Original Research

Investigation of the Coeliac Trunk Morphometry with Multidetector Computed Tomography Angiography

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ABSTRACT

Objective: Accurate knowledge of vascular anomalies is critical in surgical interventions, radiology, and organ transplantation procedures. Vascular variations during these procedures can cause serious complications. This study aimed to evaluate the coeliac trunk (CT) and its branches morphometrically, to examine possible variations with multidetector computed tomographic angiography (MDCTA), and to compare the obtained data with the findings in the literature.

Methods: In this study, abdominal MDCTA images of 126 people taken between April 2014 and April 2016 at Necmettin Erbakan University University Meram Medical Faculty Hospital were analyzed retrospectively. Variation and morphometric analysis of CT and its branches were performed. In the morphometric analysis, diameter measurements were made in centimeters (cm) and compared in terms of sex of the patients. Variation analysis was performed per a useful and simple classification we developed through a comprehensive literature review.

Results: Diameter measurements of CT (0.73±0.13, p=0.002), splenic artery (0.69±0.1, p=0.0004), common hepatic artery (0.66±0.1, p=0.042), and left gastric artery (0.27±0.11, p=0.0001) were statistically significant in men than in women (p<0.05). In our study, type I (normal trifurcation pattern - complete) was detected in 111 (88.09%) cases, and variation was detected in 15 (11.91%) cases. The distribution of these variations is from the most common to the least; type II- (bifurcation-incomplete) 8 (6.34%), type V (additional branches) 5 (3.96%), type IV (coeliomesenteric trunk) 1 (0.79%) and 1 (0.79%) unidentified case. No type III (no CT) variation was found.

Conclusion: Variations and anatomy of CT and its branches should always be taken into consideration in clinical studies, angiographic methods, and surgical interventions against possible complications.

Keywords: Anatomic variation, celiac artery, hepatic artery, multidetector computed tomography

INTRODUCTION

Vascular structure is the result of a complex biological process that is genetically programmed and controlled. Various triggers during embryological development can cause anomalies that are often seen as abnormalities (1). However, accurately identifying, understanding, and interpreting the normal arterial pathway and possible changes are of paramount importance before any external intervention. In addition, some anatomical variations may have a negative effect on blood reaching the target organ or tissue (2).

The coeliac trunk (CT) emerges as the first anterior branch of the abdominal aorta (AA) just below the aortic hiatus at the level of the intervertebral disc between the T12 and L1 vertebrae. From this root, a 1.5–2 cm length of the left gastric artery (LGA), common hepatic artery (CHA) and splenic artery (SA) branches are separated (3). Since these 3 branches were first defined by Haller, they are also referred to as "Haller Tripus," and their classical structure is accepted as such (4).

Previous research has shown that CT anatomy is not the same for all humans, and approximately 15% of the population may differ significantly from the typical branching pattern. Anatomical variations of CT are not uncommon; therefore, knowledge of the variations is mandatory for planning and conducting interventional radiology or surgical procedures. Knowledge of the anatomical structure and variations in CT is very important for liver transplants, appropriate vascular ligation or anastomosis, surgeries in the pancreatic head, and radiological procedures (5).

Previous studies have generally employed the cadaver dissection method (4, 6-8). In recent studies, radiological methods such as multidetector computed tomographic angiography (MDCTA), spiral CT, and digital subtraction angiography are more common (5, 9-23). However, new technological developments have made MDCTA an extremely sensitive and valuable imaging method in the evaluation of vascular anatomy and pathology. MDCTA minimizes artefacts that may occur and is minimally invasive as it allows the trunk to be spirally scanned with high-contrast resolution in only 1 breath holding time. It provides a very good anatomical orientation with axial and 3-dimensional (3D) images (10, 13, 24).

Thus, detailed information about vascular structures, organs, and their interrelationships can be obtained. Angiographic information required to prevent complications that may occur owing to vascular variations during surgical or interventional procedures and determine the treatment protocol can be easily provided by MDCTA (9, 12). This study aimed to examine the CT vascular pattern according to a simple and useful classification and to perform its morphometric analysis using the MDCTA method.

METHODS

Patients
The study was carried out in Necmettin Erbakan University Meram medical faculty hospital. Images of patients who requested an abdominal MDCTA in the Department of Radiology for various reasons between April 2014 and May 2016 were retrospectively analyzed. The necessary permissions for the study were taken from Gaziantep University clinical research ethics committee with the protocol number #2016/210. A total of 250 patient images were examined. Of these images, 126 (60 women, 66 men) suitable for our study were selected, and CT was evaluated morphometrically and in terms of variation.

Exclusion Criteria
Patients with: a) a history of major upper abdominal surgery, b) pathological conditions that may affect normal vascular anatomy such as hepatic segmentectomy or CT aneurysm, and c) technically inadequate CT examinations were excluded from the study.

Main Points:

- Knowledge of vascular anomalies is of great importance in modern surgery, radiology, and organ transplant procedures. Vascular variations during these procedures can cause serious complications.
- MDCTA is an excellent imaging technique. It is a fast, noninvasive tool that provides highly accurate and detailed evaluations of normal vascular anatomy and variants.
- Knowing the diameter and length of CT and its branches, anatomical structure, and variations are vital for liver transplants, placement of arterial stents, appropriate vascular ligation and anastomosis, as well as surgical and radiological procedures in caput pancreatis.

MDCTA Protocol
In the study, images obtained with a 64-channel MDCT (Siemens Somatom Sensation 64, Earlanger, Germany, 2005) device were used. The patients were placed in the supine position, and 22 Gauge branules were inserted into their visible veins in the antecubital region, and a total of 100 cc intravenous iodinated contrast material was administered at 3–4 cc per second. Following this procedure, a cranio-caudal scan was performed in the axial plane containing the abdominal area (from diaphragm to regio pubica) using the bolus technique for timing. Images were taken in the portal phase (60–65 seconds after the initiation of the contrast agent) with the following parameter settings; 120 kV, 86 mAs, effective mAs 50–170, detector area 1.2 mm, section thickness 1.5 mm, pitch 1.4, rotation speed 0.5 sec.

CT Morphometric Measurements
Transverse diameter measurements of AA, CT, LGA, CHA, and SA at the level of CT in axial reformatted and Inspace (multiplanar) images and CT root length measurement were performed by the researcher with the support of a radiologist. The root length was measured as the distance from AA to the part with bifurcation or trifurcation was measured (Figure 1).

CT Variation Analysis
CT branches were detected in the coronal, sagittal, and axial planes with the Inspace imaging technique, and possible variations were evaluated. Images in which a variation was detected were categorized according to a new classification we developed after a thorough examination of the literature (Table 1) (18, 25).

Type I: This type is accepted as the normal branching pattern of CT. Classically, all forms that include LGA, CHA, and SA and arising from a single root correspond to this type. This pattern has 2 subforms, type Ia and type Ib. Type Ia is the form in which LGA, CHA, and SA arise from a common point on the same trunk. Type Ib is the form in which LGA arises from CT as the first branch, and CHA and SA make a bifurcation at a common point from CT (Table 1).

Type II: This pattern can be defined as incomplete CT, where 2 of the 3 classical branches arise from a common point by making a bifurcation, and the third branch arises from AA or another artery. This pattern has 3 sub-forms; type IIa, type IIb, and type IIc (Table 1).

Type IIa is also called the hepatosplenic trunk. Although CHA and SA arise from a common trunk, LGA arises from a place outside this trunk. Type IIb is also called the gastrosplenic trunk, where SA and LGA arise from a common trunk, and CHA arises from a place outside this trunk. Type IIc is also called hepatogastric trunk, where CHA and LGA arise from a common trunk, and SA arises from a place outside this trunk.

Type III: It is the pattern in which CT never occurs. None of the 3 classical branches separate from a common trunk. It is the pattern in which all of them independently arise from AA (Table 1).

Type IV: In this type, the superior mesenteric artery (SMA) and CT arise from a common trunk, also called the coeliomesenteric trunk (CMT) (Table 1).

Figure 1. a-d. Coeliac trunk (CT) morphometric measurements. (a) Transverse diameter measurement of abdominal aorta in axial reformatted image at the CT level. (b) Common hepatic artery and splenic artery transverse diameter measurements on axial reformatted images. (c) Measurement of CT root length on axial reformatted images. (d) Measurement of CT root length by Inspace imaging technique.
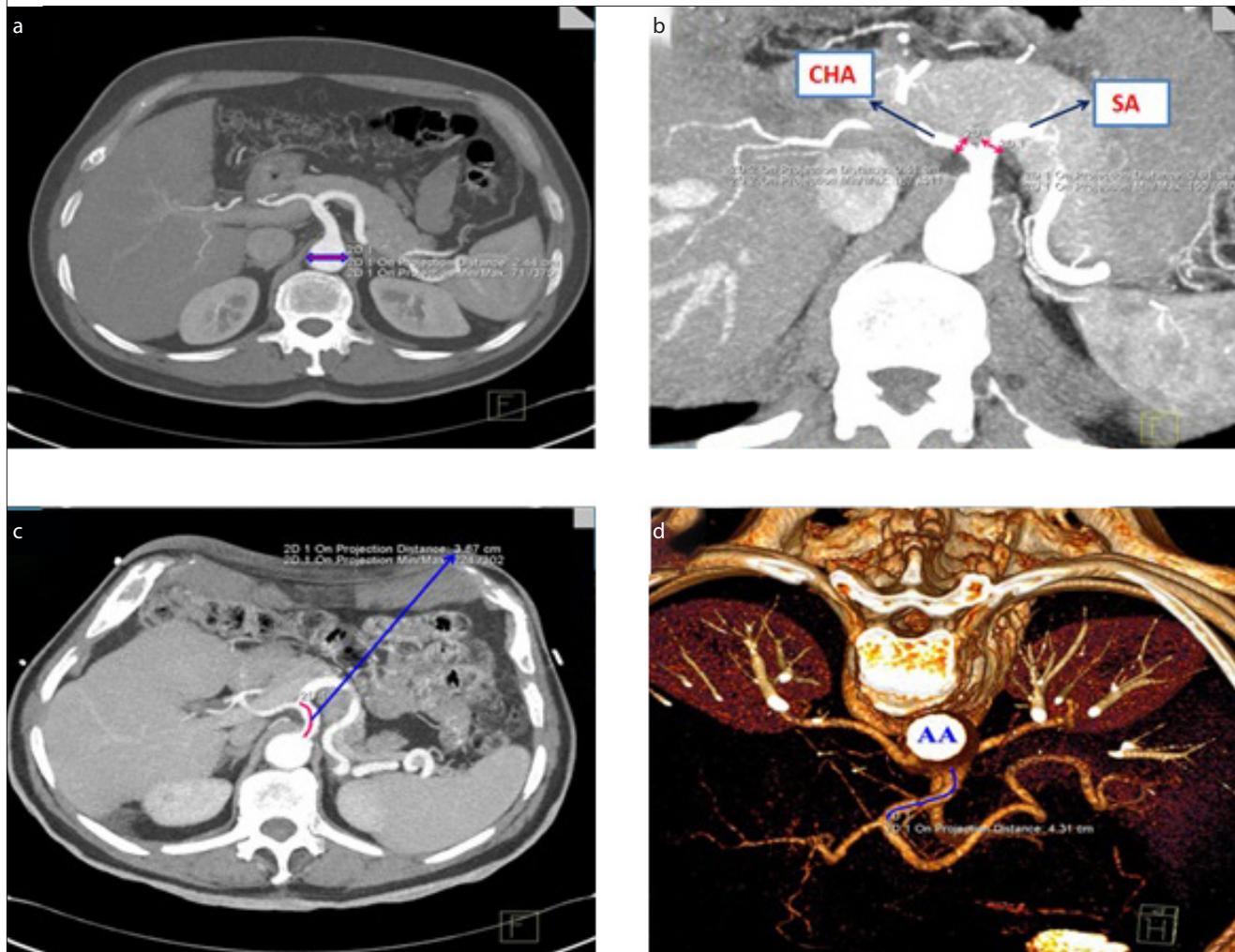
Type V: This pattern is the quadrifurcation form in which any 4th branch, in addition to the LGA, CHA, and SA branches and other than the ventral main branches, arises from the main trunk. Some do not have CHA and instead have left hepatic artery (LHA), right hepatic artery (RHA) arising from the main trunk.

Variations other than types I, II, III, IV, and V that could not be categorized in any class were classified as "other."

Image Interpretation and Statistical Analysis
Axial images were transferred to the workstation (Leonardo, Siemens, 3D and Inspace programs, Germany) for processing in 3D maximal intensity projection, multiplanar reformation, and volume rendering technique (VRT) format by multiplanar imaging method. VRT images were acquired with the Inspace software. The data obtained by radiological methods were analyzed with the statistical analyses were performed using the the Statistical Package for Social Sciences version 15.0 software for Windows (SPSS Inc.; Chicago, IL, USA). and compared according to sex by

the independent samples t test. Summary of data are expressed as mean, standard deviation, and percentage.
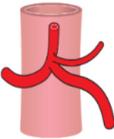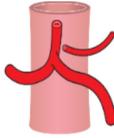
RESULTS

Morphometric Findings
The mean age was 62.5±11.75 (40–84) years in men and 60±10.1 (40–83) years in women. Morphometric measurements are given in Table 2 and Graphic 1. In our morphometric evaluation, AA (p=0.000041), CT (p=0.002), SA (p=0.0004), CHA (p=0.042), and LGA (p=0.0001) transverse diameter measurements were found to be statistically significantly larger in men than in women (p<0.05). No significant difference was found between CT root lengths (p=0.067) in terms of sex (p>0.05).

Variation Results
Type I: In our study, this type was found in 111 (88.09%) patients. This pattern was the most common type; 2 sub-forms of this pattern, type Ia and type Ib, were also observed in our study. Type Ia

Table 1. CT classification used in this study

Types		Subtypes	
Type I	Complete CT. LGA, CHA and SA present (trifurcation)	Type Ia (LGA, CHA and SA are arised from common origin)	Type Ib (LGA is arised as the first branch)
Type II	Incomplete CT (bifurcation)	Type IIa (Hepatosplenic trunk) Type IIb (Gastrosplenic trunk)	Type IIc (Hepatogastric trunk)
Type III	Absence of CT (LGA, CHA and SA arise from the AA)		
Type IV	Coeliomesenteric trunk (CT+SMA)		
Type V	Additional branc other than LGA, CHA and SA (quadrifurcation)		
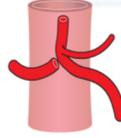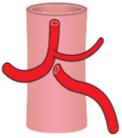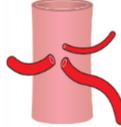
CT– Coeliac trunk, LGA–left gastric artery, CHA–common hepatic artery, SA–splenic artery, SMA– superior mesenteric artery AA–abdominal aorta

Table 2. Comparison of AA, CT, SA, CHA, LGA transverse diameters and CT length by gender (mean ± standard deviation, cm)

Measurements	Male	Female	Mean±SD	p
AA diameter	2.58±0.37	2.25±0.41	2.41±0.42	0.000041
CT diameter	0.77±0.14	0.68±0.11	0.73±0.13	0.002
SA diameter	0.62±0.13	0.53±0.10	0.57±0.12	0.0004
CHA diameter	0.47±0.10	0.42±0.11	0.45±0.11	0.042
LGA diameter	0.3±0.07	0.24±0.56	0.27±0.11	0.0001
CT length	3.2±0.75	2.9±0.66	3.12±0.71	0.067

SD: Standard Deviation

was found in 63 (50%) patients, this was the most common subform. Type Ib was detected in 48 (38.09%) patients (Figure 2) (Table 3).

Type II: This type was detected in 8 (6.34%) patients (Table 3). The most common variation was this pattern. Type IIa was found

in 5 (3.96%) and type IIb in 3 (2.38%) patients (Figure 3). Type IIc (hepatogastric trunk) pattern was not found.

Type III: It is the pattern in which CT never occurs. None of the 3 classic branches arise from a common trunk. It is the pattern

Figure 2. a, b. Type I sub-forms. (a) Type Ia; left gastric artery (LGA), common hepatic artery (CHA), and splenic artery (SA) arise from a common point on the same trunk. (b) Type Ib: LGA arises from the coeliac trunk (CT) as the first branch, and CHA and SA make a bifurcation at a common point from CT.
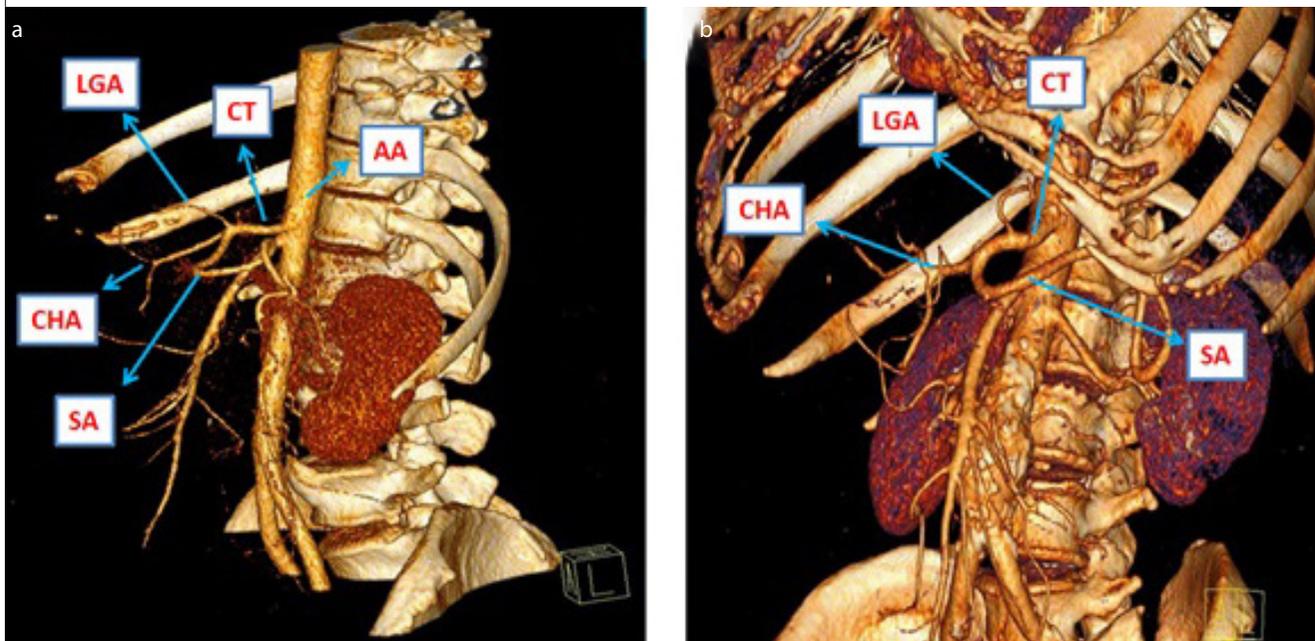
Figure 3. a, b. Type II forms encountered in the study. (a) Left gastric artery (LGA) arising from abdominal aorta. Common hepatic artery (CHA) and splenic artery (SA) making a bifurcation (type IIa - hepatosplenic trunk). (b) Type IIb CHA arising from AA. LGA and SA making a bifurcation (Type IIb-gastrosplenic trunk).
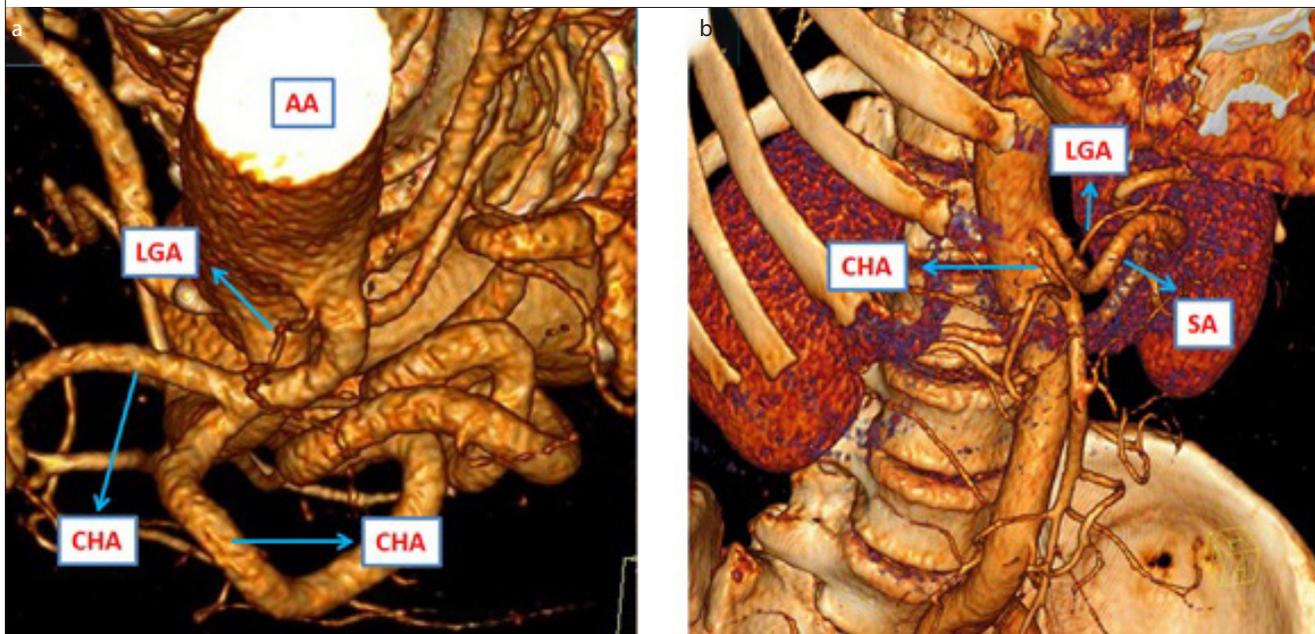
in which all of them independently arise from AA. This variation pattern was not found in our study (Table 3).

Type IV: In this type, the SMA and CT arise from a common trunk. It is also called CMT. In this study, type IV was found in 1 (0.79%) patient (Figure 4a) (Table 3).

Type V: This type was detected in 5 (3.96%) patients in our study (Figure 4b). In these variations, the gastroduodenal artery (GDA) (2 patients), left inferior phrenic artery (LIPA), and right inferior phrenic artery (RIPA) branches were identified as the 4th branch. In one patient, LHA and RHA branches were detected instead of CHA.

Odabaşıoğlu et al. Investigation of the Coeliac Trunk with MDCTA

Eur J Ther 2021; 27(1): 55–65

Figure 4. a, b. Type IV and type V forms encountered in the study. (a) Superior mesenteric artery arises from the coeliac trunk (CT), type IV coeliomesenteric trunk (CMT). (b) Type V: There is a fourth branch (quadrifurcation). Right inferior phrenic artery leaves the CT.
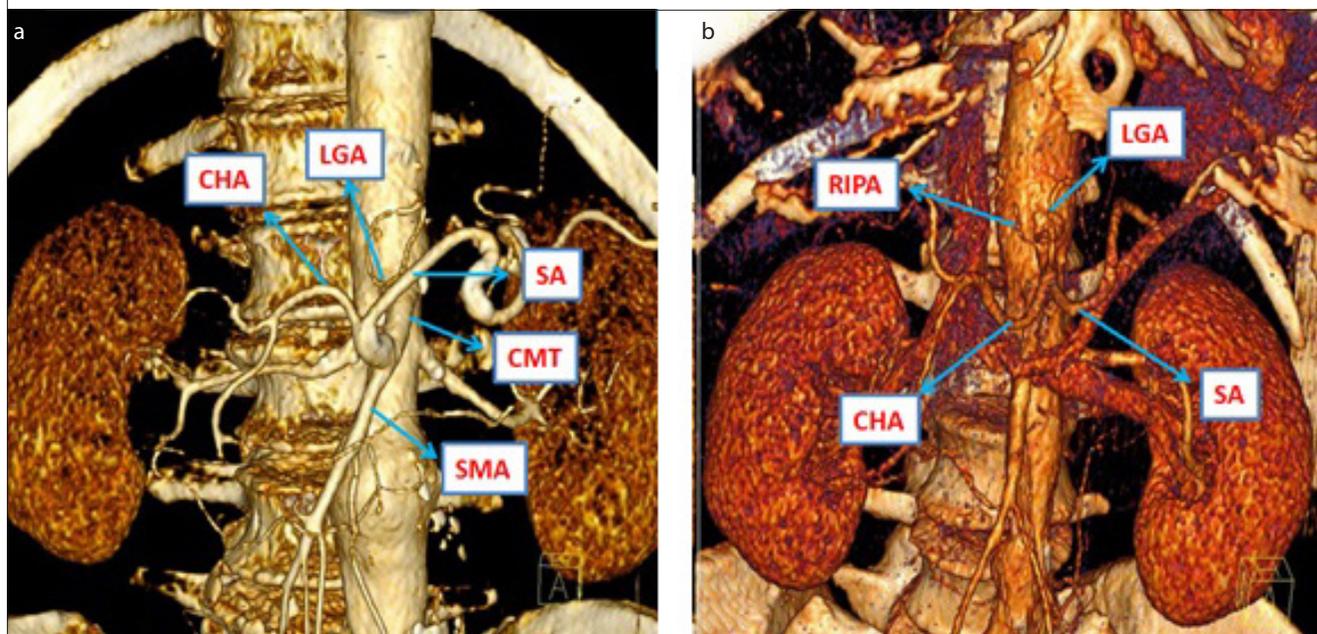
Table 3. Type and distribution of CT variation in our study

Types	Subtypes	n (%)	Total
Type I Complete CT. LGA, CHA and SA present (trifurcation)	Type Ia (LGA, CHA and SA arising from common origin)	63 (50%)	111 (88.09%)
	Type Ib (LGA arising from as the first branch)	48 (38.09%)	
Type II Incomplete CT (bifurcation)	Type IIa (hepatosplenic trunk)	5 (3.96%)	8 (6.34%)
	Type IIb (gastrosplenic trunk)	3 (2.38%)	
	Type IIc (hepatogastric trunk)	–	
Type III The absence of CT		–	–
Type IV Coeliomesenteric trunk (CMT)		1 (0.79%)	1 (0.79%)
Type V Presence of a branch except for LGA, CHA and SA. (quadrifurcation)		5 (3.96%)	5 (3.96%)
Other		1 (0.79%)	1 (0.79%)
Total		126 (100%)	126 (100%)

In our study, we could not define the variation for 1 (0.79%) patient and categorized it as "other." CT had 5 branches (pentafurcation), including SA, LHA, RHA, RIPA, and LGA; and LIPA separated from a common trunk (Table 3) (Figure 5).
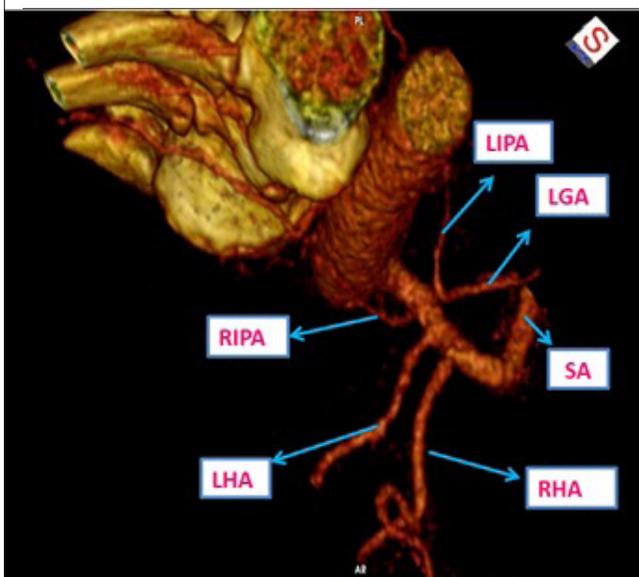
DISCUSSION

Morphometric Measurements

Knowledge of CT variations reduces the risk of trauma to the vessels in both upper abdominal surgical procedures and angio-

Table 4. Studies on CT diameter and length measurements

Researches	Method	n	CT length (cm)	CT Diameter (cm)	SA Diameter (cm)	CHA Diameter (cm)	LGA Diameter (cm)
Gosai et al (2013)	Cadaver	100	1.70±0.32	0.62±0.14			
Khan et al (2017)	MDCT	160	2.75±0.79	0.7±0.11			
Malnar et al (2010)	Cadaver	90	1.90±0.08	0.78±0.08	0.61±0.05	0.57±0.04	0.38±0.03
Neto et al (2015)	MDCT	60	2.33±0.65	0.80±0.13			
Silveira et al (2009)	Cadaver	21		0.79±0.04	0.53±0.03	0.50±0.04	0.38±0.03
Yadav et al (2014)	Cadaver	50	2.86±0.54	0.8±0.14	0.69±0.1	0.66±0.1	0.5±0.11
Panagouli et al (2011)	Cadaver	62	2.6 (±0.66)				
Pant et al (2013)	Cadaver	40	1.86	0.98			
Petrella et al (2007)	Cadaver	89	1.74 (0.35–4.0)	0.65 (0.40–0.95)			
Pinal–Garcia et al (2018)	Cadaver	140		0.72±0.13			
Seghal et al (2013)	MDCT	50	0.6–2.2	0.4–1.0			
Singh et al (2014)	Cadaver	40	1.71	0.66		0.51	
Tiwari et al (2013)	Cadaver	50	1.20±0.56				
Venieratos et al (2013)	Cadaver	77	2.8±0.8				
Current study	MDCT	126	3.12±0.71	0.73±0.13	0.69±0.1	0.66±0.1	0.27±0.11

Figure 5. Coeliac trunk has 5 branches (pentafurcation). These branches are the splenic artery, right hepatic artery, left hepatic artery, right inferior phrenic artery, and the left gastric artery with left inferior phrenic artery arise from a common trunk. In this variation, hepatic branches emerge separately instead of the common hepatic artery.

knowledge of the diameter and length of the vessels is essential for placement of arterial stents in surgery and also useful for professionals designing and developing stents (16). Awareness of the mean values of normal artery diameters specific to a particular population is very important for accurate and definitive radiological diagnosis of arterial aneurysms. In addition, evaluation of arterial diameters is essential for the follow-up of liver transplantations. However, if the diameters of the arteries are less than 0.3 cm, the patients are considered as high risk for liver transplantation. For liver transplantation, diameter of the relevant arteries of the donor >0.2 cm is stated as an absolute exclusionary criterion, and diameter between 0.2–0.3 cm is a relative exclusion criterion. Previous knowledge of a particular artery can be helpful in situations such as early diagnosis, radiological examination of an arterial stenosis, and even low arterial flow with clinical symptoms (27).

Although the anatomical features and variations of CT have been well researched in the literature, there is not much information about artery diameters, which is very important for surgical procedures and angiographic interventions. In recent years, there have been some studies about CT and its main branches, mainly by the cadaver dissection method (14, 21, 26, 28-35). In these studies, among the main branches of CT, SA was reported as the largest in diameter, and LGA was the smallest.

graphic examinations. The diameters of the branches of CT are particularly important in organ transplant surgery and definitive radiographic diagnosis of arterial aneurysms (26). In addition,

Seghal et al. (14) and Tiwari et al. (32) measured the distance from AA until the first branch arose when measuring CT length. Sing et al. (31) measured the distance from AA to CHA. In oth-

Odabaşıoğlu et al. Investigation of the Coeliac Trunk with MDCTA

Eur J Ther 2021; 27(1): 55–65

Table 5. Adaptation of the studies in the literature according to the new classification we use

Researches	Method	Number (n)	Type I	Type Ia	Type Ib	Type II	Type IIa	Type IIb	Type IIc	Type III	Type IV	Type V	Other
						Distribution of types (%)							
Adachi (1928)	Cadaver	252	89	–	–	10.8	6.4	2	2.4	–	–	–	–
Araujo et al (2015)	MDCT	60	90	–	–	10	8.3	–	1.6	–	–	–	–
Aslaner et al (2017)	MDCT	1000	89	–	–	8.2	5.4	2.8	0.01	0.01	–	–	2.2
Chen et al (2009)	Cadaver	974	89.8	66.6	23.2	8.5	4.4	3.9	0.2	–	1.5	–	–
Clement et al (2016)	MDCT+ Cadaver	639	90.5	57.6	32.1	9.5	4.5	5	–	–	–	–	–
Iezzi et al (2008)	MDCT	524	72.1	50.4	19.4	10.9	5	2.3	3.6	0.6	0.4	–	–
Lipshutz (1917)	Cadaver	83	73.4		25.3	24.1	13.3	4.8	6	–	2.4	–	–
Mburu et al (2010)	Cadaver	123	61.7			17.9	13.1	4.9	–	–	–	20.3	–
Michels (1955)	Cadaver	200	89	–	25	11	4	5.5	1.5	–	–	–	–
Osman and Abdrabou (2016)	MDCT	1000	90.5	–	–	7.7	2.8	4.3	0.6	1	0.6	–	0.2
Pinal–Garcia et al (2018)	Cadaver	140	43.6	7.1	36.4	7.1	2.8	2.8	1.4	–	–	47.9	1.4
Song et al (2010)	Spiral CT and DSA	5002	89.1	–	–	7.5	4.4	2.9	0.2	–	1.8	–	–
Sureka et al (2013)	MDCT	600	91	–	–	4.3	2.8	1.5	–	–	0.6	–	3.5
Torres et al (2015)	MDCT	1569	92.7	–	–	6.5	2.2	4.1	0.2	0.1	0.5	–	0.1
Uğurel et al (2010)	MDCT	100	89	–	–	8	3	4	1	1	2	–	–
Vandamme and Bonte (1985)	Cadaver	156	85.9	–	–	12.8	–	–	–	1.3	–	–	–
Venieratos et al (2013)	Cadaver	77	90.9	74	16.9	1.3	–	1.3	–	2.6	–	–	5.2
Wang et al (2014)	MDCT	1500	89.8	–	–	0.93	0.27	0.53	0.13	0.2	3.4	–	–
Wysiadecki et al (2017)	Cadaver	40	62.5	–	–	10	10	–	–	2.5	–	20	5
Current Study	MDCT	126	88.1	50	38.1	6.34	3.96	2.38	–	–	0.79	3.96	0.79

er studies, this part was not explicitly reported. In our study, the distance from AA to the part with bifurcation or trifurcation was measured regardless of where the first branch arose (Figures 1b and 1d). The higher CT length in our study compared with the studies in the literature may be related to this difference. As the difference of even a millimeter can change measurements, the methods should be clearly explained and be sensitive.

There was no statistically significant difference between the normal and variation groups in the studies examining diameter differences (26, 27). Tiwari et al. (32) have suggested that CT length is related to the branching pattern of CT and reported that there is a significant relationship between the short CT length and the probability of CT variation. The correlation between diameter, length, and sex was examined in our study. Diameter measurements were found to be statistically significantly larger in men than in women (p <0.05). However, there was no significant difference in terms of sex between CT root lengths.

Variations
Many studies have examined the anatomical structure of CT and its branches using different methods and reported many variations. Some of these have classified the variations of CT (4, 6-8, 36). Although the first classifications consisted of several different types, with the newly detected variations, the number of types and sub-forms have gradually increased. The classifications put forward in the past did not cover some important variations; however, current classifications, including most of the variations

reported in the literature, are quite complicated (4, 6-8, 23, 25, 36-39). Therefore, we used a new classification that we believe is simpler and more useful in our study.

In the literature, the anatomical variations of CT have been reported as bifurcation structure, presence of add-on branches, emergence with mesenteric arteries (usually SMA), or absence of CT (4-9, 11, 12, 15-20, 22-28, 36-38, 40-43). In their review, Panagouli et al. (25) have reported all CT patterns with 3 main branches as type I, regardless of whether the three main branches were of common origin or whether a branch arose from other branches. They considered all patterns outside of this structuring as variation (25). In our study, type I and its variations were accepted in this way.

The most common subform of type I in the literature is controversial. Some studies have described the form we call type Ia as a "true tripod" (true triple branching) or "classical pattern," and the form we call type Ib as "false tripod" (false triple branching) or "nonclassical" (25, 28, 36). Clement et al. (18) have accepted the type Ia form as the first form in which LGA arose from the body and type Ib as the form in which the three main branches arose from a common point, and reported that type 1a was the most common form in their studies. Similarly, Higashi et al. (39), in their study, have argued that a standard CT structure was not included in anatomy books, and they most frequently found the form in which LGA arose from the common body as the first branch, and this form was the standard CT model. However, Uflacker (36) accepted the form in which the three main branches arose from a common point as the "classical pattern" and the form in which LGA arose early as the "nonclassical pattern." Venieratos likewise named these two forms as "true tripod" and "false tripod" likewise (28). Panagouli et al. (25) have accepted the "false tripod" as the form in which one of the three main branches arose from the trunk early and divided it into three sub-forms.

When we look at the forms in the literature in which one of the three main branches arose earlier than the others, we see that LGA is the most common, and even the number of forms in which other branches arose early is much less or not at all existent (6, 12, 18, 25, 28, 36, 38, 39). Therefore, to keep the classification simple and useful, we hypothesize that type I sub-forms should be classified as the type in which only three main branches arise from a common origin or LGA arises from the other two branches earlier. In our study, type I pattern was found in 88.09% of the cases, whereas type Ia sub-forms of this pattern were found in 50% and type Ib in 38.09% of the cases. Whitley et al. (23) have reported the occurrence of the CT classic pattern in 40.62% and the nonclassic pattern in 60.41% of the cases in their review. When we examine the literature, we see that type II is the most common variation (4-9, 11, 12, 18, 19). This pattern is also referred to as the "bifurcation" structure of CT or "incomplete CT" in some studies (18, 23, 25, 33). In this, two of the three main branches arise from a common trunk, and the other arises from any other point (usually SMA or AA). Lipschutz (6), Michels (7), Adachi (8), and Uflacker (36) have classified the sub-forms of this type in different ways as if they were a separate type. These classifications can still be used by researchers today. This situation causes confusion and an increase in the number

of types used in the classification. Some studies that put forward a new classification for CT named this pattern as type II and categorized this type into its sub-forms (18, 23, 25, 37, 40). We used this classification as we thought it was more accurate. In our study, the most common variation was type II with an occurrence rate of 6.34%. Whitley et al. (23) have reported this variation as the most common variation in the literature at an occurrence rate of 7.58%. Type III, or the absence of CT, is a rare variation. Panagouli et al. (25) have reported that only Morita used this variation in previous CT classifications. However, Vandamme and Bonte (4), Uflacker (36), and Gielecki et al. (37) also included this variation in their classification. Apart from this, in recent studies Babu and Khrab (40) and Clement et al. (18) have included this variation in their classifications. Vandamme and Bonte reported the prevalence of this variation as 1.7%, Panagouli et al. as 1%, Osman and Abdrabou as 1%, Uğurel et al. as 1%, Iezzi et al. as 0.06%, Aslaner et al. as 0.01%, Wysiadecki et al. as 2.5%, Wang et al. as 0.02%, Torres et al. as 0.1%, Venieratos et al. as 2.6%, and Whitley et al. as 0.28% (4, 9, 12, 15, 17, 19, 20, 22, 23, 25). In our study, this variation was not found. Type IV is referred to as CMT in the literature; Adachi, Michel, Uflacker, Clement, and Babu and Khrab have included this variation in their classifications (7, 8, 18, 36, 40). In our study, we encountered this variation in 1 (0.79%) patient. In the literature, Adachi reported CMT incidence as 2.4%, Song et al. as 1.06%, Osman and Abdrabou as 0.6%, Gielecki et al. as 1.5%, Panagouli et al. as 0.76%, Malnar et al. as 1.7%, Wang et al. as 3.4%, Whitley et al. as 0.09%, and Torres et al. as 0.5% (8, 11, 15, 17, 19, 23, 26, 35, 37). In these studies, CMT is defined as the variation in which the 3 main branches of CT and SMA are together. Wang et al. (15) defined CMT as any 2 major branches of SMA and CT and their combinations. Thus, Wang et al. (15) reported a higher incidence of CMT than other studies. Type V was classified as a variation with any collateral branch to the 3 main branches of CT except the main branches. These add-on branches often take the form of RIPA or LIPA branches. Apart from these, these add-on branches (collateral) may be 1 of the branches of GDA, dorsal pancreatic artery, middle colic artery (MCA), accessory hepatic artery (AHA), RHA, or LHA (16).

Collateral branches are divided into parietal (PIAs) and visceral branches (MCA, hepatic, pancreatic, gastroduodenal arteries, and so on) (23). In our study, after the bifurcation structure, this variation was found most frequently at an occurrence rate of 3.96%. Some studies have not evaluated this type as a variation. Adachi did not accept this type as a variation as it contained three classical main branches, but accepted it as a subform of type I (8). Similarly, Clement et al. (18) accepted this pattern as a subform of type I in their classification. Mburu et al. have reported the prevalence of this variation as 20.3%, Pinal-Garcia et al. as 47.9%, Wysiadecki et al. as 20%, Panagouli et al. as 1.06%, Venieratos et al. as 5.2%, and Clement et al. as 0.8% (18, 22, 25, 28, 33, 42). Some studies have evaluated variations in which CT has not just four but five, six, or even seven branches as this type. Therefore, these studies have reported higher rates of variation in this type compared with the literature (22, 33, 42).

There was a variation in our study that we could not classify. As far as we know, no such variation has been reported in the literature. The CT had five branches (pentafurcation). RHA and LHA

Odabaşıoğlu et al. Investigation of the Coeliac Trunk with MDCTA

Eur J Ther 2021; 27(1): 55–65

were present instead of CHA, and PIAs were also available as add-ons. RIPA left CT directly, but LIPA had a common trunk with LGA. We classified this variation as "other" in our classification.

Studies on CT diameter and length measurements are given in Table 4, and the adaptation of the studies in the literature according to the new classification we used is given in Table 5.

Limitations
This study had some limitations. First, the study was retrospective. Second, the age distribution of the patients was not homogeneous (40–83 years). There were very few young individuals. In addition, as our study was based on the analysis of radiological images, the depiction of very thin arterial networks may have been overlooked.

CONCLUSION
Surgeons must be aware of the length and origin of the vessels to predict the possible area where arteries can be found. Such data are important not only in vascular surgery but in any surgery to prevent iatrogenesis. Data obtained from this study will be useful in laparoscopic and robotic surgeries. Knowing the anatomical structure and variations of CT and its branches is very important for liver transplantations, intra-arterial chemotherapy, hepatopancreatobiliar surgery, vascular ligation, and anastomoses in the relevant region, interventional radiology, and surgical procedures.

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