

# Investigation of coeliac trunk and superior mesenteric artery variations and literature review

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## Abstract

**Aim:** To evaluate the variations of coeliac trunk (CTR) and superior mesenteric artery (SMA) variations in Tekirdag province using computed tomography (CT) images.

**Material and methods:** The data of the patients who underwent CT angiography for any reason via the hospital online PACS were scanned retrospectively for CTR and SMA variation. The frequency of variation in the study population, the variation type and distribution by gender were statistically analyzed.

**Results:** A total of 2529 individuals, including 1703 (67.3%) males and 826 (32.7%) females, were included in the study. The prevalence of variation in the study group was 25.7% (n=650), and it was seen that there was a single variation in 579 (89.1%) individuals and a double variation in 71 (10.9%) individuals. The three most common variations were replaced right hepatic artery (HA) from SMA origin, LGA originated replaced left HA, and common HA from SMA origin (n= 340, 13.44 % ; n=120, 4.74% and n=46, 1.82 %, respectively).

**Conclusion:** Information the rates of these vascular variations provide contribution to surgical procedures and prevents more serious complications. Also, it should be carefully investigated in terms of other accompanying variation.

**Key words:** celiac artery, mesentery, computed tomography, variation

## Introduction

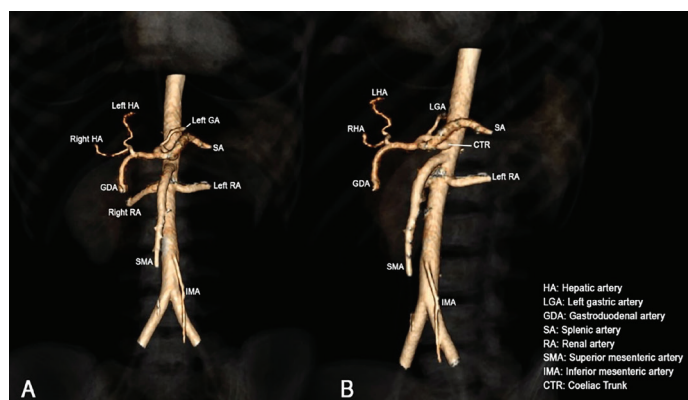
The aorta abdominalis (AA) is the continuation of the descending aorta after passing the midline diaphragm through the hiatus aorticus at the lower edge of T12 vertebra. AA gives branches from the ventral, lateral and dorsal aspects. Ventral branches are single and provide blood supply to the abdominal viscera [1,2].

During embryonic period, from the 10th to 13th vitelline arteries that communicate between the aorta and a primitive ventral anastomotic artery. The regression of the ventral anastomosis and vitelline arteries (11th and 12th) and the persistent of the 10th and 13th roots provide giving origin to the coeliac trunk (CTR) and superior mesenteric artery (SMA). These branches emerge in a single form, extending towards the primitive digestive tract after the fusion of aortae dorsales during embryogenesis. While the right gastric artery, left gastric artery (LGA) and hepatic arteries (HA) are formed from the ventral splanchnic anastomosis, the dorsal splanchnic anastomosis forms the first branches of the gastrosplenic artery, pancreaticoduodenal artery and colic artery [1-3].

CTR is the first of the ventral branches and is separated from the aorta abdominalis 20- 30 mm below the aortic hiatus. This artery has three main branches separated from the same point including splenic artery (SA), common hepatic artery (CHA), and LGA (Figure 1). In a less common type, LGA is split first, then SA and CHA are split into a separate root [2,4,5].

SMA, just below the CTR, separating from the abdominal aorta at the level of L1 vertebral body, running down in front of the third part of the duodenum and supplies small intestine [4-8].

Imaging plays an important role in the detection of arterial variations. For this purpose digital subtraction angiography (DSA) and cross sectional imaging modalities including computed tomography angiography (CTA) or magnetic resonance angiography (MRA) can be used. However, due to its minimal-invasive nature and recent advances in multidetector CT technology, thin-slice dynamic CT has replaced DSA for vascular assessment [9].



**Figure 1** - Three-dimensional reformat CTA images (A,B) show a normal arterial anatomy (HA: Hepatic artery, LGA: Left gastric artery, GDA: Gastroduodenal artery, SA: Splenic artery, RA: Renal artery, SMA: superior mesenteric artery, IMA: inferior mesenteric artery, CTR: Coeliac trunk).

The common occurrence of embryologically based variations in the anatomy of the ventral branches of the abdominal aorta requires a detailed knowledge at imaging. Therefore, the preoperative knowledge of CTR variations or before the interventional procedure, is important for physicians in order to reduce the risk of complications in abdominal dissection, radiological interventions (such as celiac and chemoembolization of liver tumors) or surgical procedures (such as liver transplantation, laparoscopic surgery, radical gastrectomy) [10-12].

In our study, we aimed to examine the variations of major arteries that play a role in nutrition of digestive organs such as stomach, liver and pancreas.

## Material and methods

### Patient collection

Between March 01, 2017 and June 15, 2021, patients with any indications who had contrast-enhanced CT angiographic examinations showing CTR structures were scanned from the archiving and communication system (PACS) in the radiology department of Tekirdağ Namik Kemal University Medical Faculty Hospital. The frequency of variation in the study population, the variation type and distribution by gender were statistically analyzed.

### Inclusion and exclusion criteria

Examinations including abdominal vascular structures (coeliac trunk, superior mesentery artery and/or renal arteries) and CT angiography images with best quality of diagnostic imaging were enrolled in the study.

CT examinations with poor image quality, non-enhanced CT images and those including pathologies affecting vascular structures (any intervention / surgery, stenosis, aneurysm, tumor) were excluded from the study.

### Ethical approval

This study was approved by the university / local human research ethics committee and all procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards (Approval Number: 2019.193.10.14)

## Data Acquisition

CT acquisitions were performed on 128 row multi-detector CT device (MDCT; Aquilion Prime, Toshiba, Otawara, Japan).

## Scanning protocol

CT scanning parameters were as following for each protocol: 100-250 mAs modulated by personal body mass index dose; 100-140 kV tube voltage, 0.5 mm x 80 collimation, 0.35 second gantry rotation time, 0.813 pitch factor, slice thickness 1 mm, slice interval 0.8 mm and 5x5mm reconstruction interval. For intravenous bolus injection of non-ionic contrast material (350 mg/100 ml, iohexol, Omnipaque; GE Healthcare, Cork, Ireland) a mechanical injector was used at a flow rate of 4.5-5.0 ml/sec.

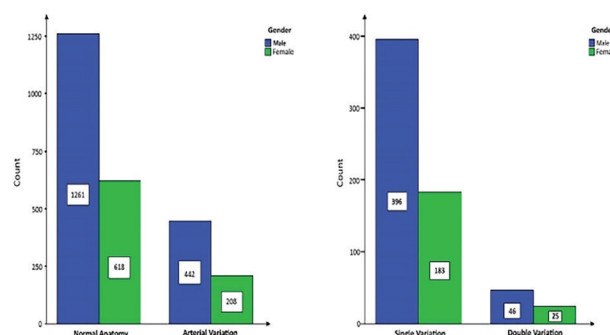
## Statistical analysis

Statistical analyzes were carried out using a statistical package program (SPSS version 17, Chicago, USA). In order to determine the prevalence in the population, the cases with variations detected in the study were compared to the general population. Their correlation with other accompanying artery variations were examined using Pearson chi-square test in the evaluation of categorical data. Statistical significance level was accepted as  $p < 0.05$ .

## Results

### Study population

CT data of a total of 4972 patients were scrutinized from PACS retrospectively. From this population 2529 individuals, 1703 (67.3%) male and 826 (32.7%) female, were included in the study. There was a single or double variation (co-variation) in 25.7% ( $n=650$ ) of these patients (Figure 2). In the variation group, 68% ( $n=442$ ) of the patients were male, and there was no statistically significant difference between the groups in terms of variation and gender ( $p=0.677$ ). The mean age of the patients was  $59.4 \pm 15.92$  years (minimum 8 years, maximum 103 years).



**Figure 2** - (A) Diagram shows the distribution of normal anatomy and arterial variation by gender, (B) The distribution of number of variations by gender.

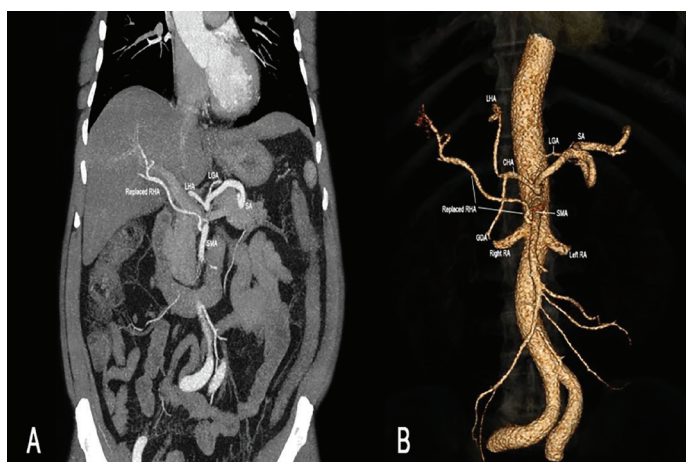
While single variation was found in 579 (89.1%) of 650 patients with variation, double variation was detected in 71 (10.9%) including 46 (64.8%) males and 25 (35.2%) females. There was no statistically significant difference in terms of gender between the groups with single and double variation ( $p=0.539$ ).

The variations by gender are summarized in Table 1. While the most common variation was found to be replaced right HA from SMA origin in 340 individuals (65.9%,  $n=234$  in males) (Figure 3), the second most common variation in 120 people was LGA originated replaced left HA (65%,  $n=78$  males) (Figure 4)

Table 1 Variation types and distribution by gender

Variation type		Male		Female		Prevalance*	
		n	%	n	%	n	%
1)	Replaced right HA from SMA origin	224	65.9	116	34.1	340	13.44
2)	Replaced left HA from LGA	78	65.0	42	35.0	120	4.74
3)	Common HA from SMA origin	31	67.4	15	32.6	46	1.82
4)	Coeliacomesenteric trunk	23	79.3	6	20.7	29	1.15
5)	Right HA from common HA	16	72.7	6	27.3	22	0.87
6)	Left HA from CHA	10	66.7	5	33.3	15	0.59
7)	Replaced right HA from coeliac trunk	11	84.6	2	15.4	13	0.51
8)	Accessory right HA from SMA origin	9	81.8	2	18.2	11	0.43
9)	CHA and SA from aortic origin	6	66.7	3	33.3	9	0.36
10)	4A segment arterial branch from proper hepatic artery origin	5	71.4	2	28.6	7	0.28
11)	Replaced right HA from aortic origin	4	80.0	1	20.0	5	0.20
12)	Absent trunk	4	100.0	0	00.0	4	0.16
13)	Accessory right HA from proper HA origin	2	66.7	1	33.3	3	0.12
14)	LGA from aortic origin	2	66.7	1	33.3	3	0.12
15)	4A segment arterial branch and left HA from proper HA origin	2	100.0	0	00.0	2	0.08
16)	LGA from SA origin	0	00.0	2	100.0	2	0.08
17)	SA from aortic origin	1	50.0	1	50.0	2	0.08
18)	Accessory left HA from LGA origin	2	100.0	0	00.0	2	0.08
19)	Accessory right HA from GDA origin	1	100.0	0	00.0	1	0.04
20)	Right HA and LGA from CHA origin	1	100.0	0	00.0	1	0.04
21)	Right and left HA(s) from CTR origin	1	100.0	0	00.0	1	0.04
22)	Accessory LGA from proper HA origin	1	100.0	0	00.0	1	0.04
23)	Left HA from coeliac CTR origin	0	00.0	1	100.0	1	0.04
24)	CHA, SA, LGA and left HA from aortic origin	1	100.0	0	00.0	1	0.04
25)	GDA from SA origin	1	100.0	0	00.0	1	0.04
26)	4A segment arterial branch and left HA from CHA origin	0	00.0	1	100.0	1	0.04
27)	CHA and LGA from SMA origin	1	100.0	0	00.0	1	0.04
28)	SA from SMA origin	1	100.0	0	00.0	1	0.04
29)	LGA and left HA originated from CTR	1	100.0	0	00.0	1	0.04
30)	LGA and left HA originating from a common trunk	1	100.0	0	00.0	1	0.04
31)	4A segment arterial branch from CHA origin	1	100.0	0	00.0	1	0.04
32)	Proper HA from aortic origin	1	100.0	0	00.0	1	0.04
33)	LGA origin accessory left HA	1	100.0	0	00.0	1	0.04

HA: Hepatic artery, LGA: Left gastric artery, GDA: Gastroduodenal artery, SA: Splenic artery, SMA: superior mesenteric artery, CTR: Coeliac trunk. \* Refers to the frequency in the study group.



**Figure 3** - Coronal CTA (A) and 3D-reconstruction (B) images show a replaced right HA from SMA origin.

and the third common variation was Common HA from SMA origin in 46 individuals (67.4%, n=31, most commonly in males) (Figure 5).

In the current study, co-variation (double variation) was found in 10.9% (n=71) of the cases (Figure 2B, Table 2).

## CT data

Scanning regions in CT were categorized into four groups including thoracic (175), thoracic-abdominal (649), abdominal (494) and abdomino-peripheral (1211).

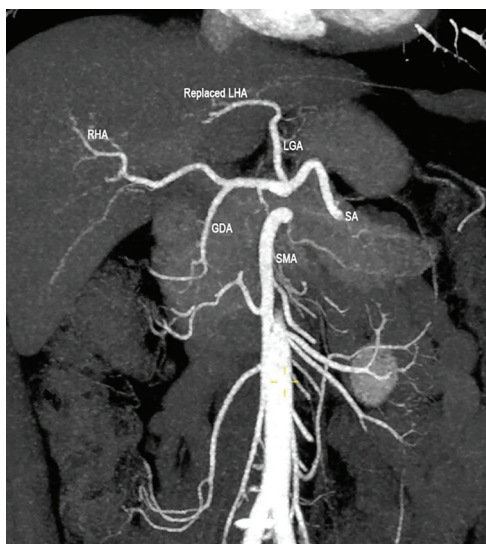
## Discussion

CTR can show a wide variety of variations. It has become very important and necessary to know these variations in order to perform surgical and interventional radiological procedures more safely. Considering the growing number of living donor liver and kidney transplants in recent years, the importance of this issue has become clearer. Technical developments in abdominal surgery have increased the importance of preoperative radiological examinations, and the early detection of these variations has directly affected the success of surgical and interventional radiological procedures [13-15].

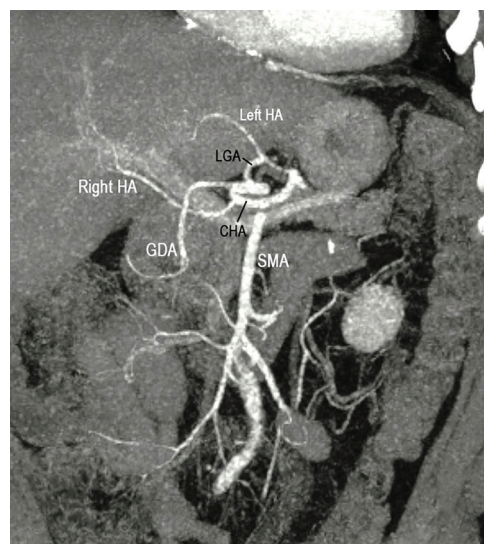
In this study, while normal vascular anatomy rate was 74.3%, it was reported as 63.6% by Fargani et al [16], 89% by Michel NA [17], 51% by Winston et al [18], 66% by De Cecco [19], and 89% by Song et al [9].

In the study conducted by Farghadani et al., the frequency of variation detected by CT angiography was 36.1%, and the

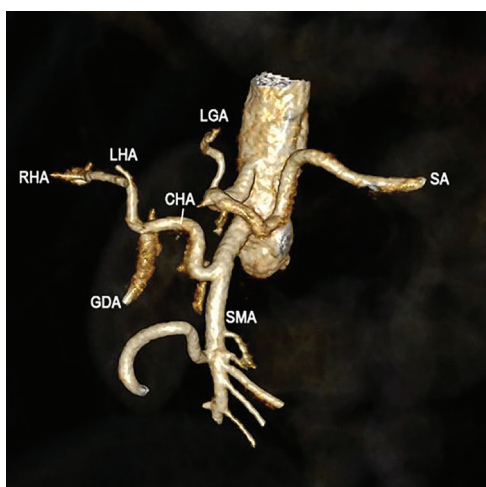




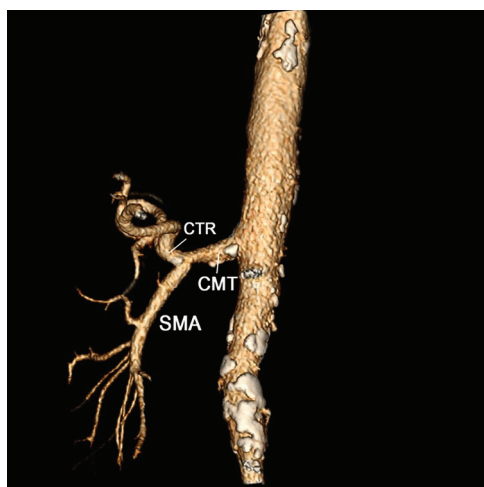
**Figure 4** - Coronal CTA image shows a replaced left HA from LGA origin.



**Figure 5** - Coronal plan CTA image shows a replaced left HA from LGA origin and right HA originating from CHA.



**Figure 6** - Three-dimensional reconstruction CTA image shows a variation of CHA from SMA origin.



**Figure 7** - Three-dimensional reconstruction CTA image shows a coeliacomesenteric trunk (CMT) variation.

Table 2

Frequency distribution of cases with double variation (co-variation, n = 71).

Variation type		Male		Female		Prevalance*	
		n	%	n	%	n	%
1)	Replaced left HA from LGA	36	69.2	16	30.8	52	2.1
2)	LGA from aortic origin	3	60.0	2	40.0	5	0.2
3)	CHA and SA from aortic origin	1	25.0	3	75.0	4	0.2
4)	Replaced right HA from SMA origin	1	100.0	0	0	1	0.0
5)	Left HA from CHA origin	1	100.0	0	0	1	0.0
6)	CHA, SA and GDA from aortic origin	1	100.0	0	0	1	0.0
7)	GDA and SA from CTR origin	0	00.0	1	100.0	1	0.0
8)	SA from aortic origin	1	100.0	0	0	1	0.0
9)	Accessory left HA from LGA	1	100.0	0	0	1	0.0
10)	GDA and SA from aortic origin	0	00.0	1	100.0	1	0.0
11)	4A segment arterial branch from CHA origin	0	00.0	1	100.0	1	0.0
12)	4A segment arterial branch from proper hepatic artery origin and left HA from LGA origin	1	100.0	0	0	1	0.0

HA: Hepatic artery, LGA: Left gastric artery, GDA: Gastroduodenal artery, SA: Splenic artery, SMA: superior mesenteric artery, CTR: Coeliac trunk. \* Refers to the frequency in the study group.

Table 3

Frequency of included cases by race and gender in the literature [23]

Year	Author	Study population (n)	Male (n)	Female (n)	Race
1917	Eaton* [24]	206	138/200	62/200	79 White (79/200), Colored (121/200)
1917	Lipshutz [25]	83	73	10	Caucasian (75/83) and negro (8/83)
1988	Nelson et al. [10]	50	24	26	-
2003	Saeed et al. [26]	52	35	17	Caucasian
2004	Matsuki et al. [27]	36	27	9	Japanese
2007	Ferrari et al. [28]	60	31	29	Caucasian †
2007	Petrella et al. [7]	89	72	17	-
2009	Chen et al. [29]	974	290	234	Japanese *
2010	Chitra [30]	50	40	10	Indian †
2010	Song et al. [9]	5002	4015	987	Korean †
2011	Natsume et al. [31]	175	54	121	Japanese †
2012	Prakash et al. [32]	50	34	16	Indian
2012	Venieratos et al. [33]	77	38	35	Caucasian-Greek
2021	Current study	2529	1703	826	Turkish (Balkan region) *

\* There were not differences between male and females.

† Not explicitly by the author but inferred in the article

most common variation was the right hepatic artery originating directly from SMA with a rate of 9.6% [16]. In our study, the frequency of variation was 25.6% and the most common variation was the right hepatic artery originating from SMA (13.44%). Although there was no statistically significant difference in terms of variation according to gender, variation was observed more frequently in males (68%). This variation was found to be 15% in the study by Winston et al [18] and 9.2% in the study by De Cecco et al [19].

The second most common variation in our study is that the left hepatic artery originates from the left gastric artery with a rate of 4.74%. Farganiet al found this variation as the second most common variation (6.9%) in their study. This variation was found to be 5.2% in the study by De Cecco et al [19], and 8% in the study by Michel and Winston et al [17,18]. The importance of this variation is that it should be detected and ligated prior to left hepatectomy [20].

The rate of originating the CHA from the SMA (Figure 6) has been shown in the literature at a rate of 2.5% [21], in our study this variation was found to be 1.82%.

While coeliacomesenteric trunk (CMT) variation was detected as 1.15% in the current study, it was reported as 2% in the literature [22] (Figure 7).

In a retrospective evaluation of 5002 patients who underwent spiral CT and digital subtraction angiography by Song et al, they found celiac axis variations in 482 (9.6%)

patients, while in our study 650 (25.7%) patients with CTR variation were selected in 2529 patient population [9].

The frequency of celiac truncus variations according to gender and race is summarized in Table 3 in the light of literature data.

## Conclusion

Thanks to the improvements and advances in imaging techniques such as MDCT angiography and three-dimensional multiplanar techniques, knowing the rates of these vascular variations in the population, contributes to surgical procedures such as interventional radiological procedures, liver and kidney transplantation and prevents more serious complications. To the best of our knowledge, the current study includes the largest variation series in Tekirdag (Balkan region) as well as across the country. According to the present data, patients detected with arterial variation should be carefully investigated in terms of possible co-variation, the prevalence of which is 11% in this region.

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