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# GASTRIC MOTILITY AFTER GASTRIC SURGERY*

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It is a great honor for me to be here today to discuss with you one of my favorite topics—gastric motility after gastric surgery. I thank you for asking me to come.

Gastric motility after gastric surgery is an important subject. Most gastric operations disturb gastric motility to some extent, and these adverse motor sequaelae can lead to unpleasant symptoms, such as bloating with meals, dumping, diarrhea or bilious vomiting.

My goal in this article is to describe how gastric operations produce changes in gastric motility that lead to such symptoms. Such knowledge may help surgeons to design operations in the future that will avoid these symptoms.

This paper is based largely on work done in man and dogs at the Mayo Clinic over the last few years. I have had a number of co-workers in these studies, not only from the United States, but also from several other countries, including Japan. These co-workers share with me the privilege of giving this paper.

## Two Gastric Regions

First of all, surgeons should be aware, as Cannon was years ago[1)], that the stomach has two distinct motor regions, a prioximal region and a distal region, and each region has its own unique motor function. The proximal stomach acts as the gastric reservoir, receiving and storing food. Its slow sustained contractions regulate intragastric pressure, and thereby control gastric emptying of liquids[2)]. In contrast, the distal stomach acts as the gastric mixer and grinder. It has a pacemaker which generates electrical cycles, called pacesetter potentials, which in turn phase the onset of peristaltic contractions[3)]. These peristaltic contractions regulate gastric emptying of solids[4)].

It follows, then, that operations on the proximal stomach ought to disturb gastric emptying in a different way than operations on the distal stomach.

Our hypothesis is that operations on the proximal stomach disturb gastric emptying of liquids, while operations on the distal stomach disturb gastric emptying of solids. In the remainder of my paper I will show you evidence that supports this hypothesis.

## Proximal Stomach

Motor Physiology. Turning first to the proximal stomach, its contractile pattern is nicely studied using an isolated pouch of the fundus and orad corpus that is completely separated from the main stomach, but yet retains its extrinsic vagal and sympathetic innervation[5]. The motor events of such a pouch, then, can be recorded without interference from contractions of the main stomach.

Two types of contractions are recorded from such an isolated, separated, gastric fundal pouch—a slow and a more rapid phasic contraction (Fig. 1). The slow phasic contractions have a period of about 1 every 3 minutes and an amplitude of about 40 cm $H_2O$. In contrast, the more rapid phasic contractions occur at a frequency of 5 per minute and an amplitude of 10-15 cm $H_2O$. These proximal gastric contractions exert a sustained pressure on the gastric content gradually forcing the content toward the distal stomach and duodenum.

Proximal gastric contractions are under careful neural and hormonal controls which adjust the strength of these contractions as the stomach fills[6,7]. This process is called gastric adaptation. As the volume in a bag positioned in the proximal stomach is increased by instilling water into the bag, the pressure across the wall of the stomach gradually increases to about 10 cm$H_2O$. Then with further expansion of the intragastric volume, no further increase in intragastric pressure occurs. The stomach adapts or accommodates to increasing distention without increasing pressure[2].

This adjustment of intragastric pressure by the proximal stomach is important, because the rate of gastric emptying depends on the difference in pressure between the stomach and the duodenum and varies with the resistance at the pylorus. Pyloric resistance to the passage of solids is usually so great, that only liquids are allowed to pass out of the stomach. With liquids, the resistance to their passage is small, and so the gradient in pressure between the stomach and duodenum is the major determinant of their rate of emptying. Because the slow, sustained contractions of the proximal stomach are the main determinant of intragastric pressure, they have a major influence on the rate of gastric emptiying.

To summarize, the proximal stomach acts as the gastric reservoir. Its slow, sustained contractions regulate intragastric pressure and thereby control gastric emptying of liquids.

Proximal gastrectomy. Resections of the proximal stomach disturb gastric accommodation and speed gastric emptying of liquids. This can be illustrated by the operation, gastric fundectomy, done in dogs. In this operation, we removed only the gastric fundus, leaving the gastric pacemaker and the entire distal stomach intact[2].

Before fundectomy the stomach accommodated to distention beautifully in each of the 4 dogs studied. After fundectomy, accommodation was impaired, and much greater increases in gastric pressure occurred with gastric distention.

The greater increases in pressure after fundectomy led to more rapid gastric emptying of liquids in each of the 4 dogs studied. Fundectomy impaired accommodation, so that increased intragastric resulted (Fig. 2). The rapid gastric emptying of liquids that occurs after gastric fundectomy can lead to dumping and diarrhea.

Proximal gastric vagotomy. The new operation, proximal gastric vagotomy, also disturbs gastric accommodation to some extent. In proximal gastric vagotomy, the vagal nerves to the fundus and corpus of the stomach are divided, but those to the antrum are left intact. The vagal fibers to the proximal stomach help to inhibit proximal gastric contractions during distention and enhance accommodation. Thus, vagal denervation of the proximal stomach might be expected to impair

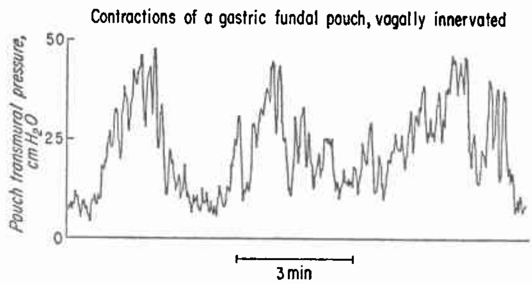


Fig. 1. Contractions of a vagally innervated gastric fundal pouch. (From Kelly, K.A., Canine gastric motility, Proc. Fourth International Symposium on Gastrointestinal Motility, Mitchell Press, Vancouver, 1973.)

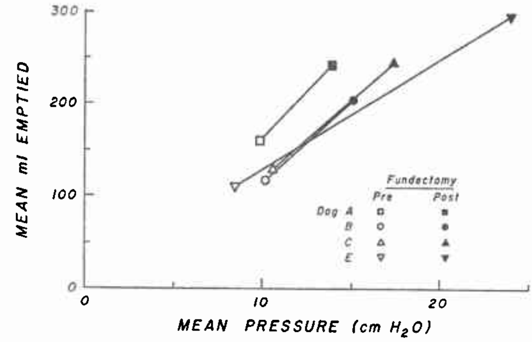


Fig. 2. Fundectomy increases transmural gastric pressure and speeds gastric emptying of 400 ml of 154 mM NaCl. (From Wilbur, B.G., Kelly, K.A. and Code, C.F.: Effect of gastric fundectomy on canine gastric electric and motor activity. Amer. J. Physiol. 226: 1445-1449, 1974)

accommodation and lead to rapid gastric emptying of liquids.

We found in dogs that gastric accommodation to distention was impaired after proximal gastric vagotomy compared to before vagotomy[7]. The mean pressure in the stomach increased to greater heights during distention after proximal gastric vagotomy than it did before vagotomy. Such greater increases in pressure with gastric distention after vagotomy cause patients to experience easy-filling or bloating after the operation.

Again, as with fundectomy, the increased intragastric pressure after proximal gastric vagotomy leads to more rapid gastric emptying of liquids[7]. And this is true for both isotonic NaCl solutions and hypertonic glucose solutions. Fortunately, the speeding in gastric emptying is seldom great enough to result in dumping and diarrhea.

In contrast, proximal gastric vagotomy, which does not greatly disturb the distal stomach and gastric peristalsis, did not alter gastric emptying of solids spheres. Whereas, complete gastric vagotomy and truncal vagotomy, both of which denervate the distal stomach, markedly slowed gastric emptying of spheres.

But before turning to the distal stomach, let me summarize the consequences of operations on the proximal stomach.

Resection or vagotomy of the proximal stomach decrease the reservoir capacity of the stomach and impair gastric accommodation. Greater increases in intragastric pressure occur with distention, and gastric emptying of liquids is faster.

## Distal Stomach

Motor physiology. Let us turn now to operations on the distal stomach. Distal gastric operations disturb gastric emptying of solids. Such disturbances can be effectively studied using radiopaque plastic spheres that have a specific gravity similar to that of gastric content. The spheres can be swallowed or placed via a tube into the stomach, and their motions in the stomach and rate of emptying can be followed fluoroscopically[8].

Once the spheres are in the stomach, they are picked up by the antral peristaltic waves which propel them toward the pylorus (Fig. 3). The spheres, however, are not allowed to pass through the pylorus because of their large size, and so they are trapped in the distal antrum, where the advancing peristaltic wave grinds them together. Finally, because they cannot pass through into the duodenum, they are retropelled forcefully toward the more proximal stomach as the peristaltic wave passes over them. This sequence of propulsion, grinding and retropulsion occurs over and over thoroughly triturating the spheres in an attempt to break them down into tiny particles that will be allowed to pass into the duodenum[9]. Once content is emptied into the duodenum, it is not allowed to reflux back into the stomach.

The plastic spheres, however, are indigestible and cannot be broken down. So they are retained in the stomach for long periods lasting 1 to 2 hours or more. Finally, a powerful burst of contractions appears during fasting, that sweeps the spheres rapidly out of the stomach[10]. This burst of contractions, called the "activity front", has been studied by Doctor Itoh who believes the burst may be the result of the periodic release of the gastrointestinal hormone motilin[11].

To summarize, the distal stomach provides continence for gastric solids. It triturates or grinds up digestible solids, and mixes gastric content with gastric juice. It expels indigestible solids during fasting with its powerful bursts of interdigestive contractions. Lastly, it provides a barricade against the reflux of duodenal content back into the stomach.

Distal gastrectomy. Resections of the antrum and pylorus markedly interfere with the pattern of emptying of solids. To study this point, we excised the distal antrum and pylorus and performed gastroduodenostomy in a series of dogs, and studied their pattern of emptying of spheres before and after the operation[4].

Before operation, the rate of gastric emptying of spheres was slow in each of 4 dogs studied. Two to 4 hours were required to empty 50% or more of the spheres. However, after operation, the ability of the stomach to retain the spheres was lost, gastric trituration was abolished, and the spheres were rapidly emptied, usually in 20 to 30 minutes. Such rapid gastric emptying can lead to dumping and diarrhea.

Distal gastric vagotomy. Vagotomy of the distal stomach also markedly alters gastric emptying of solids, as shown in a study of dogs before and after division of all of the extrinsic nerves to the antrum and pylorus, a kind of distal highly selective vagotomy[10]. Before denervation, the spheres were emptied by the powerful bursts of fasting antral contractions, usually in 2 to 4 hours. However, after denervation, these fasting bursts did not appear, antral peristalsis was greatly weakened, and the spheres emptied from the stomach very slowly in 5 of 6 dogs studied (Fig. 4). Why one dog was not affected by antral denervation is unknown. The antral denervation abolished the powerful periodic bursts of antral contractions in all the other dogs, thereby weakening the force which expels the spheres, and so slowing their rate of emptying.

In contrast to the slow rate of gastric emptying of solids after extrinsic denervation of the distal stomach, gastric emptying of liquids was unaltered. This finding emphasizes the minor role of the

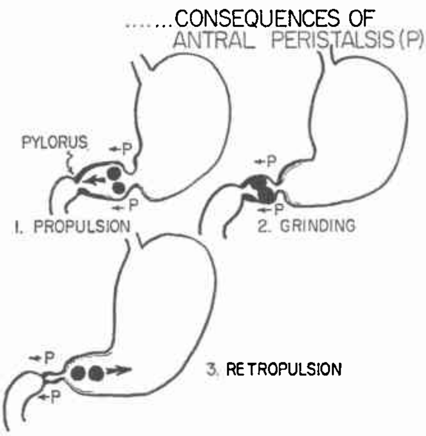


Fig. 3. Consequences of antral peristalsis[4].

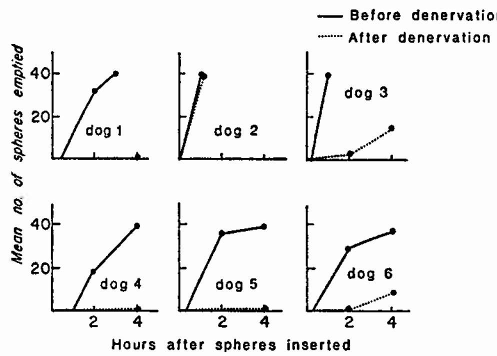


Fig. 4. Antral denervation slows gastric emptying of spheres during fasting[10].

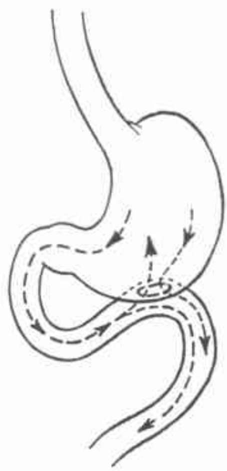

Fig. 5. Gastroenterostomy allows exit of gastric content through the new stoma as well as the pylorus, but also allows reflux of intestinal content back into the stomach through the stoma[12].

distal stomach in gastric emptying of liquids. The rate of emptying of liquids is controlled mainly by the proximal stomach.

Gastric "drainage" operations. The rate of gastric emptying of solids is so slow after vagotomy of the distal stomach that gastric "drainage" procedures, like gastroenterostomy, are usually required. However, although such operations do speed gastric emptying of solids when such emptying is sluggish, they also allow for reflux of duodenal content back into the stomach through the artificial opening (Fig. 5). Such reflux can lead to adverse sequelae such as bile vomiting, alkaline gastritis, pain and anemia.

The production of bile-reflux after gastrojejunostomy is illustrated by comparing gastric aspirates in animals before and after antral gastrojejunostomy. The aspirate before gastrojejunostomy is nearly clear. However, after antral gastrojejunostomy, the aspirate is deeply stained with bile that had refluxed from the jejunum into the stomach through the stoma[12].

Suprapyloric antrectomy. Do the distal antrum and pylorus provide the barricade to duodenal-gastric reflux? Doctor Kaichi Isono looked at this question with me last year, when we tested the combination of an operation developed in the west, proximal gastric vagotomy[13], and an operation developed by Professor Maki in Japan, suprapyloric antrectomy[14]. Would preserving the innervated distal antrum and pylorus preserve the barricade to duodenal-gastric reflux?

We found that it did. The quantity of isotonic NaCl refluxed into the stomach of dogs was no greater after the pylorus-preserving operation than before (unpublished observations). In spite of a marked stress on the pylorus produced by a rapid infusion of large volumes of NaCl into the duodenum, no greater reflux occurred after the operation than before operation. The barricade to duodenal-gastric reflux is provided by the innervated distal antrum and pylorus.

To summarize, resection or bypass of the distal stomach impairs gastric continence for solids, speeds gastric emptying of solids, and results in duodenal-gastric reflux. Vagotomy of the distal stomach impairs gastric grinding and slows gastric emptying of solids.

In closing, let me thank you for inviting me to Japan. We surgeons, even though from different countries, have a common bond in our profession that makes friends of strangers...as Issa so beautifully expressed here in Japan many years ago.

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