

The Anatomic Basis for the Variable Adequacy of Incomplete Vagotomy:

Part I: The Various Secretory and Ulcerogenic Potentials of Various Anatomic Types of Incomplete Vagotomy in Shay Rats

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IN RECENT years the secretory and ulcerogenic potential of an incomplete vagotomy has been described in terms of its adequacy. In patients without recurrent ulcer the incomplete vagotomy is considered *adequate*; in patients with recurrent ulcer the incomplete vagotomy is *inadequate*. The purpose of this report is to correlate the adequacy with the anatomic type of incomplete vagotomy.

The various anatomic types of incomplete vagotomy, and their various areas of residually innervated gastric mucosa, have been described (Pritchard, Griffith and Harkins, 1968).⁴ In the present study the secretory and ulcerogenic potentials of two types of incomplete vagotomy were compared—an intact trunk (residual innervation of an entire ipsilateral wall of the stomach) and an intact proximal branch of the anterior gastric nerve of Latarjet (residual innervation of a small segment of the proximal anterior gastric fundus).

Material and Methods

Adult male Long Evans rats weighing from 250 to 300 Gm. were used. Preliminary anatomic studies demonstrated that

the gastric vagi in rats are distributed to the stomach in the same gross and segmental pattern as that previously reported in dogs; the anterior and posterior trunks via their gastric truncal divisions innervate the anterior and posterior walls of the stomach, respectively, and the terminal branches from the gastric truncal divisions each innervate small segments of stomach (Fig. 1).

The rats were housed in individual cages in the same room and fed the same diet. The cages were equipped with raised bottoms of wide wire mesh to prevent coprophagy.

Forty-eight hours before operation, the food was withdrawn from the cages, but the rats were allowed to drink water *ad libitum*. They were anesthetized intraperitoneally with pentobarbital (Diabital) in doses of 0.1 ml. (60 mg.) per 100 Gm. of body weight. The abdomen was shaved, cleaned with septsisol and alcohol, and entered through an upper midline incision. A small self-retaining retractor was placed on the abdominal wall. The following procedures were then performed under a dissecting microscope.

Operative Procedures

Group 1: Pyloric Ligation Only (Control): The pylorus was ligated with 000 silk as described by Shay *et al.*⁶ Whenever bleeding occurred from the right gastric

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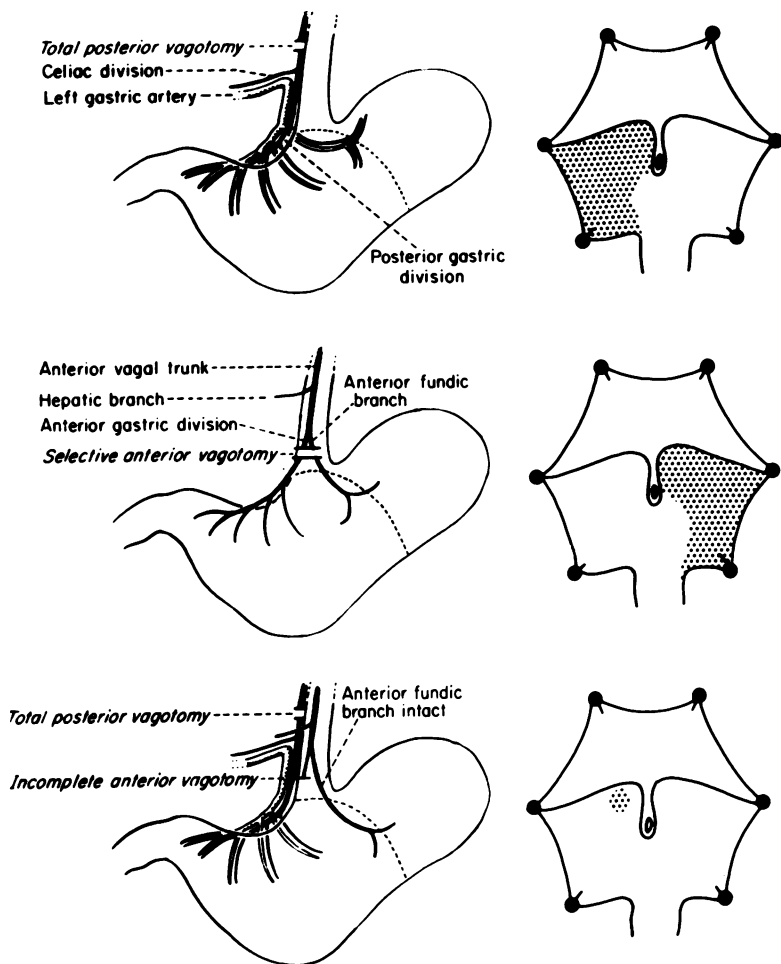
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FIG. 1. Anatomic types of incomplete vagotomy and their residual areas of innervation. The diagrams on the left show the anatomic types of incomplete vagotomy and the diagrams on the right show the corresponding areas of residually innervated gastric mucosa (shaded). These diagrams are based upon findings in rats after intravenous neutral red, which is secreted by the entire corpus but not by the rumen or antrum. Following complete gastric vagotomy the dye is no longer secreted.

Top: Following posterior vagotomy with preservation of the anterior trunk (not shown), the residually innervated anterior surface of the corpus secretes.

Middle: Following anterior vagotomy with preservation of the posterior trunk (not shown), the residually innervated posterior surface of the corpus secretes.

Bottom: Following posterior vagotomy plus incomplete anterior vagotomy with preservation of the anterior fundic branch, the small area of the residually innervated proximal anterior corpus secretes. (Modified from Legros and Griffith, 1968.³)



or gastroepiploic vessels, the rat was discarded from study.

Group II: Pyloric Ligation and Anterior Selective Vagotomy: The silk around the pylorus was kept as a traction suture to pull the stomach down. To expose the esophagogastric junction adequately, an 0000000 silk was also placed for traction on the greater curve over the serosa of the ridge between the rumen and corpus. At the cardia, the anterior gastric division and its proximal fundic branch were identified and cut. The posterior trunk was preserved.

Group III: Pyloric Ligation and Posterior Total Vagotomy: The posterior vagal trunk was cut just above its bifurcation into the celiac and posterior gastric divisions. The left gastric artery was not disturbed in order to confine the study to the ulcerogenic effect of pyloric ligation and to eliminate the necrotic effect of ligation of the left gastric artery with consequent ulcer of the corpus in rats.¹ The anterior trunk was preserved.

Group IV: Pyloric Ligation and Complete Gastric Vagotomy (Control): Anterior selective vagotomy, as in Group II,

TABLE 1. *Effects of Various Types of Vagotomy on Gastric Secretion after Pyloric Ligation (7 hrs.) 17 Rats in Each Group*

Type of Vagotomy	Gastric Secretion Study (mean \pm SD)			
	pH	Volume (cc.)	Titratable Acid	
			mEq./l.	mEq.
Gr. I.				
Both trunks intact	2.65 \pm 0.22	6.4 \pm 2.7	90.9 \pm 17.4	0.58 \pm 0.05
GR. II.				
Selective anterior vagotomy	2.93 \pm 0.31	4.1 \pm 1.2	59.0 \pm 20.4	0.24 \pm 0.02
GR. III.				
Total posterior vagotomy	2.99 \pm 0.32	4.4 \pm 1.9	61.0 \pm 15.1	0.27 \pm 0.02
Gr. IV.				
Bilateral vagotomy	4.84 \pm 1.07	2.9 \pm 0.8	17.7 \pm 9.9	0.05 \pm 0.01
Gr. V.				
Fundic branch intact	4.38 \pm 0.93	3.3 \pm 1.8	20.0 \pm 7.7	0.07 \pm 0.01

and posterior total vagotomy, as in Group III, were performed.

Group V: Pyloric Ligation and Vagotomy with the Anterior Fundic Branch Intact: As in Group III, posterior total vagotomy was performed. The anterior gastric division was then transected at the gastric cardia just below the origin of its proximal fundic branch, taking care to preserve this branch to the fundus.

After these operative procedures the abdomen was closed in two layers of interrupted silk sutures. The rats were kept warm until complete recovery and returned to their cages. They were fasted until sacrifice with lethal dose of intraperitoneal pentobarbital.

Gastric Secretion

Rats used for studies of gastric secretion were sacrificed 7 hours after operation. This time interval was chosen after preliminary experiments demonstrated that at 7 hours enough gastric juice was secreted for analysis and no ulcers developed. The gastric juice was therefore clear and not

contaminated with neutralizing exudate or blood from ulceration.

The esophagus was ligated at the gastric cardia, and the stomach removed by cutting the esophagus above this ligature and the duodenum below the pyloric ligature. The gastric juice was then drained from the stomach through a small gastrotomy in the lesser curve just proximal to the pylorus, and collected in a centrifuge tube.

The pH, volume, and total titratable acid were measured in each specimen of gastric juice. The pH was determined by the Fisher titrimeter (Model #36). The specimen was then centrifuged, and the clear supernatant layer was withdrawn for determination of titratable acidity. Titration was done with 0.01N NaOH, using an end point of pH 7 as indicated by phenol red. The results were expressed as both milliequivalents per liter and total milliequivalents.

Gastric Ulceration

Rats used for studies of gastric ulceration were sacrificed 23 hours after opera-

TABLE 2. *Effects of Various Types of Vagotomy on Gastric Ulceration after Pyloric Ligation (23 hrs.) 17 Rats in Each Group*

Type of Vagotomy	Incidence of Ulcers (%)			% of Death by Perforation
	Rumen	Corpus	Antrum	
Gr. I				
Both trunks intact	100%	23.5%	11.5%	29.4% (5/17)
Gr. II				
Selective anterior vagotomy	70.5%	0	0	23.5% (4/17)
Gr. III				
Total posterior vagotomy	76.4%	0	0	29.4% (5/17)
Gr. IV				
Bilateral vagotomy	0	0	0	0
Gr. V				
Anterior fundic branch intact	0	0	0	0

tion. The stomach was opened along the greater curve from the pylorus to the esophagus, taking care to avoid manipulation of the stomach itself. The location and the number of ulcers were noted. The per cent of death by perforation prior to sacrifice was calculated for each type of vagotomy.

Results

Gastric Secretion (7 Hours After Operation)

The findings of feces or food in the stomach, a loose pyloric ligature, or bleeding from either an ulcer or the pyloric ligation excluded the rat from study. Left for consideration were 17 rats in each of the 5 groups (Table 1).

Gastric Ulceration (23 Hours After Operation)

The ulceration was as described by Shay et al.⁶ namely, multiple small ulcers scattered throughout the stomach but predominantly in the rumen. The findings of feces or blood in the stomach or a loose pyloric ligature excluded the rat from study. Left for consideration were 17 rats in each of the 5 groups (Table 2).

Group I: Pyloric Ligation Only. Ulcers developed in all 17 rats: The number of ulcers in each rat ranged from 3 to 56 (mean: 18).

Group II: Pyloric Ligation and Anterior Selective Vagotomy: Ulcers developed in 12 of 17 rats. The number of ulcers in each rat ranged from 1 to 10 (mean: 4).

Group III: Pyloric Ligation and Total Posterior Vagotomy: Ulcers developed in 13 of 17 rats. The number of ulcers in each rat ranged from 1 to 16 (mean: 5).

Group IV: Pyloric Ligation and Complete Gastric Vagotomy: None of the 17 rats developed ulcer.

Group V: Pyloric Ligation With an Anterior Fundic Branch Intact: None of the 17 rats developed ulcer.

Discussion

The results of the two controls (Groups I and IV) confirm the constant development of gastric ulceration in rats by pyloric ligation⁶ and the constant prevention of this ulceration by complete vagotomy.² This latter constant is explained by the significant reduction in acid secretion after complete vagotomy. The results with an

intact trunk (Groups II and III) confirm the previous findings of Shay *et al.*⁷ and Rivilis *et al.*⁵ With residual innervation of one entire wall of the stomach by an intact trunk, the acid secretion is reduced but the reduction is inadequate for the prevention of ulcers in approximately 70 per cent of rats. In contrast, with residual innervation of only a small area of the fundus by an intact fundic branch (Group V), the greater reduction in acid secretion affords adequate protection against the development of ulcer in all rats.

These results provide evidence that the adequacy of an incomplete vagotomy may be correlated with its anatomic type. The inadequate incomplete vagotomy in patients with recurrent ulcer may be of an anatomic type that leaves a large area of innervated gastric mucosa. The adequate incomplete vagotomy in patients without recurrent ulcer may be of an anatomic type that leaves a small area of innervated mucosa. As will be discussed in Part II of this study, the anatomic variations of the vagal system in man predispose to the anatomic types of incomplete vagotomy studied herein. Determination of the anatomic type of incomplete vagotomy and its adequacy by means of the insulin test is the subject of Part II.

Summary and Conclusions

In pyloric ligated rats the secretory and ulcerogenic potential, or adequacy, of two anatomic types of incomplete vagotomy were compared—an incomplete vagotomy of an intact trunk (residual innervation of the entire ipsilateral wall of the stomach) and an incomplete vagotomy of the proximal anterior fundic branch (residual innervation of a small area in the proximal anterior fundus). In control groups, py-

loric ligation without vagotomy resulted in ulcers in all rats, whereas complete vagotomy markedly reduced acid secretion and no ulcers developed. With incomplete vagotomy of an intact trunk, acid secretion was reduced but this reduction was inadequate protection for the prevention of ulcers in all rats. In contrast, with incomplete vagotomy of an intact fundic branch, the reduction of acid secretion was significantly greater and approximated that after complete vagotomy; this reduction of secretion was adequate and no ulcers developed.

It was concluded that the adequacy of an incomplete vagotomy may be correlated with the area of residually innervated gastric mucosa which, in turn, may be correlated with the specific anatomic type of intact vagal fiber.

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References

1. Berg, B. N.: Gastric Ulcers Produced Experimentally by Vascular Ligation. *Arch. Surg.*, 54:58, 1947.
2. Harkins, H. N. and Hooker, D. H.: Vagotomy for Peptic Ulcer. *Surgery*, 22:239, 1947.
3. Legros, G. and Griffith, C. A.: The Abdominal Vagal System in Rats. (Accepted for publication, *J. Surg. Research.*)
4. Pritchard, G. R., Griffith, C. A. and Harkins, H. N.: A Physiologic Demonstration of the Anatomic Distribution of the Vagal System to the Stomach. *Surg. Gynec. Obstet.*, 126: 791, 1968.
5. Rivilis, G., Yaffe, M. and Preshaw, R. M.: The Effect of Unilateral Vagotomy on Gastric Secretion in the Pylorus Ligated Rat. *Proc. Soc. Exp. Biol. Med.*, 127:310, 1968.
6. Shay, H., Komarov, S. A., Fels, S. S., Meranze, D., Gruenstein, M. and Siple, H.: A Simple Method for the Uniform Production of Gastric Ulceration in the Rat. *Gastroenterology*, 5:43, 1945.
7. Shay, H., Komarov, S. A. and Gruenstein, M.: Effects of Vagotomy in the Rat. *Arch. Surg.*, 59:210, 1949.