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The clinical relevance of coeliac trunk variations

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The coeliac trunk is a surgically significant artery originating from the abdominal aorta and supplying the supracolic organs. Branches of this arterial trunk supply the primary organs of the abdomen and divert a significant volume of blood from the abdominal aorta. Past research has shown that the anatomy of the coeliac trunk is not identical for all human beings and that about 15% of the population displays significant variations from the typical branching pattern. Data derived from earlier research has been consolidated to give an account of the major variations found in the anatomy of the coeliac trunk and to put forward some theories for the cause of such variation. It is crucial to achieve full comprehension of these topics as knowledge of these variations is indispensable in operative and diagnostic procedures within the abdomen. Without understanding of the arterial architecture and knowledge of the variation characterising the patient in this critical region surgery may entail a considerable risk of an error being committed that may occasionally lead to lethal complications.

Key words: coeliac trunk, common hepatic artery, left gastric artery, splenic artery

INTRODUCTION

The coeliac trunk (CT) is the first branch that originates from the abdominal aorta just below the diaphragm and divides into the left gastric artery (LGA), the common hepatic artery (CHA) and the splenic artery (SA). Previous research on cadavers and living persons has shown a plethora of variations in CT [44, 45]. The specific aspects explored include the level at which the artery arises from the aorta as well as variations in the length and diameter of the trunk with respect to the population [1, 23, 36, 41, 43, 46]. Understanding and classifying the variations in CT is imperative in view of its relevance in various clinical and surgical cases. Knowledge of the existence of variations in the hepatic arteries is useful for planning and conducting surgical or radiological procedures of the upper abdomen. It is important during biliary tract operations, liver transplants, chemo-embolisation of a liver neoplasm, as well as other procedures performed in this region [28, 34, 37, 39, 49, 51].

The most common classical type of variation of CT is known as trifurcation (Fig. 1a) and was first observed by Haller [13] as *tripus Halleri*. It was, and still is, considered to be the normal appearance of CT. According to Haller, CT divides into CHA, SA and LGA, which usually arises as a tributary elsewhere in this trunk, while the other divisions of CT rarely occur in human populations.

The anatomical variations of CT were classified for the first time by Adachi in 1928 [1]. Investigations were performed on 252 people of Japanese origin and these formed the basis of Adachi's classification [1] of the 6 types of division of CT and superior mesenteric artery (SMA). As seen in Table 1, the hepatogastrosplenic trunk is the primary CT variant and this divides into LGA, CHA and SA. This variant

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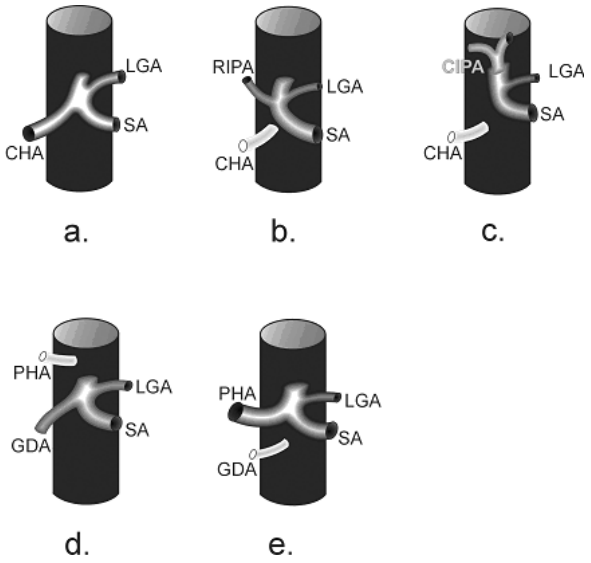

Figure 1. Trifurcation of the coeliac trunk.

Table 1. Adachi's classification of coeliac trunk variations

Trunk classification	Trunk classification number	Percentage
Hepatogastrosplenic	1	86%
Hepatosplenic	2	8%
Gastrosplenic	6	3%
Coeliacomesenteric	4	1.5%
Hepatosplenomesenteric	3	1%
Hepatomesenteric	5	0.5%

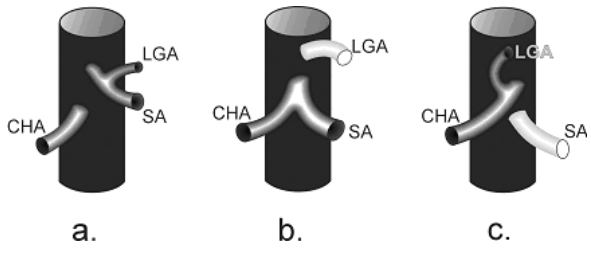

Figure 2. Bifurcations of the coeliac trunk.

is seen in 86% of the human population. The hepatosplenic trunk is the 2nd variant and this divides into CHA and SA, while LGA arises independently from the abdominal aorta (Fig. 2b). This variant appears in 8% of cases in human populations. The hepatosplenomesenteric trunk is the 3rd variant, the common origin of CHA, SA and SMA, with LGA arising directly from the aorta. It is present in 1% of the overall population. The 4th variant is the coeliacomesenteric trunk, which displays a common origin of CT and SMA from the abdominal aorta [7, 8, 26]. It appears in 1.5% of human populations. The 5th variant, known as the hepatomesenteric trunk is divided into CHA and SMA [21]. This occurs in 0.5% of cases in human populations. The gastrosplenic trunk, occurs when there is a division into LGA and SA. The common origin of LGA and SA indicates an absence of CHA, also known as a case of agenesis of CHA. In this case the liver is supplied with arterial blood by the additional (accessory) hepatic arteries. This variant appears in 3% of the overall population. Adachi's classifications [1, 42] are summarised in Table 1.

However, not all variations of branching of CT have been described in Adachi's classification. Investigations have shown that CT can divide into 2, 3, 4, 5 or even 6 branches [25, 26, 33, 47]. In some cases CT is absent and the branches arise independently from the abdominal aorta. This has been termed "agenesis of CT" by some authors [2, 3, 5, 16, 32, 38, 48].

CT has properties which allow its variations to be categorised. Kozhevnikova [23] categorised CT by the following 4 features:

— the angle of the trunk ascent from the aorta;
— the level at which the trunk arises from the aorta;
— the length;
— its change in diameter in relation to age, body build and physical constitution.

Her investigations, performed on 155 adult human cadavers, indicated that CT arose from the aorta at a level between the 11th thoracic and the 1st lumbar vertebra. She found an inverse relationship between level of ascent and age, and angle and age.

The angle at which CT arises from the aorta (between CT and the distal segment of the aorta) varies with age. The largest angle, being anywhere from 90° to 115°, can be found in newborns, whereas in adults the angle diminishes to a span of between 58° and 81°. Moreover, it has been noted that the level of the origin of CT also decreases with advancing age. The length of CT increases quickly until the age of 20 from a range of 3 mm to 8 mm in newborns to one of 15 mm to 54 mm in adults, while the diameter of CT increases from 1.5–2.0 mm in newborns to 3.1–4.3 mm in adults [23]. The diameter also decreases with advancing age, which is a significant concern for patients with arteriosclerosis. In previous classifications, labelled "pyknics" and "leptosomes", the origins of CT were found to differ in the 4 properties designated by Kozhevnikova [23]. In pyknics, the originating level of CT was observed to be higher, and the angle of ascent was also greater;

measuring between 106° and 115°. The diameter measured in this study was also found to be larger, as was the length (12–29 mm). In leptosomes, in contrast, observations have indicated that the origin of CT is lower, while the angle of ascent (< 73°) and diameter are smaller (3.1 mm), although the length was greater (39–54 mm) [23].

The direction of CT is another topographical property which varies between individuals. This direction is influenced by the origin of the hepatic artery and the topography of the pancreatic neck [47]. If CT is not the origin of the hepatic artery (*truncus gastrolienalis*), it is not directed to the right but rather to the left and appears to continue as the SA. In newborns the underdevelopment of this rightward component is also observed but it is the hepatic artery that pulls CT to the right [41, 50].

DISCUSSION

There are 6 main categories of CT variation (Table 2), depending on the number of divisions that are made [26, 33, 47]. The first category is the bifurcation of the trunk. One example of this is seen when it divides into SA and CHA, with a LGA arising independently from the abdominal aorta. This variant is present in between 1.7% and 5–6% of cases (Fig. 2b) from experimental populations [43, 47]. Further examples of this type of branching are summarised in Table 2 (Fig. 2a–c). The 2nd category of CT splits into three branches. This, the most frequent variation (Fig. 1a–e), is summarised in Table 2 [25, 26, 33, 41, 47]. One example is the classic division, which branches into LGA, CHA, largest in newborns, and SA, the largest artery in adults (Fig. 1a). The next category of CT

Table 2. Variations of the coeliac trunk

Branch class	Common branches	CT divisions	Off trunk branches	Figure
Trifurcation	LGA, SA	CHA (Tripus Halleri)	–	1a
		RIPA	CHA	1b
		CIPA	CHA	1c
		GDA	PHA	1d
		PHA	GDA	1e
Bifurcation	–	LGA, SA	CHA	2a
		CHA, SA	LGA	2b
		CHA, LGA	SA	2c
Quadrifurcation	LGA, SA, CHA	RIPA	–	3a
		LIPA	–	3b
		CIPA	–	3c
		ASRHA	–	3d
		RIPA, LIPA (no CHA)	–	3e
		DPA	–	3f
		CIPA	–	3g
Pentafurcation	–	CHA, LGA, SA, LIPA, RIPA	–	4
Hexafurcation	–	CHA, LGA, SA, ASRHA, LIPA, RIPA	–	5
Others	–	Coeliacomesenteric trunk	–	6a
		Hepatomesenteric trunk and gastrosplenic trunk	–	6b
		Hepatosplenomesenteric trunk	LGA	6c
		Hepatosplenomesenteric trunk and gastrophrenic trunk	–	6d
		Coeliac-bimesenteric trunk	–	6e
		Agenesis of CT	CHA, LGA, SA	6f

ASRHA — accessory superior right hepatic artery, CHA — common hepatic artery, CIPA — common inferior phrenic artery, DPA — dorsal pancreatic artery, GDA — gastroduodenal artery, LGA — left gastric artery, LIPA — left inferior phrenic artery, PHA — proper hepatic artery, RIPA — right inferior phrenic artery, IMA — inferior mesenteric artery, SMA — superior mesenteric artery, SA — splenic artery

branches into 4 parts. One example of such branching is seen when CT splits into LGA, SA, CHA and the anomalous RIPA (Fig. 3a). A summary of further quadruple branch divisions can be seen in Table 2 and Figures 3a–g. The final category of branching is seen when the trunk splits into 5 or 6 (Fig. 4 or 5) branches. One example of such five-fold branching (pentafurcation) is seen when the variant is made up of CHA, LGA, SA, RIPA and LIPA (Fig. 4). An example of six-fold branching (hexafurcation) is seen when the trunk branches into LGA, SA, CHA, RIPA, LIPA, and ASRHA (Fig. 5).

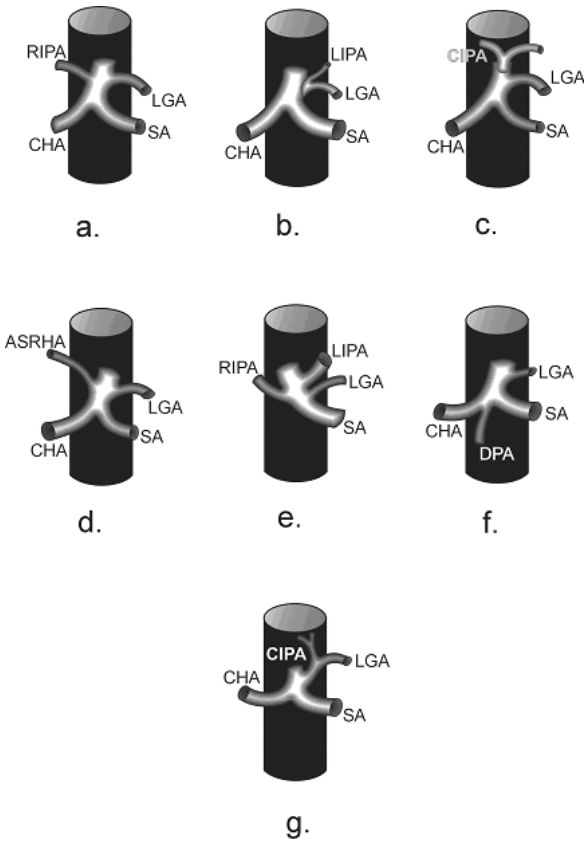

Figure 3. Quadrifurcation of the coeliac trunk.

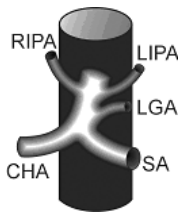

Figure 4. Pentafurcation of the coeliac trunk.

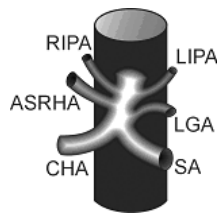

Figure 5. Hexafurcation of the coeliac trunk.

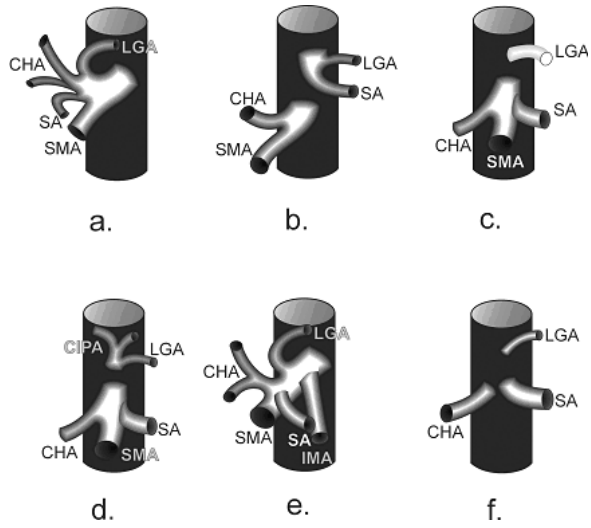

Figure 6. Other branching patterns of the coeliac trunk.

A case report presents a 39-year-old man who was referred to hospital for melaena, which lasted nearly 2 weeks. Angiography through the abdominal aorta showed a variation in the origin of the digestive arteries. CT, SMA, and IMA were visible. This variant is known as the coeliac-bimesenteric trunk (Fig. 6e), which until recently presented only variations as connections and anastomoses [35].

Another important variation is the origin of the dorsal pancreatic artery (DPA) from CT. In case studies the DPA was noted as beginning from CT between CHA and SA (Fig. 3f). It was shown to divide into a left and a right branch. The right branch gives vessels to the hepatic flexure of the colon and anastomoses with the right branch of middle colic artery [22]. This variant is a classic example of a vascular junction between CT and SMA. DPA usually arises from SA, although it can also originate in CHA, SMA or the jejunal arteries.

Surgically this is significant because knowledge of which variant category a patient belongs to can aid a surgeon during different pancreatic procedures, splenectomies and resections, for which knowledge of the gastric arteries is required [15, 19, 24, 27, 29]. The surgeon needs to know which branches supply further organs distal to the pancreas and knowledge of which variant category the patient belongs to can aid vital decision making, such as whether clipping or

redirecting blood flow is advisable for the resected arteries. The middle colic artery can originate from SA, so during colectomy and other surgical procedures of the colon these variations must be kept in mind [2, 22, 27]. In operations that require the incision of the supposed avascular area of the transverse mesocolon (as in retrocolic anastomoses) there is a risk of injury to the variant of the middle colic artery or anastomosis between CT and SMA branches [6, 8, 17, 18, 21]. Procedures involving organs which share arteries near the pancreas may also be affected if the patient variant is unknown and if the surgeon were to clip arteries that are a part of a more significant network of vessels [29, 30].

The accessory left hepatic artery or replaced left branch of the proper hepatic artery (PHA) is of importance in partial hepatectomy, gastric resection, and at any time when the hepatogastric ligament is divided. Knowledge of the variant hepatic arteries is of greatest importance in liver transplantation, since appropriate technical adjustments must be made both in organ procurement and in re-anastomosis in the recipient. The accessory hepatic arteries are an additional source of vasculature supplying the liver with arterial blood when PHA is present. The first is ASRHA, which arises from CT [37, 51]. It appears in 2% of cases (Fig. 3d). The 2nd is the accessory inferior right hepatic artery, which arises from SMA and at times gives rise to the gastroduodenal artery [6, 31], appearing in 12% of cases. Freund et al. [12] found that it occurred in 10–12% of cases, while Jones and Hardy put its incidence as high as 15% [19]. The 3rd and final artery is the accessory left hepatic artery, which arises from LGA. It is present in 18% of cases [1] or in up to 15% of cases according to Jones and Hardy [19] and 19% of cases according to Chaib [9].

These arteries are the main source of vascularisation of the liver if PHA is absent. In some cases it was even found that these accessory arteries were the only source of oxygenated blood supply to the liver. During liver transplantation these variations of the hepatic arteries play a critical role. An uncharacteristic left hepatic and right hepatic artery when CT is absent can be very difficult to follow. The right hepatic artery is not hard to dissect but is difficult to recognise. The accessory right inferior hepatic artery or replaced branch of PHA should be considered in dissection around the duodeneum and pancreas. It is important to bear it in mind during pancreatoduodenectomy [11, 12, 14]. Furthermore, the right hepatic artery arising from the aorta can be hard to identify, and may become severed during a donor operation [9]. The left hepatic artery, being smaller, is more difficult to manage owing to its anomalous origins from LGA. In the beating heart donor, the left hepatic artery is easier to identify. Knowledge of the existence of additional hepatic arteries is useful for planning and conducting surgical and radiological procedures of the upper abdomen including laparoscopic operations of the biliary tract [28, 37, 39, 40, 49, 51].

In an investigation by Rosenbusch et al. [40] a case of the inferior phrenic arteries from CT were shown to be in stenosed. If the known collateral pathways are occluded (for anatomical or haemodynamic reasons) and CT is not available, a collateral circulation can be created through the suprarenal or inferior phrenic arteries. This is especially the case if the phrenic artery origin is distal to the point of occlusion on CT. From this a phenomenon known as renocoeliac or steal syndrome may occur, particularly if the donor artery has a suprarenal branch arising from the renal artery [40].

The compression of CT by the median arcuate ligament of the diaphragm is known as Dunbar's syndrome [4, 10]. The median arcuate ligament is a tendinous arch joining the two medial borders of the diaphragmatic crura together. The partial or complete compression of CT occurs in two ways. The first is when there is a cranial emergence of CT or a caudal insertion of the left crux of the diaphragm on the lumbar vertebra. This situation causes a pathology known as abdominal angina. The main symptom of this is a postprandial cramp-like epigastric pain. The other clinical symptoms are anorexia and loss of weight. In some cases stenosis of CT by the arcuate ligament is associated with chronic calcific pancreatitis [4, 10, 20]. If CT is of greater length than normal (it is normally 1.25 cm long), the surrounding tissues could be more susceptible to disease. Patients who present with stomach pain should be evaluated for CT compression syndrome arising from the probable existence of a congenitally formed extended CT. A long CT is frequently an origin of the inferior phrenic arteries, which normally arise from the abdominal aorta [4, 20, 49, 50].

The variations of CT should be kept in mind during surgery and also in non-surgical evaluation of the patient. The variations in the anatomy of the trunk must be carefully understood in order to make proper adjustments in anastomosing the proper arteries in post-operative closing. Furthermore the arterial variations are important when matching organ procurements for transplantations.

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