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Research Article

Anatomical variations in the abdominal aorta

Abdominal aorttaki anatomik varyasyonlar

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Abstract

Aim: The aim of our study is to identify variations in the celiac artery, superior mesenteric artery (SMA), inferior mesenteric artery (IMA), renal arteries (RA), and hepatic arteries (HA) in patients who underwent multidetector computed tomography (MDCT) angiography for various preliminary diagnoses.

Materials and Methods: This study retrospectively analyzed 200 patients who underwent MDCT angiography. The Uflacker classification was used for celiac trunk variants, Michels and Hiatt classifications for HA variations, and RA were assessed for number and presence of extra-RA, with aberrant or accessory RA classified as numerical anomalies.

Results: A classical celiac trunk was present in 92.0% of patients, with variations including hepatosplenic and gastrosplenic trunks each in 3.5% of cases. The classical branching pattern of the celiac trunk was found in 91.5% of patients, while 1.0% had the left gastric artery originating from the splenic artery or directly from the abdominal aorta. SMA origin was classical in 95.5% of cases, with 2.5% showing hepatomesenteric trunk origin and 1.0% displaying bimesenteric trunk origin. For the IMA, 98.4% of patients had a classical origin. The ratio with a right RA count of 2 or more was 13%, while the ratio with a left RA count of 2 or more was 12.5%. Right HA variations were observed in 14.5% of patients, whereas left HA variations were present in 11.5%.

Conclusions: Our study identified significant anatomical variations in the celiac artery, SMA, RA, and HA in patients undergoing MSCT. The findings highlight the importance of recognizing these variations for accurate diagnosis and surgical planning.

Keywords: Celiac artery, Superior mesenteric artery, Renal artery, Anatomical variations, Celiac trunk, Hepatic artery

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Öz

Amaç: Çalışmamızın amacı, çeşitli ön tanılar için çok dedektörlü bilgisayarlı tomografi (ÇDBT) anjiyografisi uygulanan hastalarda çölyak arter, superior mezenterik arter (SMA), inferior mezenterik arter (İMA), renal arterler (RA) ve hepatik arterlerde (HA) varyasyonları belirlemektir.

Gereç ve Yöntemler: Bu çalışmada, ÇDBT anjiyografisi yapılan 200 hasta retrospektif olarak analiz edilmiştir. Çölyak trunkus varyantları için Uflacker sınıflandırması, HA varyasyonları için Michels ve Hiatt sınıflandırmaları kullanılmış ve RA'lar, sayı ve ekstra-RA varlığı açısından değerlendirilmiş, replase veya aksesuar RA'lar sayısal anomaliler olarak sınıflandırılmıştır.

Bulgular: Hastaların %92,0'sinde klasik çölyak trunkus mevcuttu ve varyasyonlar arasında hepatosplenik ve gastrosplenik trunkuslar her biri %3,5 oranında görüldü. Çölyak trunkusun klasik dallanma deseni hastaların %91,5'inde saptanırken, %1,0'inde sol gastrik arterin splenik arterden veya doğrudan abdominal aortadan kaynaklandığı görüldü. SMA orijini vakaların %95,5'inde klasik olup, %2,5'inde hepatomezenterik trunkus orijini ve %1,0'inde bimesenterik trunkus orijini vardı. İMA için, hastaların %98,4'ünde klasik bir orijin mevcuttu. Sağ RA sayısı 2 veya daha fazla olanların oranı %13 iken, sol RA sayısı 2 veya daha fazla olanların oranı %12,5 idi. Sağ HA varyasyonları hastaların %14,5'inde gözlenirken, sol HA varyasyonları %11,5 oranında mevcut idi.

Sonuçlar: Çalışmamız, MSBT yapılan hastalarda çölyak arterlerde, SMA'da, RA'da ve HA'da önemli anatomik varyasyonlar olduğunu ortaya koymuştur. Bulgular, doğru tanı ve cerrahi planlama için bu varyasyonların tanınmasının önemini vurgulamaktadır.

Anahtar Kelimeler: Çölyak arter, Superior mezenterik arter, Renal arter, Anatomik varyasyonlar, Çölyak trunkus, Hepatik arter

Introduction

The abdominal aorta is the main artery responsible for delivering oxygenated blood to the abdominal organs. It typically begins at the aortic hiatus of the diaphragm, at the level of the 12th thoracic vertebra, and extends down to the 4th lumbar vertebra [1]. In embryologic development, the digestive tube differentiates into the foregut, midgut, and hindgut, each supplied by the abdominal aorta [2]. The abdominal aorta branches ventrally into the celiac trunk, superior mesenteric artery (SMA), and inferior mesenteric artery (IMA). The celiac trunk supplies the foregut and branches into the common hepatic artery (CHA), splenic artery (SA), and left gastric artery (LGA). Traditionally, the CHA divides into right and left branches to supply the two liver lobes [3].

While the general anatomical course of the abdominal aorta is well established, variations in its structure are not uncommon. These anatomical variations can include differences in the origin, course, branching patterns, and diameters of the aorta and its branches [4]. These variations are generally asymptomatic and are most commonly identified during routine cadaver dissections or imaging and surgical procedures [5]. Multidetector computed tomography (MDCT) facilitates the detection of anatomical variations by offering submillimeter-resolution three-dimensional reconstructions, in addition to the standard assessment of vascular transverse-sections [6].

The anatomical variations of the abdominal aorta and its branches hold clinical importance in organ transplantation, laparoscopic procedures, and the management of deep abdominal injuries [7]. Hence, this study aimed to identify and determine the prevalence of variations in major arteries branching from the abdominal aorta, including the celiac artery, SMA, IMA, renal arteries (RA), and hepatic arteries (HA), using 128-slice MDCT.

Material and Methods

Following the principles set forth in the Declaration of Helsinki, this retrospective study was conducted at the Erzincan Binali Yıldırım University, Mengücek Gazi Training and Research Hospital, Radiodiagnostics Department between July 2022 and December 2023. The study received approval from the Binali Yıldırım University Clinical Research Ethics Committee (Approval Date: 06.03.2023, Number: 2023-3/5). The local ethics committee waived the requirement of informed consent due to the retrospective nature of the research.

Study population

This study retrospectively analyzed a total of 255 patients who underwent MDCT angiography for the assessment of various preliminary diagnoses, including traumatic injury, aneurysm, dissections, occlusion, and stenosis, at the Department of

Radiology during the aforementioned dates. Patients under 18 years of age, and those with significant motion artifacts or images where arterial structures could not be optimally assessed due to inappropriate contrast phases, were excluded from the study. After this exclusion process, 200 patients were enrolled in this study.

Patient files and electronic records were used to obtain demographic and clinical information, including age, gender, and computed tomography angiography findings.

Acquisition and Processing of Images

Abdominal aorta CT angiography images were acquired with a 128-slice MDCT scanner (Somatom go.Top, Siemens Healthcare, Forchheim, Germany). An 80 kVp dose was consistently maintained in all patients using a standard imaging protocol, and the mAs (180-220) was automatically set by the device based on the patient's weight. During the procedure, 1.5–2 mL/kg of non-ionic contrast agent was injected intravenously at a rate of 4 mL/sec via an automatic injector system, followed by a saline solution. The scan encompassed the area extending from 2 cm above the diaphragm to 4-5 cm below the level of the symphysis pubis. The arterial phase images were obtained at an average of 20-30 seconds, once the ROI placed on the proximal abdominal aorta reached a threshold of 150 HU. Initially, the images were acquired with a 2 mm slice thickness in the axial plane and were later reconstructed at a slice thickness of 0.625 mm. As the thin-slice axial images were analyzed on the workstation, reformats in the coronal and sagittal planes were created, and 3D reconstructions were generated using the volume rendering technique.

Sectional images were analyzed using the PACS system (Akgun PACS Viewer v7.5; Akgün Yazılım, Ankara, Turkey). A radiologist with 12 years of experience conducted a retrospective review of all CT images.

Vascular Evaluation and Classification of Variants

The Uflacker classification was utilized for detecting and categorizing anatomical variants of the celiac trunk [8]. The classification includes hepatosplenic trunk—type 2, where the CHA and SA share a common root, while the LGA originates directly from the aorta. Hepatogastric trunk—type 3 occurs when the CHA and LGA share a common root, and the SA arises separately from the aorta. Hepatosplenomesenteric trunk—type 4 is defined by a common origin of the CHA, SA, and SMA, with the LGA originating separately from the aorta. Gastrosplenic trunk—type 5 occurs when the LGA and SA share a common root, while the CHA arises separately from the aorta. Celiacomesenteric trunk—type 6 involves a common trunk for the celiac trunk and SMA. Celiaco-colic trunk—type 7 is characterized by a common trunk for the celiac trunk and colic artery. Finally, the absence of the celiac trunk—type 8 is identified when the CHA, SA, and LGA originate separately from the abdominal aorta without forming a trunk. Arterial origin variations that do not fit within this classification were categorized as other—type 9, and their specifics were explained in detail.

In assessing variations of the hepatic artery system, we applied the Michels classification from 1966 and the Hiatt classification, which modified the Michels system in 1994 [9, 10]. For RAs variations, we evaluated the number of RAs on both sides and investigated the presence of extra-RAs. Aberrant (polar) or accessory (hilar) RAs were classified as numerical anomalies.

Statistical analysis

All of the data were analyzed with IBM SPSS Statistics for Windows 22.0 (IBM Corp., Armonk, NY, USA). The normality distribution of the numerical variables was evaluated with the Kolmogorov-Smirnov test. All numerical data showed a normal distribution and were reported as mean ± standard deviation (SD). Student's T-test was used for comparisons of numerical variables between two groups, while ANOVA (post hoc: Bonferroni test) was used for comparisons involving more than two groups. Categorical variables were given as numbers and percentages, and inter-group comparisons were conducted with the Chi-square and Fisher exact tests. Significance was accepted at P-value < 0.05 (*) for all of the statistical analyses.

Results

The mean age of the patients was 60.9±15.7 years (range: 21-92), and the majority were male (n=139, 69.5%). In terms of celiac trunk origins, a classical celiac trunk was identified in 184 patients (92.0%), a hepatosplenic trunk in 7 patients (3.5%), a gastrosplenic trunk in 7 patients (3.5%), a celiacomesenteric trunk in 1 patient (0.5%), and absence of the celiac trunk in 1 patient (0.5%) (Table 1).

In terms of the origins of the celiac trunk branches, 183 patients (92.0%) had a classical pattern. Two patients (1.0%) had a LGA originating directly from the abdominal aorta; two patients (1.0%) had an LGA arising from the SA; one patient (0.5%) had an LGA originating from the CHA or proper HA (PHA); three patients (1.5%) had a CHA originating directly from the abdominal aorta; two patients (1.0%) had an absent CHA; and five patients (2.5%) had other origins. Among these patients with other origins, one had a SA originating from the

SMA, one had a right HA (RHA) originating from the celiac trunk, one had a left HA (LHA) and LGA originating as a single root from the aorta, and two had a CHA originating from the SMA. Two patients had multiple origins. In one patient (0.5%), both a LGA directly originating from the abdominal aorta and the absence of the CHA were present. One patient had three simultaneous origins: the LGA arose from the CHA or PHA, the SMA and CHA originated from a common root, and the SA directly originated from the abdominal aorta (Table 1).

Table 1. Origins of the celiac trunk and its branches.

Variables	All population n = 200
Origins of celiac trunk, n (%)	
Classical	184 (92.0)
Hepatosplenic trunk	7 (3.5)
Gastrosplenic trunk	7 (3.5)
Celiacomesenteric trunk	1 (0.5)
Absence	1 (0.5)
Origins of celiac trunk branches, n (%)	
Classical	183 (91.5)
LGA originating directly from the abdominal aorta	2 (1.0)
LGA originating from the SA	2 (1.0)
LGA originating from the CHA or PHA	1 (0.5)
CHA originating directly from the abdominal aorta	3 (1.5)
Absence of the CHA	2 (1.0)
Other	5 (2.5)
Double Origin (Both LGA originating directly from the abdominal aorta and absence of the CHA)	1 (0.5)
Triple Origin (LGA originating from the CHA or PHA, SMA and CHA sharing a common root, SA originating directly from the abdominal aorta)	1 (0.5)

Data are shown as number and percentage (%). Abbreviations: CHA, common hepatic artery; LGA, left gastric artery; PHA, proper hepatic artery; SA, splenic artery; SMA, superior mesenteric artery

The SMA origin distribution among the patients was as follows: 191 patients (95.5%) had a classical origin, 5 patients (2.5%) had a hepatomesenteric origin, 2 patients (1.0%) had a bimesenteric origin, 1 patient (0.5%) had a celiacomesenteric origin, and 1 patient (0.5%) had splenomesenteric origin. The ratio of patients with SMA branch variations was 11.0% (n = 22). In this group, 18 patients had a replaced PHA, 2 had a replaced CHA, and 2 had other branch variations (accessory RHA and splenomezenteric). Among the 18 patients with a replaced PHA, 16 were dexter type, and 2 were sinister type (Table 2).

Table 2. Origin and branch variations of the superior mesenteric artery (SMA).

Variables	All population n = 200
Origins of SMA, n (%)	
Classical	191 (95.5)
Celiacomesenteric trunk	1 (0.5)
Hepatomesenteric trunk	5 (2.5)
Bimesenteric trunk	2 (1.0)
Other	1 (0.5)
Branch variation of SMA, n (%)	
No extra branch	178 (89.0)
Yes	22 (11.0)
Variation type of SMA, n (%)	
No extra branch	178 (89.0)
Replaced PHA	18 (9.0)
Replaced CHA	2 (1.0)
Other	2 (1.0)

Data are shown as number and percentage (%). Abbreviations: CHA, common hepatic artery; PHA, proper hepatic artery; SMA, superior mesenteric artery

In terms of the origins of the IMA, 197 patients (98.4%) had a classical origin, 2 patients (1.0%) had a bimesenteric trunk, and 1 patient (0.5%) had another origin. The numbers of right and left RA and the presence of renal anomalies are summarized in Table 3. Regarding the RHA, 171 patients (85.5%) had a classical origin, 19 had a replaced origin, and 10 had an accessory origin. As for the LHA, 179 patients (89.5%) had a classical origin, 13 had a replaced origin, and 8 had an accessory origin (Table 4).

Table 3. Inferior mesenteric artery (IMA) origin, renal artery counts, and associated anomalies.

Variables	All population n = 200
Origins of IMA, n (%)	
Classical	197 (98.5)
Bimesenteric trunk	2 (1.0)
Other	1 (0.5)
Right renal artery count, n (%)	
1	174 (87.0)
2	25 (12.5)
3	1 (0.5)
Left renal artery count, n (%)	
1	175 (87.5)
2	22 (11.0)
3	3 (1.5)
Associated renal anomaly, n (%)	
No	198 (99.0)
Rotation	1 (0.5)
Horseshoe kidney	1 (0.5)

Data are shown as number and percentage (%). Abbreviations: IMA, inferior mesenteric artery.

Table 4. Origins from the right and left hepatic arteries.	
Variables	All population n = 200
Right hepatic arteries, n (%)	
Classical	171 (85.5)
Replaced	
Left gastric artery	1 (0.5)
Celiac artery	1 (0.5)
Left hepatic artery	1 (0.5)
Superior mesenteric artery	16 (8.0)
Accessory	
Aorta	1 (0.5)
Celiac artery	2 (1.0)
Left hepatic artery	2 (1.0)
Superior mesenteric artery	5 (2.5)
Left hepatic artery, n (%)	
Classical	
Replaced	
Left gastric artery	11 (5.5)
Celiac artery	11 (0.5)
Superior mesenteric artery	1 (0.5)
Accessory	
Left gastric artery	8 (4.0)
Data are shown as number and percentage (%).	

There were no significant differences in anatomical variations in the abdominal aorta between males and females (Table 5).

The classical RHA group had a higher rate of classical celiac trunk compared to the replaced and accessory RHA groups (Classical: 94.2% vs. Replaced: 78.9% vs. Accessory: 80%, $p < 0.05$), whereas the accessory group had a higher rate of celiac trunk absence (Classical: 0% vs. Replaced: 0% vs. Accessory: 10%, $p < 0.05$). The classical RHA group had a higher rate of no extra branches in SMA variations compared to the other groups (Classical: 98.8% vs. Replaced: 15.8% vs. Accessory: 70.0%, $p < 0.05$), whereas the replaced RHA group had a higher rate of replaced PHA (Classical: 0.6% vs. Replaced: 84.2% vs. Accessory: 10%, $p < 0.05$). The accessory RHA group had a higher rate of replaced CHA compared to the other RHA groups (Classical: 0.6% vs. Replaced: 0% vs. Accessory: 10%, $p < 0.05$). The IMA origin did not differ according to RHA origins (Table 6).

The classical celiac trunk was present at a similar rate in the classical and accessory LHA groups, and it was higher in these groups compared to the replaced LHA groups (Classical: 93.3% vs. Replaced: 69.2% vs. Accessory: 100%, $p < 0.05$). The distribution of SMA variation types and IMA origins did not differ among the LHA groups (Table 6).

Discussion

The abdominal aorta is the major arterial structure of the abdomen, positioned between the thoracic aorta and the arteries of the extremities. It gives rise to important branches, including the celiac trunk, SMA, RAs, and IMA, and it terminates by dividing into the bilateral common iliac arteries [11]. This vascular structure plays a crucial role in delivering oxygenated blood to the abdominal solid organs, the intestinal system, the muscles of this cavity, and the genital organs. Additionally, it mediates the transmission of blood from the thoracic segment of the aorta to the lower extremities [12]. Therefore, variations in the abdominal aorta hold clinical significance for surgical procedures [7].

Our study focused on analyzing the major arteries branching from the abdominal aorta, including the celiac artery, SMA, IMA, RA, and HA. The celiac trunk and SMA are major branches arising from the proximal ventral section of the abdominal aorta, supplying the intestinal organs. The celiac trunk, a trunkal structure approximately 1.5-2 cm in length, terminates by branching into the CHA, SA, and LGA. Our study showed that 92% of the patients had a classical complete trifurcation. In the study conducted by Türkyılmaz et al., the rate of normal trifurcation was also reported to be approximately 91% [13]. Olga et al. analyzed the anatomical variations of the major arteries branching from the abdominal aorta using 64-slice MDCT and found that in 95.5% of the patients, the typical celiac trunk divided into three arteries [6]. Other studies have reported a lower prevalence of typical celiac trunk division, ranging between 72% and 90% [14, 15]. During the development of the abdomen, three vascular structures associated with the digestive system differentiate, and anastomoses form between these structures. These anastomoses later regress, displaying individual variations. If these anastomoses regress significantly, it can result in the absence of these vascular structures, while a lack of regression in the segmental artery precursors allows these structures to originate directly from the abdominal aorta [16]. Celiac trunk bifurcation is observed in about 11% of the general population [17]. In our study, this rate was 7.5%, with a hepatosplenic trunk observed in 7 patients (3.5%), a gastrosplenic trunk in 7 patients (3.5%), and a celiacomesenteric trunk in 1 patient (0.5%). These rates were consistent with the frequencies reported in previous studies [14, 15].

The SMA arises 1 cm below the celiac trunk and runs a long course within the mesentery. It supplies a large portion of the small intestine, the cecum, the right colon, and the proximal to mid-transverse colon [18]. Fonseca Neto et al.

Table 5. Gender-based comparison of age and anatomical variations in the abdominal aorta.			
Variables	Male n = 139	Female n = 61	p
Age, years	60.8 ± 15.9	61.2 ± 15.1	0.847
Origins of celiac trunk, n (%)			
Classical	127 (91.4)	57 (93.4)	0.999
Hepatosplenic trunk	5 (3.6)	2 (3.3)	
Gastrosplenic trunk	5 (3.6)	2 (3.3)	
Celiacomesenteric trunk	1 (0.7)	-	
Absence	1 (0.7)	-	
Origins of SMA, n (%)			
Classical	132 (95)	59 (96.7)	0.910
Celiacomesenteric trunk	1 (0.7)	-	
Hepatomesenteric trunk	3 (2.2)	2 (3.3)	
Bimesenteric trunk	2 (1.4)	-	
Other	1 (0.7)	-	
Branch variation of SMA, n (%)			
No extra branch	122 (87.8)	56 (91.8)	0.471
Yes	17 (12.2)	5 (8.2)	
Variation type of SMA, n (%)			
No extra branch	122 (87.8)	56 (91.8)	0.605
Replaced PHA	14 (10.1)	4 (6.6)	
Replaced CHA	1 (0.7)	1 (1.6)	
Other	2 (1.4)	-	
Origins of IMA, n (%)			
Classical	137 (98.6)	60 (98.4)	0.206
Bimesenteric trunk	2 (1.4)	-	
Other	-	1 (1.6)	
Right hepatic arteries, n (%)			
Classical	117 (84.2)	54 (88.5)	0.715
Replaced	14 (10.1)	5 (8.2)	
Accessory	8 (5.8)	2 (3.3)	
Left hepatic artery, n (%)			
Classical	120 (86.3)	59 (96.7)	0.080
Replaced	12 (8.6)	1 (1.6)	
Accessory	7 (5)	1 (1.6)	
Data are shown as number and percentage (%). Abbreviations: CHA, common hepatic artery; PHA, proper hepatic artery; SMA, superior mesenteric artery.			

Table 6. Distribution of celiac trunk, superior mesenteric artery (SMA), and inferior mesenteric artery (IMA) variations by right and left hepatic arteries origin

Variables	Right hepatic arteries			p	Left hepatic arteries			p
	Classical n = 171	Replaced n = 19	Accessory n = 10		Classical n = 179	Replaced n = 13	Accessory n = 8	
Age, years	60.8 ± 15.4	55.9 ± 18.5	72.7 ± 9.4‡	0.025*	60.5 ± 15.8	62.1 ± 14.9	68.1 ± 14.3	0.440
Origins of celiac trunk, n (%)								
Classical	161 (94.2)	15 (78.9)	8 (80.0)	0.025*	167 (93.3)	9 (69.2)	8 (100)	0.027*
Hepatosplenic trunk	4 (2.3)	2 (10.5)	1 (10.0)		6 (3.4)	1 (7.7)	-	
Gastrosplenic trunk	5 (2.9)	2 (10.5)	-		4 (2.2)	3 (23.1)	-	
Celiacomesenteric trunk	1 (0.6)	-	-		1 (0.5)	-	-	
Absence	-	-	1 (10.0)		1 (0.5)	-	-	
Variation type of SMA, n (%)								
No extra branch	168 (98.8)	3 (15.8)	7 (70.0)	0.001*	163 (91.6)	9 (69.2)	6 (75.0)	0.129
Replaced PHA	1 (0.6)	16 (84.2)	1 (10.0)		13 (7.3)	4 (30.8)	1 (12.5)	
Replaced CHA	1 (0.6)	-	1 (10.0)		2 (1.1)	-	-	
Other	1 (0.6)		1 (10.0)		1 (0.5)		1 (12.5)	
Origins of IMA, n (%)								
Classical	169 (99.4)	19 (100)	9 (90.0)	0.107	177 (99.4)	13 (100)	7 (87.5)	0.083
Bimesenteric trunk	1 (0.6)	-	1 (10.0)		1 (0.5)	-	1 (12.5)	
Other	1 (0.6)	-	-		1 (0.5)	-	-	

Data are shown as number and percentage (%). * indicates a statistically significant difference at $p<0.05$. ‡ indicates the group that is statistically different from the other groups. Abbreviations: CHA, common hepatic artery; IMA, inferior mesenteric artery; PHA, proper hepatic artery; SMA, superior mesenteric artery.

conducted a study in which they retrospectively reviewed the medical records of 479 adult patients who underwent organ transplantation over a 13-year period, focusing on the HA anatomy of deceased donors [19]. Their study reported that 85.6% of the patients had a normal variation of the SMA [19]. In a study by Fergadani et al., the MDCT images of 607 kidney donors and trauma patients were retrospectively analyzed, and classical arterial anatomy was found in 63.9% of the cases [20]. Our study found that 95.5% of the patients had a classical SMA. This variation could be linked to the size of the patient population and differences in racial demographics. Variations like the formation of a common mesenteric artery with the SMA or the absence of the IMA are rarely observed [6, 21, 22]. This was consistent with 98.5% of patients exhibiting the classical origin of the IMA.

Anatomical variations of the HAs are relatively frequent, with a reported prevalence ranging from 13% to 48% [23]. Variations of HA in patients may be important for planning liver transplantation and donor evaluations, pancreatohepaticobiliary surgery, arterial therapies, and endovascular interventions, as well as for managing postoperative complications and follow-up care. In our study, the RHA had a classical origin in 85.5% of patients, a replaced origin in 9.5%, and an accessory origin in 5%. The LHA had a classical origin in 89.5% of patients, a replaced origin in 6.5%, and an accessory origin in 4%. Ugurel et al. conducted a retrospective analysis of 100 patients who underwent MDCT angiography of the abdominal aorta for various reasons and identified the most CHA variations based on Michels' classification. They found that the most frequent variation was a replaced RHA (Type III) at 17%, followed by a replaced LHA (Type II) at 11%, and an accessory LHA (Type V) at 10% [24]. In the literature, the most frequently observed anomalies are Michels Type III, Type V, and Type II [25]. Similar findings were observed in our study. A previous study indicated that the rate of simultaneous variation in the celiac trunk and HA branching patterns was 4.4% [26]. In our study, 5.8% of patients with a classical RHA had celiac trunk origins categorized as hepatosplenic, gastrosplenic, or celiacomesenteric trunks. Additionally, in patients with a classical type of RHA, the rate of classical origin celiac trunk was found to be higher compared to those with a replaced or accessory type of RHA. This group of patients also exhibited a higher rate of absence of extra branches in SMA branch variations. On the other hand, the rate of patients with a replaced PHA in the SMA variation type was higher in the group with a replaced RHA. Besides, the

accessory RHA type exhibited a higher proportion of replaced CHA. In the LHA, the rate of classical origin celiac trunk was lower in the replaced type compared to the other types. Additionally, in the LHA classical type, the gastrosplenic origin of the celiac trunk was lower compared to the replaced type of LHA. This situation may be due to the variational changes in vascular structures during abdominal development being interconnected through vascular anastomoses.

The RAs are vascular structures arising from the lateral wall of the abdominal aorta. Additionally, they are a significant branch of the abdominal aorta, often displaying anatomical variations in their position relative to the renal vein and in their number. The left RA is slightly shorter due to the position of the abdominal aorta on the left side [27]. In approximately 70% of individuals, the kidney is supplied by a single RA originating from the abdominal aorta [28]. Munnusamy et al. studied variations in RA branching patterns in kidney donors using CT angiography and found that 51% of kidney donors exhibited variations in the RA. Additionally, they discovered that 13% of the patients had accessory RAs on both sides [28]. In the present study, similar to the findings in the literature, the rate of accessory RAs was 13% on the right side and 12.6% on the left side.

Our study has some limitations. Firstly, it is a single-center study with a relatively limited number of patients. Another limitation is the retrospective nature of the study, which might have introduced selection bias, as the data were gathered from patients who underwent MDCT angiography for specific clinical indications. This could potentially limit the applicability of our findings to the general population. Despite the retrospective nature of our study and its being conducted at a single center, it has identified a noteworthy number of rare variations. Additionally, while we used well-established classifications for vascular variations, the study did not account for potential variations that might be present in populations with different demographic characteristics, such as ethnicity or underlying health conditions. Future studies should consider these factors to provide a more comprehensive understanding of these anatomical variations.

Conclusions

Our study identified significant anatomical variations in the celiac artery, SMA, RA, and HA in patients undergoing MSCT. The findings of this study indicate that the frequency of arterial variations is a crucial individual difference, particularly relevant in surgical contexts, and necessitates careful patient-specific evaluation before any intervention. Awareness of variation frequency is essential, as it can significantly minimize the risk of complications during surgery. Including these variations in preoperative angiography reports is of clinical importance for preventing postoperative complications, such as bleeding and ischemia, and for achieving surgical success.

Ethics Approval

The study was performed in accordance with the Declaration of Helsinki, and was approved by the Binali Yıldırım University Clinical Research Ethics Committee (Approval Date: 06.03.2023, Number: 2023-3/5).

Informed Consent

The need for informed consent was waived under the approval of the Local Ethics Committee due to the retrospective design.

Conflicts of Interest Statement

The authors declare they have no conflicts of interest.

Financial Disclosure

The authors declared that this study has received no financial support.

Availability of Data and Material

The data that support the findings of this study are available on request from the corresponding author.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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