The cardiac portion of the stomach is situated deeply in the upper abdomen and relatively well hidden. The topographic space around it is very narrow and complicated. These topographical features are produced by the liver, especially segments I, II, and III. An understanding of the relationships among compacted organs facilitates operative access by surgeons.

Keywords: cardiac portion; lesser omentum; abdominal esophagus; hiatal esophagus; omental bursa

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Introduction

Some organs and associated structures exhibit complicated and compacted arrangements in deep, narrow spaces, making operative access difficult. One such structure is the cardiac portion of the stomach, which is located in a small, narrow area and deeply situated on the inferoposterior surface of the diaphragm in the upper abdomen. It partly contacts the diaphragm directly without interference by the peritoneum; it is fixed to the diaphragm and concealed by the liver lobes. The liver lobes, lesser omentum, and hiatal esophagus are key structures in understanding the anatomy of this area. In this paper, they are described practically from the viewpoint of relationships among organs through discussion of relevant clinical cases.

For the first time, the cardiac portion of the stomach is defined here as follows. This region contains the abdominal esophagus, and the cardiac part of the stomach is located between the cardiac orifice and an imaginary semicircular line drawn from the angle of His to the point at which a line extends from the edge of the lesser gastric curvature straight upward to the lower oblique line. It is located at the level of the superior end of the xiphisternal joint about 2.5 cm to the left of the midline and about 10 cm deep (Figure 1a.).

The left gastric artery, which chiefly supplies the cardiac portion, arises from the celiac trunk and is typically the smallest branch of the celiac artery. Most commonly, it arises before the celiac ends by bifurcating into the hepatic and splenic arteries (Figure 1b.). Lymph drains from the cardia into the lymph channels and nodes situated around the lesser curvature in relation to the left gastric artery. The left cardiac lymph nodes, right cardiac lymph nodes, lymph nodes along the left gastroepiploic artery, and lymph nodes along the lesser curvature correspond to this area (Figure 1c.).
The cardiac portion of the stomach occupies a deep position in the abdomen and is roofed by the left lateral liver lobe (hepatic segments II and III), which makes operative manipulation difficult. Many anatomy texts have created valid portrayals of this portion of the abdomen. Hollinshead [1] drew a schematic of the cardiac portion without any maneuvers, but this is rarely seen in a routine operation or dissection. Instead, the cardiac portion is usually concealed. Two methods have been proposed to reveal the cardiac portion of the stomach: pulling up or removing the overlying liver lobe. Vesalius [2] pulled up the lobe, but the cardiac portion was not clearly observed. Netter [3] also pulled up the lobe and drew the area in a way that was easy for readers to understand; the illustration was very clear in the text, but encountering the same view during an operation cannot be expected by only lifting the lobe. Rohen and Yokochi [4] pulled the stomach down in addition to pulling up the lobe; this maneuver provides a view close to that seen during an actual abdominal operation.

Conversely, da Vinci [5] resected the left lateral liver lobe, segment IV, and right anterior segment to demonstrate the entire stomach. The cardiac portion is clearly viewed, but the esophagus is straight, the angle of His is lost, and no vasculature is found along the lesser curvature. Tobin [6] and Sparteholz and Spanner [7] resected the lobe as well. Via the thin lesser omentum, the caudate lobe of the liver is seen.
together with the cardiac portion of the stomach. Grant’s dissection \cite{8} is excellent. He removed both the quadrate and left lateral lobes to reveal the entire lesser omentum, consisting of the hepatogastric and hepatoduodenal ligaments. This dissection is the most effective in terms of observing the cardiac portion of the stomach. These various classic and modern dissection methods suggest that the left lateral liver lobe hides the cardiac portion of the stomach and hinders its observation and manipulation under direct vision. Therefore, to access the cardiac portion, surgeons should first be familiar with the left lateral liver lobe.

The left lateral liver lobe is adhered to the central tendon of the diaphragm by the left shorter coronary and longer triangle ligaments, which comprise anterior and posterior layers. The anterior layer continues from the left coronary ligament to the triangular ligament along the posterior periphery of the superior surface of the lobe to its left end, reflects there, and extends to the right as the posterior layer, which continues to the anterior layer of the lesser omentum. The anterior and posterior layers of the triangular ligament are closely adhered to each other; they usually do not contain any vessels and are easily grasped by the fingers because of the adequate length between the liver and diaphragm. The two layers are manipulated as one membranous sheet, which is easily divided from the diaphragm without bleeding, allowing the lobe to move freely. Figure 3 shows that the lateral liver lobe corresponding to the left lobe in a normal human body is divided from the diaphragm and pulled down with a hook in patients with situs inversus, exposing the cardiac portion of the stomach.

The left triangular ligament, including the short coronary ligament, has some characteristic anatomical features. When the ligament is divided rightward, it diverges slightly at the right end, where the inlet of the left hepatic vein to the inferior vena cava can be seen (Figure 2.) \cite{9}.

An area devoid of peritoneum is seen in the diaphragm after division of the lobe, which is bounded by the remnants of both layers, diverges gradually from the left to the right, and is identical to part of the central tendon. When the central tendon is surgically perforated in this wide area on the right side, it is very easy to enter the pericardial sac and see the posterior wall of the heart. Through this route, the omental artery is introduced into the pericardial sac and anastomosed with the branches of the coronary artery during a bypass operation (Figure 4.) \cite{10}.

Figure 3. Dissection of left lateral liver lobe from diaphragm. Arrow 1: The remnants of the right triangular and coronary ligaments. The upper edge of the lesser omentum is situated in the fissure for the ligamentum venosum. 2: Left hepatic vein. 3: Lesser omentum. 4: Stomach. 5: Diaphragm. 6: Pericardial sac. 7: Hepatoduodenal omentum. 8: Left portal vein. 9: Right lobe. 10: Round ligament of the liver (modified from Sasaki [11] with permission).
Figure 4. Bypass operation using right gastroepiploic artery. 1: Right gastroepiploic artery. 2: The left lateral liver lobe is dissected from the diaphragm and pulled downward. The vessel is introduced into the pericardial sac through incised double layers of the central tendon and parietal pericardium and is then anastomosed with the branch of the coronary artery. 3: Pericardial sac. 4: Diaphragm. 5: Branch in posterior wall of left ventricle (modified from Sasaki [11] with permission).
The triangular ligament separates the hiatal esophagus from the posterior periphery of the central tendon. The triangular ligament is a good marker with which to confirm the region of the hiatal esophagus when this portion of the esophagus must be cut to enter the intrathoracic region for surgical treatment of lower esophageal cancer or operations involving the vagal trunk (Figure 5.) [11].

Manipulation of the left lateral liver lobe is extremely important to disclose the cardiac portion of the stomach, but if the surgeon can approach from below as performed in laparoscopic operations, minimal mobilization of the left lobe may be allowed with a viewing angle from the inferior end [12].

**The lesser omentum does not demarcate the left margin of the cardiac portion**

The omentum is usually divided into two parts. The gastroduodenal ligament containing the portal triad begins from its right free margin, lies between the quadrate lobe and the caudate process of the caudate lobe (i.e., the porta hepatis), turns left and upward like the letter “J,” and continues to the thin hepatogastric ligament. It begins at the point where the ligamentum teres joins the left portal vein, attaches to the fissure for the ligament venosum, and ascends along it. In other words, the ligamentum venosum is situated in the upper periphery of the lesser omentum. The anterior layer leaves from the liver, passes the anterior cardiac portion, and continues to the posterior layer of the triangular ligament and the gastrophrenic ligament. One characteristic feature of the anterior layer is that it covers the cardiac portion like a curtain but does not enclose it. Thus, when the peritoneum must be dissected to reveal the cardiac portion of the stomach (e.g., fundoplication) [13], the demarcation of the two margins of the abdominal esophagus is not definite, and the margins are difficult to differentiate at a glance, especially the left lateral margin. This curtain-like peritoneum is not tightly adhered to the abdominal part of the stomach, and it may be easy to pinch and incise it during open surgery to reveal the target area because it can be confirmed with the fingers.

**Figure 5. Expansion of cardiac portion of the stomach.** The left lateral liver lobe is dissected from the diaphragm and pulled downward, showing the remnants of the triangular and coronary ligaments. The hiatal esophagus, hidden in the posterior layer of the ligaments, is now visible. The longitudinal incision of the hiatus readily demonstrates the vagus (modified from Sasaki [11] with permission). Arrow 1: Falciform ligament. 2: Coronary ligament. 3: Anterior vagal trunk. 4: Diaphragm. 5: Spleen. 6: Round ligament of liver.
directly. However, safer manipulation can be ensured if markers are available to visually identify the left margin during laparoscopic surgery.

Detailed gross anatomical studies of the left lateral margin of the abdominal esophagus near the angle of His have revealed the earlobe-like peritoneal appendage. This structure is found to be relatively constant, ranging from 4–21 mm × 6–40 mm × 1–4 mm in size (Figure 6.)\cite{14}. It is present on an imaginary line along which the lesser omentum adheres to the lesser curvature and continues to the diaphragm. When it is grasped and pulled anteriorly and leftward, the left margin of the abdominal esophagus is sharply defined. Furthermore, this small area is safe for incision because fewer branches of the left gastric artery and vagal nerve are present on the left than right side. Near the angle of His, only the esophageal branch of the left inferior phrenic artery is recognized\cite{14}.

The earlobe-like peritoneal appendage continues to the imaginary line drawn along the attachment of the lesser omentum to the stomach. It then seems to originate from the lesser omentum. Many anatomy textbooks and papers were searched to confirm this observation, but no satisfactory description was found. Only the description of the abdominal esophagus in Gray’s Anatomy\cite{15} may support our observation; i.e., that it is covered by the peritoneum on its front and left sides and is contained in the upper part of the lesser omentum.

The posterior layer of the lesser omentum does not cover the entire posterior part of the abdominal esophagus, but reflects near the right margin of the abdominal esophagus and continues to the posterior layer of the bursa omentalis. In other words, the lesser omentum does not entirely enclose the abdominal esophagus. Therefore, the small area of the posterior aspect of the abdominal esophagus is devoid of peritoneum and contacts the diaphragm (including the hiatal esophagus) and posterior mediastinum only via a connective tissue membrane called the phrenoesophageal ligament\cite{16}. This nude area is described below.

**The upper posterior surface of the abdominal esophagus is devoid of peritoneum and approaches the hiatal esophagus and lower part of the posterior mediastinum**

This area varies in size and form among different descriptions and drawings in many texts, but its description is present in each text. That is, it is a constant structure.

An admired drawing is that seen in the classical edition of Gray’s Anatomy (Fig. 7)\cite{17}. The nude area of the abdominal esophagus resembles a starfish. Each arm extends in a
clockwise manner at 1 to 2 o’clock, 4 o’clock, 6 o’clock, 7 o’clock, 9 o’clock, and 10 to 11 o’clock. The arm at 10 to 11 o’clock is located at the diaphragmatic end of the gastrohepatic omentum and continues to the left triangular ligament and right coronary ligament. Another arm at 4 o’clock is located at the diaphragmatic end of the gastrohepatic omentum and continues to the gastrolenal ligament. The arm at 7 o’clock forms the junction of two directions; i.e., the superior recess upward and splenic recess leftward. The left gastric artery enters the lesser omentum at 7 o’clock and runs along the lesser curvature. The arm at 9 o’clock is not mentioned in many texts; according to Grant’s [8] drawing, however, it seems to be formed by branches of the left gastric artery supplying the cardiac portion. The level of the arterial entrance into the stomach drawn by Sparteholz and Spanner [7] is higher than in other texts; i.e., the locus is at 9 o’clock. The arm at 1 to 2 o’clock is described as the gastrophrenic ligament, as seen in the drawing by Hamilton and McMinn [18]. Other texts have deleted this arm. In summary, the arms at 1 to 2, 4, 7, and 10 to 11 o’clock are relatively constant.

However, Gray’s drawing suggests a more important structure (Figure 7.). Other texts have clearly drawn the inferior phrenic artery in the nude area, but in Gray’s text, the artery can be identified only vaguely. A tough membranous layer is identifiable between the cardiac portion and diaphragm, which conceals the inferior phrenic artery. This is called the phrenoesophageal ligament (described above) and fixes the esophagus to the diaphragm. It may be a type of
fused membrane and is inherent in the esophagus, including the vagal trunk. Its purpose becomes clear when seen from the back because its membrane encloses the esophagus in addition to the posterior vagal trunk, separating them from the inferior phrenic artery and diaphragm. If it is recognized like the fused membrane seen on the posterior surface of the retroperitoneal digestive organs, surgical manipulation of the cardiac portion of the stomach will be safely performed without unexpected damage to the vagal trunk and left inferior phrenic vessels.

Part of the hiatal esophagus is also a nude area through which the esophagus enters the upper abdomen. This hiatus is formed by the loop of the right crus of the diaphragm. The loop is not situated horizontally but inclines from the upper dorsal aspect downward and rightward. The loop on the right side then covers the anterior surface of the esophagus. Conversely, the loop on the left side covers the posterior surface of the esophagus. These sides are not situated on the right and left but in front of and behind the esophagus, pinching it like a sandwich. The abdominal esophagus contacts the posterior part of the hiatus and left crus devoid of peritoneum via intervention of the connective tissue membrane. Moreover, because of downward tilting, the upper posterior surface of the abdominal esophagus is adjacent to the posterior mediastinum and is crossed by the thoracic aorta dorsally.

**Rich vessels and nerves are found in the right margin of the cardiac portion**

This area, including the posterior surface, is more complicated and risky to manipulate than the left side because of the intermingling of many branches of vessels and nerves (Figure 8.).

The left gastric artery is a proper vessel of the stomach, originating from the truncus celiacus and running upward through the left gastropiplopancreatic fold formed in the posterior wall of the omental bursa. Before it supplies the lesser curvature, it takes a unique course across the roof of the peritoneal sac, which is part of the omental bursa (Figure 9.). The roof of the superior recess is dome-like, descends downward toward the left, and continues to the roof of the splenic recess. The artery continues along the juncture of both roofs and enters the double layers of the lesser omentum. Esophageal branches chiefly arise from this artery. The leftward countertraction of the stomach makes ligation of these small vessels easy to accomplish because the small but definite space for insertion of the device between the branches to the esophagus and lesser curvature becomes easily visible with manipulation.

The left accessory or replaced hepatic artery sometimes originates from the left gastric artery as an anomaly, runs through the upper part of the gastrohepatic ligament, and supplies the left liver lobe through the hepatic portal. Its frequency is relatively high and is not negligible in liver transplantation (about 10% of 1000 cases reported by Hiatt et al. [19]). The hepatic branch from the anterior vagal nerve accompanies this artery toward the right along the upper edge of the lesser omentum. A slender branch from the hepatic artery proper or left hepatic artery may run along the upper edge of the lesser omentum in a reverse manner and supply the right margin or lesser curvature as the replaced left gastric artery [20, 21]. That is, small, slender, thin branches from the vessels and nerves occupy the superior small part of the lesser omentum.

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**Figure 8. Vessels and nerves are denser on right than left side of cardiac portion of the stomach.** The asterisk indicates the abdominal esophagus.
Figure 9. View of the cardiac portion from the back. A: The left gastric artery, which crosses over on the juncture surface between both spaces in the vicinity of the celiac branch of the posterior vagal trunk. B: Lobus caudatus. C: Anterior layer of the lesser omentum, which continues to the gastrophrenic ligament. D: Direction from the superior recess to the splenic recess. 1: Left adrenal gland. 2: Right adrenal gland. 3: Stomach. 4: Esophagus. 5: Kidney. 6: Hepatoduodenal ligament. 7: Duodenum. 8: Anterior vagal trunk. 9: Posterior vagal trunk. 10: Inferior vena cava (modified from Sasaki [11] with permission).
Although it is well known that the parasympathetic nerves supplying the stomach are the vagal nerves, only two branches are discussed here: the hepatic branch and celiac branch. Both branches should be preserved during surgical manipulation of the cardiac portion of the stomach their common feature is that they both leave from the stomach. The hepatic branch originates directly from the vagal anterior trunk after the esophagus passes through the hiatal esophagus, runs through the upper edge of the lesser omentum toward the right, and enters the portal triad through the hepatoduodenal ligament (Figure 10.). The left accessory hepatic artery originates from the left gastric artery, and the branch accompanies the artery. The celiac branch originates from the posterior trunk, leaves from the dorsal surface of the esophagus, descends along the proximal aspect of the left gastric artery, and enters the celiac ganglions. Leftward traction of the stomach clarifies the view of the bifurcation of the branch from the posterior trunk. Anterior traction of the stomach divides the celiac branch from the posterior trunk.

Although the small branches from the left gastric vein are not usually recognized, they occupy the surface of the cardiac portion and are readily visible in the esophageal varices, which are devascularized during esophageal transaction to interrupt esophageal bleeding in patients with portal hypertension [22]. There are two main routes: in the anterior route, the vessels ascend on the anterior surface of the esophagus along the anterior vagal trunk and enter the hemizygous or accessory hemizygous vein. In the posterior route, they ascend on the posterior surface of the esophagus along the posterior vagal trunk and enter the azygos vein. Other vessels enter the inferior phrenic veins. The vagal trunks are closely associated with venous routes.
The length of the abdominal esophagus is important to maintain an area for suturing in conventional Billroth II and Roux-en-Y, but it varies from 1 to 6 cm. One report described cutting the vagal nerve along with the connective tissues enclosing the esophagus at the hiatal esophagus, 3 to 5 cm from the hiatal esophagus and 2 to 3 cm under the bifurcation, they confirmed new extension of 3.7 ± 1.2 cm. The vagal trunks are like rulers that maintain the determined length and are not elastic. These trunks are closely fixed to the esophagus by connective tissue membranes, which disturb the extension of the esophagus. Then, if the trunks are cut, the esophagus slightly extends.

**The caudate lobe approximates the right margin in the superior recess of the omental bursa**

Although the caudate lobe (segment I of the liver) is in the vicinity of the cardiac portion of the stomach, few reports have described how the close topographical relationship of these structures is hidden by the lesser omentum (Figure 1c.). There is no direct contact between the two parts, but only a narrow peritoneal space (the superior recess of the omental bursa).

Embryologically, the hepatic portal in the ventral mesentery (the primordium of the lesser omentum) lies in the sagittal median plane as well as in the hepatic primordium. Thus, the primordium of the caudate lobe is the right side of the mesentery and the quadrato layer is the left. As the hepatic primordium expands toward the right posterior region, the lobus caudatus rotates from the right side to the posterior region and the position of the hepatic portal migrates from the sagittal median plane to the frontal plane. At the same time, the stomach rotates clockwise by 90° around a longitudinal craniocaudal axis, which produces the posterior space termed the omental bursa. This embryological process approximates the left margin of the caudate lobe to the right margin on the abdominal esophagus in the omental bursa, creating the J-shaped lesser omentum (i.e., the hepatoduodenal ligament) that winds leftward to continue to the gastrohepatic ligament.

The lobus caudatus is covered by the peritoneum and is free in the superior recess. The fissure for the ligamentum venosum is the left boundary of the caudate lobe, along the bed of which the lesser omentum attaches. Its anterior layer continues to the inferior layer of the left coronary ligament. The posterior layer continues to the anterior narrow surface of the lobus caudatus and then reflects along the left margin to the wide posterior surface.

Because the superior part of the lobus caudatus is extremely close to the cardiac portion, enlargement of the lobus caudatus by tumors [24] may close the superior recess and press the abdominal esophagus leftward, which may make manipulation of the cardiac portion difficult. Moreover, the ligamentum venosum ascends along the fissure (i.e., a boundary of the lobus caudatus) and enters the left hepatic vein at its confluence with the inferior vena cava. This area is also extremely close to the abdominal esophagus. During omental bursectomy, after resection of the lesser omentum, the ligamentum venosum is located beneath the hepatic branches of the vagus nerve, divided, dissected away from the fissure, and divided at its entrance into the left hepatic vein because a small percentage of these patients may have uncontrolled hemorrhage due to a patent superior aspect of the ductus venosus [25].

In conclusion, the anatomical features associated with the cardiac portion of the stomach have been thoroughly discussed in this paper, providing different viewpoints and impressions of this area.

**Conflicting interests**

The authors have declared that no conflict of interests exist.

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