Effects of Resection of Celiac and Pyloric Branches of Vagus Nerve on the Interdigestive Motor Activity of the Upper Digestive Tract and Biliary Tree

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Abstract

It has been reported that interdigestive motor activities occur in the gallbladder and sphincter of Oddi as well as in the gastroduodenal tract and truncal vagus nerves modulate the gastroduodenal motility pattern. In the present study, the vagal branches which influence on the interdigestive motor activity of these organs were determined in conscious dogs. In the normal dog, interdigestive motor activities closely related to interdigestive migrating motor complex (IMC) in the gastric antrum and descending duodenum were recorded in the gallbladder and sphincter of Oddi. In dogs whose celiac branches of the vagus nerve were chronically resected, cycle periods of interdigestive motor activity in the stomach, duodenum, gallbladder and sphincter of Oddi significantly prolonged as compared with those in the normal dog but the interrelation of them persisted. Quiescent period in motility prolonged and the active period shortened. Resection of the pyloric branches had no influence on the interdigestive motor activities in all organs. The results imply that celiac branches of the vagus nerve modulate the interdigestive motor activity in the stomach, descending duodenum, gallbladder and sphincter of Oddi.

Key words: interdigestive motor activity, upper digestive tract, biliary tract, vagus nerve, dog

Introduction

It has been demonstrated that interdigestive migrating myoelectric or motor complexes (IMCs) cyclically occur in the gastrointestinal tract during interdigestive state at periods of about 100 min in dogs, humans, and most mammals (Sarna, 1985). In the biliary system, recurring tonic and phasic contractions of the gallbladder which correspond to phase III of gastroduodenal IMC has been observed in the dog (Itoh and Takahashi, 1981; Matsumoto et al., 1985). Cyclic activity of the sphincter of Oddi during interdigestive state was also reported in the opossum (Honda et al., 1982, 1983) and the dog (Scott et al., 1988).

It is known that IMCs are initiated by motilin, which is released at constant intervals during the interdigestive state (Itoh et al., 1976, 1977, 1978; van Lier Ribbink et al., 1989). Intrinsic cholinergic mechanism may also be important for initiation of IMC (You et al., 1980; Sarna et al., 1981).
It appears that extrinsic innervation is not essential for the initiation of IMC in the gastrointestinal tract (Itoh et al., 1981; Gleysteen et al., 1985; Spencer et al., 1989; Van Lier Ribbink et al., 1989). However, truncal vagus nerves may modulate the timing of initiation and duration of IMC: Transthoracic truncal vagotomy reduced incidence of cycles and duration of phase III of IMC recurring in the stomach and small intestine in the dog (Marik et al., 1975). It is not clear which branches of abdominal vagus influence IMC pattern.

In the biliary system, regulation of the interdigestive motor activity of the gallbladder and sphincter of Oddi by vagus nerve has not been studied.

The aim of the present study is to evaluate a role of celiac and pyloric branches on the interdigestive motor activity in the stomach, duodenum, gallbladder and sphincter of Oddi.

**Methods**

Fifteen healthy adult mongrel dogs of both sexes weighing 5 to 10 kg were used. Dogs were housed in an individual cage and fed once a day with dry-typed meal (Oriental Yeast, DS) at 9:00 AM. Water was given freely. Under pentobarbital sodium anesthesia (25 mg/kg, i.v.), strain-gauge force transducers (Star Medical) were chronically sutured onto the serosa at the gastric antrum 3 cm oral to the pyloric ring, the descending duodenum contralateral to the orifice of the common bile duct in a direction to detect circular muscle contraction and the neck of the gallbladder in a direction to detect shortening of the circular direction by muscle contraction (Fig. 1). A longitudinal small incision was made at a mid portion of the common bile duct and two vinyl catheters with outer diameter of 2 mm (Atom) were inserted into the common bile duct to direction of the sphincter of Oddi and hepatic duct. The tip of the catheter directed to the sphincter was positioned at 5 mm proximal to the choledochoduodenal junction and the tip of the another catheter directed to the hepatic duct was positioned at 5 mm proximal to the choledochoduodenal junction.

Fig. 1. Arrangement for recording motility. Strain-gauge transducers were sutured at antrum (T1), descending duodenum (T2), gallbladder (T3). The catheters, C1 to record pressure change of sphincter of Oddi and C2 to evacuate a bile were inserted into the common bile duct.
proximal from the incision (Fig 1). Both catheters were crossed along running way of the common bile duct and ligated tightly. Lead wires of the transducers and catheters were taken out from the abdominal cavity through stab wounds on the lateral abdominal wall and brought out through a skin incision made between the scapula through subcutaneous tunnels on the lateral costal flank. The outer ends of the lead wires and catheters were sutured onto the skin adjacent to the skin incision. The lead wires connected with a connector. The connector was fixed on the protective jacket. Two catheters inserted in direction to the sphincter of Oddi and to the hepatic duct were connected each other when motility recording of the sphincter was not performed. By this procedure, bile allowed to discharge into the duodenum through the sphincter of Oddi.

To study the influence of the vagus branches on interdigestive motor activity, dogs were classed three groups. In Group 1 dogs, vagal innervation was left intact. In Group 2 dogs, celiac blanches of the vagus nerve which entered to the celiac and superior mesenteric ganglia were ligated with silk thread at 1 and 2 cm central to the ganglia and 5 mm long segment was then resected between the ligatures. In Group 3 dogs, innervation of the pyloric blanches of the vagus were blocked by means of resection of the ventral and dorsal major gastric nerves adjacent to the ramification of the pyloric blanches.

After three weeks recovery time from the operations, motility recordings were carried out. Before recordings, dogs were fasted for 24 hrs but water was given freely. Connecting cables from amplifiers and a low elastic vinyl tube from the infusion pump were hung from the ceiling just above the dog with an gum tube. The tube was fixed with jacket. A cable connector and lead connector from transducers was put in each other. A tube from infusion pump was also connected with the catheter inserted to the sphincter of Oddi. A catheter inserted to the cystic duct was lead to a reservoir by supplemental tube. Thus, bile excretion was done through this tube during motility recordings.

Motility of the stomach, duodenum and gallbladder was recorded on a multi-channel recorder (San-Ei, Recti-Horiz 8S) through strain amplifier (Star-Medical, FS-04M). The sphincter of Oddi was infused with physiological saline at a rate of 0.12 ml/min by an infusion pump (Nakagawa, model Truth A-II). A pressure change produced by contractions of the sphincter of Oddi was also recorded by a pressure transducer (Nihon Koden model DX-312) inserted in the infusion system. Motility was recorded at least 4 times at interval of one week in an individual dog.

Cycle periods and durations of each phase of interdigestive motor activities were measured in an individual dog of each group and expressed as mean±S.E., and n represents the number of recordings. Statistical comparisons were made using unpaired student t test. Differences in means were considered significant when p<0.05.

Results

Interdigestive motility pattern in the normal dogs

In group 1, normal dogs, interdigestive motor activity cyclically occurred in all five dogs examined. Motility patterns of the antrum, descending duodenum, gallbladder and sphincter
of Oddi during the interdigestive state were shown in Fig. 2. In this group, each phase of IMC (phase I to phase IV) was clear in the gastric antrum and the descending duodenum. Interdigestive motor activities, which were closely related with IMC of the antrum and duodenum, were also occurred in the gallbladder and sphincter of Oddi. From inspection, the pattern of the sphincter of Oddi motor activity was divided into three phases (phase A-C). Phase A demonstrated a motility quiescent period. Phase B showed a period with irregular contractions and phase C was represented by a regular phasic contractions with large amplitude. Motility patterns of phase A to C corresponded to phase I to phase III of IMC of the stomach, respectively. Interdigestive motility pattern in the gallbladder was divided into two phases (phase 1 and 2) Phase 2 showed baseline pressure increase superimposed with phasic contractions and occurred during phase II and III of IMC of the stomach. Phase 1 showed a period without phasic and tonic contractions and occurred during phase I of IMC of the stomach.

As shown in Table 1, cycle periods of interdigestive motor activity of the stomach and duodenum, and the gallbladder and sphincter of Oddi were similar (about 100 min in each organ).

Duration of each phase of the interdigestive motor activity in the stomach, duodenum, gallbladder and sphincter of Oddi was shown in Table 2. Durations of phase I, II and III+IV in the duodenum were similar to those in the stomach. Durations of phase B and C in the

![Fig. 2. Interdigestive motor activity of stomach (S), duodenum (D), gallbladder (GB) and sphincter of Oddi (SO) in normal dog. Recordings were carried out at three weeks after operation. In all organs, interdigestive motor activity recurred at intervals of about 100 min.]

<table>
<thead>
<tr>
<th>Organ</th>
<th>Normal (n=20) mean ± S.E.</th>
<th>Celiac branch resected (n=19) mean ± S.E.</th>
<th>Pyloric branch resected (n=15) mean ± S.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stomach</td>
<td>97.8 ± 4.9 min</td>
<td>132.6 ± 8.8** min</td>
<td>89.2 ± 2.9 min</td>
</tr>
<tr>
<td>Duodenum</td>
<td>98.0 ± 5.1</td>
<td>131.9 ± 8.7**</td>
<td>92.0 ± 3.1</td>
</tr>
<tr>
<td>Oddi's sphincter</td>
<td>93.4 ± 5.4</td>
<td>137.4 ± 8.3***</td>
<td>91.2 ± 6.2</td>
</tr>
<tr>
<td>Gallbladder</td>
<td>98.3 ± 4.7</td>
<td>142.6 ± 8.2***</td>
<td>96.0 ± 3.9</td>
</tr>
</tbody>
</table>

** and ***, P < 0.01 and < 0.001 as compared with normal dog.
sphincter of Oddi were similar to those of phase II and III+IV in the stomach but duration of phase A was shorter than that of phase I in the stomach ($P<0.001$). Durations of the gallbladder phase 1 and 2 were approximately same as those of phase I and phase II+III+IV in the stomach, respectively.

Delays of the onset time of phase III in the duodenum and phase C in the sphincter of Oddi from that of phase III in the stomach were $3.3\pm0.3$ min ($n=20$) and $5.3\pm0.4$ min ($n=20$), respectively. A delay of the onset time of phase 2 in the gallbladder from that of phase II in the stomach was $1.4\pm0.4$ min ($n=20$).

**Interdigestive motility after resection of celiac branches of the vagus nerve**

In group 2 dogs whose celiac branches of the vagus nerve were chronically resected, interdigestive motor activity in the stomach and descending duodenum and the gallbladder and sphincter of Oddi was also induced cyclically (Fig. 3). The order of the onset time of each phase between organs was approximately the same as that in normal dogs. Delays of the onset time of phase III in the duodenum and phase C in the sphincter of Oddi were $3.9\pm0.4$ min ($n=19$) and $3.6\pm0.2$ min ($n=13$) min. A delay of the onset time of phase 2 in the gallbladder from phase II in the stomach was $1.7\pm0.5$ min ($n=16$).

As shown in Table 1, cycle periods of IMC in the stomach and duodenum and of interdigestive motor activity in the gallbladder and sphincter of Oddi were significantly lengthened as compared with those in the normal dog. Durations of phase I in the stomach and duodenum, phase A in the sphincter of Oddi and phase 1 in the gallbladder were prolonged but durations of phase II in the stomach, phase II and III+IV in the duodenum, phase A in the sphincter of Oddi and phase 2 in the gallbladder were shortened (Table 2).

In addition to interdigestive motility pattern as observed in normal dogs (group 1), strong contractions compared with phase III of the stomach and duodenum, phase C of the sphincter

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**Fig. 3.** Interdigestive motor activity of stomach (S), duodenum (D), gallbladder (GB) and sphincter of Oddi (SO) in the dog whose celiac branches of vagus nerve were resected at three weeks before this recordings. Cycle period of interdigestive motor activity in each organs was about 140 min. The period was significantly longer than that in the normal dog. In addition, extra-contractions (EC) during silent phase of interdigestive motor cycles were suddenly occurred in stomach, duodenum, gallbladder and sphincter of Oddi.
Table 2. Duration of each phase of interdigestive motor activity in the stomach, duodenum, Oddi's sphincter and gallbladder in normal, celiac and pyloric branch-resected dogs

<table>
<thead>
<tr>
<th>Phase</th>
<th>Normal mean±S.E. (n=20)</th>
<th>Celiac branch resected mean±S.E. (n=19)</th>
<th>Pyloric branch resected mean±S.E. (n=15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stomach Phase I</td>
<td>25.7±2.2 min</td>
<td>87.2±7.3*** min</td>
<td>22.0±2.1 min</td>
</tr>
<tr>
<td>Phase II</td>
<td>57.6±4.4</td>
<td>29.4±5.1***</td>
<td>48.2±3.3</td>
</tr>
<tr>
<td>Phase III±IV</td>
<td>14.5±0.9</td>
<td>16.3±1.4</td>
<td>19.1±1.9*</td>
</tr>
<tr>
<td>Duodenum Phase I</td>
<td>26.3±2.6</td>
<td>85.4±7.0***</td>
<td>23.0±2.1</td>
</tr>
<tr>
<td>Phase II</td>
<td>57.2±3.7</td>
<td>34.8±5.3**</td>
<td>51.9±2.8</td>
</tr>
<tr>
<td>Phase III+IV</td>
<td>16.3±1.7</td>
<td>11.7±0.7*</td>
<td>17.2±1.2</td>
</tr>
<tr>
<td>Oddi’s sphincter</td>
<td>(n=20)</td>
<td>(n=19)</td>
<td>(n=17)</td>
</tr>
<tr>
<td>Phase A</td>
<td>15.1±1.0</td>
<td>82.4±6.9***</td>
<td>15.1±1.3</td>
</tr>
<tr>
<td>Phase B</td>
<td>60.9±6.1</td>
<td>38.2±6.8*</td>
<td>57.4±3.6</td>
</tr>
<tr>
<td>Phase C</td>
<td>17.5±2.1</td>
<td>16.8±1.6</td>
<td>23.6±2.2*</td>
</tr>
<tr>
<td>Gallbladder Phase 1</td>
<td>(n=20)</td>
<td>(n=16)</td>
<td>(n=16)</td>
</tr>
<tr>
<td>Phase 2</td>
<td>73.3±4.3</td>
<td>50.0±5.6**</td>
<td>70.5±3.8</td>
</tr>
</tbody>
</table>

*, ** and *** P<0.05, <0.01, <0.001 as compared with normal dog

of Oddi and phase 2 of the gallbladder were abruptly induced in all of group 2 dogs (Fig. 3). Occurrence of this motility pattern may also prolonged a cycle period of interdigestive motor activity. Interdigestive motility after resection of pyloric branches of the vagus.

**Interdigestive motility after resection of pyloric branches of the vagus nerve**

In group 3 dogs whose pyloric branches of the vagus were chronically resected, interdigestive motor activity in the stomach, duodenum, gallbladder and sphincter of Oddi were induced cyclically with similar period to those in the normal dogs (P>0.05) (Fig. 4 and Table 1).

![Graphs showing interdigestive motor activity](image)

Fig. 4. Interdigestive motor activity of stomach (S), duodenum (D), gallbladder (GB) and sphincter of Oddi (SO) in the dog whose pyloric branches were resected at three weeks before this recordings. Motility patterns were similar to those in the normal dog.
Durations of each phase in each organs were also similar to those in normal dogs, except for slight prolongation of phase III in the stomach and phase C in the sphincter of Oddi (Table 2). Delays of the onset time of phase III in the duodenum and phase C in the sphincter of Oddi were 4.8±0.4 min (n=17) and 7.5±0.8 min (n=16). A delay of the onset time of phase 2 in the gallbladder from phase II in the stomach was 1.1±0.3 min (n=16).

Discussion

The present findings redemonstrated that cyclic motor activities of the gallbladder and sphincter of Oddi whose periods were closely related to those of interdigestive motor activity induced in the stomach and descending duodenum as reported by the other investigators (Scott et al., 1988). It is revealed from the present results that vagus nerves, especially their celiac branches modulate the interdigestive motor activity in the gastroduodenal tract and the gallbladder and sphincter of Oddi.

The influence of the vagus nerve on IMC of the canine stomach and small intestine is controversial: Blockade of the cervical vagi by cooling abolished gastric IMC but did not change the intervals of phase III activity of the duodenum (Hall et al., 1982; Chung et al., 1987). Blockade of diaphragmatic vagi did not change the intervals of both gastric and duodenal IMC (Gleysteen et al., 1985). Chronic section of the thoracic vagi reduced cycles of IMC and shortened duration of phase III activity (Marik et al., 1975) while it had no influence on the IMC pattern in the stomach and duodenum (Weisbrodt et al., 1975). The present results showed that chronic resection of celiac branches of the vagus resulted in the prolongation in durations of quiescent period in the stomach, duodenum, gallbladder and sphincter of Oddi and shortening in duration of contractile phase in these organs. However, interrelation of cyclic motor activities in these organs persisted even after resection of celiac branches of the vagus nerve. On the other hand, resection of pyloric branches had no significant influence on the interdigestive motor activity. Therefore, it is suggested that celiac branches of the vagus is not essential to initiation of the interdigestive motor activities but play a role to increase in frequency of recurring motor activity during interdigestive state not only in the stomach and duodenum but also in the gallbladder and sphincter of Oddi.

Marlett et al. (1979) reported that IMC patterns of the stomach and small intestine persisted after celiac and superior mesenteric ganglionectomy while cycle periods of the IMC became irregular and lengthened after ganglionectomy. In this case, gastrointestinal innervation of not only vagus nerves but also splanchnic nerves was disrupted by celiac and superior mesenteric ganglionectomy. In the present experiments, elective resection of vagal branches entering the celiac and superior mesenteric ganglia prolonged a cycle period of interdigestive motor activity in the stomach and duodenum. Thus, it is considered that vagal nerves passing through the celiac and superior mesenteric ganglia changed period of IMC in the experiments by Marlett et al. (1979).

It is concluded that celiac branches of the vagus nerve is not essential to initiate interdigestive motor activities in the stomach, duodenum, gallbladder and sphincter of Oddi but modulate their cycle periods.
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