Physiology of the Stomach and the Duodenum

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1.1 Anatomy and Physiology of the Stomach

Stomach is a muscular, J-shaped (when empty) organ located in the upper abdomen, which lies on a variable visceral bed that includes the diaphragm, pancreas, and transverse mesocolon. The relationship of the stomach to the surrounding viscera is altered by the amount of its contents, the stage that the digestive process has reached, the degree of development of the gastric musculature, and the condition of the adjacent intestines.

The empty stomach is only about the size of the fist but can stretch to hold as much as 4 L of food and fluid, or more than 75 times its empty volume, and then return to its resting size when empty.

The stomach is connected to the esophagus, at the gastroesophageal junction, and the proximal part of the small intestine, duodenum. Based on histological differences, it can be divided into five regions, i.e.:

- The cardia—below the esophagus; contains cardiac sphincter, which prevents stomach contents from reentering the esophagus.
- The fundus—left of the cardia and below the diaphragm; usually contains air and is thus visible radiographically.
- The body—main part of the stomach, in which mixing and digestion of the food occurs.
- The pyloric antrum—where partly digested food awaits release to the small intestine.
- The pyloric canal—connecting the stomach to the small intestine; the pyloric sphincter, located in this part, controls the movement of digested food from the stomach to the duodenum and prevents the contents of the latter reenter the stomach.

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J. Fichna (ed.), *Introduction to Gastrointestinal Diseases Vol. 2*,
DOI 10.1007/978-3-319-59885-7_1

In the absence of food, the stomach deflates inward, and its mucosa and submucosa fall into a large fold called a ruga.

The stomach wall consists of several layers, namely:

- The mucosa (mucous membrane)—the inner lining of the stomach that consists of three components: the epithelial lining, the lamina propria, and the muscularis mucosae. It contains specialized cells that produce hydrochloric acid (parietal cells) and proteolytic enzyme pepsin (chief cells, in the inactive proenzyme form of pepsinogen), mucus (mucous cells—the goblet cells which make up the surface layer of the simple columnar epithelium, to protect the lining of the stomach), and hormones (e.g., gastrin). Additionally, parietal cells secrete intrinsic factor, which is necessary for the absorption of vitamin B12 in the small intestine.
- The submucosa—a layer of loose areolar tissue with some elastic fibers, which contains blood and lymph vessels, and nerve cells.
- The muscularis propria (muscularis externa)—the main muscular layer of the wall, with three layers of smooth muscles: an inner oblique, middle circular, and an external longitudinal layer.
- The serosa (visceral peritoneum)—a thin layer of loose connective tissue covering the stomach from the outside.

Gastric motility and secretion is controlled by both neural and hormonal signals. The stomach receives innervation from several sources: (1) sympathetic fibers via the splanchnic nerves and celiac ganglion (synapse) supply blood vessels and musculature, (2) parasympathetic fibers from the medulla travel in the gastric branches of the vagi, and (3) sensory vagal fibers include those concerned with gastric secretion. A number of hormones have been shown to influence gastric motility—for example, both gastrin and cholecystokinin act to relax the proximal stomach and enhance contractions in the distal stomach.

Gastric secretion occurs in three phases: cephalic, gastric, and intestinal.

- The cephalic phase (reflex phase) of gastric secretion, which is relatively brief, takes place before food enters the stomach. The smell, taste, sight, or thought of food trigger this phase, and gastric secretion is, here, a conditioned reflex.
- The gastric phase of secretion lasts 3–4 h and is triggered by local neural and hormonal mechanisms stimulated by the entry of food into the stomach.
- The intestinal phase of gastric secretion has both excitatory and inhibitory elements. The duodenum has a major role in regulating the stomach and its emptying in this phase.

Physiological function of the stomach is mixing and digesting food, which is also temporarily stored in this organ. The food in the stomach is transformed into a liquid termed chyme, which, by rhythmic muscular contractions (peristalsis) of the pyloric part, is emptied into the duodenum for absorption. In this process, called gastric emptying, rhythmic mixing waves force about 3 mL of chyme at a time

through the pyloric sphincter and into the duodenum. The rest of the chyme is pushed back into the body of the stomach, where it continues mixing. This process is repeated when the next mixing waves force more chyme into the duodenum.

The stomach does not allow absorption of the food to a great extent; however, water, alcohol, and some lipid-soluble compounds, including aspirin and other NSAIDs, may pass from the stomach to the circulation.

Of note, the entrance of food into the stomach tends to cause the ileum to empty into the large intestine. This is called a gastroileal reflex.

1.2 Anatomy and Physiology of the Duodenum

Duodenum is a C-shaped organ extending from the pylorus to the duodenojejunal flexure. Anatomically, it contains four parts; the second (descending) part of the duodenum receives bile, pancreatic, and accessory pancreatic ducts; each duct usually has a sphincter. The bile and pancreatic ducts frequently unite and form a short hepatopancreatic ampulla.

Similarly to other parts of the small intestine, duodenum functions include mechanical and chemical digestion and absorption of the nutrients. Of note, the contents of the stomach are completely emptied into the duodenum within 2–4 h after the meal. Different types of food take different amounts of time to process: foods heavy in carbohydrates empty fastest, followed by high-protein foods. Meals with a high triglyceride content remain in the stomach the longest. Since enzymes in the small intestine digest fats slowly, food can stay in the stomach for 6 h or longer when the duodenum is processing fatty chyme.

Acknowledgments This work was supported by grants from the Medical University of Lodz (503/1-156-04/503-11-001 to JF) and from the National Science Center (#UMO-2013/11/B/NZ7/01301 and #UMO-2014/13/B/NZ4/01179 to JF).

Further Reading

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