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Original Article

Anatomic variations of the celiac trunk and hepatic arterial system with digital subtraction angiography

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ABSTRACT

Background/Aims: Anatomical variation of the abdominal arteries is important. Historic and modern anatomists, radiologists, as well as surgeons have reported and accumulated anatomical variations with a morphological and clinical interest. During graft procurement and reconstruction, accidental injury of the hepatic artery is more likely in the presence of hepatic arterial variation, which can be a common clinical entity. During cadaveric dissection and diagnostic radiological imaging, various types of vascular anomalies are frequently found in human abdominal viscera, especially the celiac trunk. The aim of the present study is to determine anatomical variations in the celiac trunk and hepatic arterial system.

Materials and Methods: Digital subtraction angiography data were collected from 152 consecutive donor patients (103 males and 49 females, aged between 6 and 77 years) who underwent orthotopic liver transplantation.

Results: We examined the anatomy of the celiac trunk in a total of 152 consecutive patients. In total, 62.5% (95/152) of patients showed the classical trifurcation of the celiac trunk. Variant right hepatic arteries arising from the superior mesenteric artery were observed in 17.8% (27/152), the hepatic arteries arising from the left gastric artery were found in 13.1% (20/152), and common hepatic arteries arising from the superior mesenteric artery were observed in 6.6% (10/152) of patients.

Conclusion: These data are useful for planning and performing surgical and radiological procedures of the upper abdomen.

Keywords: Celiac trunk, hepatic arteries, digital subtraction angiography, anatomic variations

INTRODUCTION

Anatomical variations of the celiac trunk (CT) have been noted in 25-75% of observed cases and are without a doubt clinically significant (1,2). Investigating the anatomical variations of donor hepatic arteries and exploring the measures that can be taken to avoid accidental hepatic artery injury could be of vital importance during graft procurement and reconstruction. It is well known that differences arising during embryonic developmental stages lead to a range of variations in this vasculature (2,3).

During cadaveric dissection and diagnostic radiological imaging, various types of vascular anomalies are frequently found in human abdominal viscera (4-6). The CT arises just below the aortic hiatus at the T12/L1 level, superior to the pancreas. It is the first anterior branch of the abdominal aorta. The abdominal vessels, especially the CT and superior mesenteric artery (SMA), frequently show diverse anomalies in their origin and course (7-9). In 75-90% of individuals, it runs horizontally forward for approximately 1.25 cm (8,9). The trunk may be shorter or longer than usual and its length varies between 8 mm and 40 mm (9,10). The trifurcation of the CT was first described by Haller in 1756 and this "tripus Halleri" was and is still considered to be the normal appearance of the CT (8). The classical description of the CT states that, at the upper border of the pancreas, it divides into three branches: the left gastric artery (LGA), the common hepatic artery (CHA), and the splenic artery (SA) (5,10). Following Haller's description for the branching pattern of the CT, several authors made an effort to

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compare different types of variations in order to determine a single scheme (5,8,9).

The best classification for basic use is the one by Vandamme and Bonte because it is simple but comprehensive (10). According to them, the LGA, CHA, and SA are the main braches of the CT, whereas others such as the inferior phrenic arteries, arteria colica media, arteria pancreaticoduodenalis superior, and arteria pancreaticoduodenalis inferior are the collaterals. The common hepatic artery gives rise to the gastroduodenal artery and continues up to the hilum of the liver as the hepatic artery proper. Immediately before entering, the portal hepatic artery proper divides into the right and left hepatic arteries (8,11).

In rare cases, all three components (LGA, CHA, and SA) are branched independently from the aorta (1,12,13). In addition, it has been reported that the CT unites with the SMA at their origins to form a common trunk, the celiacomesenteric trunk (CMT) (9,14). Nayak (15) reported a common celiacomesentericophrenic trunk (CMPT). Moreover, Noment et al. (16) reported a case in which all three arteries were converted into one trunk, namely the celiacobimesenteric trunk (CBMT). Koizumi et al. described a case in which the dorsal pancreatic artery (DPA) originated from the CA (17). In fetal studies, an absence of the CT has been reported in 28% of cases, and rarely a double CT has been observed (17,13).

Anatomical variations of the hepatic arteries and the CT are of considerable importance in liver transplants, laparoscopic surgery, radiological abdominal interventions, and penetrating injuries to the abdomen (14,18,19). Especially in liver transplantations, a detailed knowledge of the branching pattern of the CT is essential to achieve surgical arterial anastomoses (20,21). Furthermore, for both surgical approaches and interventional radiology, a detailed vascular mapping is of importance (22).

The aim of this study was to examine the anatomical variations that occur in the celiac trunk-hepatic arterial system and their prevalence.

MATERIALS AND METHODS

Angiographic images of 152 consecutive patients (100 males and 52 females, aged between 6 and 77 years) who underwent celiac angiography were evaluated with the consent of the ethics committee at Baskent University Hospital. All subjects were healthy individuals undergoing surgery as donors for liver transplantation. Angiograms were obtained in order to evaluate the vascular anatomy of the liver before transplantation. All digital subtraction angiography (DSA) interventions were performed in the angiographic suite (Siemens Multistar TOP, Germany). Arterial catheterization was performed through the common femoral artery. After the placement of a 5- or 6-French introducer sheath, flush aortography was performed to evaluate the anatomy of the visceral vessels. Selective angiograms of the CT were obtained using a 4- or 5-French reverse shaped catheter. Is osmolar contrast medium (Visipaque 320 mg/mL; Amersham Health, GE Healthcare) was used for all procedures. Images were obtained from at least two different angles and anatomic variations of the CT were noted. The remaining procedures were performed according to the indications for angiographic intervention.

Groups of mean age according to the sex were compared by Student's t-test. Results were expressed as mean ± standard deviation. Distributions of the frequencies of the five types according to the sex were analyzed by the likelihood ratio test. Results were expressed as frequencies and percentages. A p-value of <0.05 was considered statistically significant. The SPSS 17.0 statistical software was used for statistical analyses.

RESULTS

Variations in the origin of the CT and in its branching pattern were grouped into the following four types (Figure 1); classification was based on DSA in all patients.

Type I: *The classical trifurcation of the CT (division into three branches: the LGA, CHA, and SA)*
Type II: *The right hepatic arteries arising from the SMA*
Type III: *The left hepatic arteries arising from the LGA*
Type IV: *The CHA arising from the SMA*

Angiograms of 152 patients (100 males and 52 females) were evaluated in order to determine variations in the branching pattern of the CT. The classification in the present study was

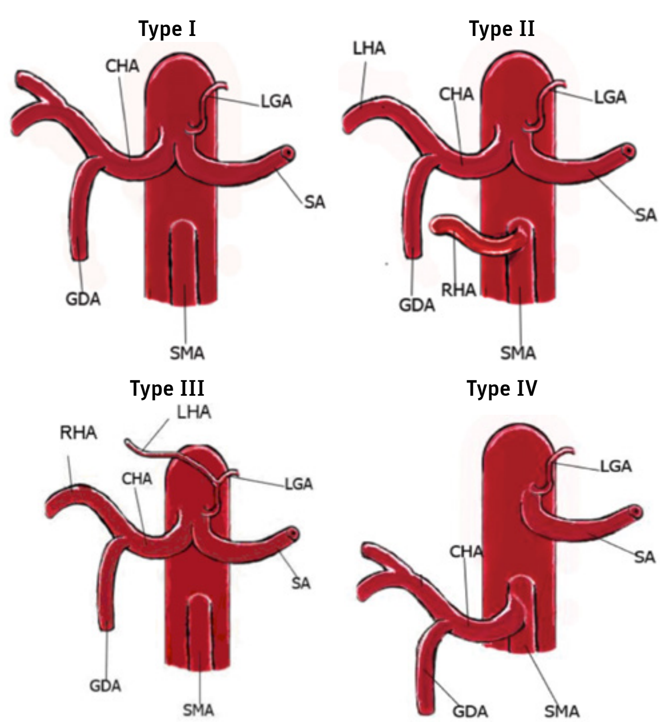

Figure 1. Anatomy of the celiac trunk and hepatic arteries in this study. SMA: superior mesenteric artery; CHA: common hepatic artery; RHA: right hepatic artery; LHA: left hepatic artery; SA: splenic artery; LGA: left gastric artery; GDA: gastric dexter artery (right gastric artery)

mainly based on variations in the origin of the hepatic artery and the branching pattern of the CT (Figure 2). The age ranges of the subjects included in this study ranged from 6 to 77 years. However, no significant difference was observed among the Type groups (classes) related to age (p=0.410). Furthermore, no significant age difference was observed between males and females (p=0.607).

Out of 152 patients, the CT was divided into three branches (the LGA, CHA, and SA) in 62.5% of patients (95/152), the right hepatic arteries arose from the superior mesenteric artery in 17.8% (27/152), the left hepatic arteries arose from the superior mesenteric artery in 13.1% (20/152), and the common hepatic arteries arose from the left gastric artery in 6.6% (10/152) (Table 1).

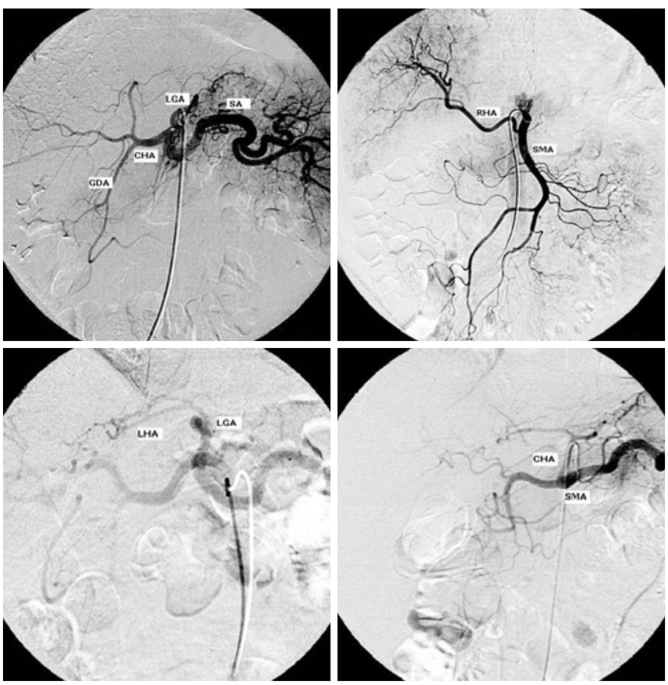

Figure 2. a-d. The classification in the present study was mainly based on variations in the origin of the hepatic artery and the branching pattern of the CT. SMA: superior mesenteric artery; CHA: common hepatic artery; RHA: right hepatic artery; LHA: left hepatic artery; SA: splenic artery; LGA: left gastric artery; GDA: gastric dexter artery (right gastric artery)

The incidence of classical trifurcation of the CT (Type I; 62.5%) was significantly higher than other variations (p<0.001). No significant differences were observed among the remaining four groups. In a comparison between sexes, variation Type I was observed in 63.5% of females and 62% of males. During the radiological evaluation of the angiograms, 17.3% of males and 18% of females were Type II, 17% of males and 5.7% of females were Type III, and 3% of males and 13.5% of females were Type IV. The incidence of the fourth CT pattern was significantly higher in females (p<0.05). The distribution of the abovementioned five types of CT patterns according to the sex is presented in Table 2.

DISCUSSION

Hepatic vascular anatomy is important to surgeons who are evaluating donors and recipients in the living adult donor liver transplantation programs. Classic vascular anatomy serves as a guide to understanding the vascular supply and drainage patterns. Multiple vascular variants exist, but their importance varies (1,4,5). In this study, anatomic variations of the CT and hepatic artery of 152 patients at Baskent University were analyzed. Classic vascular anatomy was observed in only 62.5%of them. Most (37.5%) of the recipients and donors had some form of vascular anatomic variant detected on CT angiography.

Various classifications have been reported previously for variations in the origin of the CT and the branching pattern of the hepatic artery (4,5). One of these was the Uflacker classification, which is as follows: Type I, classical trifurcation of the CT; Type II,

Table 2. The incidence of anatomic variation of the celiac trunk according to the sex

Classification	Male = n (%)	Female = n (%)
Type I	62 (62.0)	33 (63.5)
Type II	18 (18.0)	9 (17.3)
Type III	17 (17.0)	3 (5.7)
Type IV	3 (3.0)	7 (13.5)
Total	100 (100)	52 (100)

Table 1. The incidence of anatomic variation of the celiac trunk and hepatic artery in the present study

Description	Classification	Number of cases (%) N=152	F=52 M=100
The classical trifurcation of the CT (It divides into three branches: the left gastric artery, the common hepatic artery, and the splenic artery).	Type I	95 (62.5%)	F=33 M=62
The right hepatic arteries arising from the superior mesenteric artery.	Type II	27 (17.8%)	F=9 M=18
The left hepatic arteries arising from the left gastric artery.	Type III	20 (13.1%)	F=3 M=17
The common hepatic arteries arising from the superior mesenteric artery.	Type IV	10 (6.6%)	F=7 M=3

F: female; M: male

hepatosplenic trunk; Type III, hepatogastric trunk; Type IV, hepato-splenic-mesenteric trunk; Type V, gastrosplenic trunk; Type VI, celiac-mesenteric trunk; Type VII, celiac-ocolic trunk and Type VIII, no celiac trunk (22). On the other hand, Michels and Hiatt determined the variation in the origin of the hepatic artery in a more comprehensive manner (22,23) (Table 3).On the basis of the above mentioned three types of classification, we classified our findings into four groups (Table 1 and Figure 1).

In a retrospective study on1000 patients by Michels and Hiatt, variations in the morphological structure of the CT were classified into six types depending on the origin of the hepatic artery, as detailed in the present study (22,23). The classical trifurcation of the CT was reported as Type I by the authors and observed in 75.5% of individuals. The pattern in which the replaced left hepatic artery or the accessory left hepatic artery arose from the LGA was determined as Type II, and 9.7% of the subjects belonged to this type. However, the same variation was reported as Type III in the present study, and 13.1% of the patients had this type of CT on angiography. According to the classification by Hiatt et al., in Type III, the replaced right hepatic artery or accessory right hepatic artery arose from the SMA and was observed in 10.6% of the cases. The same CT pattern was determined as Type II in the present study, and it was observed in 17.8% of the patients. Hiatt et al. determined another variation as Type IV (this did not exist in the present study); in this type, the right hepatic artery arose from SMA, whereas the left hepatic artery arose from the LGA. However, this type was observed in only 2.3% of the patients. In their study, Hiatt et al. observed that the common hepatic artery gave rise to the SMA and had this pattern. This pattern wastermed as Type IV in the present study, and its incidence was not as low as that observed in the study by Hiattet al. (6.6%) (22).

In another study by Vandame et al.,four different CT branching patterns were described (21). The classical trifurcation of the CT into the CHA, LGA, and SA were reported as Type I. The incidence of this type was relatively higher (86%) than all other types, as reported in the other studies (21). In the present study, classical trifurcation of the CT was observed in 62.5% of the patients, higher than the incidence of all the other types. Nevertheless, the incidence of the classical CT pattern was relatively lower than that reported by Vandamme et al. In Type II described by Vandamme et al., the CHA and SA arose from the descending aorta by a common trunk, namely the splenohepatic trunk; 15%of their patients belonged to this type. However, none of the variations determined in the present study belonged to this type. In Type III reported by Vandamme et al., the CHA and LGA had a common trunk, namely the hepatogastric trunk, forming the CT, and the SA arose directly from the descending aorta. Although Vandamme et al. observed this type of variation in 6% of patients, such a variation did not exist in the present study. In the last type determined by Vandamme et al. (21) (Type IV), the SA and LGA had a common trunk originating from the abdominal aorta (splenogastric trunk). A similar pattern was determined as Type II in the present study. Although this pattern was only observed in 6.6% of the patients in the study by Vandamme et al., its incidence in the present study was significantly higher (17.8%).

In another study by Ugurel et al. (23), variations in the CT and the branching pattern of the renal arteries were evaluated on angiograms and, in 89.0% of the patients, classical trifurcation of the CT was observed. Hepatogastric trunk was observed in only in one of the 100 patients. However, in the present study, this type of variation was observed in 20 of 152 patients. The hepatosplenomesentric trunk was observed in only one patient in the study by Ugurel et al. In the present study, CH arose

Table 3. Hepatic artery variations: the Michel's and Hiatt's classifications

Michelsclassification	Hiatt classification	Hepatic artery variation
Type I	Type I	Normal anatomy (classical trifurcation)
Type II	Type II	The replaced left hepatic artery originating from the left gastric artery
Type III	Type III	The replaced right hepatic artery originating from the superior mesenteric artery
Type IV	Type IV	Co-existence of Types II and III
Type V	Type II	The accessory left hepatic artery originating from the left gastric artery
Type VI	Type III	The accessory right hepatic artery originating from the superior mesenteric artery
Type VII	Type IV	The accessory left hepatic artery originating from the left gastric artery and the accessory right hepatic artery originating from the superior mesenteric artery
Type VIII	Type IV	The accessory left hepatic artery originating from the left gastric artery and the replaced right hepatic artery originating from the superior mesenteric artery
Type IX	Type V	The common hepatic artery originating from the superior mesenteric artery
Type X	NOD*	The right and left hepatic arteries originating from the left gastric artery
NOD	Type VI	The common hepatic artery directly originating from the aortat

NOD: not otherwise described in the literature

Original Article

from the SMA in 10 patients (Type IV). The gastrosplenic trunk and splenomesenteric trunk described by Ugurel et al. were not observed in the present study. In both studies, the highest incidence belonged to the classical CT trifurcation (Type I).

Based on a literature review, the most commonly observed variation of the hepatic artery was the one originating from the SMA (Type III: 6-15.5%),followed by Type II in which the left hepatic artery arose from the LGA (24,25). The incidence of this type is between 2.5% and 10% in studies till date. However,in the present study, the above mentioned Type III variation was observed in 13.1% of patients, relatively higher than the rate reported in the literature. On the other hand, Type IV in which the CHA arose from the SMA was not frequent in the present study, which is similar to the results of earlier studies (24,25). In this study, the CHA arose from the SMA only in 10 of 152 subjects.

Left gastric artery originating directly from the abdominal aorta, as well as the SA and CHA forming a common trunk is rarely reported in the literature (26). Chen et al. (27) reported this type of variation (26); however, it was not observed in the present study. The LGA frequently originates from the descending aorta by a common trunk together with the SA of the CHA instead of arising from the CT as a separate artery. In 17.8% of patients in the present study, the LGA formed a common trunk together with the SA. All of the above mentioned variation are of great importance for clinicians during surgical approaches related to the stomach or the distal end of the esophagus.

Vandamme et al. observed the absence of the CT in 1.25% of their patients (21). Bergman et al. published a meta-analysis of "no celiac trunk reports" in the literature and calculated an average CT absence rate of 0.4 % (28). In the study by Ugurel et al., the CT was absent in 1 of 100 cases (23). Absence of the CT was not observed in the present study.

Kostelic et al. (29) believed that 50% of anomalous hepatic arterial configurations were technically incompatible or had potentially adverse effects on the outcome of surgery; our liver transplantation team has rarely excluded patients with such variants from being donors. However, knowledge of thesevariants is vital to the transplantation surgeon. Although certain variants are more crucial than others, because they may produce different technical difficulties or challenges, all of the variants noted on DSA are discussed with the surgeon prior to surgery.

We believe that arterial variations should not be ignored during abdominal operative procedures, because many complications can be avoided by detailed knowledge of the anatomic variations. The information reported here will contribute to the literature and play a significant role during surgeries of the abdominal region as well as in angiographies.

Conflict of Interest: No conflict of interest was declared by the authors.

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Original Article

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