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Review Article

Variant anatomy of the coeliac trunk –Review of literature with a case report

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Abstract

Variations of arteries in the abdomen frequently include the coeliac, renal and gonadal arteries. These anatomic variations are often responsible for variety of clinical conditions and pose major considerations during surgeries. Thorough knowledge of normal and variant anatomy of major unpaired arteries originating from the abdominal aorta is necessary to accomplish successful abdominal operations and to avoid complications. During routine dissection we came across a variation in the coeliac trunk. Instead of normal trifurcation of the coeliac trunk, we observed three separate trunks arising from the abdominal aorta: gastrophrenic trunk, hepatosplenic trunk and hepatophrenic trunk. The incidence and developmental as well as clinical significance of these variations having crucial surgical importance are discussed with a detailed review of the literature.

Keywords: Coeliac trunk, Coeliac trunk variations

1. Introduction

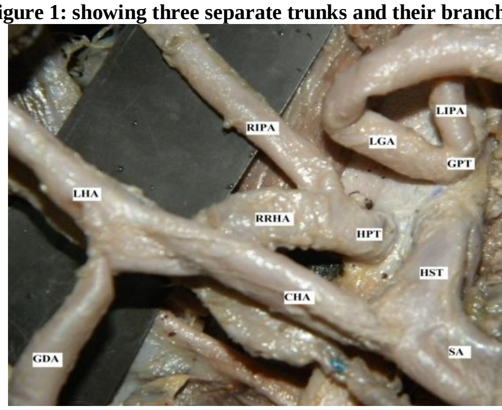
The coeliac artery, commonly known as the coeliac trunk (CT), is a major visceral branch of the abdominal aorta originating at its anterior contour just below the aortic hiatus of diaphragm at the level of T12- L1 vertebral bodies. It is about 1.5-2 cm long and 6-8 mm in diameter. It passes almost horizontally forward and divides into 3 branches – left gastric, splenic and common hepatic arteries[1,2]. The most common form of the CT is tripodal. According to Michels, this tripodal form occurs in 55% of individual[3]. Van Damme and Bonte reported that this form occurs in 86% of individuals[4]. The trifurcation of CT was first described by Haller in 1756. This "Tripus Halleri" is still considered to be the normal appearance of the CT[5-11], although many variational patterns of the CT have been described. It appears that only 87.6% of the CT exhibited the classical trifurcation, while an incomplete CT accounted for 12.2% and absence of the CT was extremely rare[8]. Anatomical variations in the branching pattern of the CT are of considerable importance in liver transplants, laparoscopic surgery, radiological abdominal interventions and penetrating injuries to the abdomen. Knowledge of these variations is important for proper preoperative diagnosis and planning of surgical and radiological procedures.

The aim of this review is to emphasize the importance of variation of the CT in previously reported cases in literature to discuss the incidence and its developmental significance and to report a case which prompted this review.

2. Case report

During routine dissection of the posterior abdominal wall, we observed anomalous branching pattern of the CT in a 50 yr old male cadaver. The CT and its branches were carefully dissected and the surrounding structures were delineated. The classical trifurcation of the CT was absent; instead three separate trunks were seen: gastrophrenic, hepatosplenic and hepatophrenic (Figure 1).

Figure 1: showing three separate trunks and their branches



GPT: Gastrophrenic trunk, **HPT:** Hepatophrenic trunk, **HST:** Hepatosplenic trunk. **LGA**: left gastric artery, **LIPA:** left inferior phrenic artery, **RIPA:** right inferior phrenic artery, **RRHA:** replaced right hepatic artery, **CHA:** common hepatic artery, **SA:** splenic artery, **LHA:** left hepatic artery, **GDA:** gastroduodenal artery

The gastrophrenic trunk arose from left anterolateral wall of the abdominal aorta, 2 cm distal to the aortic hiatus. It travelled forward for about 5 mm and divided into left gastric artery (LGA) and left inferior phrenic artery (LIPA). Approximately 5 mm distal to the gastrophrenic trunk, there was origin of hepatosplenic trunk from left anterolateral wall of the aorta. It ran forward for about 2 cm and divided into splenic artery (SA) and common hepatic artery (CHA). An interesting finding was that the CHA after giving the gastroduodenal artery became continuous as the left hepatic artery to supply the left lobe of liver. Still 6 mm distal to the hepatosplenic trunk, another trunk, hepatophrenic trunk arose from anterior aspect of the aorta. It ran forward for about 1 cm and gave off replaced right hepatic artery (RRHA) and right inferior phrenic artery (RIPA). The RRHA ran upwards and to the right passing behind the portal vein and common bile duct to supply the right lobe of liver.

3. Review of literature and Discussion

The CT usually arises from the abdominal aorta and trifurcates into its three branches: left gastric, splenic and common hepatic arteries. If two of its branches have a separate origin, there is no coeliac trunk left[12]. Van Damme states that the CT does not trifurcate into its three main branches as is usually depicted, but it bifurcates into the splenic and common hepatic arteries. The third branch, the left gastric artery is a mobile vessel whose origin may slide between the aortas, all over the CT up to a trifurcation[12].

The high incidence of anatomical variations of the CT and its branching pattern was widely described in the literature as observed to vary from classical trifurcation[13-19] to abnormal trifurcation[10,14,20]. bifurcation[10,11,13-18,21-23], quadrifurcation[6,10,13,15-17,19,20,22,24-26], pentafurcation[5,9,10,13,15,20,25,27-32], hexafurcation[13], heptafurcation[33] and even absence[4,8,13,14,16-18] of the trunk. Generally additional branches other than the normal branches are referred to as collaterals[5, 21, 27, 29, 32, 33]. Reported collaterals of the CT include the inferior phrenic, aberrant right hepatic, gastroduodenal, middle colic, dorsal pancreatic, left superior suprarenal, left middle suprarenal, duodenal or ileal arteries[5,6,9,10,13,15,16,19,20, 24-33]. Presence of additional arteries may provide collateral circulation which may be important during liver transplant, laparoscopic surgeries, and radiological abdominal interventions in day to day clinical practice[29].

Several authors have studied the branching pattern of the CT[10, 13-16, 18, 19, 22, 32]. They showed that the organization of the CT and its branches presents several variations which are summarised in table 1 and the study of this variability is of clinical significance. It was observed that only 79.8% of the CT exhibited the classical trifurcation. The bifurcation of the CT accounted for 6.6%, absence of the CT in 0.8% and presence of collateral in 12.6%.

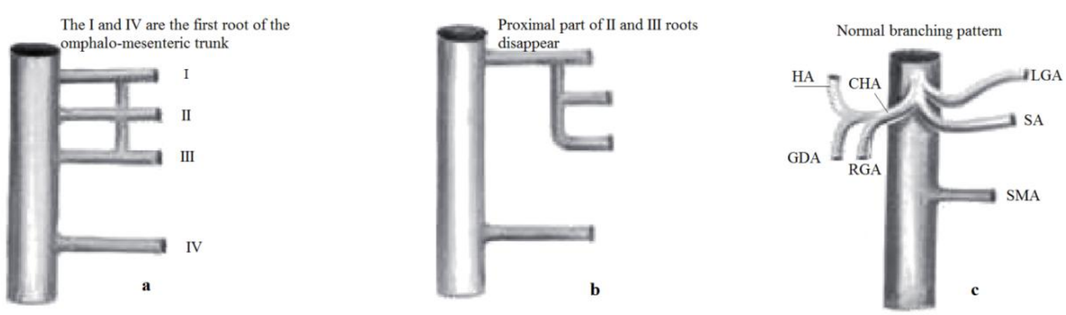
Table 1: Variations in the branching pattern of the CT in the literature

Author	Population studied	Sample size	Trifurcation %	Bifurcation %	Collaterals %	No CT	HSM/ SM trunk
Tiwari	Indian	50	84	2	14	-	
Chitra	Indian	50	40	6	54	-	
Ugurel	Turkish	100	89	8	-	1	2
Mburu	Kenyan	123	61.8	17.9	20.3	-	
Petrella	Brazilian	89	82	5.6	10.1	2.3	
Prakash	Indian	50	86	10	-	4	
Jacob	Indian	40	97.5	-	2.5		
Silveria	Brazilian	21	85.7	9.5	4.8	-	
Krishna	Indian	50	92	-	8	-	
Total		573	79.8	6.6	12.6	0.8	0.2

(**HSM**- hepatosplenomesenteric, **SM** - splenomesenteric)

Differences arising during several developmental stages in the embryonic process lead to a range of variations in these vascular structures. Each dorsal aorta, even before the stage of its fusion, gives ventral splanchnic branches which supply the gut and its derivatives. Initially, these ventral branches are paired. With the fusion of the dorsal aorta, the ventral branches fuse and form a series of unpaired segmental vessels in the form of 4 roots which run in the dorsal mesentery of the primitive gut. These roots divide into ascending and descending branches to form longitudinal anastomotic channels. The proximal parts of two central roots disappear and distal portions join with the 1st root to form classical 3 branches of the CT and 4th root forms the superior mesenteric artery. Retention or disappearance of parts of this primitive arterial plexus could give rise to numerous anatomical variations in the CT[26,34].

Figure 2: Diagram showing normal (a-c) development of the coeliac trunk (Source – Kalthur *et al*[26])



Anatomical variations of the coeliac arterial system were defined according to Michels' internationally recognized classification[35].

Table 2: Michels' classification of the coeliac trunk

Types	Coeliac trunk variation
1	Hepato-spleno-gastric trunk (Normal branching)
2	Hepatosplenic trunk (LGA arises separately)
3	Hepatosplenomesenteric trunk (LGA arises separately)
4	Hepatogastric trunk (SA from aorta or SMA)
5	Gastrosplenic trunk (CHA from aorta or SMA)
6	Coeliaco-mesenteric trunk – (SA,LGA,CHA and SMA arise from a common trunk)
7	Coeliac-colic trunk (middle colic arises from the CT)

(**LGA**- left gastric artery, **SA-** splenic artery, **CHA-** common hepatic artery, **SMA-** superior mesenteric artery)

Ugurel[14] quoted Uflacker's classification which is a modification of Michels' classification. (Table 3)

Table 3: Uflacker's classification of the coeliac turnk

Types	Uflacker's classification
I	Classic coeliac trunk
II	Hepatosplenic trunk
III	Hepatogastric trunk
IV	Hepatosplenomesenteric trunk
V	Gastrosplenic trunk
VI	Coeliac-mesenteric trunk
VII	Coeliac-colic trunk
VIII	No coeliac trunk

The hepatosplenic trunk (Type II) and separate LGA from the aorta have been reported in the literature[10,13-16,18,21,22,36,37]. The LGA commonly arises from the CT as one element of its trifurcation. However, some authors have reported it as arising independently from the aorta[8,18,36]. Skandalakis has stated that, in approximately 90% of individuals the LGA is a branch of the CT, while in 4% it arises from the gastrosplenic trunk; in 3% it has a direct aortic origin and in 2% it is a branch of hepatogastric trunk. However it may arise from the CHA, SA or SMA[12]. In the present case, we found the common trunk of LGA and LIPA - gastrophrenic trunk, arising from the aorta which was similar to Ucerler's finding[23]. Nayak[27] mentioned the same finding reported by Cavdar.

The inferior phrenic arteries (IPAs) are two small arteries which supply the diaphragm. They usually arise from the abdominal aorta just below the aortic hiatus. However, they aris**e** almost frequently from the CT either separately or by a single stem common to both sides[1,2].

McVay Anson[38] stated the incidence of origin of IPA as follows: Coeliac trunk- 46.8%, Aorta- 45.1%, Renal artery- 4.9%, Left gastric artery- 2.6% and Hepatic artery- 0.5%. Pamidi[21] and Gujaria[28] quoted the observations of Piano *et al* stating the origin of IPAs from a) the aorta itself (61.6%), b) ventro-visceral arteries (coeliaco-mesenteric system of aorta) including the coeliac trunk (28.2%), and left gastric artery (2.9%), c) the latero-visceral arteries (adreno-renal system) including the middle adrenal artery (2.9%) and renal artery (4.3%).

Mburu studied 123 specimens and observed the origin of IPA from the CT in 4.9%[15]. The previous study conducted by Tiwari[20] and Petrella[25] showed the origin of RIPA alone from the CT in 2% and 5.62%, LIPA alone in 4% and 21.35%, whereas both IPAs in 4% and 7.86% respectively. The origin of LIPA from the LGA is also described in the literature[7,21,22,33,38]. The knowledge of this type of variation shows that surgeons must be cautious to avoid unintentional sectioning of small calibre arteries, as it may occur during the coeliac artery decompression.

The IPAs have received increased attention in the recent years after the discovery of involvement of right or left IPA in the arterial supply and growth of hepatocellular carcinoma (HCC). The IPA is a major source of collateral or parasitized arterial supply to HCC, second to hepatic artery. The great importance of such knowledge lies in the fact that an unresectable HCC can be treated by transcatheter embolisation of not only its typical blood supply, the right or left hepatic arteries, but also by embolisation of RIPA, if involved[20].

The CHA arises from the CT, passes forward and to the right along the upper border of head of pancreas. Here it gives off the gastroduodenal artery and continues as proper hepatic artery. At the portahepatis, it divides into right and left hepatic arteries to supply the corresponding lobes of the liver. According to Michels[3] this normal anatomy was seen in 55% of the cases whereas Hiatt[39] and Abdullah[40] reported it in 75.7% and 68.1% of cases respectively.

Sathidevi observed that the proper hepatic artery instead of dividing into right and left hepatic arteries simply continued as the right hepatic artery alone while the left hepatic artery arose from left gastric artery[24]. In the present case, proper hepatic artery continued as left hepatic artery and the right hepatic artery arose from the aorta.

When the right hepatic artery does not arise from the proper hepatic artery or common hepatic artery, its origin is shifted to the aorta or any of the arteries whose normal course is towards right side of the aorta like superior mesenteric, gastroduodenal, right gastric or coeliac trunk[17,41]. When the hepatic artery arises from a source other than the terminal end of the CT, it is considered as aberrant hepatic, usually found in one third of cases. These aberrant hepatic arteries are of two types, replacing and accessory. An aberrant replacing hepatic artery is a substitute for the normal hepatic artery which is absent. An aberrant accessory hepatic artery appears in addition to one that is normally present. An aberrant right hepatic artery usually arises from the superior mesenteric artery or the aorta[35]. The presence of replaced right or left hepatic arteries can be life saving in patients with bile duct cancer because they are further away from the bile duct and tend to be spared from the cancer, making excision of the tumour feasible[24].

Michels' classic autopsy series of 200 dissections[3], published in 1960, defined ten different types of anatomic variations of hepatic artery and has served as the benchmark for all subsequent contributions in this area. Andujar *et al*[42] investigated 1081 donor livers and compared the findings with Michels' classification. They also found 2 new types which are not included in Michel's classification as shown in Table 4.

Table 4: classification of the hepatic arterial system

Type	Hepatic artery variation	Michels' classification %	Rafael Lopez classification %
I	Normal pattern	55	70
II	A replaced LHA originating from LGA	10	9.7
III	A replaced RHA originating from SMA	11	7.8
IV	Replaced RHA and LHA	1	3.1
V	An accessory LHA from LGA	10	3.9
VI	An accessory RHA from SMA	7	0.6
VII	Accessory RHA and LHA	1	0.6
VIII	A replaced right or left hepatic artery with the other hepatic artery being an accessory artery	2	0.3
IX	Common hepatic artery originating from SMA	2.5	2.5
X	RHA and LHA originating from LGA	0.5	0
XI	CHA originating from the SMA	-	0.3
XII	CHA originating from the aorta	-	0.7

Hiatt[39] and Abdullah[40] modified Michels' classification and classified the hepatic arteries into six types.

Table 5: modification of Michels' classification

Types	Hepatic artery variation	Hiatt's classification %	Abdullah's classification %
I	Normal	75.7	68.1
II	Replaced or accessory LHA	9.7	8.1
III	Replaced or accessory RHA	10.6	10.2
IV	Replaced or accessory RHA + Replaced or accessory LHA	2.3	6.4
V	CHA from SMA	1.5	1.6
VI	CHA from aorta	0.2	0.3

The present case showed a replaced RHA from abdominal aorta in the form of hepatophrenic trunk which is not consistent with any type described under Michels' and Hiatt's classification. Ugurel *et al*[14] noted the incidence of replaced RHA in 17% of cases and that especially from the aorta in 1%. The RHA arising from the aorta can be hard to identify and may be divided during the donor operation[17]. Bhardwaj studied 60 cadavers and found the origin of RHA from proper hepatic artery in 65%, from common hepatic artery in 20%, from superior mesenteric artery in 8.3% and from coeliac artery in 6.7%[41]. Out of 180 dissections, Jones and Hardy noted the origin of replaced RHA from SMA in 18%, from gastroduodenal artery in 6% and from right gastric artery or aorta in 1.6%[17]. John Stauffer *et al* retrospectively reviewed[43] 191 patients who underwent pancreaticoduodenectomy with the help of preoperative imaging and identified replaced RHA from SMA in 12%.

The hepatic artery variations can usually be explained by embryonic development. The liver is supplied during the foetal life by 3 arteries – right hepatic artery from the superior mesenteric artery, left hepatic artery from the left gastric artery and common hepatic artery from the coeliac trunk. With further development, the blood supply assumes the adult pattern, with atrophy of both right and left hepatic arteries and the common hepatic artery gives the right and left hepatic arteries supplying the whole liver. This adult pattern occurs in around 67% of individuals[41]. Anatomical variations correspond to the result of partial or complete persistence of the foetal pattern[40].

The variations which are reported here have already been reported as individual cases of variations but occurrence of variations of left gastric artery, splenic artery, common hepatic artery, inferior phrenic arteries and right hepatic artery in the same individual have not been reported yet.

It is an accepted fact that variations of the CT do frequently exist and thus its presence may not be undermined. Knowledge of variation found in the present case is very useful in surgical, oncologic or interventional procedures and should be kept in mind to avoid complications. In our opinion, arterial variations should not be ignored during abdominal operative procedures. Complications in abdominal surgeries could be avoided with the accurate knowledge of the anatomical variations of the CT. Preoperative knowledge of the variations of the CT and its branches is essential for surgeons, particularly in the present era of minimal access surgeries.

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