Title page

Title: Ear-lobe-like peritoneal appendage near the angle of His: a useful landmark for demarcating the lateral margin of the gastric cardia

Short running title: Ear-lobe-like structure gastric cardia

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Abstract mini-abstract and keyword page

Abstract

The gastric cardia, that is, the small area around the cardiac orifice including the abdominal esophagus, is an important target area for abdominal and thoracic surgeries, especially for laparoscopic procedures. In this study of 28 cadavers, a peritoneal ear-lobe-like structure near the angle of His was identified as a useful indicator of the lateral margin of the abdominal esophagus, which is otherwise obscure because the peritoneum continues to the diaphragm without definite demarcation of this margin. This structure, which appears equivalent to the epiploic appendages, was found to be relatively constant (present in 22/28, 78.6% of 28 cadavers), ranging from 4–21 mm × 6–40 mm × 1–4 mm in size, triangular, round, or leaf-like in shape, containing fat, and on an imaginary line along which the lesser omentum adheres to the lesser curvature and continues to the diaphragm (18/22, 81.8%). This indicator is associated with the lesser omentum and part of the gastrophrenic ligament and could serve as a useful indicator of the margin of the gastric cardia, thus aiding surgeons performing laparoscopic surgery in this region.

Mini-abstract

We here describe a frequently identifiable ear-lobe-like appendage that indicates the margin of the gastric cardia, which is otherwise often difficult for laparoscopic surgeons to demarcate.

Key words: gastric cardia, abdominal esophagus, laparoscopic surgery, peritoneal ear-lobe-like

structure, lesser omentum.

Introduction

The gastric cardia, which comprises a small region near the cardiac orifice and the abdominal esophagus, is an important area for surgeons performing procedures such as fundoplication for hiatal hernia (Stylopoulos & Rattner 2005), esophagogastrectomy for cancer (Robinson 1960) and vagotomy for gastric ulcer (Olbe 1994). However, it is a difficult area for surgeons to access, partly because the left lateral segment of the liver covers its right aspect, creating a very narrow space. Additionally, the peritoneum covers its anterior aspect like a curtain (Sasaki 2006), continuing to the lesser omentum on the right and to the gastrophrenic ligament on the left without completely enclosing the abdominal esophagus. This makes it difficult to demarcate the gastric cardia, particularly the left margin of the abdominal esophagus. However, because the peritoneum is only loosely adherent to the gastric cardia proper, it can easily be lifted with forceps, safely incised, and peeled off to disclose this region, at least in open procedures, that is, laparotomies.

The introduction and increasing popularity of laparoscopic surgery (Gordon & Magos 1989), which is characterized by remote control and manipulation of inserted laparoscopic and related devices through small skin incisions, has dramatically changed operative techniques, partly because laparoscopic procedures provide different anatomical challenges than are encountered with open surgery. One such challenge is to achieve clear demarcation of margins of structures or organs. In open surgery, such demarcation is mainly achieved by direct visualization and palpation,

the surgeon's fingers being used to distinguish textures and thus differentiate tissue layers. However, because complex instruments are interposed between the organ or anatomical region and the surgeon's fingers, such palpation is less practicable in laparoscopic surgery. Both margins of the gastric cardia, particularly the left margin of the abdominal esophagus, are difficult to visualize directly.

However, the clearer and more precise visualization and magnification provided by laparoscopic surgery has allowed definition of details of topographic anatomy, including remarkably tiny structures such as short folds or vessels, which have gone almost unnoticed in standard gross anatomy. Analysis of characteristics of structures and the relationships between them ranging from their gross anatomy down to histological detail is now possible. The space surrounding the gastric cardiac is like a compressed matchbox—small, narrow, and complicated—within which many structures are packed, including parts of the esophagus, stomach, liver, diaphragm, left gastric vessels, inferior phrenic vessels, vagal nerves, lesser omentum, and peritoneal folds. All these structures are magnified by the endoscopes used in the laparoscopic surgery, resulting in visualization of very complicated topography.

While teaching a course in dissection in 2015, we encountered a case of *situs inversus*, which is characterized by mirror image of organs such as the heart (dextrocardia), in the cadaver of a 93-year-old man who had died of pneumonia. The reported incidence of *situs inversus* varies

between 1/4000 and 1/20,000, and a proportion of affected individuals have associated ciliary dysfunction (Dutta & Sarma 2014). When this cadaver was dissected with students and observed in detail, a tiny, fatty, peritoneal appendage, which we here refer to as “the gastric ear lobe”, was identified along the left margin of the abdominal esophagus near the angle of His. When it was retracted to the right in this cadaver (in normal subjects to the left), the left margin was clearly visible. (Kahrilas et al. 2008) have reported that, in individuals with hiatal hernia—herniation of the fundus through the esophageal hiatus of the diaphragm and into the mediastinum—such a structure is not immediately apparent. However, when the fundus is pulled in a caudad direction towards the abdominal cavity, poorly-developed gastric ear lobes are identifiable. Therefore, to determine whether this structure is always present and could be used as an indicator of the left margin of the gastric cardiac, we undertook the present study in which we dissected, observed and analyzed 28 cadavers with our focus on characterizing this structure.

Materials and Methods

Thirty cadavers used in a course in dissection in 2015 were initially included in this research. They comprised 18 women and 12 men aged from 63 to 100 years (average age 86.5 years). Two cases were excluded, because their gastric cardias could not be examined because of peritoneal dissemination of cancer or prior total gastrectomy. Relevant characteristics of the 28 eligible cadavers are summarized in Table 1.

After opening the abdomen according to Kasai's method (Kasai 1993), the left triangular ligament was cut to the coronary ligament and the left lateral segment retracted anteriorly and to the right as far as possible with a hook to facilitate examination of the gastric cardia. First, the ear-lobe-like appendage and its attachment were identified, if present. Then its position, dimensions, and shape were measured, documented in writing, and photographed.

In two cases, one with *situs inversus* and the other with a para-esophageal hiatal hernia, the relevant anatomic region was dissected in detail, sketched, and photographed to determine the blood supply to the gastric cardia and innervation from the vagal nerve.

The Ethics Committee of Shinshu School of Medicine approved the use of human cadavers for the above project (No. 3328). Written consent for cadaver dissection was obtained from these individuals and their next-of-kin prior to their death.

Results

Ear-lobe-like structures were definitely identified on the left lateral margin of the abdominal esophagus near the angle of His in 22/28 cases (78.6%). Moreover, when present this structure was invariably on an imaginary line along the attachment of the lesser omentum to the lesser curvature of the stomach (Fig. 1a,b). Additionally, the end of the structure was usually adherent to the diaphragm (18/22 cases; 82%).

The ear-lobe-like structures were fatty, covered by peritoneum, and similar in appearance

to the epiploic appendages often seen along the taenia coli of the large intestine, the main difference being that they are solitary structures at a single point on the left margin of the abdominal esophagus (near the angle of His), not at several points along the margin (Fig. 2a). They were generally yellow and varied in size and shape (Fig. 2a–c). They were 4–21 mm (mean 13.1±5.6 mm) wide, 6–40 mm (mean 24.3±8.4 mm) long. Fig. 2a shows an example of a large, but thin leaf-like structure whereas Fig. 2b shows a typical well-developed, large, thick appendage. Fimbria-like appendages were also identified (Fig. 2c). Small, poorly-developed appendages were also seen, the structure rarely being completely absent. Relevant characteristics of each appendage are summarized in Table 2.

In the case with *situs inversus* and the typical dextrocardia, the gastric cardia was revealed by pulling the right lateral segment (equivalent to the left lateral segment in normal individuals) to the right (Fig. 3). This cadaver's ear-lobe-like appendage was triangular and very thin. After pulling the triangular fatty appendage to the right, incising the anterior peritoneum from the ear-lobe-like structure to the medial side of the abdominal esophagus and peeling it off, the blood vessels and vagus nerve were dissected in detail (Fig. 4), resulting in identification of an accessory gastric artery originating from the hepatic artery (Fig.4d). This is a rare variation of hepatic arteries, occurring in about 2% of individuals (Lippert & Pabst 1985). The lateral region was characterized by a paucity of blood vessels and nerve fibers. Only one tiny vessel from the inferior

phrenic artery and a few delicate nerve fibers were seen. Conversely, on the medial side there were abundant but fine blood vessels. The upper part of the abdominal esophagus was supplied by a vessel from the hepatic artery proper running along the upper region of the lesser omentum, that is, between the pars condensa and pars flaccida, beside the hepatic branch of the anterior vagal trunk, whereas the left gastric artery supplied the lower part of the abdominal esophagus. The nerve fibers passed through the anterior surface of the abdominal esophagus to the anterior plane of the stomach. The medial side had denser vessels and nerve fibers than the lateral side. Based on the findings of this anatomical dissection, it is safer to operate on the lateral than the medial side of the abdominal esophagus and the gastric ear lobe is an excellent and precise indicator of the location of the lateral margin.

No gastric ear lobe was identified on initial dissection of the cadaver with a hiatal hernia. The greater omentum was seen on the left side of the herniated part of the esophagus (Fig. 5a). The gastric cardia and angle of His were not identified. However, a bulge was noted along the lower esophagus in the lower posterior mediastinum (Fig. 5b). When pressure was applied to this bulge from thoracic side, the stomach could be gently pulled out, revealing the gastric cardia and fundus. A poorly developed, but definite small ear-lobe-like appendage was then identified adjacent to the diaphragm (Fig. 5c).

Next, the peritoneum was peeled off from the point of the ear-lobe-like structure. The

lateral side received only small twigs from the posterior vagal trunk and no other blood vessels were distinguishable with the naked eye (Fig. 6a). The vasculature on the medial side was more complex, comprising thin vessels from the left gastric vessels and small twigs from the anterior vagal trunk (Fig. 6b). The hepatic branch from the vagal trunk originated a little superior to the gastric cardia and ran to the porta hepatis through the upper region of the lesser omentum. Thus, in this case also, the medial side of the esophagus was complex and the lateral side simpler and safer and the gastric ear lobe was a valuable indicator of the demarcation between the lateral margin of the abdominal esophagus and the gastric cardia.

Discussion

A solitary, peritoneal-covered, gastric ear-lobe-like appendage near the angle of His has not previously been described. This appendage clearly differs from the fatty tassels that can occur in most regions of the lesser omentum: the latter are subject to focal fat infarction presenting as appendagitis, which can be diagnosed by ultrasonic identification of a hyperechoic mass and computed tomography evidence of a well-circumscribed inflammatory lipomatous mass between the left hepatic lobe, lesser gastric curvature and pancreatic body, associated with increasing atypical epigastric pain (Coulier 2006) (Robert et al. 2015). These authors have reported that the inflammation region is mainly in the hepatogastric ligament and have not reported the gastric ear-

lobe-like appendages described here. Neither has this structure been recognized as meaningful in the field of anatomy. We are the first to report that it is a useful indicator for surgeons, especially those attempting to demarcate the lateral margin of the gastric cardia when performing laparoscopic surgery in this region.

Two issues are pertinent here: the reason(s) for difficulty in clearly demarcating the margins of the abdominal esophagus or gastric cardia, especially laterally, and what the gastric ear lobe actually is.

The first issue is associated with the meso-esophagus, an embryologic structure that is not a typical mesentery, lacking a serosal or fascial structure that conveys vessels, ducts and nerves, as pointed out by Hamilton and (Hamilton & Mossman 1972). Rather, it consists of mesenchymal tissue, is contiguous with the vertebrae, and contains the aorta and large fetal adrenal glands in the abdominal area in addition to the esophagus (Hwang et al. 2014). The meso-esophagus has no vessels. It originally has bilateral pleuroperitoneal canals lined with mesothelium and these differentiate into parietal, serosal, and parietal peritoneum during fetal development. Thus, the meso-esophagus has no intrinsic mesothelium; rather, it is covered by mesothelium. With the development of the diaphragm, the meso-esophagus is divided into two regions, the anterior containing the esophagus and the posterior containing the aorta and extending towards the vertebrae. Thus, the abdominal esophagus is directly adherent to the

diaphragm without interposition of the peritoneum. Simultaneously, the meso-esophagus becomes part of the phrenico-esophageal ligaments, which attach the esophagus to the diaphragm. The peritoneum covers both the diaphragm and the abdominal esophagus. Further, according to Hwang et al., large fetal adrenal glands attach to and protrude into the meso-esophagus along the abdominal esophagus. As embryologic development progresses, the adrenal glands become small adult-type glands and separate from the esophagus. The abdominal esophagus, adrenal glands, and diaphragm are covered by the same peritoneum and in the same plane, obscuring the left margin of the gastric cardia and abdominal esophagus. The close geometric relationship between the left adrenal gland and the abdominal esophagus is not completely lost in adult. When performing laparoscopic supragastric left adrenalectomy, incision of the gastrophrenic ligament and retraction of the fundus reveals the left adrenal gland (Basso et al. 1999), that is, these regions are still in close proximity in adults.

On the right, the peritoneum covering the abdominal esophagus anteriorly is continuous with the anterior layer of the lesser omentum, which meets the posterior layer along its medial margin. Therefore, the right margin is more clearly defined than the left. Thus, the obscureness of the left margin of the abdominal esophagus can be traced to its embryologic development.

The gastric ear lobe is an identifiable indicator of the location of the otherwise poorly demarcated left margin. Like the epiploic appendages seen along the taenia coli, it contains fat;

however, it does not contain lymph nodes. As shown in Fig. 1, the gastric ear lobe is on an imaginary line drawn along the attachment of the lesser omentum to the stomach. Thus, it appears to originate from the lesser omentum. We searched a large number of anatomy text books and articles for confirmation of this observation, but found no satisfactory descriptions of the structure herein described. The only text to partially support our observations was Gray's Anatomy (Wiiliams et al. 1989), which describes the abdominal part of the esophagus as follows: "… covered by peritoneum on its front and left side, it is contained in the upper part of the lesser omentum". Further, this text points out that it continues to the gastrophrenic ligament. In agreement with this, we found that the gastric ear lobe continues to the diaphragm. However, Gray's Anatomy (Williams et al. 1989) does not document the existence of the ear-lobe-like structure described here, which was present in almost 80% of our cases and, when present, was a clear indicator for demarcating the left margin of the abdominal esophagus.

In conclusion, we here describe the gastric ear lobe, an ear-lobe-like appendage that could serve a useful indicator of the lateral margin of the gastric cardia, thus aiding surgeons performing laparoscopic surgery in this region.

Conflict of interest

The authors have no conflicts of interest to disclose.

Acknowledgements

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Figure legends

Fig. 1. Photographs of (**a**) a representative thin gastric ear lobe (arrow) on the red line of the edge of lesser curvature of the stomach. (**b)** Fimbria-type of gastric ear lobe on a line crossing the anterior part of the lower abdominal esophagus. L: left lateral segment of the liver, which has been retracted to the right. S: anterior part of the stomach; D: diaphragm.

Fig. 2 Photographs of various types of the gastric ear lobes, including those shown in Fig. 1 (2a-3; 2c-2). (**2a, 1–5)** Arrows show several thinner-type gastric ear lobes, which are about 1 mm thick and leaf-like or triangular in shape. (**2b, 1–3)** Thicker-type gastric ear lobes, which are about 4 mm thick and relatively round. (**2c, 1, 2)** Fimbria-type gastric ear lobes, which are usually thin.

Fig. 3 (**a)** Dextrocardia in the cadaver with *situs inversus*. A: atrium equivalent to the right atrium; V: Ventricle equivalent to the right ventricle. (**b)** The gastric cardia (dotted circle) with the gastric ear lobe (long arrow) A: atrium equivalent to the right atrium; D: diaphragm; F: fatty appendage; L: liver. The short arrow indicates the triangular ligament of the liver. (**c)** Schematic representation of the characteristics shown in 3b. D: diaphragm; L: liver.

Fig. 4 Dissection of the gastric cardiac part in the cadaver with *situs inversus*. (**a)** The anterior

part of the abdominal esophagus proper has been revealed by pulling and lifting the lobe (star) to the right and incising the peritoneum to the left. (**b)** After retracting it to the right, the lateral side has been dissected and the inferior phrenic artery identified (arrow). (**c)** The medial side has been dissected to reveal the gastric vessels (arrow). (**d)** Schematic representation of dissection findings. AGA: accessory gastric artery from the hepatic artery; GA: gastric artery (equivalent to the left gastric artery); IPA: inferior phrenic artery; PHA: proper hepatic artery.

Fig. 5 The cadaver with hiatal hernia. (**a)** The fundus is not recognizable; only the greater omentum is visible. (**b)** A bulge in the diaphragm (arrow) is visible in the lower posterior mediastinum (D). L: liver; S: stomach; GO: greater omentum.

Fig. 6 (**a)** The hernia has been reduced, revealing the gastric cardia. A poorly developed gastric ear lobe is visible (arrow). (**b)** The vagal nerves and left gastric artery are indicated by arrows (short: vessel, long: nerve fibers). (**c)** Schematic representation of features shown in 6b depicting the blood supply (left gastric vessels) and vagal nerve fibers close to the cardiac part of the hiatal hernia. The gastric cardia is mainly supplied by twigs from the left gastric vessels. No branches of the inferior phrenic vessels were detected. The posterior region near the angle of His is supplied by a branch of the splenic artery (posterior gastric artery, not shown here). The hepatic and celiac

branches are far enough from the gastric cardia to be peeled off from the gastric cardia proper. ***:** gastric cardia; CB: celiac branch; D; diaphragm; F: fundus; HB: hepatic branch; L: liver; LGA: left gastric artery; S: stomach.

Tables

Table 1. Relevant characteristics of the 28 cadavers

age, sex	cadavers
60-69 (y)	1
70-79 (y)	5
80-89 (y)	12
90- (y)	10
mean (y)	86.1 (63-100)
median (y)	86.5 (n = 28)
Sex (M/F)	12/16

cause of death, anamnesis	cases
malignant tumor	7
cerebrovascular disorder	7
heart disease	5
pneumonia	10
diabetes mellitus	2
renal failure	6
(Plural choice is possible)	

Table 2. Dimensions and shapes of the gastric ear lobes.

size (mm)	attachment site	thickness	miscellany
8 × 6	D+L	thin (< 2mm)	extremely thin
4 × 16			
15 × 21			
21 × 13			
12 × 32	D+L	normal (2-4 mm)	visceral inversion
11 × 18			
10 × 18			
18 × 26			
15 × 31			
19 × 21			
18 × 28			
7 × 28			elastic nodular structure
10 × 27			
18 × 28			
11 × 27	D+L	thick (> 4 mm)	massive
19 × 40			
15 × 37			
21 × 25			
19 × 40	nearly D only	thin	extremely thin
7 × 19, 6 × 19	nearly L only	normal × 2	double
4 × 22	L	thick	
subobsolete	-	-	*
	-	-	*
	-	-	
	-	-	
	-	-	
none	-	-	
	-	-	

D: Diaphragm; L: Lesser omentum; *: gastric cardia adhesion with fibrous connective tissue.

*Figures

Fig. 1

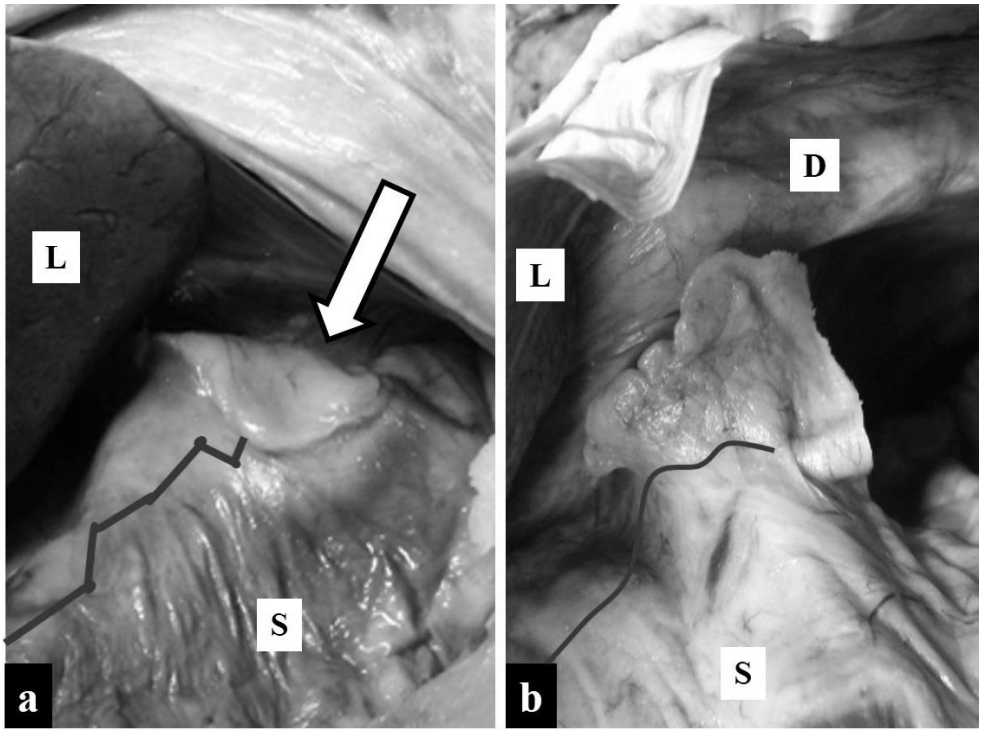

Fig. 2

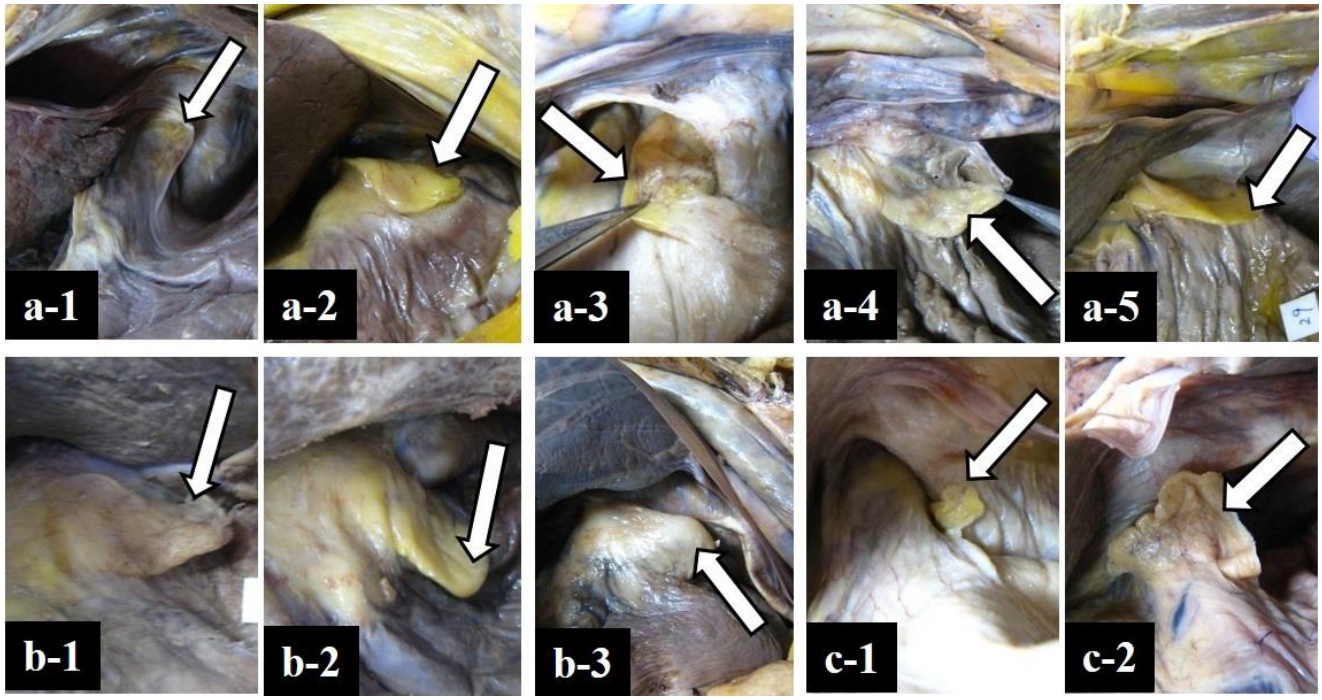

Fig. 3

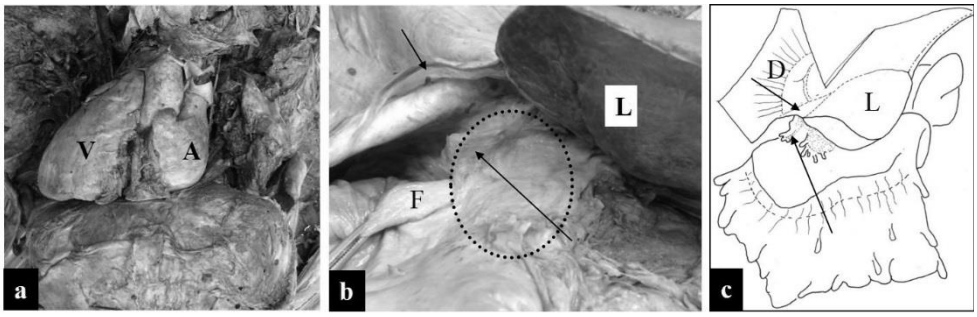

Fig. 4

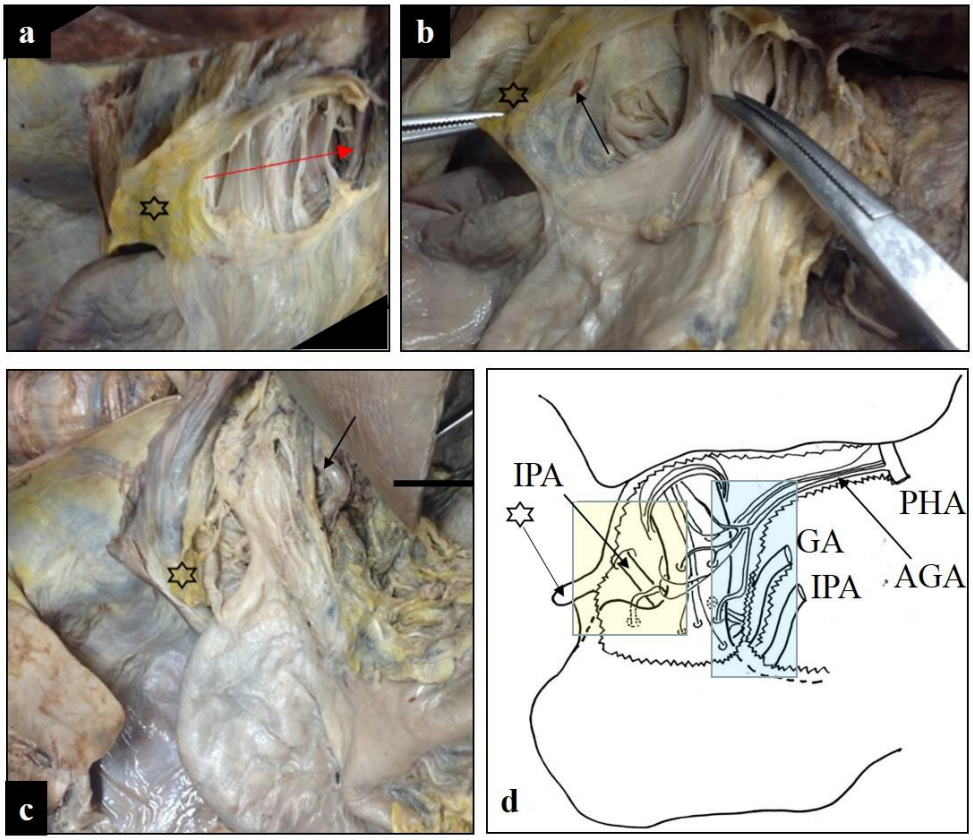

Fig. 5

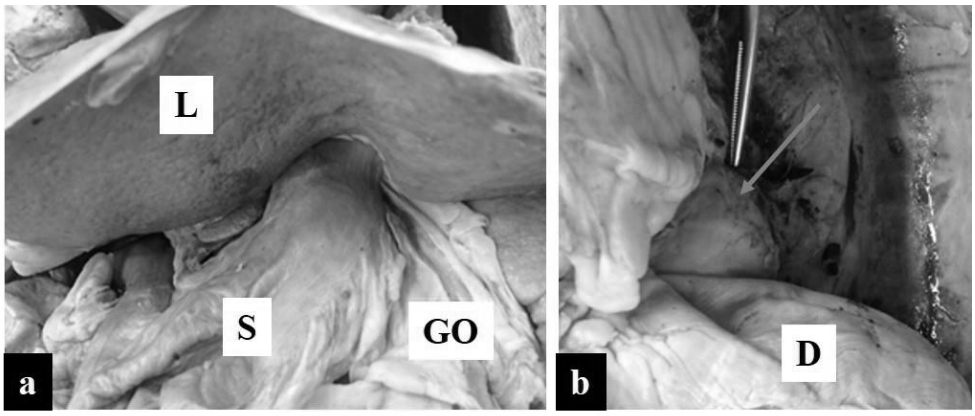

Fig. 6