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ARAŞTIRMA / RESEARCH

Examination of the main branches of aorta abdominalis with multi-detector computed tomography angiography

Aorta abdominalis'in ana dallarının multi-dedektör bilgisayarlı tomografik anjiyografi ile incelenmesi

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Abstract

Purpose: The aim of this study was to examine the main branches of abdominal aortae (AA) and to make evaluation by carrying out some measurements by considering gender difference.
Materials and Methods: This study was designed as a retrospective research subjecting multi-detector computed tomography (MDCT) angiography images of 200 individuals (61 women, 139 men). Coeliac trunk (CT), superior mesenteric artery (SMA), right renal artery (RRA), left renal artery (LRA), inferior mesenteric artery (IMA) were examined by abdominal aortae and its branches. The cases of these arteries with anatomical variation were classified, and vertebral outflow levels originated from AA and the mean of distance measurements with each other were recorded. In addition, sagittal and transverse diameter measurements at the level of the main branches of AA were conducted, all examined data were compared according to gender.
Results: While normal CT anatomy was observed in 91% of 200 cases, the rate of CT variations was 9%. The replaced right hepatic artery originated from SMA was found only in one patient. No variation was observed in IMA. No significant difference was determined between genders in most of the vertebral outflow levels of the arteries examined.
Conclusion: Diagnosing mesenteric and renal arterial variations is of vital importance in colon, hepatobiliary and renal transplantations, and vertebra levels of these arteries, diameter and distance measurements provide convenience for clinical staff and cadaver dissection in anatomy.
Keywords: MDCT, abdominal aortae, variation

Öz

Amaç: Çalışmamızda, aorta abdominalis (AA)'in ana dallarını incelemeyi ve bazı ölçümler yaparak cinsiyet farkını da göz önüne alıp değerlendirmeyi amaçladık.
Gereç ve Yöntem: Çalışmamız, 18-97 yaş aralığında; 200 kişinin (61 kadın, 139 erkek) Multi- dedektör bilgisayarlı tomografi (MDBT) anjiyografi görüntüsünde retrospektif olarak yapılmıştır. Aorta abdominalis ve dallarından, Truncus coeliacus (TC), arteria mesenterica superior (AMS), arteria renalis dextra (ARD), arteria renalis sinistra (ARS), arteria mesenterica inferior (AMI) incelendi. Bu arterlerin anatomik varyasyon gözlenen olguları sınıflandırıldı ve AA'den orjin aldığı vertebra çıkış seviyeleri, birbirleri ile olan uzaklık ölçümlerinin ortalamaları kaydedildi. Ayrıca AA'in ana dalları seviyesinde sagittal ve transvers çap ölçümleri yapıldı ve incelenen tüm veriler cinsiyet faktörüne göre karşılaştırıldı.
Bulgular: 200 vakanın %91'inde normal TC anatomisi, % 9'unda ise TC varyasyonları izlenmiştir. AMS'dan çıkan replase sağ hepatik arter varlığı sadece bir hastada tespit edildi. AMI'da varyasyon izlenmedi. İncelenen arterlerin vertebra çıkış seviyelerinin genelinde cinsiyetler arasında anlamlı bir farklılık gözlemlenmedi.
Sonuç: Mezenterik ve renal arteriyel varyasyonların farkında olunması, kolon, rectum, hepatobiliyer, pankreatik hastalıklarda ve renal tranplantasyonlarda hayati önem taşır ve bu arterlerin vertebra seviyeleri, çap ve mesafe ölçümleri klinik çalışanlarına ve anatomide kadavra diseksiyonlarında büyük kolaylıklar sağlar.

Anahtar kelimeler: MDBT, aorta abdominalis, varyasyon.

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INTRODUCTION

Descending aorta, one of the parts of aortae, is called pars abdominalis aortae in abdominal cavity after aortic hiatus in diaphragma, and stretches out between the lower edge of the 12th thoracic vertebral body and the 4th lumbar spine or the lower edge of this vertebra. It gives off 6 important visceral branches feeding the organs in the abdominal region and is divided into end branches named right common iliac artery and left common iliac artery being bifurcated at the level of 4th lumbar spine (bifurcatio aortae). It is placed at midline that is in front of columna vertebralis while it was at the 12th thoracic vertebra. However, when it is gone downwards, it moves to the left of the centerline. Being quite thick at the starting point, its diameter decreases with each branch it produces[1,2].

Diagnosing vascular anatomy is a guiding option for surgeons and radiologists both during many surgical interventions to be performed in the abdominal region, such as major hepatobiliary, pancreatic surgery, and kidney transplantation and before interventional radiological process. It is also very important in determining treatment types, deciding on surgical dissection in the prevention or minimising hemorrhagic and ischemic complications due to iatrogenic injury[3].

Conventional catheter angiography (CCA) is considered a significant standart in vascular imaging, and it is mostly a reliable method. However, as it is an invasive process, it has a complication risk of 1%[4,5]. The significance of computed tomography (CT) has increased highly in vascular studies after MDCT angiography began to be used. In addition, with the technological developments in this field, the MDCT angiography has been replaced with CCA as it now enables preoperative evaluation of vascular anatomy and evaluation of abdominal organ parenchyma[6].

Accurate definition of clinically determined abdominal vascular variations, naming them properly, and identifying more complex variation associations are of quite importance in refreshment of previous anatomic literature. For this reason, we aimed to measure and then discuss the variations seen in anatomy of coeliac trunk, superior mesenteric artery, renal artery and inferior mesenteric artery, AA outflow levels, sagittal and transverse diameters and distances.

MATERIALS AND METHODS

This study was designed as a retrospective research by subjecting MDCT images on abdominal region of the patients applied to the University of Sakarya Faculty of Medicine Radiology Clinic. First of all, an ethical approval was received (SAU/04/12/2017-E.18568), and our study was carried out in accordance with the World Medical Association Helsinki Declaration.

Sample

The cases in which normal vascular anatomy was affected by surgical intervention, the cases with gastric resection, major hepatic resection, jejunoileal resection, colonic resection, anterior rectal resection, pancereato-duodenectomy, liver, pancreas, intestine or multiorgan transplantations and the cases with insufficient MDCT image quality for the evaluation of vascular anatomy were excluded. Of all MDCT images, 200 cases appropriate for our study was selected (61 women-139 men), and necessary morphometric measurements were carried out on the images. While the mean age of women in our study was 56.4 (18-97), this was 57.4 (19-86) for men. Measurements were made by a single researcher to minimize the error coefficient. Help from an expert radıologue when requıred.

MDCT Angiography Image Protocol

The images in 0.5 mm section thickness were obtained in the arterial phase by utilising MDCT (Toshiba Aquilion 64 Ct Scanner (Toshiba medical systems Corporation, Tochigi, Japan) in axial plan covering abdomen region (from basis pulmones to regio pubica) after the cases included in this study were given iodized contrast agent by antecubital way in supine position. These source images were evaluated by Aquarius 3D Workstation, TeraRecon, USA, and images were created after being processed in the formats of 3D (axial, sagittal and coronal plane) MIP (maximum intensity projection) and MPR (multiplanar reformation) by multiplanar imaging method. In reformatted images, the distance measurements of coeliac trunk, superior mesenteric artery, right renal artery, left renal artery, inferior mesenteric artery from the main branches of AA and their vertebra levels in which they were originated were determined. Transverse and sagittal diameter measurements of AA at various levels were made in axial, sagittal and coronal plan images, and anatomical variations of the main branches of AA were examined.

Measurements

In axial reformat images of MDCT Angiography on 200 patients, transverse and sagittal diameter measurements were made at the level of AA's Coeliac Trunk, Superior Mesenteric Artery, Renal Artery and Inferior Mesenteric Artery. In measurements regarding Coeliac Trunk, the detection of vertebra level of Coeliac Trunk, in which it is originated from AA, on sagittal, coronal and axial images and distance measurement of CT origin to SMA, RRA, LRA, IMA origin were performed. In measurements related to Superior Mesenteric Artery, the determination of vertebra level of SMA, in which it is originated from AA, on sagittal, coronal and axial images and distance measurement of SMA origin to RRD, LRA, IMA origin were conducted. In measurements regarding RRD, the detection of vertebra level of RRD, in which it is originated from AA, on sagittal, coronal and axial images was carried out. In measurements related to LRA, the detection of vertebra level of LRA, in which it is originated from AA, on sagittal, coronal and axial images was made. In measurements related to IMA, the determination of vertebra level of IMA, in which it is originated from AA, on sagittal, coronal and axial images and distance measurement of IMA origin to RRD and LRA origin were performed.

The types of variations examined in the main branches of the aorta abdominalis are given below. Uflacker's classification, covering 8 typings[7], was utilised in CT variations examined on AA main branches, and other encountered variations of CT were named after as type 9 (Table 1).

Tablo 1. Types of variations used in the examination of the AA and its main branches

Branch	Variation Types	
CT	Type 1	It is called 'hepatos plenic -gastric trunk' classic celiac artery anatomy when major hepatic artery, splenic artery and left gastric artery are originated from AA as a common root
	Type 2	It is named after 'hepatosplenic trunk if LGA is originated from aorta directly while major hepatic artery and splenic artery are originated as a common root
	Type 3	It is called 'hepato-gastric trunk' if splenic artery is originated from aorta directly while major hepatic artery and LGA are originated as a common root
	Type 4	It is named 'hepatosplenic -mesenteric trunk if LGA is originated from aorta directly while hepatic artery, splenic artery and SMA are originated as a common root
	Type 5	It is called 'gastro-splenic trunk' if hepatic artery is originated from aorta directly while LGA and splenic artery are originated as a common root
	Type 6	It is called 'celiac-mesenteric trunk' if celiac artery and SMA are originated as a common truncus
	Type 7	It is named after 'celiac-colic trunk' if celiac artery and colic artery create a common truncus
	Type 8	It is named 'celiac trunk absence' if hepatic artery, splenic artery and LGA are originated separately from abdominal aorta without creating any truncus
	Type 9	Other variations of coeliac trunk
SMA	Type 1	The presence of SMA originated from the AA (normal anatomy)
	Type 2	The presence of replaced right and/or accessory right hepatic artery originated from SMA
	Type 3	'Celiac-mesenteric trunk' (celiac artery and SMA originate as a common trunk)
	Type 4	'Hepato-splenic-mesenteric trunk' (major hepatic artery, splenic artery and SMA originate as a single trunk and LGA originates from aorta directly[6,8]
IMA	Type 1	The presence of a single IMA from the abdominal aorta (normal anatomy)
	Type 2	IMA originating from AA by forming a common trunk with SMA and/or the major hepatic artery
	Type 3	IMA (double IMA) originating from abdominal aorta in two separate branches
	Type 4	Accessory renal artery originating from IMA
RA	Type 1	The presence of a renal artery on the right and left sides (normal anatomy) originating from AA
	Type 2	The presence of a single renal artery feeding both kidneys
	Type 3	The presence of a double renal artery on the right and a single on the left
	Type 4	The presence of a single renal artery on the right and a double on the left side
	Type 5	The presence of two or more renal artery in the right and left kidneys
	Type 6	The presence of three or more renal artery in the right and left kidneys[9]

*AA= Abdominal aorta, Coeliac trunk (CT), Superior Mesenteric Artery (SMA), Renal Artery (RA), Inferior Mesenteric Artery (IMA)

Statistical analysis

All obtained data were analysed by utilising "Statistical Packages for the Social Science" (SPSS) 21 statistics program on a computer with Windows XP operating system. While evaluating the study data, parametric tests were used because numerical variables were suitable for normal distribution of the data. While evaluating the study data, frequency distribution (number, percentage) for categorical variables and descriptive statistics (mean, standard deviation) for numerical variables were given. In examining the difference between categorical variables with two groups, the "significance test of the difference between two averages" (independent sample t test), and the relationship between the two categorical variables was tested with the chi-square test and $p<0,05$ value was accepted statistically significant.

RESULTS

Of the variation classifications examined in the major branches of AA, CT was determined as the variation typing with most Type 1 by 9% while Type 3 (5%) and Type 8 (5%) (Figure 1) were found to be the ones seen least.

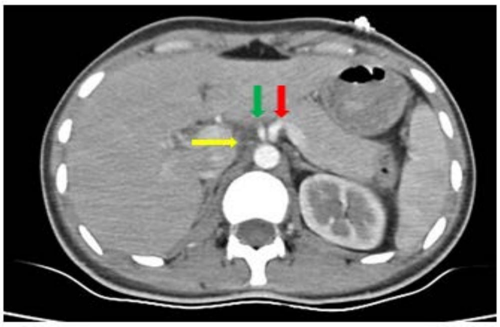


Figure 1. CT absence. Separate origination of LGA, CHA and LA from AA (type 8) *(green arrow Common Hepatic Artery (CHA), yellow arrow Left Gastric Artery (LGA), red arrow Lienal Artery (LA)).

Of the variation typings used in RA, it was found out that whereas the presence of a renal artery on the right and left sides (Type 1) observed most, the presence of two or more renal arteries on the right and left sides (Type 5) was identified least by 2.5% (Figure 2).

When examining SMA, Type 1 (99.5%) was seen most while Type 2 (5%) was seen least. Type 1 normal anatomy was observed in 100 % of the patients from the variation typings we examined in IMA. Other variation typings were not determined. When comparing the rates of all variation typings between genders, no significant difference was concluded between them ($p>0.05$) (Table 2).

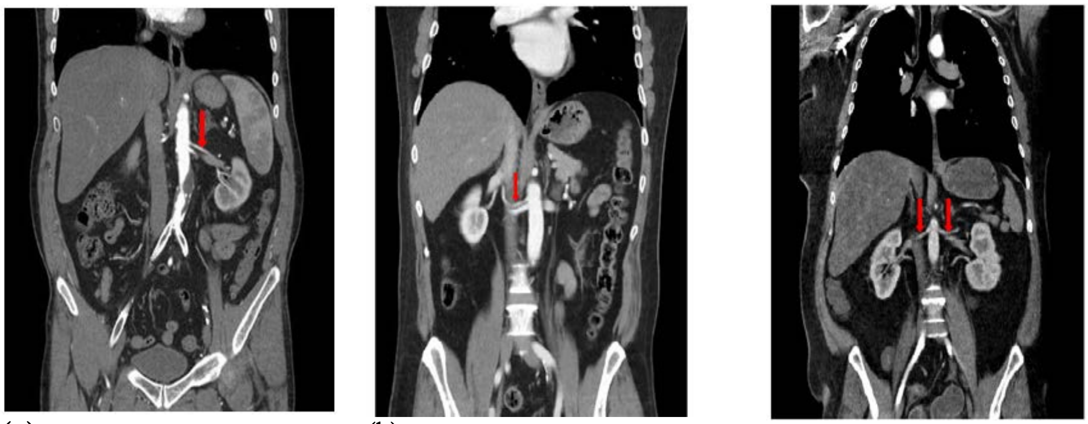
CT was compared in 4 outflow levels in which it originates from AA, and it was seen that the vertebra level in which CT originates from AA was generally (%52.5), and it was mostly T12 lower level according to genders (Female=55.7%, Male=51.1%). When outflow from T12 upper level was evaluated in line with gender difference, there was a statistically significant difference ($p=0.037$) ($p<0.05$).

No statistically significant difference was found in other outflow levels ($p>0.05$) (Table 3). When examining the vertebra levels in which LRA originated from AA, L2 upper vertebra level was observed most by 34.5% among 5 levels. Regarding RRA, L1 lower vertebra level was seen most by 36% while the ones between L1-L2 (6%) were observed least. There was no statistically significant difference in output levels in both renal arteries according to the gender factor ($p>0.05$) (Table 4-5).

When examining the vertebra levels in which SMA originated from AA, L1 upper vertebra level was seen most by 45.5% while the ones between L1-L2 (6%) were observed least, and a significant difference was determined between genders in L1 lower level regarding outflow levels ($p=0.017$) ($p<0.05$). No statistical difference was identified in other levels ($p>0.05$) (Table 6).

It was found out that IMA originated from AA most at L3 lower (39.0%) and least at L2 lower (0.5%), and there was a significant difference only in the vertebra level between L2-L3 regarding the comparison between genders ($p<0.05$). No statistically significant difference was determined in other levels ($p>0.05$) (Table 7).

In this study, minimum and maximum values and mean and standard deviation results of the transverse and sagittal diameters were evaluated at the level of the main branches of AA. When considering the factor of gender, the measurements in transverse and sagittal diameters were statistically significant ($p<0.001$) (Table 8).



(a) (b) (c)

Figure 2. (a) The presence of double renal artery on the left sides originating from AA (Type 4) *(→ double left renal artery (LRA)) (b) The presence of double renal artery on the right sides originating from AA (Type 3) *(→ double right renal artery (RRA) (c) The presence of double renal artery on the right and left sides originating from AA (Type 5)*(→ double right renal artery (RRA) and double left renal artery (LRA).

Table 2. The comparison of variation typings investigated in the main branches of AA according to gender

Main branches	Types	Number Percentage	Gender		Total	p	
			Female	Male			
CT Types	Type 1	n	58	124	182	0.547	
		%	95.1	89.2	91		
	Type 2	n	1	9	10	0.148	
		%	1.6	6.5	4.5		
	Type 3	n	1	0	1	0.130	
		%	1.6	0	0.5		
	Type 5	n	0	3	3	0.247	
		%	0	2.2	1.5		
	Type 8	n	1	0	1	0.130	
		%	1.6	0	0.5		
	Type 9	n	1	3	4	0.809	p>0.05
		%	1.6	2.2	2		
*Type 4, 6 and 7 were not included in table as not seen in cases. ** chi-square test							
RA Types	Type 1	n	50	112	162	0.817	
		%	82.0	80.6	81		
	Type 3	n	8	13	21	0.424	
		%	13.1	9.4	10.5		
	Type 4	n	3	21	12	0.669	
		%	4.9	10.5	6		
	Type 5	n	0	5	5	0.133	p>0.05
		%	0	3.6	2.5		
* Type 2 and 6 were not included in table as not seen in cases. ** chi-square test							
SMA Types	Type 1	n	61	138	199		
		%	100	99.3	99.5		
	Type 2	n	0	1	1		
		%	0	0.7	0.5		
IMA Types	Type 1	n	61	139	200		
		%	100	100	100	p>0.05	

* Type 2, 3 and 4 were not included in table as not seen in cases.; ** chi-square test;*** Coeliac trunk (CT), superior mesenteric artery (SMA), renal artery (RA), inferior mesenteric artery (IMA)

Table 3. The comparison of vertebra outflow levels of CT originating from AA according to gender

Gender		Vertebra Outflow Levels					Total
		T12 upper	T12 middle	T12 lower	T12-L1 between	L1 upper	
Female	n	1	8	34	3	15	61
	%	1.6	13.1	55.7	4.9	24.6	30.5
Male	n	14	13	71	10	31	139
	%	10.1	9.4	51.1	7.2	22.5	69.5
Total	n	15	21	105	13	46	200
	%	7.5	10.5	52.5	6.5	23.0	100
	p	*0.037	0.424	0.543	0.723	0.547	p>0.05

*p<0.05, ** chi-square test

Table 4. The comparison of vertebra outflow levels of LRA originating from AA according to gender

Gender		Vertebra Outflow Levels					Total
		L1 upper	L1 middle	L1 lower	L1-L2 between	L2 upper	
Female	n	2	6	18	7	19	9
	%	3.3	9.8	29.5	11.5	31.1	14.8
Male	n	9	11	41	16	50	12
	%	6.5	7.9	29.5	11.5	31.1	8.6
Total	n	11	17	59	23	69	21
	%	5.5	8.5	29.5	11.5	34.5	10.5
	p	0.361	0.653	0.998	0.994	0.508	0.193

* chi-square test

Table 5. The comparison of vertebra outflow levels of RRA originating from AA according to gender

Gender		Vertebra Outflow Levels					Total
		L1 upper	L1 middle	L1 lower	L1-L2 between	L2 upper	
Female	n	2	14	20	1	24	61
	%	3.3	23.0	32.8	1.6	39.3	30.5
Male	n	10	19	52	11	47	139
	%	7.2	13.7	37.4	7.9	33.8	69.5
Total	n	12	33	72	12	71	200
	%	6	16.5	36	6	35.5	100
	p	0.283	0.103	0.530	0.085	0.451	p>0.05

* chi-square test

Table 6. The comparison of vertebra outflow levels of SMA originating from AA according to gender

Gender		Vertebra Outflow Levels						Total
		L1 upper	L1 middle	L1 lower	T12-L1 between	L1-L2 between	L2 upper	
Female	n	33	9	12	3	1	3	61
	%	54.1	14.8	19.7	4.9	1.6	4.9	30.5
Male	n	58	22	51	6	1	1	139
	%	41.7	15.8	36.7	4.3	0.7	0.7	69.5
Total	n	91	31	63	9	2	4	200
	%	45.5	15.5	31.5	4.5	1.0	2.0	100
	p	0.105	0.846	*0.017	0.850	0.547	0.050	p>0.05

*p<0.05, ** chi-square test

Table 7. The comparison of vertebra outflow levels of IMA originating from AA according to gender

Gender		Vertebra Outflow Levels						Total
		L2 middle	L2 lower	L2-L3 between	L3 upper	L3 middle	L3 lower	
Female	n	0	0	6	23	7	25	61
	%	0	0	9.8	37.7	11.5	41	30.5
Male	n	4	1	4	48	29	53	139
	%	2.9	0.7	2.9	34.5	20.9	38.1	69.5
Total	n	4	1	10	71	36	78	200
	%	2.0	0.5	5.0	35.5	18.0	39.0	100
	p	0.180	0.506	*0.037	0.665	0.111	0.703	p>0.05

*p<0.05, ** chi-square test

Table 8. The comparison of measurement means of transverse and sagittal diameter (DIA) according to gender at the level of main branches of AA

Diameter measurements	Min.	Max.	$\bar{x}$±S	Female (n=61) $\bar{x}$±S	Male(n=139) $\bar{x}$±S	Result
CT Transverse DIA	15.40	30.60	23.01±2.83	21.23 ±2.67	23.78±2.53	t =6.43 p=0.001*
CT Sagittal DIA	14.80	31.40	22.35±3.11	20.53±2.91	23.15±2.85	t =5.95 p=0.001*
SMA Transverse DIA	13.75	28.70	21.25±2.70	19.53 ±2.55	22.01 ±2.42	t =6.55 p=0.001*
SMA Sagittal DIA	12.20	28.50	20.90±3.01	19.10±2.74	21.69±2.78	t =6.09 p=0.001*
RA Transverse DIA	12.20	28.70	19.26±2.80	17.60±2.69	20.00±2.53	t =6.04 p=0.001*
RA Sagittal DIA	12.18	27.00	18.90±2.66	19.23±2.19	19.63±2.53	t =6.42 p=0.001*
IMA Transverse DIA	12.50	29.20	17.62±2.47	18.32±2.01	16.02±2.34	t =6.65 p=0.001*
IMA Sagittal DIA	11.30	29.40	17.19±2.57	15.53±2.00	17.92±2.45	t =6.65 p=0.001*

*p<0.001, ** T test, *** coeliac trunk (CT), superior mesenteric artery (SMA), renal artery (RA), inferior mesenteric artery (IMA)

The average distance between CT and SMA, main branches of AA, was measured to be 15.35 mm for male and 14.45 mm for female. This difference was not statistically significant (p>0.05). The average distance between CT and IMA was measured to be 31.31 mm for male and 84.98 mm for female, the difference was significant (p<0.05). The average distance between CT and RRA was found to be 31.31 mm for male and 28.16 mm for female with a statistically significant difference (p<0.05). The average distance between CT and LRA was determined to be 33.94 mm for male and 32.47 mm for female, which was not statistically significant (p>0.05). The average distance between SMA and IMA was identified to be 75.22 mm for male and 70.52 mm for female with a statistically significant difference (p<0.05). The average distance between SMA and RRA was found to be 16.07 mm for male and 13.54 mm for female with a statistically significant difference (p<0.05). The average distance between SMA and RRA was determined to be 19.00 mm for male and 17.77 mm for female, which was not statistically significant (p>0.05). The average distance between IMA and RRA was concluded to be 59.51 mm for male and 56.37 mm for female with a statistically significant difference (p<0.05). The average distance between IMA and LRA was measured to be 56.61 mm for male and 51.65 mm for female with a statistically significant difference (p<0.05) (Table 9).

Table 9. The comparison of distance measurements of AA main branches between each other according to the gender

Distance between arteries	Min	Max	x̄ ±S	Female(n=61) x̄ ±S	Male(n=139) x̄ ±S	Result
CT – SMA	5.00	30.00	15.08±4.36	14.45±4.57	15.35±4.26	p=0.098
CT –IMA	48.00	115.00	89.00±11.42	84.98±10.35	90.76±11.46	p=0.001*
CT – RRA	15.00	105.00	30.35±9.17	28.16±7.31	31.31 ±9.75	p=0.015*
CT-LRA	15.00	69.00	33.49±7.80	32.47±8.72	33.94±7.36	p=0.074
SMA-IMA	24.00	100.00	73.79±11.35	70.52±9.43	75.22±11.85	p=0.002*
SMA-RRA	2.00	84.00	15.30±8.20	13.54±5.78	16.07±8.97	p=0.046*
SMA-LRA	3.00	50.00	18.63±7.38	17.77±6.93	19.00±7.56	p=0.225
IMA-RRA	6.00	90.00	58.55±11.98	56.37±9.32	59.51±12.88	p=0.011*
IMA-LRA	18.00	85.00	55.10±11.38	51.65±8.98	56.61±12.00	p =0.002*

*p<0.05, ** Mann-Whitney U test, *** Coeliac trunk (CT), superior mesenteric artery (SMA), right renal artery (RRA), left renal artery (LRA), inferior mesenteric artery (IMA)

DISCUSSION

Prediagnosis of differences in vertebral outflow levels of mesenteric arteries of Abdominal Aortae, distances between them, sagittal and transverse diameters in the outflow roots are of quite importance in interventional radiology and surgery. What is more, identifying and imaging the anatomic variations of mesenteric arteries clearly are of vital importance in interventions related to abdominal organs (liver transplantation, hemoembolization of liver tumours, hepatobiliary diseases, pancreatectomy, aortic aneurysm and colorectal surgery) and laparoscopic interventions[6,10].

Various studies were examined in the literature on vertebra origin levels of CT. In the study by Selveraj and Sundaramurth the origin level of CT was determined to be 10.7 % in T12 vertebra level, 70.7% between T12-L1 and 18.6% in L1 vertebra level[11]. It was urged by Yan et al. that it originated from the lower level of T1 and upper level of T12 in 0.3% of the cases, from the upper level of T12 in %7.6 of the cases, from the lower level of T12 and the upper level of L1 in 86.0% of the cases and from the lower level of L1 in 6.1% of the cases, and there was not any significant difference between genders[12]. In this study, we examined T12 vertebra level in 3 parts as upper, middle and lower related to CT vertebra origin levels of the cases (T12 upper, T12 middle and T12 lower). For this reason, we found the level seen most as T12 52.5%, which was different from previous studies. There was only a difference between genders in T12 upper level.

In literature, many researchers attempted to classify truncus anomalies and variations of coeliac trunk according to branch pattern. While the first classification was made by Lipshutz in 1917, the latest classification was conducted by Uflacker in 1997, and the variations of coeliac trunk were shown in 8 types[7,13,14]. This is the classification used most in recent studies.

In the study carried out by Acu et al. in line with the classification of Uflacker, they reported 88.6 % normal celiac artery anatomy and 11.4% celiac artery variation[6]. The most common celiac artery variation was reported to be hepato-gastric trunk by 3.8%. The variations observed in celiac artery anatomy were hepatogastric trunk by 3.8%, gastrosplenic trunk by 3.4%, hepatogastric trunk by 2.6%, gastrosplenic-mesenteric trunk by 0.6% and celiac-mesenteric trunk by 0.6%, and 0.4% celiac trunk was not seen. The main hepatic artery abdominal was determined to be directly originated from the aorta in both of these. Osman and Abdrabou used the classifications of both Uflacker and Michel when identifying coeliac trunk and hepatic artery variations in MDCT angiography images of Egyptian patients[15]. Type 1 normal anatomy and type 5 gastrosplenic trunk were determined to be the most frequent variations in 90.5% and 4.3% of the cases, respectively. In addition, 2.8% of cases were found to have Type 2 hepatosplenic trunk, 0.6% of them had Type 3 hepatogastric trunk and Type 6 celiac-mesenteric trunk. Type 4 hepatosplenic-mesenteric trunk and Type 7 celiac-colic trunk were not detected. Type 8 celiac trunk absence was determined to be 1%, which was also found at the same rate in this study. In this study, of CT variations, the most observed one was type 1 by 91%, which is similar to the ones found in the above-mentioned studies. Different from previous studies, we carried out comparisons according to gender differences, but there was no statistically significant difference. Renal artery variations increase the risk of complication in donor's kidney to a great extent, which result in technical differences and longer anastomosis time [16,17,18]. A successful renal stent implantation requires to diagnose the origin of renal arteries in the aorta[19]. Beregi et al. investigated the outflow origin of BT and renal arteries in T12, L1, L2, L3 vertebra levels and by dividing each vertebra into three levels as upper, middle and lower[19]. They also identified that the outflow of right renal artery was mostly seen in L1 lower by 22% while the outflow of left renal artery was mostly observed in L1-L2 vertebra by % 22. Ozkan et al. argued that right renal artery originated most from L1 upper and L2 lower vertebras by 98 % while this rate was 97 % for the left renal artery[22]. They also reported that RRA originated most from L1 vertebra (43%) while LRA originated most from L2 vertebra (38%). In this study, LRA originated most from L2 upper vertebra by 34.5%, and RRA outflow level was generally observed to be in L1 lower vertebra (36%) regarding cases. In addition, we also investigated gender difference but no significant difference was achieved between outflow levels and gender.

Diagnosing variations in renal vascular anatomy is of paramount importance before laparoscopic donor or partial nephrectomy, in vascular treatment of renal artery stenosis and open surgery or endovascular treatment of abdominal aortic aneurysm[21].

In their study on renal artery variations, Gumus et al. observed normal anatomy in 71.0 % of cases and the presence of multiple renal artery in 27.0% of cases[22]. Double renal artery was determined in 14.4% of cases in right side while this was 15.7% for left side. In addition, 3 and more renal arteries were found in 9 cases in right side while this was 3 renal artery in 5 cases in left side. Any significant difference was not found between genders. Palmieri et al. reported more than one renal arteries in 61.5% of cases (56% right and 67% left) by indicating that this variation was seen in 65% of men and 58% of women[23]. They identified 6 renal arteries by 2% in the left renal artery in women while this was maximum 4 renal arteries in a single side for men. However, they emphasized that the difference between genders was not significant. Of the AR variations, the most observed one was type 1 by 81% that is the presence of one renal artery in both kidneys. The second most seen one was type 3 by 10.5% (double renal arteries on the right, single renal artery on the left) and type 4 by 6% (double renal arteries on the left, a single renal artery on the right). The presence of double renal arteries at right and left sides was only found in 2.5% of cases. No statistically significant difference was determined when AR variations were compared according to gender difference.

In their study on anatomical variations of CT and SMA, Ferrari et al. reported that 98.3% of SMA originated from the aorta at the L1 vertebra level and they found celiac-mesenteric trunk by 1.7%[24]. Double truncus was seen in 26.7 of hepatomecenteric trunk cases while a common trunk was identified in 83.3% of them and only one artery was observed in 3.3% of them. Similar to our study, it was reported that the outflow level of IMA was L3 vertebra lower level in 100% of cases. In addition, any significant difference was not found between genders in this study regarding L2-3 vertebra level.

Acu et al. observed normal SMA anatomy in 84.6 of all cases and SMA variations in 15.4% of them[6]. The most observed SMA variation was replaced right hepatic artery variation originating from arteria mesenterica superior by 10.2%. They did not identify any IMA variation in their study. Their results are in accordance with our study. Kornafel et al. found out superior mesenteric artery variation in 2% of the cases in their study[25]. They reported that celiac-mesenteric trunk was seen most in cases by 1.5 % while 0.5 % of them had hepatomecenteric trunk. They did not find any IMA variation as in our results. Having information on diameter and length of arteries is effective in inserting arterial stents in surgical operations, which is also useful for the ones designing and developing stents[26].

Yahel et al. determined the distance between CT and SMA as 1,6 cm and the average distance between SMA and IMA as 6,8 cm in cadavers. In this study, the average distance between CT and SMA was found to be 15.08 mm while the average distance between

SMA and IMA was determined to be 73.79 mm[27]. Beregi et al. reported the average distance between SMA and LRA as 18 mm and the average distance between SMA and RRA as 14.5 mm[19]. In their studies on investigating cadavers regarding the relationship of visceral branches of AA with RAs, Pennigton and Soames measured the diameter of the aorta as 24.9±4.8 mm at the level of CT, as 24.4±4.20 mm at the level of SMA and 21.1±5.5 mm at the level of IMA[28]. They determined the distances between branches as follows: 0,92 cm between CT and SMA, 1,1 cm between SMA and RA, 5,68 cm between RAs and IMA.

The measurements achieved in the study of Pennigton and Soames are similar to the ones found in this study[28]. We compared the measurements of females and males, and determined significant difference regarding the distances between CT-IMA, CT-RRA, SMA-IMA, SMA-RRA, IMA-RRA, IMA-LRA. The distances of females between branches were generally shorter. We can suggest that the physical difference between female and male may become effective in this difference.

Takahashi et al. investigated positional relationship CT, SMA and RA on Japanese cadavers[29]. They found CT branching to be 40% at T12 vertebra, 40% between T12/L1 vertebra and 20% at L1 vertebra. They measured the longitudinal diameter of CT at the level of branches of the aorta as 7.4 ± 2.6 mm, its transverse diameter as 8.1 ± 3.4 mm, the longitudinal diameter of SMA as 7.6 ± 2.4 mm, its transverse diameter as 7.4 ± 2.6 mm. Turba et al. carried out measurements on AA and RA on angiography images[30]. They reported that the diameter of AA was smaller in females with a statistically significant difference. The measurement results are in accordance with our results and support the difference between genders.

The fact that our results were not confirmed by conventional angiography and surgery is one of the limitations of this study. However, most of our results are in accordance with the ones in conventional angiography literature and anatomic data. In addition, MDCT Angiography is a non-invasive, 3D and high reliable imaging method, which can be found easily today.

To conclude, ıt is extremely important for surgeons, radiologists and transplantation team who work meticulously in this region to know the vessel variations and the relationship between the vessels in this region. There are many studies in the literature on vascular variations but we measured the outflow levels, sagittal and transverse diameters of the main branches of AA and their distances from each other, and investigated their variations by considering the gender difference. This allowed us to evaluate more than one data and results altogether.

Yazar Katkıları: Çalışma konsepti/Tasarımı:FA; Veri toplama: KK, FA; Veri analizi ve yorumlama: FA; Yazı taslağı: FA, KK; İçeriğin eleştirel incelenmesi: FA, KK; Son onay ve sorumluluk: FA, KK; Teknik ve malzeme desteği: -; Süpervizyon: KK; Fon sağlama (mevcut ise): yok.
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