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Experimental Study of Pylorus and Pyloric Vagus Preserving Gastrectomy

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In an attempt to prevent the sequelae of conventional gastrectomy, such as rapid gastric emptying, dumping syndrome, intestinal content reflux, indigestion, and poor absorption, we have devised the pylorus and pyloric vagus preserving gastrectomy (PPVPG). Experimenting on 48 dogs, we found theoretic grounds for using our design and obtained the desired effects—retaining the merits of conventional subtotal resection of the stomach, with acidity reduction, while avoiding the above-mentioned complications.

The purposes of the study were threefold: (1) to design and master a new surgical technique (pylorus and pyloric vagus preserving gastrectomy, or PPVPG); (2) to record the electromyogram of smooth muscle action potentials and the intraluminal pressure changes caused by it so as to observe the vagal effect on the pyloric sphincter; and (3) to conduct a comparative study between PPVPG and the Billroth I and II operations in terms of changes in body weight, gastric emptying time, intestinal content reflux, reduction of gastric acidity, and histologic alterations. We hoped to collect data that could be applied to clinical application of this operation.

Materials and Methods

Forty-eight hybrid dogs, disregarding sex difference, with body weight 15 to 25 kg, were divided randomly into four groups: group A—Billroth I; group B—Billroth II; group C—PPVPG; group D—controls. Under ketamine anesthesia, 70% of the stomach was resected in the first three groups, and then different anastomosis modes were performed. In the control group, laparotomy was done without gastric resection. In all four groups the gastric fluid and tissue were examined pathologically, and electromyography of smooth muscle was done and intraluminal pressure changes measured. Each dog's body weight, free gastric HCl, total gastric acid, gastric pH, and gastric concentrations of sodium and cholic acid were determined before and after the operation.

PPVPG Technique

The operation starts by dissecting the large curve from a point 2 cm above the pylorus to the last two branches of the left gastroepiploic artery. On the small curve, the dissection is done close on the gastric wall; the anterior and posterior vagal trunks, hepatic branches, and the last two branches of the Latarjer vagus innervating the pyloric region are carefully preserved; only the vagus branches innervating the body of the stomach are selectively excised. With the upper part of the stomach cut off, the small curve is closed in one layer; 3 cm on the large curve is reserved for anastomosis. The remaining antral mucosa is removed by incising, in a concave shape, the antral seromuscular layer from the small curve to the large curve above a point where Latarjer nerves are preserved; also incised is the proximal mucosa 0.7 to 0.8 cm away from the pyloric ring. The distal mucosa is anastomosed to all layers of the large curve, and the antral seromuscular flap is attached to the vagus branches, sutured at the anastomosed point (Fig. 1).

Effect of Vagus on Pyloric Sphincter

Electromyography of the canine smooth muscle action potential was done, and the intraluminal pressure was measured with the help of a bipolar electrode and a water bag sensor; it was traced by a two-channel physical recorder (Fig. 2). Figure 2, I shows the electromyogram and intraluminal pressure curves with the antrum mucosa stripped and the remaining seromuscular flap formed into a cecus embedded with a water bag sensor. It can be seen that an action potential is immediately followed by a rhythmic stomach contraction. Figure 2, II shows the curves after PPVPG; they resemble those of the control group (Fig. 2, III), demonstrating that rhythmic sphincter action is preserved by retaining the pyloric vagus.

Resection of the pyloric vagus (Fig. 3) results in: (1) the action potential of smooth muscle decreasing significantly (8–12 times lower than normal); (2) asynchronous action between potential and contraction; and (3) frequent spastic contraction of the pylorus. The spastic contraction was apparently caused by the action of the intramural nerve plexus or the automatic rhythm of the smooth muscle—not by the action potential of the vagus.

Table 1 shows the effects of the preserved or resected pyloric vagus on the electromyogram and on intraluminal pressure. Observations of this experiment show that the action of the pyloric vagus:

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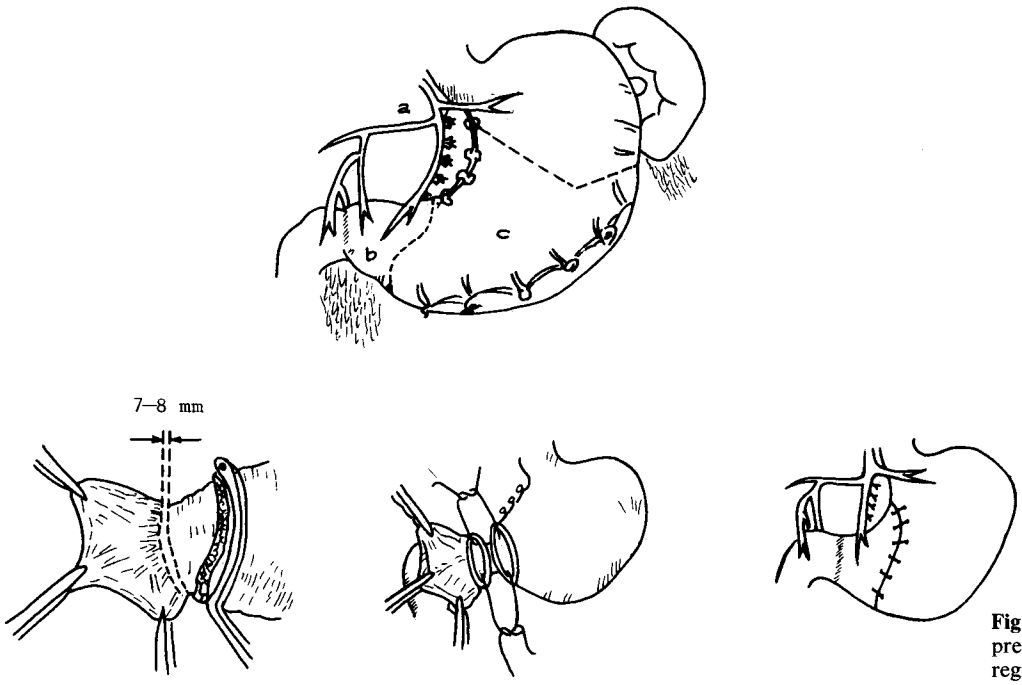

Fig. 1. Schema of PPVPG. a: vagus preserved; b: antrum mucosa stripped region; c: stomach resection region.

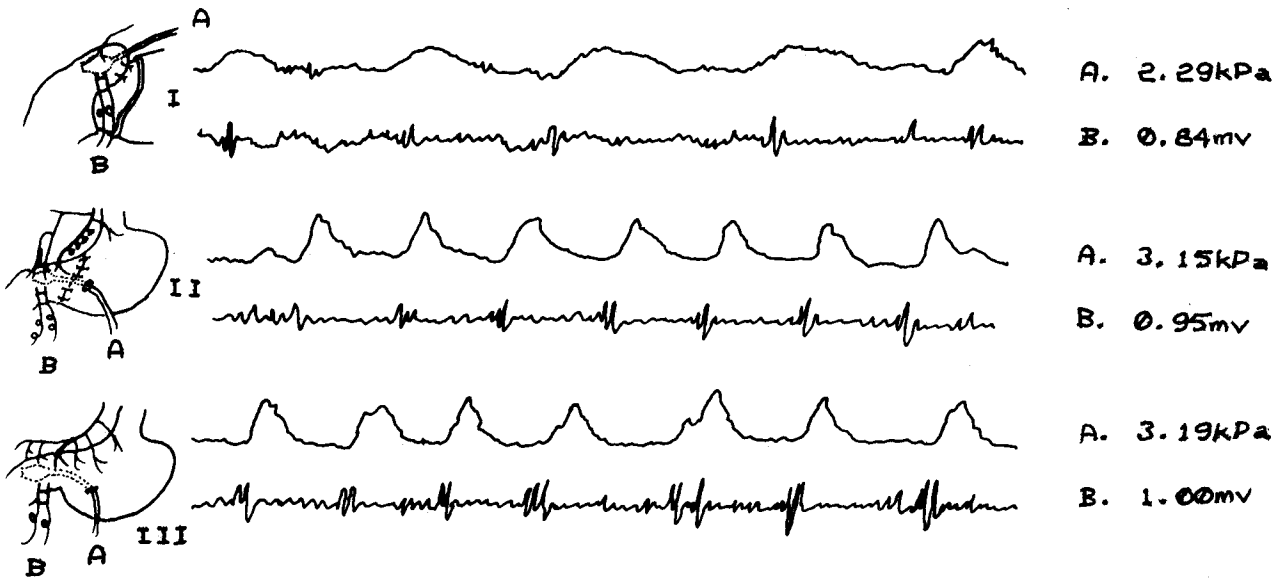

Fig. 2. Electromyogram and intraluminal pressure. A: intraluminal pressure; B: electromyogram; I: sutured antrum seromuscular flap; II: post-PPVPG; III: control group.

1. Has something to do with the action potential of the smooth muscle, speeding up the spread of the basic electrical rhythm (slow wave), thereby facilitating formation of the action potential and initiating the rhythmic contraction of the stomach. Spastic contraction of the stomach after resection of the vagus is not started by the action potential and hence is not rhythmic; it is apt to result in delaying gastric emptying and retaining gastric fluid.
2. Gives rise to the action potential of the smooth muscle and contraction of the stomach (the waves of the two are synchronized) and it makes the contraction and diastole of the stomach rhythmic by regulating their range and frequency; moreover, the pyloric sphincter opens and closes whenever necessary, facilitating gastric emptying. The physiologic function of the sphincter cannot be effectively preserved without having the pyloric vagus preserved.

Statistical Treatment

Comparison of polynomials was checked by the fourfold table probability test or the χ test and others by the t-test or corrected

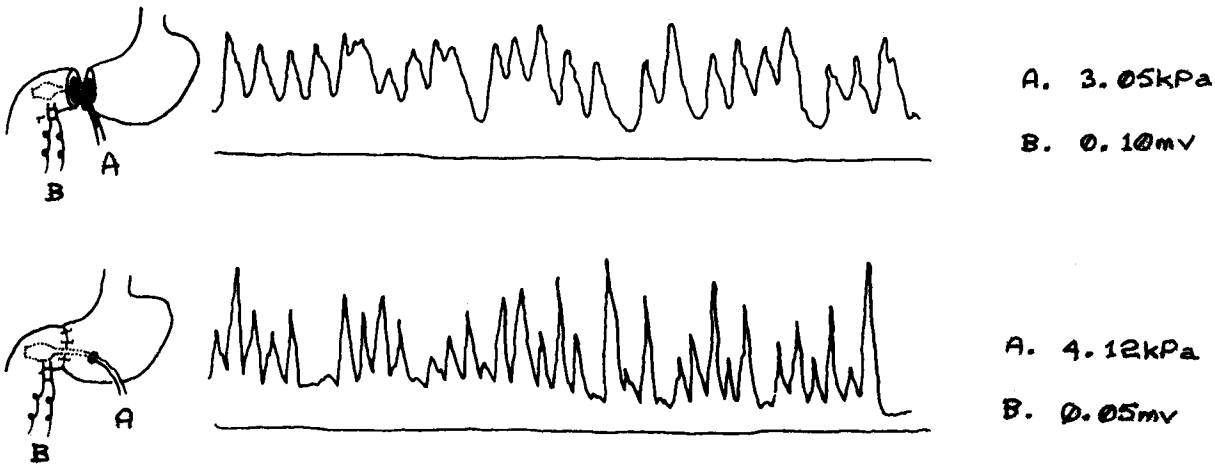

Fig. 3. Electromyogram and intraluminal pressure of gastrectomy without preserving the pyloric vagus. A: intraluminal pressure; B: electromyogram; I: transecting antrum and pyloric vagus; II: transecting antrum and pyloric vagus with the antrum anastomosed.

Table 1. Effect of the pyloric vagus on electromyography and intraluminal pressure.

Measurement	Vagus preserved ($n = 6$)	Vagus resected ($n = 6$)	p
Action potential (mV)	0.855 ± 0.26	0.057 ± 0.043	<0.01
Intraluminal pressure (kpa)	3.273 ± 0.426	3.645 ± 0.608	>0.05

t-test in cases of heteroscedastic variance. The AST-286 computer (made in the United States) was used.

Results

After operation, all the dogs were fed the same food. Gastric emptying time was measured 4 months after operation by roentgenographic contrast examination. The other indices were measured 6 months after operation.

Body Weight

In comparison with the preoperative value, the mean body weight loss was 0.41 kg for the PPVPG group, 1.58 kg for the Billroth I (BI) group and 1.75 kg for the Billroth II (BII) group, each of the three notably different from the other ($p < 0.01$).

Reduction of Gastric Acid

In the PPVPG group, the mean reduction of free HCl was 3.75 ± 4.363 mmol/L ($p < 0.05$), and total acid reduction was 29.917 ± 17.969 mmol/L ($p < 0.01$). Postoperative free HCl was 0.4 mmol/L, and total mean acid was 19.3 mmol/L. The basic acid output was reduced by 63.1%, and the maximal acid output was reduced by 59.2% on average. The pH of gastric juice increased 2.5. All three indices show no marked difference from those of the BI and BII groups ($p > 0.05$).

Gastric Emptying Time

After fasting for 8 hours, the dogs of two groups were given a meal consisting of barium sulfate; gastric emptying time was completed in 60 to 150 minutes for 91.7% of the PPVPG dogs, similar to that of the control group, whereas the figures were 66.7% for the BI dogs and 0% for the BII dogs (Table 2). The gastric emptying time for the Billroth groups was significantly more rapid than that for the other groups.

Table 2. Gastric emptying time.

Operation mode	<30 min	<60 min	<90 min	<120 min	<150 min
PPVPG	0	1	3	3	5
BI	1	3	5	2	1
BII	8	4	0	0	0
Control	0	0	3	3	6

There were marked differences between the first three modes ($p < 0.01$) but no marked differences between the first and the last modes ($p > 0.05$).

Table 3. Variation of cholic acid concentration in gastric juice before and after operation.

Operation mode	t	p
BI	3.663	<0.01
BII	3.403	<0.01
PPVPG	0.228	>0.05

Duodenogastric Reflux

Duodenogastric reflux was measured by observing the concentration of cholic acid and sodium ion of gastric juice and bacterial culture.

1. Cholic acid concentration (Table 3): The postoperative cholic acid concentration of the BII and BI groups was significantly higher than that before operation ($p < 0.01$), but no marked difference was observed in the PPVPG group ($p > 0.05$).
2. Sodium ion concentration (Table 4): Significant differences were observed in the BI and BII groups before and after

Table 4. Variation of sodium concentration in gastric juice before and after operation.

Operation mode	t	p
BI	12.342	<0.01
BII	2.902	<0.05
PPVPG	0.857	>0.05

operation ($p < 0.05$), but no marked difference was found in the PPVPG group ($p > 0.05$).

3. Bacterial culture: It was positive in the BI and BII groups and negative in the PPVPG group with only one case positive.

The above results indicate that enterogastric reflux occurred in the BI and BII groups, but almost none was seen in the PPVPG group.

Pathologic Examination

The endogastritis of the remained stomach is divided into mild, moderate, and severe degrees according to the extent of infiltration by inflammatory cells. (1) Mild degree: the number of inflammatory cells increased; one-third of the mucosa layer was infiltrated mainly by lymphocytes. (2) Moderate degree: infiltration into the mucosa up to one-third to two-thirds. (3) Severe degree: infiltration of more than two-thirds of the mucosal layer. Endogastritis occurred in the BI and BII groups; 83.3% and 75.0%, respectively, were of moderate degree. In the PPVPG group, 66.7% of the remaining mucosa was normal; only a few dogs had mild endogastritis, resembling that which occurred in the control group.

Discussion

In an attempt to prevent the dumping syndrome, Killen et al. [1] resected 50% to 70% of the canine stomach; they retained 2 cm of the distal antrum, removed the remained antrum mucosa, anastomosed the mucosa of the corpus and duodenum and then sutured the seromuscular coat. This operation has not been applied clinically because of its high mortality rate and the difficulty stripping the mucosa. Later, Maki [2] continued the study and formally advanced a pylorus-preserving gastrectomy (PPG), which resected most of the antrum and the corpus 2 cm from the pyloric ring and retained the remaining antrum mucosa. PPG has successfully prevented the dumping syndrome and duodenogastric reflux in 50 cases of gastric ulcer since its clinical application in 1964, but it failed in terms of the speed of gastric emptying. According to other reports, gastric retention may reach 40% and last as long as 6 months [3].

The chief reason for gastric retention, judged by our experimental study, could be the incision of the vagus (innervating the pylorus), which consists of excitatory and inhibitory postganglionic fibers. The former speeds the spread of the basic electrical rhythm (slow wave), facilitates formation of an action potential (which causes rhythmic contraction of the stomach), and diastolizes the stomach. By coordination of the two, the stomach contracts and diastolizes rhythmically. With the vagus resected, the action potential of the gastric smooth muscle is notably decreased, and autonomous contraction of gastric smooth muscle is induced by the homogenetic rhythm of the smooth muscle and the intramural nerve plexus. The uncontrolled spastic contraction leads to delayed gastric emptying and gastric retention. In our view, the physiologic function of the pyloric sphincter cannot be preserved without preserving the vagus, which innervates the pylorus.

Through comparative experimental studies, we have shown that PPVPG has an advantage over conventional Billroth gastrectomy in terms of reducing acid secretion. Moreover, complications that follow a Billroth operation, such as rapid gastric emptying, indigestion, duodenogastric reflux, and gastric retention, are avoided. This operation has thus experimentally proved to be highly applicable to the treatment of peptic ulcer.

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Thanks are due to Prof. Zhang Yibin of the Physiology Group of Shanxi workers and the staff of the Medical College, who gave us much assistance in the course of our experiments.

Résumé

Dans le but de prévenir les séquelles de la gastrectomie traditionnelle, telles que la vidange gastrique précoce, le dumping, le reflux rétrograde du contenu intestinal, d'autres perturbations diverses de la fonction digestive et notamment de l'absorption, une technique de résection gastrique conservant le pylore ainsi que son innervation est décrite. Après expérimentation chez 48 chiens, nous présentons les bases théoriques et les avantages d'une telle résection gastrique évitant les complications mentionnées, tout en conservant les qualités d'une réduction d'acidité.

Resumen

Con el propósito de prevenir en cuanto sea posible las secuelas de la gastrectomía convencional, tales como vaciamiento rápido del estómago, síndrome de dumping, reflujo del contenido intestinal, indigestión y mala absorción, y otras complicaciones indeseables, hemos diseñado la presente gastrectomía conservadora del píloro y del vago pilórico. Mediante experimentación en 48 perros, pudimos hallar los fundamentos teóricos de nuestra propuesta operación y obtener los efectos deseados—retener los méritos de la resección subtotal convencional del estómago y la reducción de ácido, pero evitando las complicaciones mencionadas.

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