Effects of Intestinal Muscular Wrapping on Remnant
Intestinal Motility after Massive Small Bowel Resection
in Conscious Canines

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Abstract

We searched the effect of the muscular valve on the management of short bowel
syndrome. The motility of the remnant intestine with a special muscular valve after 80% of
massive distal small bowel resection (MSBR) was evaluated in conscious dogs. The valve
(muscular ring) was made by the autointestinal muscle layer holding vascular pedicle.
Interdigestive and postprandial bowel motility using bipolar electrodes and/or contractile
strain gauge force transducers 2–4 weeks after the surgery, and data of this group (Group I)
were compared to the motility in dogs after MSBR without valve construction (Group II)
and in controls (Control). Results; Fasting duodenal migrating myoelectric (or motor) com-
plexes (MMCs) in Group I occurred at longer intervals than in Control and almost similarly
to those in Group II. MMCs arising from the duodenum were often interrupted before the
jejunum above the valve and the anastomosis. The velocity of duodenal MMC propagation
was slowed in every intestinal segment including that from the duodenum to the proximal
jejunum, and to the jejunum above the anastomosis. Transit time in MSBR group (I and II)
from the duodenum to the terminal ileum was extremely shorter than in Control, but there
were no differences between in Groups I and II. The duration of the postprandial period
without duodenal MMCs in Group I was significantly prolonged than in Control, but was
shorter than that in Group II. The muscular valve was frequently activated, and the
jejunum covered with the valve was contracted frequently which synchronized with the
valve activity. It seemed the valve worked as sphincter. However, intestinal obstruction
was not occurred through the jejunum covered by the valve. In conclusion, changes in gut
motility after MSBR with the valve construction compensate for the shortened intestine and
maintain the bowel content earlier postoperatively in comparison with the MSBR alone, and
also contribute to the adaptive increase in the remnant intestinal absorption.

Key words: intestinal motility; massive small bowel resection (MSBR); short bowel
syndrome; intestinal valve; small intestine
Introduction

In various pediatric surgical bowel diseases, including malrotation, midgut volvulus, multiple intestinal atresia, necrotizing enterocolitis, intestinal ischemia, and intestinal necrosis secondary to strangulation ileus, and in several adult diseases such as irradiation enteritis and mesenteric vascular thrombosis, massive small bowel resection (MSBR) has to be inevitably performed. After such surgery, patients suffer from the serious symptoms of malabsorption and malnutrition, which comprise the short bowel syndrome. To prevent severe diarrhea and malabsorption in short-term after MSBR, several optional surgical procedures have been tried to delay food transit time and expand absorption area (Mitchell et al., 1984; Thompson and Rikkers, 1987). To slow down the accelerated transit time, valve construction by auto-intestine have been attempted with conflicting results. We performed a muscle layer valve construction which circularly covered around the residual jejunum after MSBR, i.e., the valve was wrapped 5 cm proximal to the jejunoileal anastomosis, which was formed of auto-intestinal mucosal layer ablation. Limited numbers of literature of intestinal motility after MSBR using myoelectric or strain gauge transducers have been reported (Wittman et al., 1984; Kitahara, 1986; Uchiyama et al., 1992, 1996). Motility of the remnant intestine was continuously measured using myoelectric or strain gauge transducers in postoperative conscious canines. And we evaluated the usefulness of constructing the circular muscle valve after MSBR in terms of the myoelectric motor activity, comparing the motility with those after MSBR alone and controls.

Materials and Methods

Surgical Procedures

Experimental subjects: Dogs weighting 9 to 12 kg underwent laparotomy under sodium pentobarbital anesthesia with ventilatory support and intravenous infusion. Intestinal length was measured at the antimesenteric side after atropine sulfate injection, and sites for device placement and the length of resection were determined.

Small bowel was massively resected and a muscular valve was constructed (Group I, N = 3): Namely, 80% MSBR and an end-to-end jejunoileal anastomosis were performed, preserving about 50 cm of the proximal jejunum from the ligament of Treitz and 10 cm of the terminal ileum. Then the 2 cm jejunum proximal to the resection range was isolated with vascular pedicle and opened at antimesenteric site, and then the mucosal layer of it was carefully removed by a scalpel. Thereafter, consequent seromuscular layer of the short jejunal segment was wrapped circularly around the jejunum at 5 cm above the anastomosis as a muscular valve. Bipolar electrodes and/or force transducers were then implanted in the following sites, the duodenum (D), the proximal jejunum (J1 : 10 cm distal to the ligament of Treitz), the jejunum above the muscular valve (J2), the jejunum covered by the valve (Jv), the seromuscular surface of the valve (Mv), the jejunum 3 cm above the anastomosis (J3), and the terminal ileum 5 cm below the anastomosis (TI) (Fig. 1).

MSBR alone was done (Group II, N = 5): 80% distal MSBR and an jejunoileal anastomosis
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Fig. 1. Operative procedure and implantation sites of electrodes and/or force transducers in group I. A 80% massive small bowel resection (MSBR) with a wrapped muscular valve made by autointestine above the anastomosis. A force transducer is placed at the jejunum covered by the valve (Jv) and a electrode is implanted at the jejunal muscular layer made as the valve (Mv).

were performed and measuring devices were then implanted similarly in D, J1, the jejunum 5 cm above the anastomosis (J3), and TI.

Control group (Control, N = 5): Laparotomy was performed, electrodes and/or force transducers were implanted in D, J1, the jejunum at 45 cm from the ligament of Treitz (J3), the middle ileum, and the terminal ileum 5 cm above the ileocolic junction (TI).

After the recovery period of 2 weeks, when usual bowel movement with formed stool (1-3 times a day) was observed, each intestinal motility was continuously recorded for the subsequent 2 weeks and analyzed.

**Measuring instruments**

Bipolar electrodes were fabricated in our institution and strain gauge force transducers were purchased from the Star Medical Company (Tokyo Japan). Electromyograms (EMG) were recorded with an EMG amplifier (Fukuda Densi Co., Niigata, Japan), and contraction curves were also recorded through an amplifier (Star Medical Co.). Three multichannel recorders (Nihon Koden Co., Tokyo Japan) were used, which enabled simultaneous EMG and contraction curve recording at various velocities (2.5 mm/min, 10 mm/min, and 1 mm/sec).

**Recording Conditions**

Small bowel motility was continuously recorded in the fasting state (interdigestive state) and after meals (postprandial state) for about 2 weeks. Dogs were held in cages which permitted physiologic activity and sleeping. They were usually supplied food once a day and water freely. The leads from the dogs were connected to the amplifiers and recorders in an
adjacent room.

**Analysis of intestinal motility**

The migrating myoelectric (or motor) complex (MMC) periodically propagates from the proximal to the distal bowel in the fasting state (Szurszewski, 1969; Carlson et al., 1972; Ito, 1981; Sarna, 1985). From recorded motility, we analyzed the duration of the MMC of each part, the interval between MMCs at various sites in the intestine, the propagation pattern of the duodenal MMC to the distal bowel, the frequency of propagation of duodenal MMCs to the terminal ileum, the propagation time of MMCs, the propagation velocity of MMCs along each intestinal segment. Basic electric rhythm (phase I; resting phase) is recorded by time constant at 0.3 second, and spike potential (phase III; acting phase with strong contraction) is exclusively recorded at 0.03 second in each intestine. And postprandial period without duodenal MMC activity (the interval between food intake and the initial duodenal MMC) was measured. Ryan’s multiple comparison test was used to evaluate the statistical significance of the results. Data is described as mean±SD.

**Ethical Considerations**

All studies were practiced under the guidelines indicated by related laws and regulations for animal experimentation. And this study was approved by the Ethical Committee on Animal Experimentation of Niigata University.

**Results**

Group I (MSBR with muscular valve): In fasting state, MMCs initiated from the duodenum (duodenal MMC) occurred at an interval of 159.4 minutes, which was significantly longer than in controls, but similar to that in Group II (Table 1, Fig. 2). Of 79 duodenal MMCs recorded, 90% propagated to J1 (proximal jejunum), 77% to J2 (above muscular valve), 70% to J3 (above

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<th>Table 1. Interval between duodenal MMC in the fasting state and the length of the postprandial period without duodenal MMC</th>
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<tr>
<td><strong>Group I (MSBR with a valve)</strong></td>
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<tr>
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<tr>
<td>Interval between</td>
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<tr>
<td>duodenal MMC in the fasting</td>
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<tr>
<td>state (N=3, n=55)</td>
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<tr>
<td>No. of intervals or meals</td>
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<td>Postprandial period</td>
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<tr>
<td>without duodenal MMC after meals</td>
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<tr>
<td>No. of intervals or meals</td>
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<td>(N=5, n=27)</td>
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MSBR; 80% massive small bowel resection, N, no. of dogs; n, no. of intervals or meals. Values are given as mean±SD. *p<0.01 (Ryan’s multiple comparison test)
Effects of muscular valve on short bowel

- fasting state -

recording speed: 2.5mm/min

Duodenum: D

Proximal jejunum: J1

Jejunum above valve: J2

Jejunum covered by valve: Jv

Muscular valve: Mv

Jejunum above anastomosis: J3

Terminal ileum: TI

60 min.

Fig. 2. Small intestinal motility in a fasting dog with a valve after MSBR (Group I). Migration of a duodenal MMC to the terminal ileum. Such propagation occurred in 54% of duodenal MMCs. In addition to migration MMC, a lot of small contractions occur according to muscular valve activity at the jejunum covered by a valve (Jv).

<table>
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<th>Table 2. Frequency of duodenal MMC propagation to the distal intestine</th>
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<td>Duodenum (D)</td>
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<tr>
<td>Proximal jejunum (J1)</td>
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<tr>
<td>Jejunum above valve (J2)</td>
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<tr>
<td>Jejunum above anastomosis (J3)</td>
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<tr>
<td>Terminal ileum (TI)</td>
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Significance vs. control: *p<0.01. Significance each other: *p<0.05.

anastomosis), and 54% to TI (terminal ileum). The frequency of propagation remained significantly lower than in controls through the intestine and was lower than in Group II by TI (Table 2). The overall propagation velocity from D to TI was 1.4 cm/min, with velocities of
Table 3. Propagation velocity of duodenal MMC along the length of intestine, transit time from duodenum to terminal ileum

<table>
<thead>
<tr>
<th></th>
<th>Group I (MSBR with a valve) (cm/min)</th>
<th>Group II (MSBR alone) (cm/min)</th>
<th>Control (laparotomy) (cm/min)</th>
</tr>
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<tbody>
<tr>
<td>Duodenum (D)</td>
<td>2.6 ± 0.1 (n=71)</td>
<td>2.1 ± 0.3* (n=88)</td>
<td>3.5 ± 1.1 (n=300)</td>
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<tr>
<td>Proximal jejunum (J1)</td>
<td>2.9 ± 0.4 (n=61)</td>
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<tr>
<td>Jejunum above valve (J2)</td>
<td>1.6 ± 0.4* (n=55)</td>
<td>1.9 ± 0.6* (n=80)</td>
<td>3.4 ± 0.5 (n=291)</td>
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<tr>
<td>Jejunum above anastomosis (J3)</td>
<td>0.4 ± 0.1* (n=43)</td>
<td>0.7 ± 0.2* (n=76)</td>
<td>2.1 ± 0.2 (n=284)</td>
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<tr>
<td>Terminal ileum (TI)</td>
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<tr>
<td>Overall from D to TI</td>
<td>1.4 ± 0.1* (n=43)</td>
<td>1.4 ± 0.3* (n=76)</td>
<td>2.3 ± 0.2 (n=284)</td>
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<tr>
<td>Transit time from D to TI</td>
<td>(minute)</td>
<td>(minute)</td>
<td>(minute)</td>
</tr>
<tr>
<td></td>
<td>54.3 ± 8.0* (n=43)</td>
<td>53.5 ± 8.2* (n=76)</td>
<td>129.5 ± 9.0 (n=284)</td>
</tr>
</tbody>
</table>

Significance vs. control: *p<0.01, **p<0.05.

Duodenum: D

- fasting state -

recording speed: 10 mm/min

Proximal jejunum: J1

Jejunum above valve: J2

Jejunum covered by valve: Jv

Muscular valve: Mv

Jejunum above anastomosis: J3

Terminal ileum: TI

10 min.

Fig. 3-a. Small intestinal motility in a fasting dog with a valve after MSBR (Group I). Frequency of muscular activity in each intestine and a muscular valve. At Jv, frequency of small contractions according to Mv activity are slower than that of strong contractions occurred relating to the contiguous jejunal activity.
0.7 cm/min from J2 to J3 beyond Jv, 1.6 cm/min from J1 to J3 via J2, and 0.4 cm/min from J3 to TI. The each velocity among each intestine from D to TI was significantly prolonged than that in controls (Table 3). Propagation time of duodenal MMCs took 54.3 minutes from D to TI, was significantly shortened than in controls, and was similar to that in Group II (Table 3).

In addition to the periodical MMC propagation from the duodenum to the terminal ileum, spike potentials were frequently took place at a muscular valve (Mv), and small contractions occurred at the jejunum covered by the valve (Jv) which were synchronized to spike potential of Mv. Occasionally, strong contractions outbreak at Jv migrating to the jejunum above anastomosis (J3) was observed (Figs. 2 and 3). To clarify motility relationship among each jejunal site, frequency of basic electric rhythm (BER), spike potential (SP) and contraction were measured at each jejunal or Mv (Fig. 3a, 3b). BER and SP of Mv were equal to 12/min, moreover frequency of small contraction of Jv was 12/min in resting phase. On the other hand, frequency of strong contraction of Jv at phase III was 18/min and that of J3 was 18/min, and the frequency at those strong contraction was same as its original jejunal frequency of BER or SP. As for Jv at resting period, small contraction was occurred synchronizing to the frequency of SP of surrounded muscle (Fig. 3b). Even at resting phase of the jejenum, Jv repeated a number of small contractions with the frequency equal to Mv activity (12/min). During the active period, MMC activity from oral jejunum and large contraction having propagation
capacity to the jejunum above anastomosis were taken place according to its original contraction frequency (18/min).

After meals (200 g of meat containing 170 Calories), strong contractions and high amplitude spike potentials disappeared almost concurrently throughout intestine, and irregular small contractions or low amplitude activity continued for 13 to 23 hours (Fig. 4). The mean postprandial period without duodenal MMCs was 15.4 hours, significantly shorter than in Group II, but still longer than in controls (Table 1). Dogs were raised smoothly without symptoms one and half years after surgery. At sacrifice, epithelial hyperplasia and slight intestinal dilatation were seen in the remnant jejunum, and obstruction or stenosis was not seen at the jejunal part surrounded by the muscle valve.

Group II (MSBR alone): In fasting state, duodenal MMCs occurred at a mean interval of 153.1 minutes, which was significantly longer than in controls (Table 1). In addition, truncated MMCs and contractions occurred frequently in J3. Of 104 duodenal MMC recorded, 73% propagated to the terminal ileum. This frequency of propagation was significantly less than in controls (Table 2). The propagation velocity was 1.4 cm/min overall (Table 3). Propagation of duodenal MMCs took 53.5 minutes to TI. The postprandial period was markedly increased to 22.5 hours (from 17 to 27 hours), which was significantly longer than in Group I and in controls.
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Control group: In the fasting state, duodenal MMCs occurred periodically at a mean interval of 126.1 minutes. Of 303 duodenal MMCs recorded, 94% propagated through the proximal jejunum and jejunum to the terminal ileum. The overall propagation velocity from D to TI was 2.3 cm/min. Propagation of duodenal MMCs took 129.5 minutes to the terminal ileum. After meals, the myoelectric complex disappeared and remained suppressed for 7 to 10 hours. The mean postprandial period was 7.8 hours (Table 1).

Discussion

After massive small bowel resection (MSBR), the short bowel syndrome occurs, with severe diarrhea and malabsorption due to the accelerated transit time of the intestinal contents and to the reduced surface areas available for absorption and digestion. This condition is well known as intestinal hurry (Rickham et al., 1977; Grosfeld et al., 1986). Several operative procedures have been endeavoried both clinically and experimentally to slow the intestinal transit time as a management of short bowel syndrome (Mitchell et al., 1984; Thompson and Pikkers, 1987). Construction of valve by using autografts intestine is one of the operative methods, and several types of valve creation have been reported, such as intussuscepting intestinal segment like a nipple at the anastomosis; proximal to distal (Grier et al., 1971; Careskey et al., 1981; Lopez et al., 1981; Ricotta et al., 1981; Myrvold et al., 1984), distal to proximal (Waddell et al., 1970); circumferential ablation of seromuscular layer and invaginating the denuded mucosa into the intestinal lumen (Schiller et al., 1967; Hidalgo et al., 1973; Diego et al., 1982; Stacchinì et al., 1982), an submucosally tunneling intestinal segment (Vinograd et al., 1984). Though valve formation was reported partially effective owing to lengthened transit time or increased absorptive capacity in the short bowel syndrome, constructed valves may lose their sphincter function with time. In addition, a high rate of complications including obstruction, anastomotic leakage, necrosis of the valve and intussusception has been reported (Waddell et al., 1970; Lopez et al., 1981; Ricotta et al., 1981). The study on myoelectric and motor activity after MSBR with intestinal valve has been rarely reported.

We searched the effect of the muscular valve with preserved vascular pedicle on the management of short bowel syndrome. The valve function was measured by myoelectric and motor activity in conjunction with entire small intestinal motility. In comparison with Group II underwent MSBR alone, not only the motility of jejunum surrounded by the valve but also whole small intestinal motility were significantly influenced by the muscular valve motility.

In Group I, overall transit time of the duodenal MMCs from the duodenum to the terminal ileum was not statistically longer than in Group II. Interval between duodenal MMCs in fasting state was significantly longer than controls but similar to that in Group II. Propagation velocity of duodenal MMC from the jejunum above the valve to the terminal ileum tended to be slower than in Group II. Postprandial period was statistically prolonged than in controls, but shortened than in Group II. These indicate, in Group I (MSBR with the valve), intestinal preparation for intake of next food occurs and compensative function for shortened intestine
is promoted earlier than in Group II.

The results imply muscle layer valve around the jejunum dose not induce stenosis, and acts like a sphincter muscle. Since Jv showed a number of small contractions which were activated by the muscle valve even at resting phase of the jejunum. Moreover, strong contractions probably stimulated by muscle activity of the valve or propagated from proximal jejunum were occurred with its jejunal origin with migration capacity to the distal intestine. It was suggested wrapped intestinal muscular layer have action on both blocking at resting phase as sphincter and passing through at migrating phase without obstruction.

In conclusion, the valve surrounding the jejunum above anastomosis, which is made of oral jejunum of resected jejunal line, having 2 cm length with vascular pedicle, could have a sphincter-like function and contribute to preserve intestinal contents without obstruction.

References


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