ORIGINAL ARTICLE

DOI: 10.4274/nkmj.galenos.2021.52523
Nam Kem Med J 2022;10(1):87-94

Normal Distance Measurements Between the Origins of the Major Branches of the Abdominal Aorta on Computed Tomography Angiography in Children

Çocuklarda Bilgisayarlı Tomografi Anjiyografisinde Abdominal Aortun Ana Dallarının Orijinleri Arasındaki Normal Mesafe Ölçümleri

Edis ÇOLAK

University of Health Sciences Turkey, Dr. Behçet Uz Pediatric Diseases and Surgery Training and Research Hospital, Clinic of Radiology, İzmir, Turkey

ABSTRACT

Aim: The aim of the present study was to determine the normal distances between the origins of the major branches of the abdominal aorta, and their distances to the aorta at the diaphragmatic region and iliac bifurcation on multidetector computed tomography (MDCT) angiography in pediatric patients.

Materials and Methods: The MDCT angiography scans obtained from 245 children aged between 0 and 18 years (mean age±standard deviation, 8.48±5.14 years) were retrospectively re-evaluated. The distances between the origins of the celiac trunk (CTR), superior mesenteric artery (SMA), right renal artery (RRA), left renal artery (LRA), and inferior mesenteric artery (IMA) were measured. The distance measurements between the aorta at the diaphragmatic region, iliac bifurcation, and the origins of the major branches (CTR, SMA, RRA, LRA, IMA) were performed as well.

Results: The distances between the abdominal aorta and its branches were reported to vary in the age groups. All the distance measurements increased significantly with increasing age ($p<0.0001$). The distances between the aorta at the diaphragmatic region and the origins of the major branches were significantly higher in girls ($p<0.05$). The origin of the RRA was higher than the LRA in 51.8% of the study population.

Conclusion: This study is the first to provide data on the distances between the abdominal aorta and its branches in children. The present results may contribute to enhance the efficacy and safety of the endovascular and surgical procedures in the abdominal region.

Keywords: Abdominal aorta, major branches, computed tomography angiography, pediatrics

ÖZ

Amaç: Çok dedektörlü bilgisayarlı tomografi (ÇDBT) anjiyografi ile pediatrik hastalarda abdominal aort ana dallarının orijinleri ile diyafragmatik aort ve iliak bifurkasyon arasındaki normal mesafelerinin ölçülmesi amaçlandı.

Gereç ve Yöntem: Yaşları 0-18 yaş arasında değişen 245 çocuktan (ortalama yaş±standart sapma, 8,48±5,14 yıl) elde edilen ÇDBT anjiyografi tetkikleri retrospektif olarak değerlendirildi. Çölyak trunkus (ÇT), superior mezenterik arter (SMA), sağ renal arter (RRA), sol renal arter (LRA) ve inferior mezenterik arter (İMA) orijinleri arasındaki mesafeler ölçüldü. Diyafragmatik aort, iliak bifurkasyon ve ana dalların orijinleri (ÇT, SMA, RRA, LRA, İMA) arasındaki mesafe ölçümleri de yapıldı.

Bulgular: Abdominal aort ile dalları arasındaki mesafelerin yaş grupları arasında değiştiği tespit edildi. Yaş ilerledikçe tüm mesafe ölçümlerinin anlamlı olarak arttığı gözlemlendi ($p<0,0001$). Kızlarda diyafragmatik aort ile majör dalların orijinleri arasındaki mesafe anlamlı olarak daha uzundu ($p<0,05$). Çalışma popülasyonunun %51,8'inde RRA'nın orijini LRA'dan daha yüksek yerleşim göstermekteydi.

Sonuç: Bu çalışma, çocuklarda abdominal aort ile dalları arasındaki mesafeler hakkında veri sağlayan ilk çalışmadır. Mevcut sonuçların, karın bölgesindeki endovasküler ve cerrahi prosedürlerin etkinliğinin ve güvenliğinin artırılmasına katkıda bulunacağını umuyoruz.

Anahtar Kelimeler: Abdominal aort, ana dallar, bilgisayarlı tomografi anjiyografi, pediatri

Address for Correspondence: Edis ÇOLAK MD, University of Health Sciences Turkey, Dr. Behçet Uz Pediatric Diseases and Surgery Training and Research Hospital, Clinic of Radiology, İzmir, Turkey
Phone: +90 533 724 94 95 **E-mail:** edisezgicolak@gmail.com **ORCID ID:** orcid.org/0000-0001-5191-0491
Received: 16.06.2021 **Accepted:** 22.11.2021

INTRODUCTION

The widespread availability of low dose, contrast-enhanced multidetector computed tomography (MDCT) has significantly reduced the need for invasive conventional angiography providing useful information on the vascular anatomy of the human body[1].

Several cadaveric and radiological series in adults have reported that the distances between the major branches of the abdominal aorta are highly variable in relation to age, gender, and ethnicity. Knowing the distances between the anatomical landmarks is important especially for the vascular surgeons and interventional radiologists to avoid complications during the surgical and endovascular procedures in the abdominal region[2,3]. However, to the author's knowledge, no previous study has examined the distances between the abdominal aorta and its branches in children of various age groups.

The objective of the present study was to determine the normal distances between the origins of the major branches of the abdominal aorta, and their distances to the aorta at the diaphragmatic region and iliac bifurcation on MDCT angiography in pediatric patients.

MATERIALS AND METHODS

Patients

A descriptive cross-sectional and retrospective study design was adopted. From March 2014 to February 2019, a total of 827 children who underwent abdominal CT examinations for various reasons were retrospectively evaluated. The exclusion criteria were listed as follows: Subjects over 18 years of age; CT examinations performed without intravenous contrast agents (n=300); vascular distortion caused by the presence of abdominal tumor mass or lymphadenopathy (n=87); massive ascites (n=31); active bleeding caused by polytrauma (n=7); supernumerary renal arteries (n=127); severe vertebral scoliosis or kyphosis (n=16); and CT images of insufficient quality for analysis (n=14).

The MDCT angiography images of 245 children with normal body weight for chronological age were finally enrolled in the current study. The study flowchart is shown in Figure 1.

CT Protocol and Analysis of The CT Findings

The abdominopelvic contrast-enhanced CT examinations were performed with a 32 multi-slice CT scanner (SOMATOM go. Now, Siemens, Erlangen, Germany). The non-ionic iodinated contrast agent (Iobitridol, 300 mg I/mL) was injected intravenously by using a power injector (dose: 1-2 mL/kg, injection rate: 2 mL/s). To adhere to as low as reasonably achievable (ALARA) principle, the CT scans were made at a tube voltage of 80-120 kV and tube current of 20-350 mAs depending on the patient's weight. The CT parameters were as follows: Tube rotation time, 0.3-0.5 s; pitch, 1; and reconstruction interval, first multiplanar data reconstruction with a slice thickness less than or equal to 3 mm was performed to identify the abdominal aorta and its branches.

A single board-certified radiologist (European Board of Radiology) performed all the measurements for this study. The maximum distance measurements between the abdominal aorta and its branches were obtained in the arterial phase from sagittal-oblique sagittal and coronal-oblique coronal CT images. The curve of the abdominal aorta was taken into consideration. To measure the distance between the origins of the major branches, a line parallel to the abdominal aorta was drawn between the inferior margin of the cranially situated vessel and the inferior margin of the caudally positioned vessel (Figure 2A). The distance between the aortic hiatus and the origins of the major branches was measured between the inferior margin of the vessel and the horizontal line, which represents the diaphragmatic level (Figure 2B). The length between the iliac bifurcation and the origins of the major branches was measured between the inferior border of the vessel and the horizontal line, which passes through the bifurcation level (Figure 2C).

The distances between the origin of the celiac trunk (CTR) and superior mesenteric artery (SMA); CTR and right renal artery (RRA); CTR and left renal artery (LRA); and CTR and inferior mesenteric artery (IMA) were measured. The distance measurements between the SMA-RRA, SMA-LRA, SMA-IMA, IMA-RRA, and IMA-LRA were performed as well. Moreover, the distances between the aorta at the diaphragmatic region, aortic bifurcation, and the origins of the major branches (CTR, SMA, RRA, LRA, IMA) were reported.

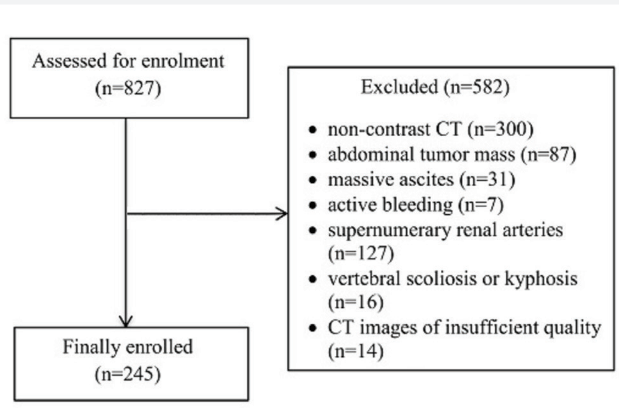

Figure 1. Flowchart for study selection

CT: Computed tomography

Ethical Statement

The study protocol was approved by University of Health Sciences Turkey, Dr. Behçet Uz Pediatric Diseases and Surgery Training and Research Hospital, Ethics Committee (protocol number: 2019/285, date: 11.04.2019). The declaration of Helsinki was preserved. The need for informed consent was waived by the ethics committee.

Statistical Analysis

The normality of continuous data was assessed visually using histograms and Q-Q plots for each measurement. The variables had a normal distribution and were expressed as mean±standard deviation (SD), and the categorical variables were presented as frequencies and percentages. The chi-square and one-way ANOVA tests were used to compare categorical and continuous data, respectively. Significant correlations were determined by the Pearson correlation test. Statistical Package for the Social Sciences (SPSS) software (version 20.0, SPSS Inc., Chicago, IL, USA) was used for statistical analyses. The level of significance was set at a p value of less than 0.05.

RESULTS

Demographic Data

The study population consisted of 134 (54.7%) boys and 111 (45.3%) girls aged between 0 and 18 years (mean age±SD, 8.48±5.14 years; 95% confidence interval 7.83-9.13 years). The subjects were classified into six groups according to their age (Table 1).

Distances Between the Origins of the Major Branches

The mean distances between the origins of the CTR-SMA, CTR-RRA, CTR-LRA, and CTR-IMA were 12.8±4.2 (range; 4.7-27.2), 22.1±6.6 (range; 6.4-45.1), 23.0±6.6 (range; 6.2-48.3), and 67.0±17.8 (range; 16.6-116.1) mm, respectively. The mean distances between the origins of the SMA-RRA, SMA-LRA, and SMA-IMA were 9.3±5.4 (range; 0.9-32.1), 10.3±5.3 (range; 1.0-29.6), and 54.2±15.2 (range; 11.9-99.8) mm, respectively. The mean distances between the origins of the IMA-RRA and IMA-LRA were 45.8±14.4 (range; 9.6-87.5) and 44.6±13.9 (range; 9.5-84.5) mm, respectively.

Table 1. Distribution of study population according to age and gender

Groups (%)	Age	Male (n)	Female (n)	Total (n)
Group 1 (7.3)	0-12 month	12	6	18
Group 2 (13.9)	1-3 year	20	14	34
Group 3 (19.2)	4-6 year	31	16	47
Group 4 (24.5)	7-10 year	31	29	60
Group 5 (17.1)	11-14 year	21	21	42
Group 6 (18.0)	15-18 year	19	25	44
Total	0-18 year	134	111	245

n: Number of patients

Figure 2. Computed tomography angiography of the abdominal aorta of a 4-year-old male patient. The oblique sagittal image demonstrates the distance measurement between the celiac trunk (black arrow) and superior mesenteric artery (white arrow) (A). The oblique coronal image shows the distance measurement between the left renal artery (black arrow) and the line that represents the aorta at the diaphragmatic region (B). The oblique coronal image demonstrates the distance measurement between the left renal artery (black arrow) and the line that represents the aortic bifurcation level (C)

The origin of the RRA was higher than LRA in 127 (51.8%) patients. The origins of the renal arteries were at the same level in only 50 (20.4%) cases. The origins of the renal arteries according to age groups were as follows: Group 1 [RRA higher than LRA (n=8); LRA higher than RRA (n=4); RA at same level (n=6)]; group 2 [RRA higher than LRA (n=14); LRA higher than RRA (n=8); RA at same level (n=12)]; group 3 [RRA higher than LRA (n=25); LRA higher than RRA (n=14); RA at same level (n=8)]; group 4 [RRA higher than LRA (n=31); LRA higher than RRA (n=16); RA at same level (n=13)]; group 5 [RRA higher than LRA (n=25); LRA higher than RRA (n=10); RA at same level (n=7)]; and group 6 [RRA higher than LRA (n=24); LRA higher than RRA (n=16); RA at same level (n=4)].

The distances between the origins of the major branches increased significantly with increasing age ($p<0.0001$ for all). Gender was not associated with any of these measurements ($p>0.05$ for all). Data for the distances between the origins of the major branches according to age and gender are summarized in Table 2.

Distances Between the Aorta at the Diaphragmatic Region and the Origins of the Major Branches

The mean distances between the aortic hiatus and the origins of the CTR, SMA, RRA, LRA, and IMA were 38.8±13.7 (range; 6.4-101.0), 51.5±15.8 (range; 11.1-116.5), 58.4±17.0 (range; 16.6-115.5), 60.2±17.3 (range; 16.3-117.7), and 104.0±27.7 (range; 26.2-180.9) mm, respectively. The distances between the aorta at the diaphragmatic region and the origins of the major branches showed a significant positive correlation with age ($p<0.0001$ for all). These measurements were higher in girls than boys and this gender difference reached the statistically significant level ($p<0.05$ for all).

The distances between the aortic hiatus and the origins of the major branches according to age and gender are reported in

Table 2. The mean distances between the origins of the CTR, SMA, RRA, LRA, and IMA according to age groups and gender

Distances (mm)		Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	p values
CTR-SMA	F	8.7±1.6	10.0±1.5	11.9±2.6	13.1±3.8	16.7±4.7	14.5±3.7	p<0.001
	M	6.4±1.1	9.5±2.2	10.9±1.5	12.4±2.9	14.9±3.6	18.4±2.2	
	T	7.2±1.7	9.7±1.9	11.3±1.9	12.7±3.4	15.8±4.2	16.2±3.6	
CTR-RRA	F	12.7±2.6	17.9±3.1	22.9±8.0	24.3±5.0	25.3±5.8	24.3±3.9	p<0.001
	M	12.1±3.3	15.6±3.8	20.3±4.7	22.6±4.3	25.2±7.0	29.5±5.8	
	T	12.3±3.0	16.6±3.7	21.2±6.1	23.4±4.7	25.2±6.3	26.5±5.4	
CTR-LRA	F	13.8±3.3	18.4±3.2	23.4±7.0	25.1±4.6	27.1±3.6	25.4±3.6	p<0.001
	M	13.1±5.1	16.2±3.6	20.7±4.9	23.9±5.3	27.8±6.7	28.9±6.5	
	T	13.3±4.5	17.1±3.6	21.6±5.8	24.5±5.0	27.4±5.3	26.9±5.3	
CTR-IMA	F	40.3±6.7	50.8±5.0	64.1±12.1	70.2±9.9	80.6±15.6	76.9±12.1	p<0.001
	M	34.7±9.2	49.1±6.4	59.6±9.5	69.1±9.1	81.9±14.8	88.1±13.9	
	T	36.6±8.7	49.8±5.8	61.1±10.6	69.7±9.5	81.2±15.0	81.8±13.9	
SMA-RRA	F	3.9±1.4	7.9±4.2	10.9±7.9	11.2±5.5	8.6±6.9	9.8±5.5	p<0.001
	M	5.7±2.6	6.1±3.8	9.4±4.8	10.1±4.0	10.3±5.6	11.0±4.9	
	T	5.2±2.4	6.9±4.0	9.9±5.9	10.7±4.8	9.4±6.3	10.3±5.2	
SMA-LRA	F	5.1±2.7	8.4±4.0	11.5±6.9	12.0±4.8	10.4±6.0	10.9±4.7	p<0.001
	M	6.7±4.3	6.7±3.5	9.7±4.9	11.4±4.6	12.8±5.2	10.4±6.6	
	T	6.2±3.8	7.4±3.8	10.3±5.7	11.7±4.7	11.6±5.7	10.7±5.5	
SMA-IMA	F	31.5±6.2	40.8±5.4	52.1±12.2	57.2±8.8	63.9±14.3	62.5±12.0	p<0.001
	M	28.3±8.5	39.6±6.6	48.7±9.9	56.7±8.5	66.9±12.8	69.7±13.1	
	T	29.4±7.8	40.1±6.1	49.9±10.7	56.9±8.6	65.4±13.5	65.6±12.9	
IMA-RRA	F	28.0±5.7	33.5±3.7	39.9±4.8	46.9±8.0	57.9±15.9	54.9±9.2	p<0.001
	M	22.3±6.6	32.9±5.6	37.6±8.7	48.1±7.7	60.6±12.4	59.7±11.5	
	T	24.2±6.7	33.1±4.9	38.4±7.6	47.6±7.8	59.3±14.1	56.9±10.4	
IMA-LRA	F	25.8±5.0	33.2±3.2	39.7±6.7	46.2±8.3	55.8±16.5	52.3±10.7	p<0.001
	M	21.9±5.2	33.2±6.7	37.2±7.5	47.0±7.6	58.9±12.0	56.2±11.7	
	T	23.2±5.3	33.2±5.5	38.0±7.3	46.6±7.9	57.3±14.4	54.0±11.2	

Data are presented as mean±standard deviation. P values were obtained using One-Way ANOVA test; p value <0.001 was considered highly significant.

F: Female, M: Male, T: Total, CTR: Celiac trunk, SMA: Superior mesenteric artery, RRA: Right renal artery, LRA: Left renal artery, IMA: Inferior mesenteric artery

Table 3. The age-dependent distributions of these distances are presented in Figure 3.

Distances Between the Iliac Bifurcation and the Origins of the Major Branches

The mean distances between the iliac bifurcation and the origins of the CTR, SMA, RRA, LRA, and IMA were 89.7±24.5 (range; 31.6-142.1), 77.0±21.6 (range; 25.4-122.5), 70.2±21.0 (range; 21.4-118.2), 68.5±19.8 (range; 21.7-111.4), and 24.7±9.7 (range; 4.7-51.5) mm, respectively. The mean distance between the aorta at diaphragmatic region and iliac bifurcation was 128.7±33.3 (range; 38.0-207.5) mm.

Children's age was significantly associated with the distances between the aortic bifurcation and the origins of the main branches ($p<0.0001$ for all). Gender did not have a significant impact on these distance values ($p>0.05$ for all). The mean distances between the aortic bifurcation and the origins of the major branches according to age and gender are presented in Table 4. The age-dependent distributions of these distances are demonstrated in Figure 4.

DISCUSSION

The present study is the first to calculate the distances between the origins of the major branches of the abdominal aorta and their distances to the aorta at the diaphragmatic region and iliac bifurcation in children aged 0 to 18 years. Here, we emphasize that knowing the distances between the major branches of the abdominal aorta may contribute to enhancing the safety and quality of the endovascular procedures in the abdominal region. The contrast-enhanced MDCT allows comprehensive and fast imaging of the abdominal aorta and its branches, thus minimizing the need for sedation in children[2]. Moreover, low dose CT provides images with a radiation dose that is much lower than conventional CT[4]. The three-dimensional multiplanar reformations present unique viewing and measuring advantages as well[5]. As a result, MDCT has become a valuable tool in the evaluation of vascular anatomy and pathologies in children[3,6]. The distance measurements between the abdominal aorta and its branches have been reported in various radiological and cadaveric studies focusing only on adults or both adults and children. Thus, a comparison of the present results with those from previous studies was undertaken with caution due to the differences in the age of patients, methodological approach, and geographical location.

A cadaveric study, carried out by Ozan et al.[7], reported the mean distance between CTR and SMA, RRA, and LRA as 18.0, 30.0, and 33.2 mm, respectively. According to Lawton et al.[8], the average CTR-SMA, CTR-RRA, and CTR-LRA distances on MDCT were 16.7±5.0, 30.7±7.9, and 30.5±7.7 mm, respectively. Arslan and Karacan[9] reported the mean distances for CTR- SMA, CTR-RRA, CTR-LRA, and CTR-IMA as 15.08±4.36, 30.35±9.17, 33.49±7.80, and 89.00±1.42 mm, respectively. Most of the studies measured the mean CTR-SMA distance between 14 and 18 mm[10-12]. The origins of the RRA and LRA were located between 28.5-32 mm, and 27-36 mm below the CTR, respectively[10,12]. A recent MDCT angiography study by Ekingen et al.[13] reported the mean CTR-SMA and CTR-IMA distances as

Table 3. The mean distances between the aorta at the diaphragmatic region and the origins of the CTR, SMA, RRA, LRA, and IMA according to age groups and gender

Distances (mm)		Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	p values
Aorta at diaphragmatic region-CTR	F	25.6±7.1	28.1±8.5	32.7±8.8	40.5±10.7	53.9±11.2	46.1±16.8	p<0.001
	M	20.7±7.4	30.3±7.3	35.5±9.0	40.7±9.0	41.5±12.5	46.6±16.4	
	T	22.3±7.5	29.4±7.8	34.5±8.9	40.6±9.8	47.7±13.3	46.3±16.4	
Aorta at diaphragmatic region-SMA	F	34.3±8.5	38.1±8.5	44.7±8.7	53.5±12.7	70.6±13.2	60.6±16.5	p<0.001
	M	27.1±8.1	39.8±7.1	46.4±9.0	52.7±9.0	56.4±12.9	65.0±15.8	
	T	29.5±8.8	39.1±7.6	45.8±8.8	53.1±10.8	63.5±14.7	62.5±16.1	
Aorta at diaphragmatic region-RRA	F	34.9±9.6	45.5±10.7	56.2±8.8	60.4±13.7	77.1±11.9	65.7±13.4	p<0.001
	M	31.5±12.6	47.4±11.4	54.3±9.7	57.7±10.9	66.5±15.2	71.9±19.5	
	T	32.6±11.5	46.7±11.0	54.9±9.3	59.0±12.3	71.8±14.5	68.3±17.8	
Aorta at diaphragmatic region-LRA	F	38.6±8.3	45.8±9.8	56.7±7.6	62.8±13.1	79.5±12.0	67.4±15.5	p<0.001
	M	32.8±13.4	46.5±10.6	55.1±10.1	59.5±10.4	67.9±14.4	78.0±18.4	
	T	34.8±12.0	46.2±10.1	55.6±9.3	61.1±11.8	73.7±14.3	72.0±17.4	
Aorta at diaphragmatic region-IMA	F	66.3±9.8	78.5±8.9	92.9±9.5	108.8±18.1	133.5±22.8	122.7±20.9	p<0.001
	M	54.5±18.0	73.9±12.0	91.1±14.6	107.3±12.5	122.6±12.8	137.1±17.9	
	T	58.5±16.5	75.8±10.9	91.7±13.0	108.0±15.3	128.0±19.0	128.9±20.7	

Data are presented as mean±standard deviation. P values were obtained using one-way ANOVA test; p value <0.001 was considered highly significant.

F: Female, M: Male, T: Total, CTR: Celiac trunk, SMA: Superior mesenteric artery, RRA: Right renal artery, LRA: left renal artery, IMA: Inferior mesenteric artery

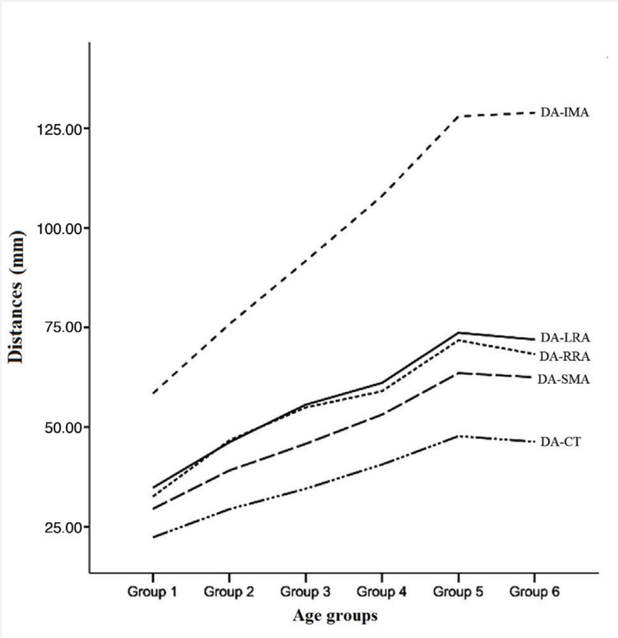

Figure 3. The graph shows the age-dependent distribution of the distances between the aorta at the diaphragmatic region (DA) and the origins of the celiac trunk (CTR), superior mesenteric artery (SMA), right renal artery (RRA), left renal artery (LRA), and inferior mesenteric artery (IMA

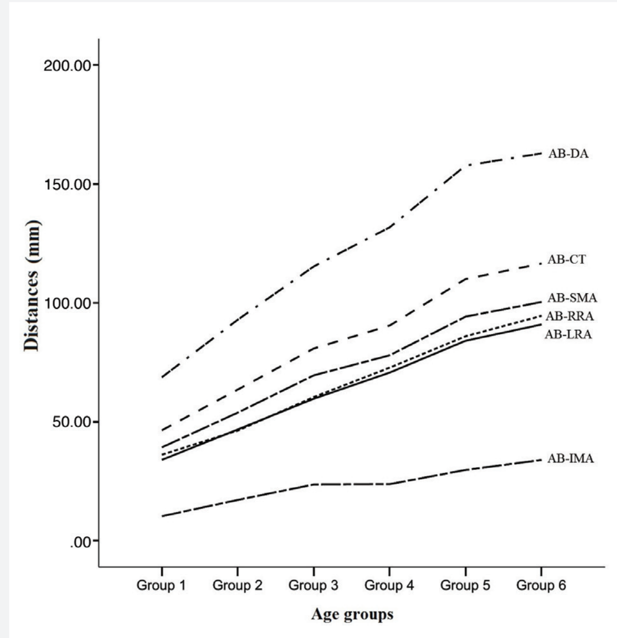

Figure 4. The graph demonstrates the age-dependent distribution of the distances between the aortic bifurcation (AB), aorta at the diaphragmatic region (DA), and the origins of the celiac trunk (CTR), superior mesenteric artery (SMA), right renal artery (RRA), left renal artery (LRA), and inferior mesenteric artery (IMA)

Table 4. The mean distances between the iliac bifurcation and the origins of the CTR, SMA, RRA, LRA, and IMA according to age groups and gender

Distances (mm)		Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	p values
Iliac bifurcation-CTR	F	48.9±4.5	66.5±5.6	82.0±10.5	91.6±9.5	112.0±14.5	107.9±13.9	p<0.001
	M	45.2±13.2	61.5±8.6	80.2±10.9	89.5±13.5	108.1±14.9	128.1±9.9	
	T	46.4±11.0	63.6±7.8	80.8±10.7	90.5±11.7	110.1±14.7	116.6±15.9	
Iliac bifurcation-SMA	F	40.1±3.8	56.6±6.0	70.1±10.4	78.5±7.7	95.3±13.5	93.4±13.0	p<0.001
	M	38.8±12.3	52.0±8.9	69.3±11.4	77.5±11.5	93.2±13.4	109.6±8.5	
	T	39.3±10.2	53.9±8.0	69.5±10.9	78.0±9.8	94.2±13.3	100.4±13.8	
Iliac bifurcation-RRA	F	39.7±3.4	49.1±4.9	58.6±6.2	71.7±9.2	88.9±13.1	88.3±11.6	p<0.001
	M	34.4±8.3	44.3±8.6	61.4±10.0	73.8±8.1	83.1±13.6	102.8±10.6	
	T	36.1±7.4	46.3±7.6	60.4±8.9	72.8±8.6	86.0±13.5	94.6±13.2	
Iliac bifurcation-LRA	F	35.9±3.6	48.9±5.7	58.0±7.0	69.2±7.8	86.5±11.6	86.6±11.1	p<0.001
	M	33.0±7.1	45.3±8.7	60.6±9.5	72.1±8.8	81.7±12.6	96.6±8.8	
	T	34.0±6.2	46.8±7.7	59.7±8.7	70.7±8.4	84.1±12.2	90.9±11.2	
Iliac bifurcation-IMA	F	66.3±9.8	78.5±8.9	92.9±9.5	108.8±18.1	133.5±22.8	122.7±20.9	p<0.001
	M	54.5±18.0	73.9±12.0	91.1±14.6	107.3±12.5	122.6±12.8	137.1±17.9	
	T	58.5±16.5	75.8±10.9	91.7±13.0	108.0±15.3	128.0±19.1	128.9±20.7	
Iliac bifurcation-aorta at diaphragmatic region	F	74.5±9.8	94.7±10.4	114.7±7.7	132.1±16.1	165.9±19.8	154.0±21.6	p<0.001
	M	65.9±19.3	91.8±10.7	115.7±15.8	131.6±14.3	149.6±15.9	174.7±15.4	
	T	68.7±16.9	93.0±10.5	115.3±13.5	131.8±15.1	157.8±19.6	162.9±21.6	

Data are presented as mean±standard deviation. P values were obtained using One-Way ANOVA test; p value <0.001 was considered highly significant.

F: Female, M: Male, T: Total, CTR: Celiac trunk, SMA: Superior mesenteric artery, RRA: Right renal artery, LRA: Left renal artery, IMA: Inferior mesenteric artery

13.5±0.37 and 89.40±0.99 mm for males and 12.20±0.33 and 84.80±0.92 mm for females, respectively.

These studies were performed on adults and cannot be considered relevant for pediatric patients. The current study is the initial and unique imaging study to evaluate the vascular distances in children according to their age and gender. The mean distances between the origins of the CTR-SMA, CTR-RRA, CTR-LRA, and CTR-IMA were between 20% and 30% lower than those reported in adults[7-9,13]. Moreover, these distances increased significantly with age possibly related to aortic elongation with the age and body height of the children. Although not statistically significant, these distances were slightly longer among females probably due to the fact that girls in the pubertal and prepubertal periods tend to be taller than the boys. These findings were consistent with previously published results[8,14].

Sośnik and Sośnik[15] measured the SMA-RRA and SMA-LRA distances in 324 cadavers aged between 0 and 90 years. The average distance between SMA and renal arteries in children aged 0 to 20 years was 3.3±2.5 mm for the RRA and 4.1±3.7 mm for the LRA. The values reported by Sośnik and Sośnik[15] were nearly 60% lower than ours. The reasons for this discrepancy might be explained by the differences in the diagnostic tools, age of the study population, and geographical factors. Previous studies conducted on adult patients found that the origins of the RRA, LRA, and IMA were located between 2-84 mm, 3-50 mm, and 24-100 mm below the SMA, respectively[7,9,14,15], and were nearly 50% higher than the ranges reported in our study.

We found no data in the literature on the distances between IMA and renal arteries in the pediatric population. The mean distance between IMA and renal arteries in adults was 58.55±11.98 mm for the RRA and 55.10±11.38 mm for the LRA[9]. Our distance measurements were more than 20% lower than those reported in adults[9,14]. In the current study, the origin of the RRA was higher than LRA, which is in agreement with previous reports on adults[8,16].

Anamaria et al.[14] postulated that the origins of the CTR, SMA, RRA, LRA, and IMA in adults were located between 5.1-42.0 mm, 31.6-64.1 mm, 28.4-76.7 mm, 30.4-76.8 mm, and 107.4-153 mm below the level of the diaphragmatic aortic hiatus, respectively[14]. In the present study, the distances between the aorta at the diaphragmatic region and the origins of the major branches in children were between 40% and 65% lower than those reported by Anamaria et al.[14] Moreover, these distances were significantly longer among females, which is in disagreement with the previous study[14]. This evidence could be important in order to plan different diagnostic and treatment procedures in boys and girls; however, the clinical impact of this finding is still to be determined.

Yahel and Arensburg[10] measured the distances between aortic bifurcation and the origins of the unpaired splanchnic arteries in thirty-four adults and eight cadavers aged between 4 and 11 years. The average distances from the CTR, SMA, and IMA to the aortic bifurcation were 125.0±16.8 mm, 109.8±15.5 mm, and 41.8±6.9 mm, respectively[10]. Our distance measurements were approximately 35% lower than those reported by Yahel and Arensburg[10]. This discrepancy may have resulted from the selection bias, a small number of cadavers, and the differences in the diagnostic approach. These distances were not associated with gender, which is consistent with the findings reported by Yahel and Arensburg[10].

A previous MDCT study on adults showed that the origins of the RRA and LRA were located between 59.3-113 mm and 59.2-109 mm above the aortic bifurcation, respectively[14]. The distance from the aorta at the diaphragmatic region to the aortic bifurcation was between 135.3 and 183.0 mm[14]. These results were approximately 60% higher than those reported in the current pediatric study.

The normative data for the distances between the origins of the major branches of the abdominal aorta, and their distances to the aorta at the diaphragmatic region and iliac bifurcation in pediatric patients may show wide variations due to the differences in the geographical, racial, ethnic, and genetic factors. Thus, we recommend that reference data for the vascular distances should be determined on a national level.

Study Limitations

Our study had several limitations that should be acknowledged. The presented findings were compared with the results of similar studies on adults due to the lack of currently available standardized measures for children. There was also no "gold standard" measurement tool for confirming the CT results. We did not evaluate the diameters and the topographic location of the main branches of the abdominal aorta in relation to the vertebral bodies, which should be addressed in future studies. This was a single-center study including a limited number of patients in each age group, so that future multicenter studies of a larger pediatric population are recommended to verify our findings.

CONCLUSION

In conclusion, to the best of our knowledge, this is the first study to report the distances between the abdominal aorta and its branches in children up to 18 years of age. Our results might be used as a reference tool for determining the position of the major branches of the abdominal aorta which in turn may help to reduce the endovascular and surgical procedure-related complications in pediatric patients.

Ethics

Ethics Committee Approval: The study protocol was approved by University of Health Sciences Turkey, Dr. Behçet Uz Pediatric Diseases and Surgery Training and Research Hospital, Ethics Committee (protocol number: 2019/285, date: 11.04.2019).

Informed Consent: Retrospective study.

Peer-reviewed: Externally peer-reviewed.

Financial Disclosure: The author declared that this study received no financial support.

REFERENCES

1. Bayindir P, Bayraktaroglu S, Ceylan N, Savas R, Alper HH. Multidetector computed tomographic assessment of the normal diameters for the thoracic aorta and pulmonary arteries in infants and children. Acta Radiol. 2016;57:1261-7.
2. Whitehouse H, Eriksson S. 'A systematic review of pre-operative CT angiography for microsurgical reconstruction in the paediatric population'. J Plast Reconstr Aesthet Surg. 2021;74:1355-401.
3. Komarnicka J, Brzewski M, Banaszkiewicz A, Maciąg R, Krysiak R. Computed tomography (CT) angiography in pre-embolization assessment of location of gastrointestinal bleeding in paediatric patient with granulomatosis with polyangiitis (Wegener's granulomatosis) - case report. Pol J Radiol. 2017;82:589-92.
4. Zhao P, Hou Y, Liu Q, Ma Y, Guo Q. Radiation dose reduction in cardiovascular CT angiography with iterative reconstruction (AIDR 3D) in a swine model: a model of paediatric cardiac imaging. Clin Radiol. 2016;71:716.e7-716.e14.
5. Lee EY, Siegel MJ, Hildebolt CF, Gutierrez FR, Bhalla S, Fallah JH. MDCT evaluation of thoracic aortic anomalies in pediatric patients and young adults: comparison of axial, multiplanar, and 3D images. AJR Am J Roentgenol. 2004;182:777-84.
6. Oguz B, Haliloglu M, Karcaaltincaba M. Paediatric multidetector CT angiography: spectrum of congenital thoracic vascular anomalies. Br J Radiol. 2007;80:376-83.
7. Ozan H, Alemdaroglu A, Sinav A, Gümüsalan Y. Location of the ostia of the renal arteries in the aorta. Surg Radiol Anat. 1997;19:245-7.
8. Lawton J, Touma J, Sénémaud J, de Boissieu P, Brossier J, Kobeiter H, et al. Computer-assisted study of the axial orientation and distances between renovisceral arteries ostia. Surg Radiol Anat. 2017;39:149-60.
9. Arslan F, Karacan K. Examination of the main branches of aorta abdominalis with multi-detector computed tomography angiography. Cukurova Med J. 2020;45:1679-89.
10. Yahel J, Arensburg B. The topographic relationships of the unpaired visceral branches of the aorta. Clin Anat. 1998;11:304-9.
11. Mazzaccaro D, Malacrida G, Nano G. Variability of origin of splanchnic and renal vessels from the thoracoabdominal aorta. Eur J Vasc Endovasc Surg. 2015;49:33-8.
12. Panagouli E, Lolis E, Venieratos D. A morphometric study concerning the branching points of the main arteries in humans: relationships and correlations. Ann Anat. 2011;193:86-99.
13. Ekingen A, Hatipoğlu ES, Hamidi C. Correction to: Distance measurements and origin levels of the coeliac trunk, superior mesenteric artery, and inferior mesenteric artery by multiple detector computed tomography angiography. Anat Sci Int. 2021;96:332.
14. Anamaria B, Ionut B, Petru B. The distance between the diafragm and the origin of the collateral branches of the abdominal aorta. ARS Medica Tomitana. 2018; 24:101-7.
15. Sośnik H, Sośnik K. Studies on renal arteries origin from the aorta in respect to superior mesenteric artery in Polish population. Folia Morphol (Warsz). 2020;79:86-92.
16. Beregi JP, Mauroy B, Willoteaux S, Mounier-Vehier C, Rémy-Jardin M, Francke J. Anatomic variation in the origin of the main renal arteries: spiral CTA evaluation. Eur Radiol. 1999;9:1330-4.