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Common and separate origins of the left and right inferior phrenic artery with a review of the literature

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In a 94-year-old male cadaver, upon which routine dissection was being conducted, a rare variation was found in the gastrophrenic trunk (GPT), the common trunk of the left gastric artery (LGA), right inferior phrenic artery (RIPA), and left inferior phrenic artery (LIPA); the GPT arises from the abdominal aorta. A hepatosplenic trunk accompanied the variation. In this variation, the RIPA first branched from the GPT and then to the LIPA and LGA. Variations in the common trunk of the LIPA and RIPA in the GPT are common, but to our knowledge, a variation (separate inferior phrenic artery in the GPT) similar to our findings has not been previously reported. We discuss the incidence and developmental and clinical significance of this variation with a detailed review of the literature. Knowledge of such a case has important clinical significance for invasive and non-invasive arterial procedures. Therefore, different variations concerning the LGA and inferior phrenic artery should be considered during surgical and non-surgical evaluations. (Folia Morphol 2017; 76, 3: 408–413)

Key words: separate left gastric artery, inferior phrenic artery, gastrophrenic trunk, vascular development, cadaver

INTRODUCTION

Knowledge of vascular variation around the stomach and liver is clinically important, particularly when planning for surgical resection in patients with cancer of the stomach and liver or for transcatheter arterial chemoembolisation in unresectable hepatocellular carcinoma [15].

The anatomy and embryological development of the left gastric artery (LGA) and inferior phrenic artery (IPA) are complicated because of the complex embryogenesis and collocated relationships with the abdominal aorta and coeliac trunk (CT) [15, 16]. The normal pattern of the CT constituted by the LGA, splenic artery, and common hepatic artery was present in 87.94% of cases in a summary of 8 studies [16]. The IPA arises from each side of the abdominal aorta or CT just under the diaphragm, most often between the T12 and L2 vertebra [6, 23].

Many developmental anomalies of the IPA and LGA have been reported. For instance, the right inferior phrenic artery (RIPA) and left inferior phrenic artery (LIPA) arise separately or from a common trunk [7]. In addition, there are variations wherein the common trunk of the RIPA and LIPA (IPAT) arises from

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Table 1. Incidence of variants in common origin of the inferior phrenic artery trunk as reported in large series reports

References	Intervention (derivation)	No. of subjects examined	All	Abdominal aorta	Celiac artery	Left gastric artery	Other artery
Adachi [1]	Cadaver	74	18	11	6	1	–
Pick et al. [23]	Cadaver	200	63	37	26	0	–
Greig et al. [6]	Cadaver	425	132	77	52	3	–
Kahn [10]	Cadaver	50	13	13	0	0	–
Piao et al. [22]	Cadaver	68	10	6	4	0	Middle adrenal artery
Loukas et al. [15]	Cadaver	300	34	22	12	0	–
Basile et al. [2]	Cadaver	200	74	42	32	0	–
So et al. [25]	Cadaver	580	0	0	0	0	–
Kim et al. [11]	Cadaver	152	0	0	0	0	–
Ozbulbul et al. [20]	Angiography	200	72	32	40	0	–
Kim et al. [13]	Cadaver	23	0	0	0	0	–
Gurses et al. [7]	Cadaver	26	9	4	5	0	–
Ozbulbul et al. [21]	Cadaver	93	34	16	18	0	–
Bergman et al. [3]	Cadaver	848	282	167	115	0	–
Total	–	3239	741 (22.9%)	427 (13.2%)	310 (9.6%)	4 (0.12%)	–

the LGA, abdominal aorta, or CT [1–3, 6, 10, 12, 13, 15, 20–23, 25]. There are also anomalies wherein the IPAT arises from the gastrophrenic trunk (GPT), renal-phrenic trunk, coeliacomesenteric trunk, or GPT [4, 8, 9, 14, 16–19, 22, 24, 26, 28–30]. Moreover, there are several reports regarding the anatomy of the GPT [9, 16, 22, 29]. First, the GPT branches from the abdominal aorta, and then it branches to the IPAT and LGA [9, 16, 22, 29]. Variations in the branches of the IPAT and LGA from the GPT are also common [9, 16, 22, 29].

However, we found an instance where the RIPA first branched from the common trunk of the LIPA and LGA and then branched to the LIPA and LGA. The aim of the current study was to describe this rare variation of the IPAT and to review the variations in previously reported cases. The incidence and developmental significance of this variation are also discussed.

MATERIALS AND METHODS

This case results from the dissection of a 94-year--old Japanese adult male cadaver (cause of death: valvular disease); this cadaver was selected from the bodies used for research and gross anatomy practice at Tokai University School of Medicine in 2015. The cadaver was free of obvious diseases of the liver, stomach, and related vessels. Gross dissection was performed using the customary procedure. The vascular anatomical relationship around the stomach and liver was specifically observed. For this purpose, we removed the veins and nerves around the stomach and liver and the branches of the upper mesenteric arteries and carefully examined the structures. The incidence of an IPAT in cadaver dissection and clinical observation is shown in Table 1, and case reports of GPT are shown in Table 2.

RESULTS

The cadaver had a GPT from the abdominal aorta. The GPT arose directly from the anterior abdominal aorta wall, immediately left of the midsagittal plane, at the upper edge of the Th11 vertebral body. First, the RIPA branched from the common trunk of the LIPA and LGA, and then the LIPA and LGA branched. The RIPA and LIPA coursed posterior to the liver and drained into the inferior diaphragm. The LGA coursed anterior to the lesser curvature of the stomach and anastomosed with the right gastric artery (Fig. 1). The common trunk of the RIPA and left GPT had an endoluminal diameter of approximately 4.2 mm, LGA of 2.1 mm (proximal side) to 3.8 mm (distal side), the RIPA of 3.2 mm, and the LIPA of 3.1 mm. The hepato-

Table 2. Summary of reported cases of the gastrophrenic trunk in the literature and the present case

References	Intervention (derivation)	Type of common inferior phrenic artery	Type of separate inferior phrenic artery	Left gastric artery	Splenic artery	Hepatic artery
Piao et al. [22]	Cadaver	Gastrophrenic trunk	–	Gastrophrenic trunk	Hepatospleno-medentric trunk	Hepatospleno-medentric trunk
Hirai et al. [8]	Cadaver	Gastrophrenic trunk	–	Gastrophrenic trunk	Hepatospleno-medentric trunk	Hepatospleno-medentric trunk
Yi et al. [29]	Cadaver	Gastrophrenic trunk	–	Gastrophrenic trunk	Hepatosplenic trunk	Hepatosplenic trunk
Matusz et al. [16]	Angiography	Gastrophrenic trunk	–	Gastrophrenic trunk	Hepatospleno-medentric trunk	Hepatospleno-medentric trunk
Present case	Cadaver	–	Gastrophrenic trunk	Gastrophrenic trunk	Hepatosplenic trunk	Hepatosplenic trunk

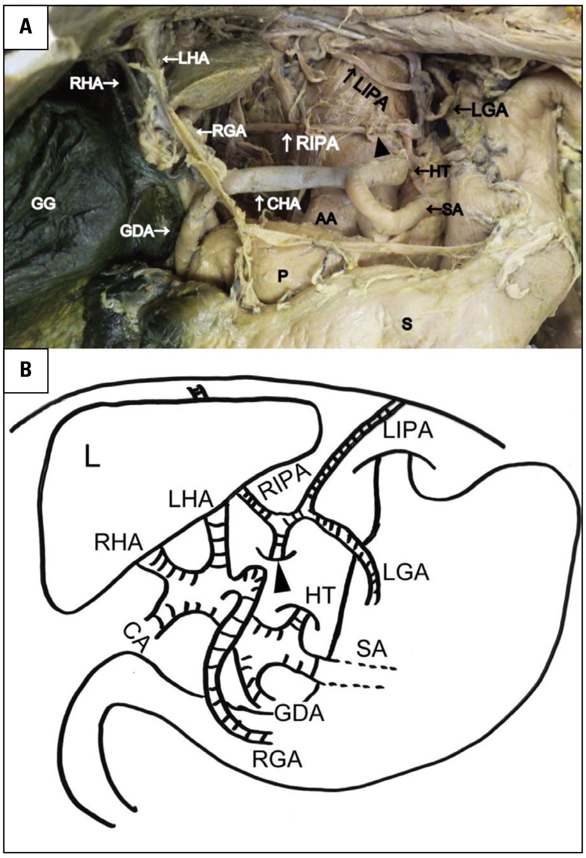

Figure 1. Photograph (**A**) and schematic illustration (**B**) of the gastrophrenic trunk (GPT) in the cadaver of a 94-year-old Japanese man. The photograph (**A**) and schematic illustration (**B**) are ventral views. The black arrowheads indicate the GPT; AA — abdominal aorta; LGA — left gastric artery; RGA — right gastric artery; RIPA — right inferior phrenic artery; LIPA — left inferior phrenic artery; CHA — common hepatic artery; SA — splenic artery; GDA — gastroduodenal artery; LHA — left hepatic artery; RHA — right hepatic artery; CA — cystic artery; L — liver; GG — gallbladder grand; P — pancreas; HT — hepatosplenic trunk; S — stomach.

splenic trunk arose from the abdominal aorta inferior to the GPT (approximately 10 mm). The hepatosplenic trunk, with a length of ~7 mm, diverged into the common hepatic artery and splenic artery (Fig. 1). The diameter of these arteries was determined using a catheter typically used for trans-catheter arterial chemoembolisation of hepatocellular carcinoma. The common hepatic artery divided into the gastroduodenal artery and proper hepatic artery (Fig. 1). The right gastric artery branched from the left and right hepatic artery trunk, and the cystic artery branched from the right hepatic artery. Other abdominal arteries displayed normal courses.

DISCUSSION

Herein, we have described variations in the branch of the GPT in a cadaver. A rare variation was found in the branch of the right and left IPA and LGA from the GPT, a hepatosplenic trunk arising from the abdominal aorta.

The inferior phrenic arteries (IPAs) arose from each side of the abdominal aorta or CT just inferior to the diaphragm. The RIPA and LIPA can arise separately from the abdominal aorta or from an IPAT [7]. Loukas et al. [15] gave an account of their findings concerning various aspects of the IPAs in their dissection of 300 cadavers. They reported that an IPAT was present in 11.3% (34/300), with the IPAT arising from the abdominal aorta in 64.7% (22/34) and from the CT in 35.2% (12/34). Matusz et al. [16] reported, based on 1,696 cases from 6 reports, that the IPAT arose from the abdominal aorta in 21.4% of cases, the CT in 13.5% of cases, and the LGA in 0.07% of cases. According to our statistics, the incidence of an IPAT

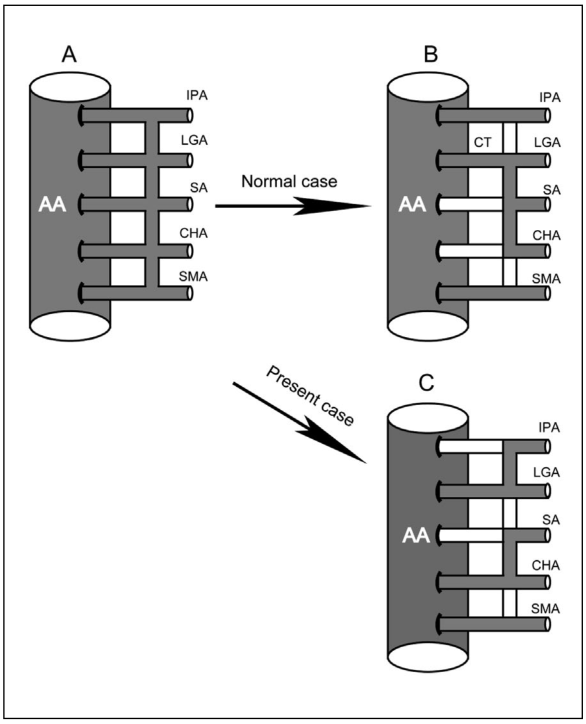

Figure 2. Schematic representation of embryonic development of the ventral primitive segmental arteries; **A.** In the early embryo, the aorta gives off dorsal, lateral (not represented), and ventral primitive segmental arteries. A longitudinal ventral artery anastomoses the primitive segmental arteries; **B.** Standard further evolution of the ventral primitive segmental arteries with development of the inferior phrenic artery (IPA), coeliac trunk (CT), and superior mesenteric artery (SMA); **C.** Putative development of the ventral primitive segmental arteries in the present case. The left gastric artery (LGA) arises independently from the abdominal aorta (AA). The hepatosplenic trunk constitutes the splenic artery (SA) and the common hepatic artery (CHA).

was 22.9% (Table 1), arising from the abdominal aorta in 13.2% of cases, the CT in 9.6%, and the LGA in 0.12% (Table 1). On the other hand, Loukas et al. [15] reported that both the RIPA and LIPA (bilateral symmetry of IPA origins independent of a common stem) most commonly arose from the CT (37%), followed by the abdominal aorta (29%); a common origin occurred from the renal arteries in 4% of specimens and from the LGA in 1%. If the RIPA and LIPA arose from the same vessel, arising separately was more common than to arise as an IPAT. Moreover, when there is a separate origin, they often arise from the CT, whereas when there is a common origin, they often arise from the abdominal aorta.

Case reports of GPT are shown in Table 2. Generally, GPT arise from the abdominal aorta and then branch to the LGA and IPAT. Moreover, the hepatic and splenic arteries commonly form a hepatosplenic trunk. In our case, the GPT arose from the abdominal aorta, the RIPA branched from the common trunk of the LIPA and LGA, and the LIPA branched from the LGA. Previous reports showed that the IPAs branched from the IPAT, which originated from the GA. However, in the current study, the IPAs branched separately from the GA. This is a rare finding.

Tandler [26] and Morita [18] demonstrated in human embryos that the primitive metameric intestinal arteries (vitelline arteries) are connected by a longitudinal anterior anastomosis. Namely, four primitive splanchnic branches arising from the abdominal aorta in early human embryos are connected by the ventral longitudinal anastomosis between the four roots of the omphalomesenteric artery, of which the central two disappear and the longitudinal anastomosis joins the first three roots (Fig. 2). The gastric, common hepatic and splenic arteries originate from this longitudinal anastomosis. In addition, the IPAs arise from the cranial side of the GA [22]. Retention or disappearance of parts of this primitive arterial plexus could give rise to numerous anomalous variations of the IPA, CT, and superior mesenteric artery (Fig. 2) [30]. Generally, the primitive ventral splanchnic branches arising from the abdominal aorta in the early human embryo are connected by the ventral longitudinal anastomosis between the roots of the omphalomesenteric artery, of which the first root is preserved and the longitudinal anastomosis between the first and second roots disappears, thus the LGA becomes independent (Fig. 2) [29]. The third root and the longitudinal anastomosis between the third and the fourth roots disappear, and then the longitudinal anastomosis between the second and the third roots join the second root, creating the hepatosplenic trunk. Generally, the IPAs arise separately [22] and do not form a common trunk by anastomosing with the CT. When the IPAs do not anastomose with the CT or exhibit a delayed anastomosis with the CT, they are considered to form an IPAT. To the best of our knowledge, where there is a GPT, the IPAs form a common stem at the anastomosis with the LGA (Table 2). However, in the current study, since the IPAs demonstrated an accelerated anastomosis with the LGA, the IPAs might have branched separately from the LGA.

Although descriptions of the RIPA and LIPA are typically brief and lack detail in anatomy textbooks, in recent years they have received increased attention in the clinical literature. In particular, transcatheter arterial chemoembolization is widely used to manage unresectable hepatocellular carcinoma. Extrahepatic collateral arteries supply the hepatocellular carcinoma, even when the hepatic artery is patent [14]. This stems largely from the discovery of the involvement of the IPAs in the arterial supply and growth of hepatocellular carcinoma [5, 27]. Kim et al. [11] analysed the extrahepatic collateral vessels supplying the hepatocellular carcinoma in 3,179 patients and revealed that the RIPA is the most common vessel that supplies peripherally located liver hepatocellular carcinomas. Furthermore, the LIPA and LGA also supply liver hepatocellular carcinomas (in order, the supply is the RIPA, omental branch, adrenal artery, intercostal and subcostal arteries, cystic artery, LIPA, right internal mammary artery, renal or renal capsular artery, branch of superior mesenteric artery, LGA, and right gastric artery). The presence of a rare course of the LGA, RIPA, and LIPA complicates selective arterial chemoembolization of the liver parenchyma. Separate branching of the IPAs from the LGA is a new anatomical variant. The combination of the LGA originating directly from the abdominal aorta, with the presence of the hepatosplenic trunk, is a very rare condition.

CONCLUSIONS

In conclusion, awareness of variations in the IPA, CT, and superior mesenteric artery is important for anatomists, interventional radiologists, oncologists, vascular, and abdominal surgeons. Knowledge of the variations in the origin and distribution of the IPAs is important when considering transcatheter arterial chemoembolisation for the treatment of unresectable hepatocellular carcinomas.

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