Manometric and Electromyographic Studies on the Effect of Transection of Canine Stomach on the Pyloric Motor Function

Tsuneo Shiratori, Toshihiko Okabayashi, Kyoji Sugawara and Nobumasa Harata

Department of Surgery (Prof. T. Maki), Tohoku University School of Medicine, Sendai

To elucidate motor function of the pylorus, manometric and electromyographic studies were carried out on the canine stomach following transection and end-to-end anastomosis at various levels such as proximal 1/3, 1/2, distal 1/3, distal 1/4, and at 4, 3, 2, and 1 cm proximal to the pyloric ring.

Transections at the body of the stomach caused slight or no increase in contraction pressure of the pylorus, a slight increase in the incidence of anti-peristalsis and slight or no prolongation of the discharge interval. On the other hand, transaction at the borderline between the corpus and antrum of the stomach resulted in a marked increase in contraction pressure of the pylorus, a marked increase in the incidence of anti-peristalsis and a marked prolongation of the discharge interval. The results suggested excitation of the pylorus. As the level of transection approached the pyloric ring, the electromyogram taken from the pylorus showed the evidence of excitation but the contraction pressure of the pylorus gradually lowered, probably because of a small amount of muscular remnant in the pyloric portion. The contraction pressure of the pylorus was approximately equal to the control value when a transection was made at 1.5 to 2.0 cm proximal to the pyloric ring.

Recently, Sugawara and Shiratori et al. investigated the effect of transection at the borderline between the corpus and antrum of the stomach with the aid of electromyography and obtained the result that the anti-peristaltic discharges became more frequent and the discharge interval of normo-peristalsis more prolonged in the portion distal to the transection. This indicates the importance of anti-peristalsis in the pathogenesis of pylorospasm or passage disturbance at the pylorus after gastric resections with the pyloric antrum left behind. Shiratori et al. noted previously that section of the vagus or splanchnic nerves did not significantly influence the result. The above-mentioned condition seems to be caused by interruption of the stomach wall itself and suggests the presence of a regulatory mechanism in the upper part of the stomach over the lower.

In the present paper, the attitude of the pylorus is described especially in relation to the contraction pressure of the pylorus and an electromyographic pattern after transection of the stomach.

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MATERIALS AND METHOD

Sixty-four healthy mongrel dogs weighing about 10–15 kg were used. After fasting for 24 hours the stomach was exposed under anesthesia with thiopental sodium, 20 mg per kg of body weight, at a room temperature of 20–24°C. Contraction pressure and electromyograms of the pylorus were recorded following transec-

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**Fig. 1.** Level of transection and setting of the electrodes.

**Fig. 2.** Electrode and balloon manometer.
tions and two layer anastomoses at right angles to the longitudinal axis of the organ at various levels, i.e., proximal 1/3 and 1/2, distal 1/3 and 1/4, and at 4, 3, 2 and 1 cm proximal to the pyloric ring (Fig. 1).

To measure contraction pressure, a 4×4×10 mm latex balloon was connected to a strain-gauge transducer with a polyethylene tube of 1.4 mm in inside diameter (Fig. 2). After introducing a deflated balloon through the fundus of the stomach and securing its end to the duodenal bulb, the balloon was filled with air and placed exactly inside the pyloric ring (Fig. 3). Two bipolar electrodes were fixed to the anterior wall along the longitudinal axis of the stomach, one at the pyloric ring and the other 2 cm proximal to it. Each bipolar electrode consisted of two silver-chromium needles of 0.1 mm in diameter and 1.5 mm apart (Fig. 2). A multichannel pen-writing polygraph, made by San-ei Instrument & Co., and an oscillograph were used to record the contraction pressures and electromyograms. Contraction pressure was expressed by the height of the peak of the wave from the base line.

Fig. 3. Schematic drawing of the apparatus.

Fig. 4. Contraction pressure curve and electromyograms.
A; Contraction pressure curve at the pyloric ring
B; Electromyogram taken at 2 cm proximal to the pyloric ring
C; Electromyogram taken at the pyloric ring
Nomo-peristalsis : b and c
Anti-peristalsis : a,d,e, and f
Electromyograms were read with special reference to the incidence of anti-peristalsis and discharge interval at the pyloric ring (time constant 0.03 sec). The action potentials of normo-peristalsis were recorded first by the proximal electrode B (b and c) and the action potentials of anti-peristalsis were recorded first by the distal electrode C (a, d, e and f) (Fig. 4).

RESULTS

A) Motor function of normal stomach of dogs

In normal stomachs, the motor action of the stomach consists mostly of normo-peristalsis originating from the upper part of the body and passing slowly toward the pylorus. Spike discharges always appeared preceding the peak of mechanogram of contraction pressure (Figs. 4 and 5-I). Anti-peristalsis was seen only in 3 of 64 dogs in total. The incidence of anti-peristaltic discharges in all discharges was 1.2%. The average discharge interval of anti-peristalsis was 16.5 sec, which was slightly longer than 15.4 sec of normo-peristalsis (Table 1).

**Table 1. Discharge interval at the pyloric ring**

<table>
<thead>
<tr>
<th>Level of transection</th>
<th>Normo-peristalsis</th>
<th>Anti-peristalsis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean discharge</td>
<td>Incidence (%)</td>
</tr>
<tr>
<td></td>
<td>interval (sec)</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>15.4 (±2.43)</td>
<td>98.8</td>
</tr>
<tr>
<td>Proximal 1/3</td>
<td>14.7 (±2.73)</td>
<td>95.2</td>
</tr>
<tr>
<td>1/2</td>
<td>16.2 (±2.02)</td>
<td>75.3</td>
</tr>
<tr>
<td>Distal 1/3</td>
<td>24.0 (±4.62)</td>
<td>47.4</td>
</tr>
<tr>
<td>Distal 1/4</td>
<td>22.6 (±4.48)</td>
<td>33.4</td>
</tr>
<tr>
<td>4cm from the pylorus</td>
<td>22.3 (±4.65)</td>
<td>29.7</td>
</tr>
<tr>
<td>3cm from the pylorus</td>
<td>21.6 (±4.47)</td>
<td>23.6</td>
</tr>
<tr>
<td>2cm from the pylorus</td>
<td>21.5 (±4.23)</td>
<td></td>
</tr>
<tr>
<td>1cm from the pylorus</td>
<td>20.2 (±2.34)</td>
<td></td>
</tr>
</tbody>
</table>

* Indistinguishable normo- and anti-peristalsis

**Table 2. Contraction pressure of the pyloric ring**

<table>
<thead>
<tr>
<th>Level of transection</th>
<th>Mean contraction pressure (cm H₂O)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normo-peristalsis</td>
</tr>
<tr>
<td>Control</td>
<td>4.6</td>
</tr>
<tr>
<td>Proximal 1/3</td>
<td>4.2</td>
</tr>
<tr>
<td>1/2</td>
<td>6.6</td>
</tr>
<tr>
<td>Distal 1/3</td>
<td>9.0</td>
</tr>
<tr>
<td>Distal 1/4</td>
<td>8.4</td>
</tr>
<tr>
<td>4cm from the pylorus</td>
<td>8.0</td>
</tr>
<tr>
<td>3cm from the pylorus</td>
<td>5.5</td>
</tr>
<tr>
<td>2cm from the pylorus</td>
<td></td>
</tr>
<tr>
<td>1cm from the pylorus</td>
<td></td>
</tr>
</tbody>
</table>

* Indistinguishable normo- and anti-peristalsis
The average contraction pressure at the pylorus during normo-peristalsis was 4.6 cm H$_2$O, whereas that during anti-peristalsis was 5.4 cm H$_2$O. Thus there was a tendency toward pressure elevation during anti-peristalsis (Table 2).

**B) Motor function of canine stomach following transection-anastomosis**

The motor function of the canine stomach following transection-anastomosis was compared with the unoperated stomach as a control with the aid of electromyography and manometry (Fig. 5).

1) **Transection-anastomosis at the proximal 1/3 level.** When the stomach was transected and anastomosed at the proximal 1/3 level, no peristalsis occurred in the part oral to anastomosis, but near-normal peristalsis appeared at the point about 1 cm distal to the line of anastomosis and propagated distally toward the pylorus with corresponding spikes and contraction pressure (Fig. 5-‡U).

In 2 out of 8 cases of this group, anti-peristaltic discharges were noted. The average incidence of anti-peristaltic discharges in all discharges was 4.8%. Anti-peristalsis also had a longer discharge interval (18.8 sec) than normo-peristalsis (14.7 sec), and no significant deviation was shown between the control and the proximal 1/3 transection cases (Table 1).

The same trend was noted in contraction pressures at the pyloric ring; 4.2 cm H$_2$O in normo- and 4.3 cm H$_2$O in anti-peristalsis (Table 2).

2) **Transection-anastomosis at the 1/2 level.** In transection-anastomosis at the 1/2 level, the upper part of the stomach did not elicit any recognizable peristaltic motion following the operation, but the distal part did show normo-peristalsis occurring just distal to the line of anastomosis traveling regularly toward the pylorus with the same frequency as the control stomach. Their spike discharges were slightly longer in interval and the contraction pressure was slightly higher than those of the control (Fig. 5-‡V).

In 2 out of 8 cases of this group, anti-peristaltic discharges were noted. The average incidence of anti-peristaltic discharges in all discharges was 24.7%, which were much higher than those of the control and the proximal 1/3 groups. The mean discharge interval of anti-peristalsis (21.1 sec) was longer than that of normo-peristalsis (16.2 sec).

The mean contraction pressures of the pylorus were 6.6 cm H$_2$O during normo-peristalsis, and 7.4 cm H$_2$O during anti-peristalsis, both values being higher than those in the control and the proximal 1/3 group (Table 2).

3) **Transection-anastomosis at the level of distal 1/3.** Following transection-anastomosis at the level of distal 1/3, normo-peristalsis was observed in the portion oral to the anastomotic line, and its frequency was either the same as or slightly lower than that of the control.

Two types of peristalsis were noted in the portion distal to the anastomotic line; one was normo-peristalsis originating at the site just distal to the line to propagate toward the pylorus with longer intervals than peristalsis in the portion
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Fig. 5. Contraction pressure curves, electromyograms and levels of transection.

I ; Control
II ; Proximal 1/3
III ; 1/2
IV ; Distal 1/3
V ; Distal 1/4
VI ; 4 cm from the pyloric ring
VII ; 3 cm from the pyloric ring
VIII ; 2 cm from the pyloric ring
IX ; 1 cm from the pyloric ring
A; Contraction pressure curves at the pyloric ring
B; Electromyograms taken at 2 cm proximal to the pyloric ring
C; Electromyograms taken at the pyloric ring

oral to the anastomotic line, and the other was the strongly contracting anti-peristalsis starting near the pyloric ring and ascending toward the line of anastomosis (Fig. 5–IV). Anti-peristaltic discharges were noted electromyographically in 5 of the 8 dogs of this group. The incidence of anti-peristaltic discharges in all discharges was 52.6%. The mean discharge intervals were 24.0 sec and 27.2 sec in normo- and anti-peristalses, respectively (Table 1).

The average pyloric contraction pressures were 9.0 cm H₂O in normo- and 9.3 cm H₂O in anti-peristalses, and were more markedly elevated than those of the control, proximal 1/3, and 1/2 groups (Table 2).

4) Transection-anastomosis at the level of distal 1/4. In the part above the distal 1/4 transection line normo-peristaltic discharges occurred at a frequency nearly equal to or lower than that of the control stomach.

In the part below the transection line, however, 6 of the 8 dogs of this group showed anti-peristaltic discharges. The incidence of anti-peristaltic discharges was 66.6% in all discharges. This value was higher than that of the distal 1/3 group. The average discharge interval of anti-peristalsis was 24.6 sec which was longer than 22.6 sec of normo-peristalsis (Table 1).

The average values of contraction pressure during normo-peristalsis were 8.4 cm H₂O and 8.7 cm H₂O during anti-peristalsis and were lower than those of the distal 1/3 group but still higher than those of the other groups (Table 2 and Fig. 5-V).
5) Transection-anastomosis at the level 4 cm proximal to the pyloric ring. Transection-anastomosis at the level 4 cm oral to the pylorus was followed by normoperistalsis of normal discharge interval in the part proximal to the line of anastomosis. On the other hand, 6 out of 8 dogs showed anti-peristalsis in the portion distal to the line. The average incidence of anti-peristaltic discharges in all discharges was 70.3%. No significant difference from the distal 1/4 group was found in the average discharge intervals of this group, the intervals being 22.3 sec for normo- and 24.1 sec for anti-peristalses. It was noted also that the interval of anti-peristaltic discharge in this group had a tendency toward prolongation as compared with that of normo-peristalsis (Table 1 and Fig. 5-VI).

The average values of contraction pressure of the pyloric ring were 8.0 and 8.3 cm H₂O during normo- and anti-peristalses, respectively. These values were lower than those of the distal 1/3 and distal 1/4 transection groups, but higher than those of the control and the groups of more proximal transection (Table 2).

6) Transection-anastomosis at the level 3 cm proximal to the pylorus. The transection-anastomosis at the level 3 cm proximal to the pylorus evoked normoperistalsis almost similar in its pattern to that of the control in the part proximal to the line of anastomosis, and anti-peristalsis in the distal part was noted in all 8 dogs of this group. The incidence of anti-peristaltic discharges was 76.4% of all discharges. The average rates of discharge intervals were 21.6 sec for normo- and 23.8 sec for anti-peristalses, which were about the same as those of groups of the distal 1/4 and 4-cm-from-pylorus transection, but shorter than that of the distal 1/3, and longer than those of the groups of more distal transection. The discharge interval of anti-peristalsis was longer than that of normo-peristalsis in this group, too (Table 1 and Fig. 5-VII).

The average contraction pressures at the pylorus were 5.5 cm H₂O in normo- and 5.6 cm H₂O in anti-peristalses, which were lower than those of the 4-cm-from-pylorus and distal 1/3 groups, but higher than those of the control and proximal 1/3 groups. The contraction pressure of anti-peristalsis exceeded that of normo-peristalsis (Table 2).

7) Transection-anastomosis at 2 cm proximal to the pylorus. Eight dogs were included in this group. Transection-anastomosis at 2 cm from the pylorus brought about normal or slightly prolonged peristaltic motion in the part above the transection line, but the entire antral portion below the line contracted at the same time and made it difficult to differentiate normo- from anti-peristalsis not only grossly but also myographically.

The average discharge interval at the pylorus was 21.5 sec and was shorter than those of the groups of transection below the distal 1/3, but more prolonged than those in the groups of transection more proximal than 1/2 and the control (Table 1 and Fig. 5-VIII).

The average contraction pressure of 5.0 cm H₂O was higher than those of
the control and proximal 1/3 groups, but obviously lower than those in other groups (Table 2).

8) Transaction-anastomosis at the level 1 cm proximal to the pylorus. Normo-
peristaltic motion similar to the control occurred in the part above the transection
line 1 cm from the pylorus, whereas discharges, which were neither grossly nor
myographically identifiable, occurred in the portion distal to the line of anastomosis.

The average discharge interval in all 8 dogs of this group was 20.2 sec on the electromyogram in the part distal to the transection line, and did not differ greatly from that of the 2-cm-from-pylorus group (Table 1 and Fig. 5-IX). The pyloric ring contraction averaged 3.4 cm H₂O in pressure and was lower than the pressure of any other groups including the control (Table 2).

In summary, a higher contraction pressure of the pylorus was obtained during anti-peristalsis than during normo-peristalsis (Fig. 4 and Table 2), but the height of contraction pressure differed according to the level of transection-anastomosis. The contraction pressure during both normo- and anti-peristalses after proximal 1/3 transection was close to the control value, but it was moderately higher than
the control value after 1/2 transection, and highest after distal 1/3 transection. The elevated contraction pressure was recorded until the transection line reached 4 cm from the pyloric ring. Beyond the limit the pressure decreased gradually as the transection lines approached the pylorus. The transection at a level 3 cm from the pylorus showed an obvious depression in contraction pressure as compared with one of 4 cm from the pylorus, but contraction pressure was close to the control value after transection at 2 cm from the pylorus. Transection at 1 cm from the pylorus elicited subnormal pressure (Figs. 5, 6 and Table 2). Thus the contraction pressure of the pylorus was closely related to the amount of the remnant antrum.

As to anti-peristaltic discharge, which suggests increased motor function of the pylorus, only a slight increase in its incidence was noted in the 1/2 transection group, and a moderate increase in the distal 1/3 and distal 1/4 transection groups, but the most frequent anti-peristalsis was seen in the 3-cm-from-pylorus group.

The discharge interval of anti-peristalsis was longer than that of normo-
peristalsis (Fig. 4 and Table 1), but both of them showed similarly prolonged or shortened patterns when the level of transection was the same. In the proximal 1/3 group, therefore, the discharge interval was almost equal to that of the control group, but that of 1/2 transection group was slightly longer than that of the control. While the discharge interval of the distal 1/3 transection group was prolonged, the groups between distal 1/4 and 1-cm-from-pylorus lines showed a distinct prolongation, although there was a tendency toward shortening as the transection line approached the pylorus (Figs. 5, 7 and Table 1).
DISCUSSION

The present study revealed that the transection-anastomosis at various levels of the canine stomach caused stronger peristaltic motion with prolonged discharge interval, more frequent anti-peristalsis in the portion distal to the anastomosis and an increase in contraction pressure of the pylorus. In the part proximal to transection, however, normo-peristalsis prevailed and no obvious differences were noted in its discharge interval and in its excitability before and after transection. These electromyographic findings coincide well with the experimental data reported by Sugawara,¹ and Shiratori et al.,²,³ and seem to explain the reason why pylorospasm and retention of the gastric content occur in daily practice of surgery.
after gastric resections with pyloric antrum left behind. Shiratori et al. were of the opinion that the pylorospasm and passage disturbance at the pylorus might not be due to section of the vagus nerves but due to transection of the wall of the stomach itself. Their findings and the fact that 'the lower the line of transection of the stomach, the more often was the incidence of anti-peristalsis' led us to conclude the presence of some controlling mechanism in the upper part of the stomach over the lower part and the existence of pace makers of normo- and anti-peristalses in different parts of the stomach, as had been pointed out by Sugawara, Shiratori et al. and Shiratori.

As stated above, the contraction pressure of the pylorus, the discharge interval and the incidence of anti-peristalsis did not differ much from those of the control group after transections above the 1/2 line, but transections between the distal 1/3 and 4 cm from the pyloric ring showed further elevation in contraction pressure, prolongation in the discharge interval and increase in the incidence of anti-peristalsis. In the groups distal to the level of 4 cm from the pyloric ring, a dissociation of each factor occurred; the contraction pressure decreased markedly, the discharge interval was shortened slightly and the incidence of anti-peristalsis increased gradually. In other words, the contraction pressure decreases as the level of transection approaches the pyloric ring, even if the myogram shows the excitation of the musculature of the pylorus.

This dissociation of myographic hyperactivity and reduced contraction pressure was explained as follows. The myograph was interpreted as a record of action potentials of the muscle in a limited area around the electrode. On the other hand, the contraction pressure in this experiment seemed to be dependent on the breadth of the remaining antrum. Therefore, when the line of transection approached the pyloric ring, an outstanding diminution in contraction pressure of the pylorus could be seen because of a decrease in the area of the remaining antral portion in spite of excitation.

It is clear from the present experiments that the contraction pressure of the pylorus, that may play an important role in inducing passage disturbance at the pylorus, is lowest when the transection is limited between 1.5 and 2 cm proximal to the pyloric ring. This result provides the theoretical ground for Maki's pylorus-preserving gastrectomy in which the pylorus is preserved from 1.5 to 2 cm from the pyloric ring. We have never encountered rapid emptying or pylorospasm necessitating an additional drainage procedure at the pylorus in the 58 cases operated upon in our department.

Transection in the corpus of the stomach resulted in unchanged or only slightly increased hyperactivity of the pylorus, while transection at the border-line between the corpus and antrum of the stomach caused a sharp increase in motor function of the pylorus. It was suggested that the antrum was regulated by the stimuli from the proximal portion of the stomach. The reason of enhanced excitation of the pylorus after distal transections was sought in the weakening or interruption of the regulation from the upper part of the stomach. This hyper-
activity can also be clinically observed as pylorospasm after proximal or segmental gastric resection.

References


