducted (normally aborally) waves of electric activity that serve as a pacemaker rhythm or basal electrical rhythm (BER). In the human stomach, for instance, a pattern of three slow waves per minute is typical. In the colon, where slow patterns are more varied in frequency and slightly more complicated, the term 'electrical control activity' (ECA) has been used to describe the colonic slow wave pattern.[5] Slow waves were originally thought to be conducted along the longitudinal layer of smooth muscle in the intestinal wall, but more recent evidence suggests that the submucosa/circular muscle interface may be the site of conduction.[6]

The second type of electric activity recorded from gastrointestinal smooth muscle is spike wave activity. Spike waves are believed to represent the summarized activity of a group of cells in the circular smooth muscle layer depolarizing and contracting in unison. The recorded spike wave activity of smooth muscle in the gastrointes-

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tinal tract may be analogous to the action potential recorded from a single excitatory cell such as a neuron. Spike wave activity must be present for peristaltic gastrointestinal contractions to occur, but the spike wave activity can only occur in relation to the appropriate segment of the slow wave. Not all slow waves have associated spike waves, but greater spike wave activity in general indicates more peristaltic activity.

During the fasted state the gut remains relatively quiescent in terms of spike activity. However at widely spaced intervals (about 1 hour apart in human stomach and intestine) a slowly conducted wave of strong peristaltic activity, recorded as a large number of spike waves associated with every slow wave present for a period of several minutes, is observed. This is called the migrating motor complex.[7] Fasting intestinal myoelectric activity occurs in several stages or phases in relation to the migrating motor complex (MMC). A period of near-complete absence of spike wave activity (phase I) is followed by a longer period of intermittent spike wave activity (phase II) leading to the relatively short MMC (phase III) followed by a short period of decreasing spike wave frequency (phase IV). Eating disrupts this fasting pattern and a generalized pattern of increased spike wave activity, a vigorous phase II-like pattern with frequent but not constant spike waves, occurs. These myoelectric patterns are believed to represent corresponding changes in the contractile peristaltic patterns of the bowel and its response to digestive stimuli.[8,9]

Studies of gastrointestinal tract motility using the parameter of myoelectric activity have shown that the use of seromuscular recording electrodes produces the most artifact-free and interpretable recordings. This technique has been used to record myoelectric activity during or after surgery for the stomach,[10-12] small intestine,[13,14] and colon.[15] However these studies were generally done on isolated areas of the gut and addressed only the type of BER present. Aldrete's group[16,17] more recently has confirmed that gastric slow wave activity is unchanged in the postoperative state following gastric surgery with or without vagotomy.

In 1976 Dauchel et al.[18] described the myoelectric activity of the gut for 7 days after cholecystectomy in a group of 13 patients. They observed increased spike wave activity in the small bowel immediately after operation. Sarna[5,19] subsequently has described the BER of the colon, or ECA, as well as colon spike wave activity, or electric response activity (ERA), in the postoperative state. Condon[20] has recently studied human colonic activity in the immediate postoperative period and attributed postoperative ileus to a lack of colonic function.

The purpose of this study was to describe the postoperative myoelectric activity patterns present in stomach, small intestine, and colon for a large group of patients for a period of 1 month after operation. It is hoped that these data will further define recovery of motility for the gastrointestinal tract during 'normal' transient postoperative ileus. We also hypothesized that traditionally used clinical parameters of examining the patient for bowel sounds and noting the passage of flatus and stool may not correlate well with the actual temporal recovery of myoelectric activity.

Materials and Methods

Forty-four patients undergoing major abdominal surgery were included in this study. None of the procedures included vagotomy. Patients were chosen at random and studied prospectively. For the purpose of this study, postoperative ileus was considered to be the clinical manifestations of hypomotility that were experienced by patients. At times these included symptoms of nausea, bloating, and cramps, all of which resolved by postoperative day 7 or earlier. Resolution of postoperative ileus was characterized clinically by the passage of flatus or stool. Patients who continued to experience problems of ileus past postoperative day 7 were considered to have prolonged postoperative ileus and were removed from this study. Informed voluntary consent was obtained from each patient under the guidelines of the University of Virginia Human Investigation Committee.

At the end of their surgical procedures all patients underwent placement of 28-gauge stainless steel bipolar recording electrodes (cardiac pacing wires, A and E Medical Corp., Farmingdale, NJ). These were partially imbedded into the seromuscular layer of the gastrointestinal tract at various selected locations (Fig. 1). Locations included the fundus (n = 20), body (n = 29), and antrum (n = 17) of the stomach as well as the jejunum (n = 44) approximately 15 cm distal to the ligament of Treitz and the mid-transverse colon (n = 14). Wires were brought out percutaneously through the anterior abdominal wall and placed under a sterile dressing until needed for study.

Whenever possible patients were studied within the first 12 to 24 hours after surgery, then daily until postoperative day 4 or 5 and then every other day until discharge. In some instances, at the patient's request or for medical reasons, recording sessions were not performed on all prescheduled days. Recordings were also obtained from most patients at approximately 1 month after operation. These later recordings were believed to approximate as well as possible the patient's unoperated state because clinical recovery of gastrointestinal function had long since occurred. Recording wires were removed by gentle traction after the last recording session.

Most patients had nasogastric suction for the first 24 to 48 hours, at which time the tube was removed. All

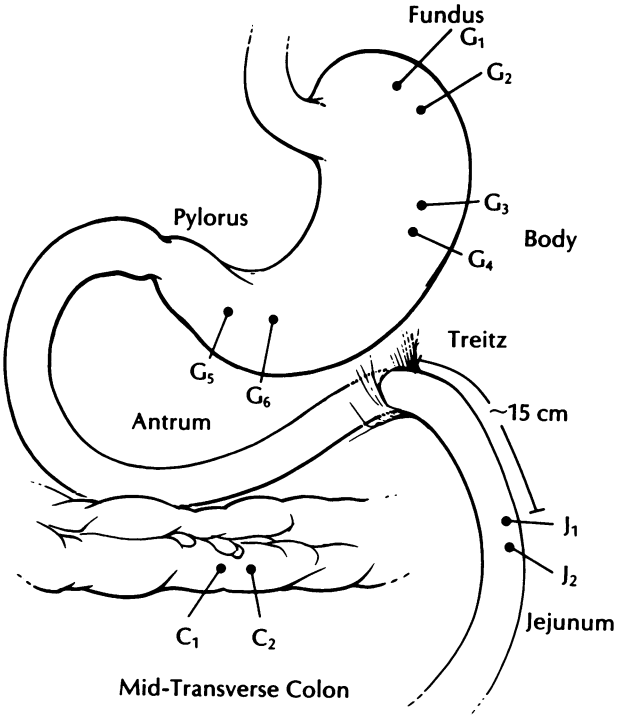

FIG. 1. Placement of seromuscular myoelectric recording wires in pairs to serve as bipolar electrodes along the gastrointestinal tract. G, gastric, J, jejunal, C, colonic.

patients were fasted for at least 8 hours before each recording session. Recordings were performed in continuous 90-to-120–minute sessions while patients lay quietly on a stretcher or bed. Data were recorded using either a Sensormedics R611 8-channel dynograph recorder or a Hewlett Packard Model 7758B Stripchart Recorder with 8811-A bioelectric amplifiers and a 3960 instrumentation recorder (Palo Alto, CA).

All patients were examined daily by the same physician at the recording session. The patient's abdominal exam and the presence or absence of bowel sounds were noted. Patients were questioned regarding passage of flatus and the patient's nursing were records checked for record of bowel movements and vomiting. Records were also made of each patient's subjective feeling of nausea, bloating, and cramps.

Data were analyzed for slow wave frequency (BER), presence of spike activity, percentage of slow waves with spike activity, presence of MMCs, and colonic discrete and continuous electric response activity (DERA and CERA, respectively). Data analysis was done by hand and with the aid of a Dell Model 200 personal computer (Dell Computer Corp., Austin, TX) and a modified ASYST software package (ASYST Co., Rochester, NY). Data are expressed as mean ± standard error of the mean.

Results

Slow Waves

Slow waves or BER were noted on all the initial postoperative recordings from each gastrointestinal area. Gastric BER was usually present and discernible in the fundus, occurring in 87% to 94% of recordings. All recordings from the gastric body and antrum had distinct BER patterns at all times after operation. This cyclic activity was very organized and constant at approximately three cycles per minute on the initial tracings and subsequent ones through the 1-month recordings. There was no difference in frequency of the BER between the three gastric areas at any time and there was little change in overall frequency on a day-to-day basis (Table 1). Signals were diminished in amplitude in the area of the fundus compared to the body and were greatest in amplitude in the antrum (Fig. 2).

Jejunal BER was also present in an organized regular manner on all initial postoperative recordings. The BER was approximately 11 cycles per minute (cpm) on the first tracings and continued without change to the 1-month tracings (Table 2, Fig. 3).

The colon presented the most complex slow wave pattern. Three distinct slow wave frequencies were observed: a low frequency range of 2 to 3 cpm, a mid range of 9 to 14 cpm, and a high range of 20 to 28 cpm (Table 3). All three frequencies were noted in the early postoperative recordings; however all three were not always present on individual recordings. All three ranges were found superimposed on each other or individually. Mid frequency range waves were predominant during the first 1 to 2 postoperative days, with the high frequency range waves occurring more frequently with time until the colon resembled a 'recovered' pattern around postoperative day 5.9 ± 1.5. Low frequency range slow waves were present with little change in predominance throughout the study.

Spike Activity

Gastric spike activity was present on all initial recordings done after surgery. This activity occurred only in a minority of recordings from the gastric fundus. In those few patients who demonstrated spike potentials in the gastric fundus, the frequency of occurrence of the spike potentials was highly variable (Table 4). Spike activity

TABLE 1. *Gastric Slow Waves (cycles per minute)*

Day	1–2	3–4	5–7	1 Month
Fundus	3.07 ± .07	2.95 ± .09	2.83 ± .06	3.06 ± .17
Body	3.09 ± .06	3.18 ± .09	2.99 ± .05	3.04 ± .08
Antrum	3.08 ± .07	3.17 ± .11	2.93 ± .06	3.00 ± .13

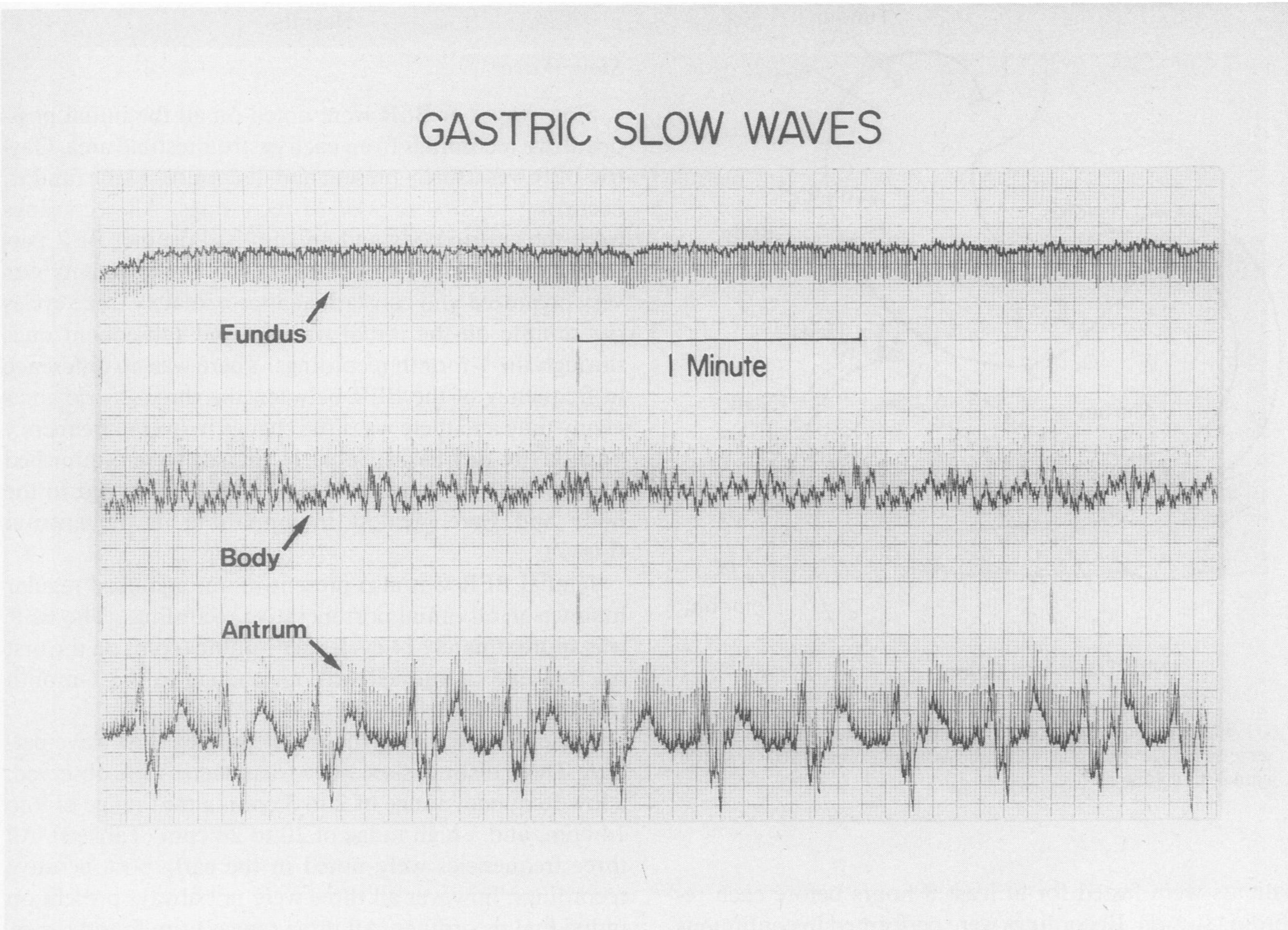

FIG. 2. Myoelectric recordings of the basal electrical rhythm (BER) from fundus, body, and antrum of the stomach.

was more prevalent in the gastric body, occurring in increasing numbers of patients with the passage of time. The antrum, however, displayed the most consistent spike activity of any area of the stomach (Table 4, Fig. 4). As with the gastric body, increasing numbers of patients had antral spike wave activity present with the passage of time after operation. In those patients having such findings, there was no difference in the amount of spike activity in the antrum at any time during the postoperative course.

Migrating motor complexes (also known as areas of phase III activity), in which almost all slow waves during a 2-to-3-minute period have associated spike waves, were seen in each gastric area studied during the initial postoperative period. However they were not demonstrated in all patients, and there was no consistency to their presence or absence in any gastric area throughout the study.

TABLE 2. *Jejunum Slow Waves (cycles per minute)*

Day	1–2	3–4	5–7	1 Month
	11.22 ± .11	11.17 ± .12	10.90 ± .11	10.91 ± .16

They were more prominent in the body and antrum and in general there appeared to be no consistent propagation of the phase III-like activity to the antrum from the body.

Jejunal phase II and phase III activity was very consistent throughout the early and late postoperative periods and was no different from that observed on the 1-month recordings (Table 5). Phase III-like activity was seen up to three and four times in the same patient during a 90-minute recording session. This activity was noted during every study period, including the 1-month recordings. These bursts of activity lasted 3 to 4 minutes, with more than 95% slow waves associated with spike potentials (Fig. 3).

Colonic spike activity in the form of discrete electric response activity (DERA) returned on postoperative day 2.1 ± 0.3. This was generally associated with the presence of mid frequency range slow waves. Continuous electric response activity (CERA) returned at 5.9 ± 0.4 days, and at this time the colon tracings resembled a recovered myoelectric pattern no different from that of the 1-month recordings (Fig. 5).

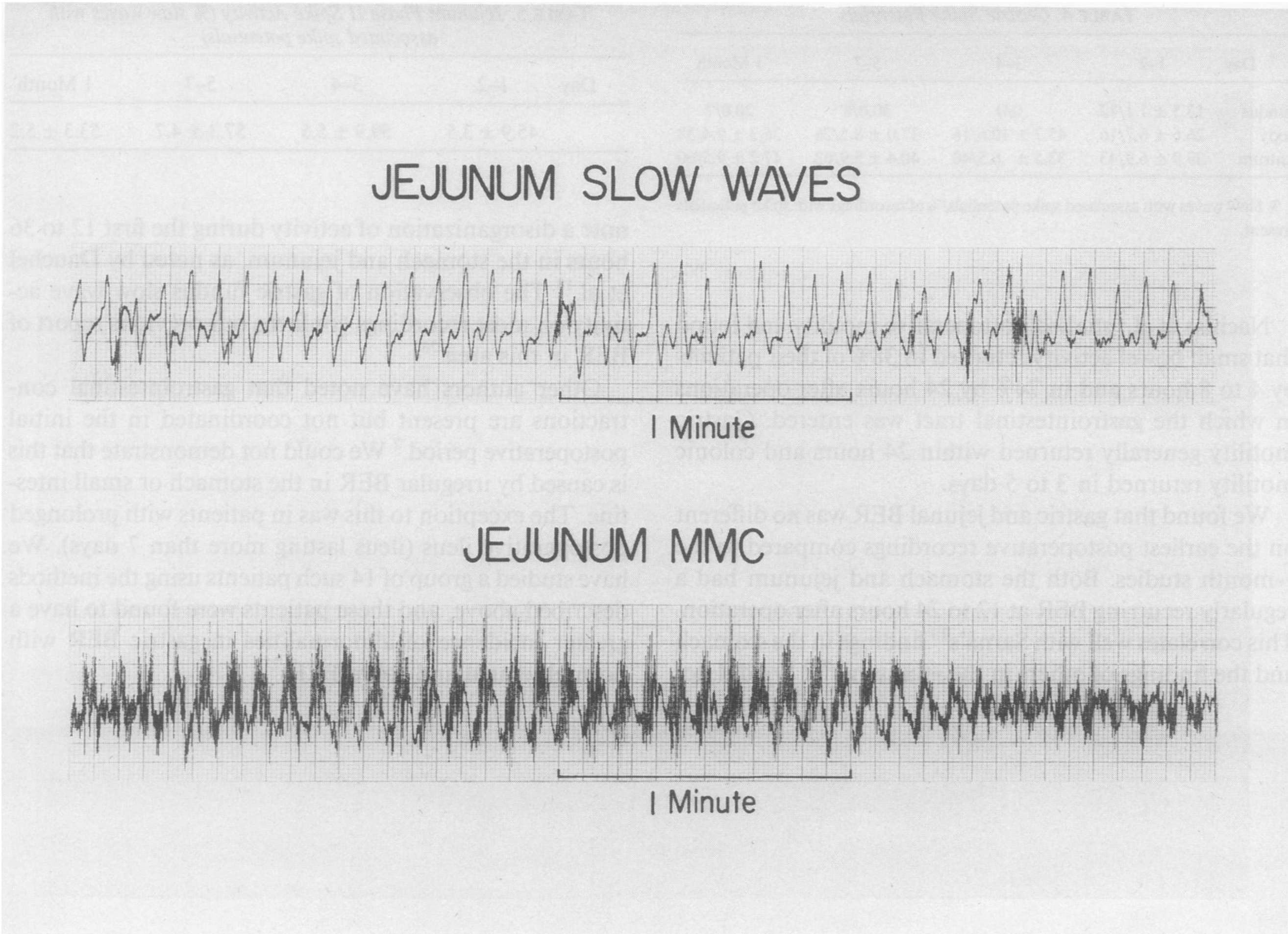

FIG. 3. Myoelectric recordings of basal electrical rhythm (BER) and a migrating motor complex (MMC) of the jejunum. Note the presence of spike potentials associated with all slow waves during the MMC.

Recovery of bowel sounds occurred at day 2.4 ± 0.4 and had no correlation to the time that patients were noted to pass flatus or stool (5.1 ± 0.2 days after operation). The presence of bowel sounds also correlated poorly with resolution of the symptoms of gastrointestinal hypomotility. Patients often had normal active bowel sounds despite continued symptoms of ileus with bloating and nausea. Bloating, distension, and cramps generally began on postoperative day 2 to 3 and resolved by postoperative days 4 to 6. Passage of flatus usually preceded the first bowel movement and the two events generally occurred within 24 hours of each other.

TABLE 3. *Colon Slow Waves (cycles per minute)*

Day	1–4	5–7	1 Month
Frequency			
Low	2.79 ± .08	2.83 ± .11	3.05 ± .16
Mid	11.29 ± .21	10.63 ± .27	11.40 ± .82
High	24.77 ± .76	23.88 ± .76	23.67 ± .84

Discussion

The phenomenon of postoperative ileus is generally transient, and until recent times, when greater emphasis has been placed on decreasing length of hospitalization for financial reasons, there was little motivation to attempt to modify or correct such a process that usually was self-limited. Transient postoperative ileus would also seem to be an excellent model through which to study mechanisms that turn bowel function off and on. The combination of these factors stimulated our investigation of the patterns of recovery of gastrointestinal tract myoelectric patterns during transient postoperative ileus and its resolution.

Alvarez[21] described the slow wave or BER of gastric myoelectric activity in 1922. Since that time myoelectric activity in the small bowel and colon has also been extensively studied and characterized. Because others have shown that myoelectric activity correlates well with gastrointestinal motility,[8,9,22] we chose to use this parameter to examine the relationship of bowel sounds and passage of flatus and stool to gastrointestinal function.

TABLE 4. *Gastric Spike Potentials*

Day	1–2	3–4	5–7	1 Month
Fundus	13.5 ± 1.1/13	0/0	30.0/8	20.0/7
Body	26.6 ± 6.7/16	45.7 ± 10.6/16	37.0 ± 8.5/26	36.3 ± 9.4/38
Antrum	39.9 ± 6.9/43	33.5 ± 6.5/40	40.4 ± 5.9/62	47.2 ± 9.5/60

% Slow waves with associated spike potentials/% of recordings with spike potentials present.

TABLE 5. *Jejunum Phase II Spike Activity (% slow waves with associated spike potentials)*

Day	1–2	3–4	5–7	1 Month
	45.9 ± 3.5	59.9 ± 5.5	57.3 ± 4.7	53.3 ± 5.2

Nachlas et al.[2] studied postoperative motility and found that small bowel activity returned in 38% of their patients by 4 to 8 hours and in 74% by 24 hours after operations in which the gastrointestinal tract was entered. Gastric motility generally returned within 24 hours and colonic motility returned in 3 to 5 days.

We found that gastric and jejunal BER was no different on the earliest postoperative recordings compared to the 1-month studies. Both the stomach and jejunum had a regularly recurring BER at 12 to 24 hours after operation. This correlates well with Sarna's[23] findings in the stomach and the findings of others in the jejunum.[24,25] We did not note a disorganization of activity during the first 12 to 36 hours in the stomach and jejunum, as noted by Dauchel et al.[18] The observation of gastric fundus slow wave activity on most recordings confirms our previous report of BER in this area.[26]

Other authors have noted that gastrointestinal contractions are present but not coordinated in the initial postoperative period.[2] We could not demonstrate that this is caused by irregular BER in the stomach or small intestine. The exception to this was in patients with prolonged postoperative ileus (ileus lasting more than 7 days). We have studied a group of 14 such patients using the methods described above, and these patients were found to have a greater incidence of abnormalities in gastric BER with normal jejunal and colon BER.[27]

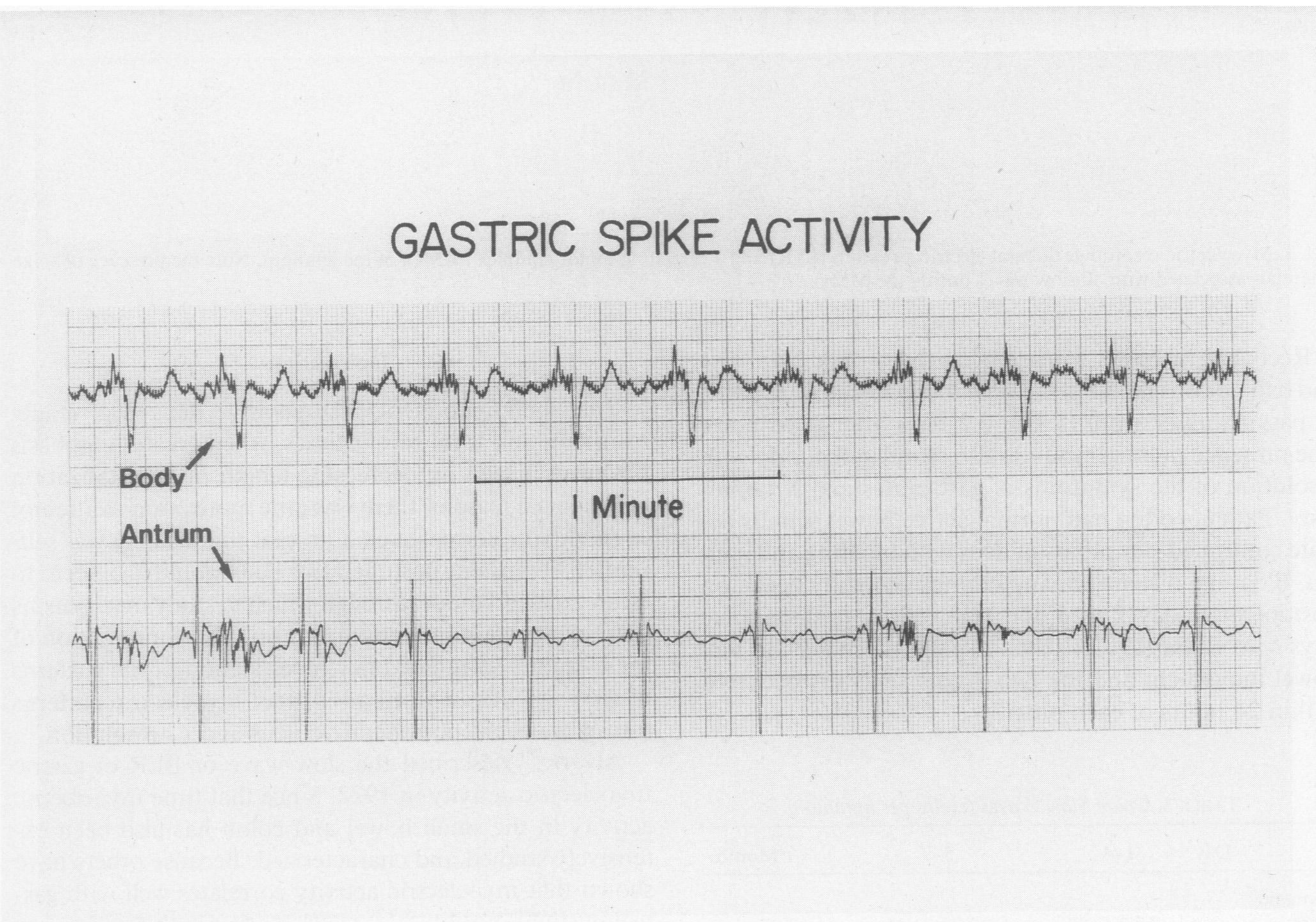

FIG. 4. Gastric spike activity showing antral spike activity occurring independently of any spike activity in the body of the stomach.

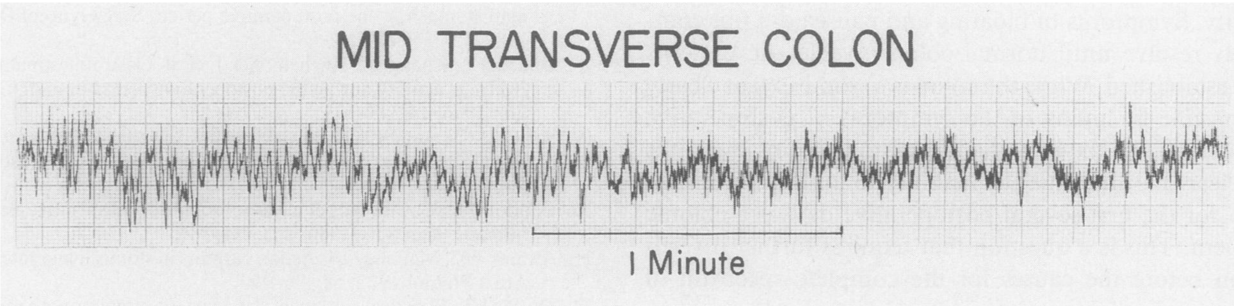

FIG. 5. Recovered pattern of colon myoelectric activity showing electrical control activity (slow waves) and electrical response activity (spike potentials).

Gastric antral and jejunal spike activity was also found to be no different in the initial postoperative recordings from the 1-month recordings. Jejunal phase II and phase III activity occurred in a cyclic fashion. Gastric spike activity correlated well with function. In the fundus, where the stomach serves as a reservoir, there were few spikes and few bursts of phase III-type activity. Activity increased toward the body and antrum; in these areas bursts of phase III activity became more prominent. This coincides with the increased contractile and grinding activity of the antrum.

The colon was the last area to establish a normal BER and spike activity pattern. We noted a low and mid frequency range that agree with those reported by Sarna,[19] Bueno,[28] and Taylor,[29] as well as a higher range of 20 to 28 cpm similar to that reported by Huizinga.[30] Recordings similar to the 1-month tracings showing a fairly equal predominance of mid and high frequency range BER were not present routinely until the fifth to sixth postoperative day. Low frequency BER was present without change in predominance with time.

Colon spike activity also was delayed in its return. Discrete electric response activity was at times present on postoperative day 1, but a normal spike activity pattern with both DERA and CERA was not present until day 5 or 6. This correlated well with the patient's clinical signs of passage of flatus and stool and relief of abdominal cramps and bloating.

While the fasting phase II myoelectric pattern in the jejunum appeared to be normal in the first postoperative recordings, there is some question whether the small bowel is capable of converting to the fed pattern in the first 1 to 2 postoperative days. We have studied several patients in a different protocol who were given liquids during the postoperative day 1 and 2 recording sessions. The small bowel did not usually convert to a fed-type pattern on those days, while it did in those same patients by postoperative days 3 and thereafter. We have also noted in patients receiving jejunal tube feedings on postoperative days 1 and thereafter that the small bowel did not convert to a fed pattern.[31] Because this observation in the small intestine temporally correlates well with return of gastric function after operation, it suggests the possibility that some unknown factor from the stomach, perhaps myoelectric coordination or hormonal or neural feedback, is required to convert the small bowel to the fed pattern.

The pathophysiology of postoperative ileus is poorly understood. Initial investigators of this problem cited the effects of perioperative medications,[32] while others[33] believed the problems of fluid and electrolyte imbalances, hypoproteinemia, and reflex inhibition were the primary cause. Rough handling of the intestine has been believed to be the cause of ileus,[34] as has duration of the operative procedure.[35] Each of these last two factors has been shown to be of little consequence in primate studies.[24]

More recently the pathogenesis of ileus after surgery has been attributed to an increased effect of the sympathetic nervous system.[36] Elevated catecholamine levels in the postoperative state,[37] as well as the finding of increased synthesis and release of norepinephrine in the bowel wall after operation,[38] all suggest that sympathetic neural influences may be a factor. Regulatory reflexes and controlling mechanisms within the enteric nervous system itself may play a key role, as may the many circulating peptide hormones that have been shown to influence intestinal activity in a variety of animal and human studies.[39–43]

Bowel sounds appear to have little relation to myoelectric function and we could not find any correlation with activity in the gastrointestinal tract and return of myoelectric activity in any area to return of bowel sounds. Bowel sounds were often present and 'normal' when the patient was still experiencing abdominal discomfort and sounds were often hypoactive or absent when the patient appeared to be doing well.

The gastric fundus, body, antrum, and the jejunum have normal patterns of BER and spike activity in the fasted state as early as 12 to 24 hours after operation. The colon is the last to regain a recovered, normal type of pattern. Bowel sounds have little correlation with myoelectric activity, although passage of flatus and stool coincides closely with return of normal colon myoelectric activity. Symptoms of bloating and nausea did not completely resolve until normal colon myoelectric patterns were established. While the colon is to some extent clearly responsible for many of the symptoms of postoperative ileus, especially the bloating, distention, and cramps, it is not clear that the patient's inability to take oral nourishment for the first several postoperative days is a colonic problem. This is a question that requires further investigation before the causes for the complete spectrum of postoperative ileus symptoms can be resolved.

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References

1. Hoyer A. Abdominal distension and intestinal activity following laparotomy. Acta Radiol 1950; 83 (Suppl):43–189.
2. Nachlas MM, Younis MT, Roda CP, Wityk JJ. Gastrointestinal motility studies as a guide to postoperative management. Ann Surg 1972; 175:510–522.
3. Farrar JJ, Ingelfinger FJ. Gastrointestinal motility as revealed by study of abdominal sounds. Gastroenterology 1955; 29:789–799.
4. Baker LW, Dudley HA. Auscultation of the abdomen in surgical patients. Lancet 1961; ii:517–519.
5. Sarna SK, Bardakjian BL, Waterfall WE, Lind JF. Human colonic electrical control activity (ECA). Gastroenterology 1980; 78:1526–1536.
6. Chambers MM, Kingrea YJ, Bowes FL. The role of the submucosa in the generation of electrical activity in human circular colonic muscle. Gastroenterology 1986; 91:1048.
7. Wingate DL. Backwards and forwards with the migrating complex. Dig Dis Sci 1981; 26:641–646.
8. Bass P. In vivo electrical activity of the small bowel. *In* Code Handbook of Physiology. Vol. 4, Sect. 6. Baltimore: Williams & Wilkins, 1968. pp.2051–2074.
9. Code CF, Szurszowski JH, Kelly KA, et al. A concept of control of gastrointestinal motility. Vol. 5, Sect. 6. *In* Code CF, Heidel W, eds. Handbook of Physiology. Washington, DC: American Physiol Society, 1968. p. 881.
10. Monges H, Salducci J. A method of recording the gastric electrical activity in man. Am J Dig Dis 1970; 15:271–276.
11. Kwong NK, Brown BH, Whittaker GE, et al. Electrical activity of the gastric antrum in man. Br J Surg 1970; 57:912–916.
12. Couturier D, Roze C, Paolaggi J, et al. Electrical activity of the normal human stomach: a comparative study of recordings obtained from the serosal and mucosal sides. Am J Dig Dis 1972; 17:969–976.
13. Daniel EE, Carlow DR, Wachter BT, et al. Electrical activity of the small intestine. Gastroenterology 1959; 37:268–281.
14. Nielubowicz J, Folga J, Wiekowska W. Electroenterolography. Arch Surg 1965; 90:698–707.
15. Taylor I, Duthie HL, Smallwood R, Linkens D. Large bowel myoelectric activity in man. Gut 1975; 16:808–814.
16. Aldrete JS, Shepard RB, et al. Effects of various operations on the electrical activity of the human stomach recorded during the postoperative recovery period. Ann Surg 1972; 195:662–9.
17. Aldrete JS, Shepard RB, Jimenez H. Autocorrelation, cross correlation and coherence analyses of the electrical activity of the human stomach in the postoperative period. Surg Gynecol Obstet 1982; 154:359–365.
18. Dauchel J, Schang JC, Kachelhoffer J, et al. Gastrointestinal myoelectrical activity during the postoperative period in man. Digestion 1976; 14:293–303.
19. Sarna SK, Waterfall WE, Bardakjian BC, Lind JF. Types of human colonic electrical activities recorded postoperatively. Gastroenterology 1981; 81:61–70.
20. Condon RE, Cowles VE, et al. Resolution of postoperative ileus in humans. Ann Surg 1986; 203:574–581.
21. Alvarez WC, Mahoney LJ. Action currents in stomach and intestine. Am J Physiol 1922; 58:476–493.
22. Duthie HL. Electrical activity of the gastrointestinal smooth muscle. Gut 1974; 15:669–681.
23. Sarna SK, Bowes KL, Daniel EE. Postoperative gastric electrical control activity (ECA) in man. *In* Daniel Proc. 4th International Symposium on Gastrointestinal Motility, Banff, 1973. pp. 73–83.
24. Graber JN, Schulte WJ, Condon RE, Cowles VE. Relationship of duration of postoperative ileus to extent and site of operative dissection. Surgery 1982; 92:87–92.
25. Woods JH, Erickson LW, Condon RE, et al. Postoperative ileus: a colon problem? Surgery 1978; 84:527–533.
26. Waldhausen JHT, Schirmer BD. Role of the stomach in postoperative ileus. Presented at 12th International Symposium on Gastrointestinal Motility. Gmunden, Austria, 1989.
27. Schirmer BD, Shaffrey M, Bellahsene BE, McCallum RW. Identification of activity in the fundus of the human stomach. Dig Dis Sci 1987; 32:926.
28. Bueno L, Fioramenti J, Ruckebusch Y, et al. Evaluation of colonic myoelectric activity in the health and functional disorders. Gut 1980; 21:480–485.
29. Taylor I, Duthie HL, Smallwood R, Linkens D. Large bowel myoelectric activity in man. Gut 1975:16:808–814.
30. Huizinga JD, Stern HS, Chou E, et al. Electrical basis of excitation and inhibition of human colonic smooth muscle. Gastroenterology 1986; 90:1197–1201.
31. Waldhausen JHT, Schirmer BD. The effects of tube feeding on postoperative ileus. Presented at Assoc for Academic Surg, November 1989, Louisville, KY.
32. Bisgard JD, Johnson EK. The influence of certain drugs and anesthetics upon gastrointestinal tone and motility. Ann Surg 1939; 110:802.
33. Aird I. A Companion in Surgical Studies, 2nd ed. Edinburgh: E and S Livingstone, Ltd, 1957. p. 824.
34. Moyer CA, Rhoads JE, Allen JG, Harlan HN. Surgery Principles and Practice, 3rd ed. Philadelphia: JB Lippincott, 1965. p. 1009.
35. Davis L. Christopher's Textbook of Surgery, 9th ed. Philadelphia: WB Saunders, 1968. p. 742.
36. Schwartz SI. Principles of Surgery. New York: McGraw Hill, 1969. p. 854.
37. Smith J, Kelly KA, Weinshilbaum RM. Pathophysiology of postoperative ileus. Arch Surg 1977; 112:203–209.
38. Dubois A, Koprin IJ, Pettigrew KD, et al. Chemical and histochemical studies of postoperative sympathetic activity in the digestive tract of rats. Gastroenterology 1974; 66:403–407.
39. Itoh Z, Honda R, Hiwatashi K, et al. Motilin induced activity in the canine alimentary tract. Scand J Gastroenterology 1976; 39 (Suppl):93–110.
40. Schang JC, Kelly KA. Inhibition of canine interdigestive proximal gastric motility by cholecystokinin octapeptide. Am J Physiol 1981; 240:G217–220.
41. Owyang C, Achem-Karem SR, Vonik AI. Pancreatic polypeptide and intestinal migrating motor complex in humans. Effect of pancreaticobiliary secretion. Gastroenterology 1983; 84:10–17.
42. Thor K, Rosell S, Rkaeus A, Kager L. (Glu[4]) neurotensin changes the motility pattern of the duodenum and proximal jejunum from fasting type to fed type. Gastroenterology 1982; 83:569–574.
43. Thor K, Rosell S. Neurotensin increases colonic motility. Gastroenterology 1986; 90:27–31.