



# Anatomical Evaluation of The Major Vessels with Ultrasound in Children Undergoing Cardiac Surgery

## Kardiyak Cerrahi Geçiren Çocuklarda Majör Damarların Ultrason ile Anatomik Olarak Değerlendirilmesi

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### ABSTRACT

**Objective:** The aim of this study was to evaluate anatomically bilateral internal jugular veins (IJVs), carotid arteries (CAs), femoral veins (FVs) and femoral arteries (FAs) in pediatric patients undergoing cardiac surgery using ultrasonography (USG) guidance.

**Methods:** A retrospective study was conducted involving 78 patients. The patients were divided into five different categories (0-1, 1-6, 6-12, 12-24 months and >24 months). The diameter (Dm) and depth (Dp) of the bilateral IJVs, CAs, FVs and FAs were measured with USG. The anatomical positions of the IJV, CA, FV and FA and variations were evaluated. The correlations of the Dm and Dp of the major vessels with age, height, weight, body surface area (BSA), and body mass index were analyzed.

**Results:** The Dms and Dps of IJV, CA, FV and FA were significantly different between the groups. The rate of anatomical variation was 23.1% in the right IJV, 28.2% in the left IJV, 19.2% in the right FV, and 28.2% in the left FV. The Dms and Dps of the major central vessels were significantly correlated with age, height, weight, and BSA. The regression coefficient indicated that the 1 year age increase was associated with an increase of 0.414 mm in the right IJV (RIV) Dm. And each 1 kg increase in weight was associated with an increase of 0.169 mm in the RIV Dm.

**Conclusion:** We found a high correlation between vascular Dms and age, weight, height, and BSA in children with congenital

### ÖZ

**Amaç:** Bu çalışmada kalp cerrahisi geçiren pediatrik hastalarda ultrasonografi (USG) rehberliği ile bilateral internal juguler ven (IJV), karotis arter (CA), femoral ven (FV) ve femoral arterin (FA) anatomik olarak değerlendirilmesi amaçlanmıştır.

**Yöntemler:** Yetmiş sekiz hastayı içeren retrospektif bir çalışma dizayn edildi. Hastalar beş farklı yaş kategorisine ayrıldı (0-1 ay, 1-6 ay, 6-12 ay, 12-24 ay ve >24 ay). USG ile bilateral IJV, CA, FV ve FA çap (Dm) ve derinlikleri (Dp) ölçüldü. IJV, CA, FV ve FA'nın anatomik pozisyonları ve varyasyonları değerlendirildi. Majör damarların Dm ve Dp'si ile yaş, boy, ağırlık, vücut yüzey alanı (VYA) ve vücut kitle indeksi arasındaki korelasyonu analiz edildi.

**Bulgular:** İJV, CA, FV ve FA Dm'si ve Dp'si gruplar arasında anlamlı farklılık gösterdi. Anatomik varyasyon sağ İJV'de %23,1, sol İJV'de %28,2, sağ FV'de %19,2 ve sol FV'de %28,2 idi. Majör damarların Dm'si ve Dp'si yaş, boy, ağırlık ve VYA ile anlamlı derecede korele idi. Regresyon katsayısı, 1 yıllık yaş artışının sağ İJV Dm'sindeki 0,414 mm'lik bir artışla ve ağırlıktaki her 1 kg'lık artışın sağ İJV Dm'sindeki 0,169 mm'lik bir artışla ilişkili olduğunu gösterdi.

**Sonuç:** Konjenital kalp hastalığı olan çocuklarda vasküler Dm'ler ile yaş, ağırlık, boy ve VYA arasında yüksek bir korelasyon bulduk. Kardiyak cerrahi geçirecek pediatrik hastalarda kateter girişimlerinden önce uygun damar ve kateter boyutunu belirlemek için majör damarların USG ile değerlendirilmelidir.

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heart disease. Major vessels should be evaluated by using USG to determine the appropriate vessel and catheter size before catheter interventions in pediatric patients undergoing cardiac surgery.

**Keywords:** Internal jugular vein, femoral vein, femoral artery, correlation, ultrasound

**Anahtar Sözcükler:** Internal juguler ven, femoral ven, femoral arter, korelasyon, ultrason

## Introduction

In pediatric cardiac surgery, central venous cannulation (CVC) is mandatory for fluid-blood replacement, inotropic drug support, drug administration, and central venous pressure monitoring, just as arterial cannulation (AC) is also mandatory for continuous arterial pressure monitoring and frequent arterial blood sampling (1). Although the bilateral internal jugular veins (IJVs), subclavian veins (SVs), and femoral veins (FVs) are used for CVC, the radial artery and femoral artery (FA) are more frequently used for AC (2-4).

In most clinics, cannulation attempts are still performed using the anatomical landmark method. However, in pediatric patients, especially those with congenital heart disease, cannulation is difficult because of the diameter (Dm) of the small vessels, difficulty in finding the puncture vessel, and anatomical variations (3). With the increase in the use of ultrasound (USG), the success of CVC and AC administrations has increased and processing time and hospital costs have decreased (4-7). Another advantage of using USG is that it allows for anatomical examination before the intervention to determine the Dm and variations of the major vessels, to select the appropriate size catheter, and to apply cannulation in the correct localization (8). Some studies have also emphasized the correlation between vascular Dm and catheter size in terms of development of thrombosis, and researchers have emphasized that it is important to determine the appropriate catheter size for the vessel Dm using USG for anatomical evaluation before the intervention (9). In addition, USG reduces complication rates such as hematoma, arterial puncture, and pneumothorax in pediatric CVS, which is one of the most risky surgeries, by allowing fewer interventions and optimal vessel selection (10-12). It is a known fact that as the age of children decreases, the Dm of the vessels also shrinks. Thus, the area of the operation is narrower, and the cannulation procedures become more difficult, resulting in an increase in complication rates (13).

The Dm of the central arteries/veins and the anatomical relationships of these vessels may vary in pediatric patients undergoing cardiac surgery. This situation makes catheter administrations more difficult than in healthy patients and requires more experience and effort during administration. Therefore, the use of USG during CVC and/or AC administrations has become more important because of the possibility of anatomical variation, thrombosis, and bleeding in pediatric cardiac surgery patients, who are already at high risk.

In this study, we aim to evaluate anatomically the bilateral IJVs, carotid artery (CAs), FVs, and FAs in pediatric patients

undergoing cardiac surgery using USG guidance and to determine the benefit of the findings in establishing the puncture vessel, needle length, and catheter Dm. Simultaneously, this study examines the correlation of the Dm and depth (Dp) of the major vessels with age, height, weight, body surface area (BSA), and body mass index (BMI).

## Methods

### Patients

This retrospective, observational, and descriptive study was conducted at local ethics committee of the hospital. The study was conducted after obtaining approval of the local ethics committee and in accordance with the principles of the Helsinki Declaration. Seventy-eight pediatric patients who underwent cardiac surgery between 01 January 2019 and 01 January 2020 and who underwent central venous catheter and/or FA catheter with USG were included in the study. Patients were divided into five different age categories (0-1 months, 1-6 months, 6-12 months, 12-24 months, and >24 months) to obtain measurements representing the general population. Written consent was obtained from the parents of the patients. Emergency patients, those with a history of operation or cannulation in the jugular or femoral region, and those allergic to the USG gel were excluded from the study. In addition, one patient whose right FA could not be visualized was excluded.

The demographic and clinical characteristics of patients, including age, gender, height, body weight, diagnosis, and presence of additional diseases, were recorded from medical records and observation forms. BSA was calculated in square meters (m<sup>2</sup>) using the Mosteller formula: BSA: [height (cm) x weight (kg)/3,600]<sup>1/2</sup> (14). The BMI values of the patients were also calculated.

### Measurements

In our clinic, most catheter administrations in pediatric cardiac surgery are performed using anatomical evaluation of large veins and arteries accompanied by USG and selection of the appropriate vessels after detection of any variations. For this purpose, in our clinic, the bilateral IJVs, CAs, FVs, and FAs of each patient are routinely evaluated. Patients' USG data and other parameters are recorded in the files.

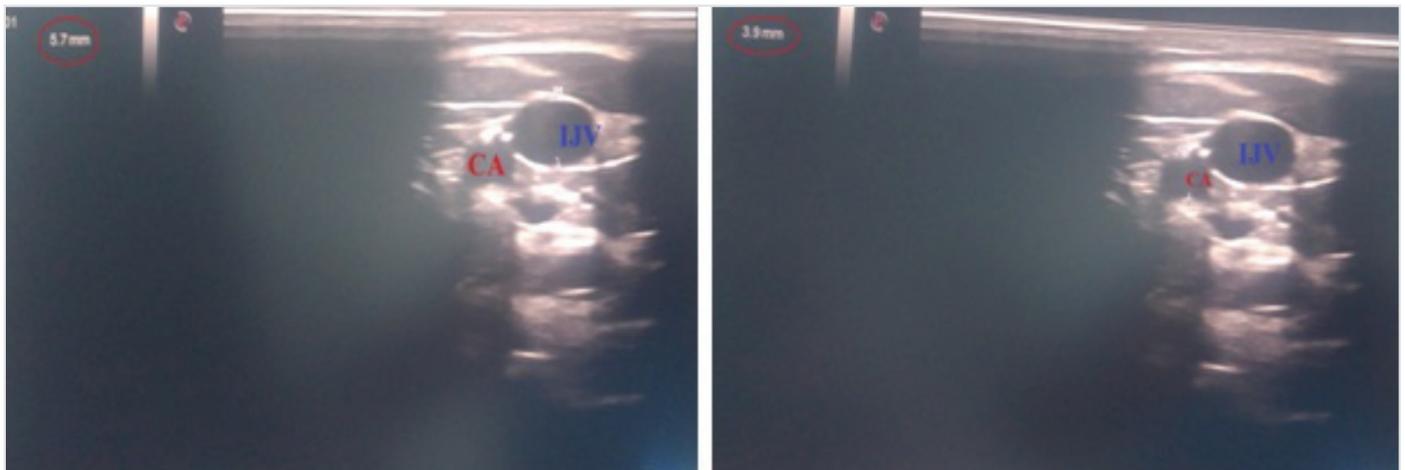
After a 4 or 6-hour fasting period, patients were taken to the operation room, and standard anesthesia monitoring was performed. During the preoperative fasting period, the patients were given maintenance intravenous fluid according to the Holiday and Segar formula. The standard anesthesia regimen

consisted of general anesthesia. For induction, 0.1 mg/kg midazolam, 2-3 mg/kg propofol, 1-2 µg/kg fentanyl, and 0.6 mg/kg rocuronium were applied. After orotracheal intubation, mechanical ventilation was initiated without the use of positive end-expiratory pressure.

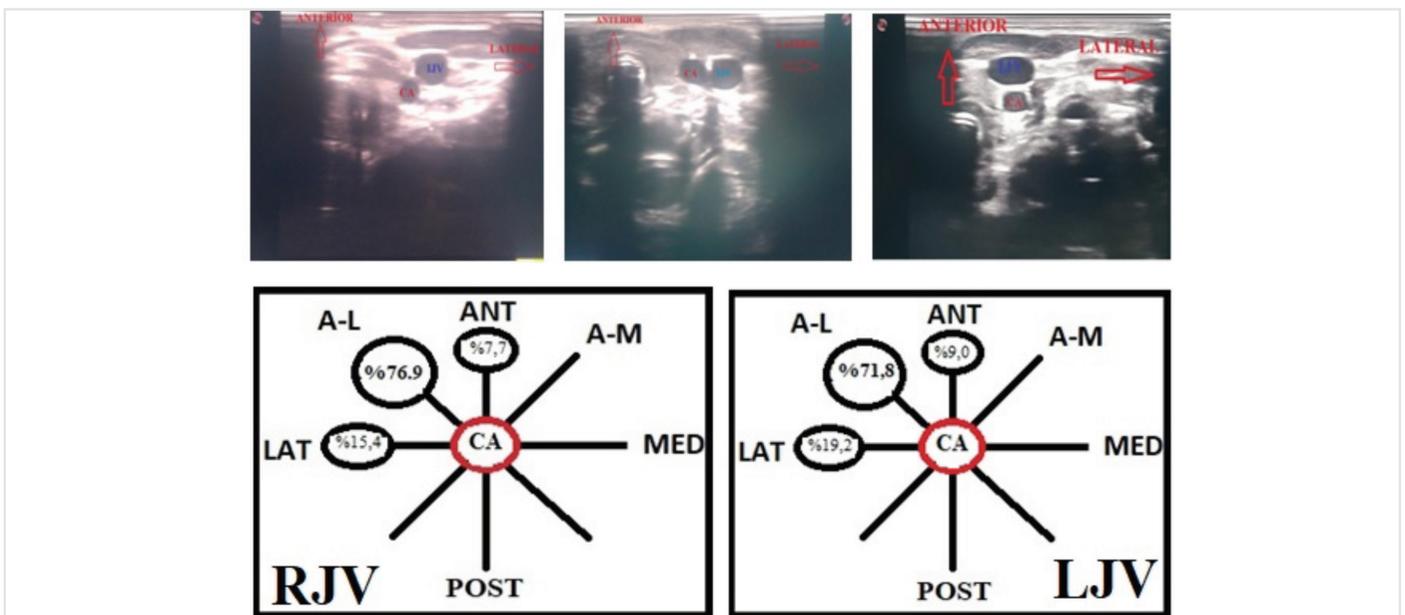
For all measurements, we used a USG device (Esaote, MyLab Six, the Netherlands) with a linear probe (5-12 MHz). IJV and CA measurements were obtained with patients in the supine position and after the head was turned about 15° to the opposite side. The practitioner placed the linear probe at the level of the cricoid cartilage with minimal compression to the neck. We performed the scan by visualizing the IJV on the short axis in the middle of the neck as suggested by the RaCeVA protocol (8). The Dm of the anteroposterior vessels and Dp of the IJV were measured on the short axis and recorded (Figure 1). The anatomical positions

of the IJV and CA relative to each other (eight quadrants: anterior, posterior, medial, lateral, anteromedial, anterolateral, posteromedial, and posterolateral) and variations were evaluated and recorded bilaterally (Figure 2).

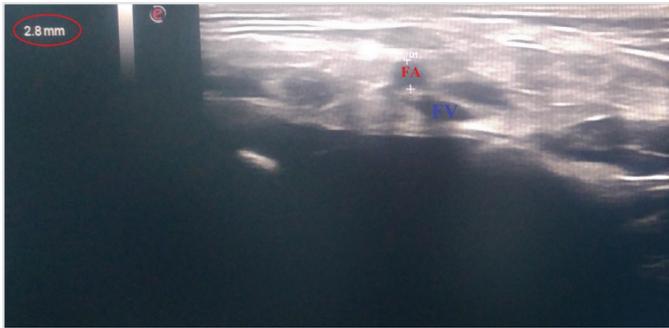
The FA-FV Dm and FA Dp were measured with the patients in the supine position and the thigh abducted at approximately 30°. The linear probe was placed with minimal compression on the FA pulsation 1 cm below the inguinal ligament. While the practitioner was on the side of the patient, the Dm of the anteroposterior vessels and FA Dp were measured on the short axis and recorded (Figure 3). The anatomical positions of the FA and FV relative to each other (possible eight quadrants: anterior, posterior, medial, lateral, anteromedial, anterolateral, posteromedial, and posterolateral) and variations were evaluated bilaterally and recorded (Figure 4).



**Figure 1.** Vascular diameter measurements of the right IJV and CA in a 7-month-old boy  
IJV: Right internal jugular vein, CA: Carotid artery



**Figure 2.** Anatomical variations of the IJV and CA  
IJV: Right internal jugular vein, CA: Carotid artery



**Figure 3.** Vascular diameter measurements of the right FA and FV in a 17-month-old boy  
 FA: Femoral artery, FV: Femoral vein

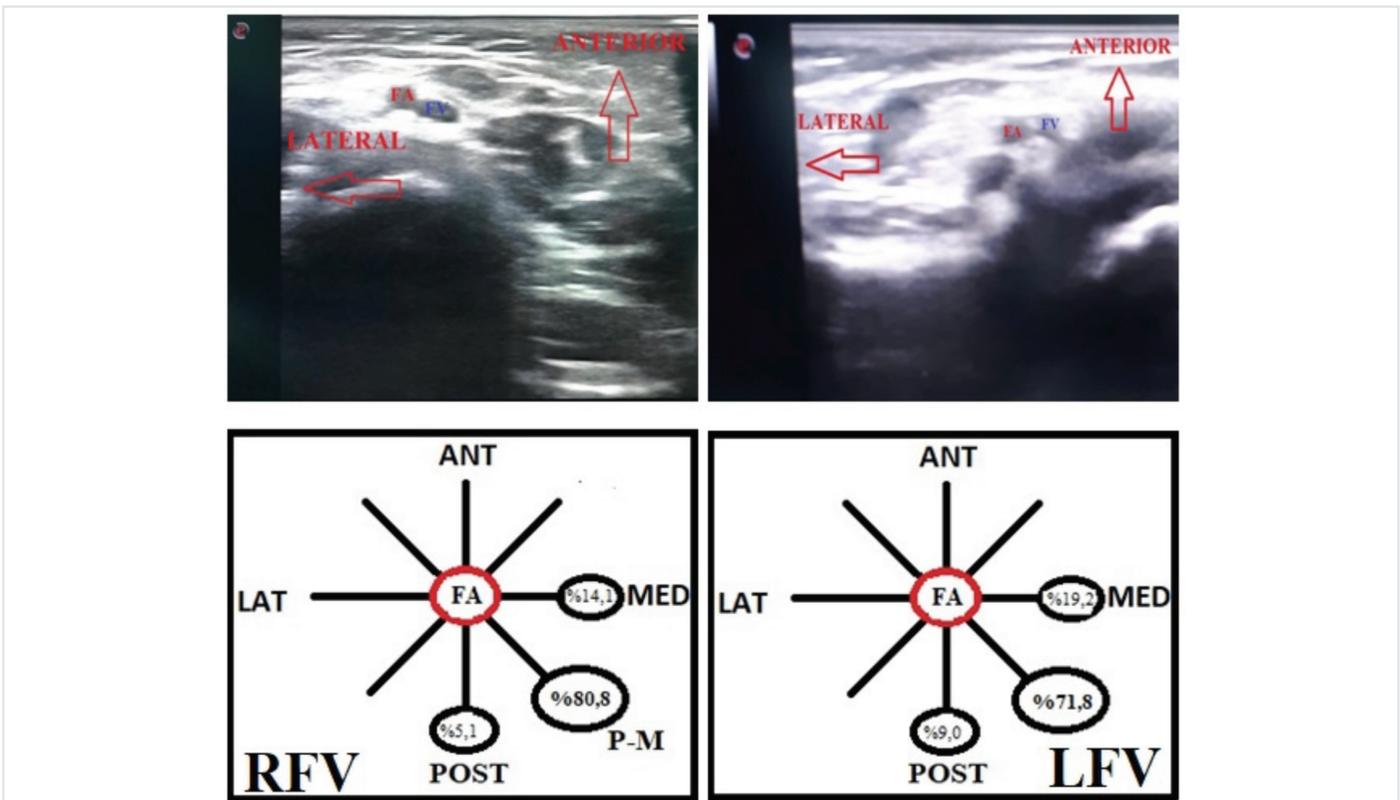
The inner Dm of all vessels were measured anteroposteriorly using a caliper. For Dp, the distance from the skin surface to the anterior wall of the vessel was measured in millimeters. All measurements were performed by two anesthesiologists with USG training and at least 5 years of experience in USG use for interventional procedures and with continuous experience in pediatric CVS. After sterilization conditions were confirmed, the central venous catheter and/or FA catheter was inserted with USG by determining the appropriate vessel. The dimensions of the administered catheters were recorded.

**Statistical Analysis**

The SPSS 22.0 for Windows (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. All measurements were expressed

in millimeters. Statistical data were expressed as mean and standard deviation, and categorical data were expressed as frequency and percentage. Categorical data in the groups were compared using chi-square test; the results were given as percentage (n). Pearson chi-square test was used to compare the difference between right and left sides. Kolmogorov-Smirnov test was used to determine whether the numerical data fit the normal distribution. Although the data matching the normality distribution were evaluated using one-way analysis of variance, the Kruskal-Wallis test was used to compare the data that did not conform to the normal distribution. In all comparisons,  $p < 0.05$  was considered significant. The relationship between the Dms of bilateral IJVs and FAs, the most frequently used central vessels, and the age was tested with separate, simple linear regressions. Correlation evaluations of normally distributed numerical data were performed by Pearson correlation test, whereas numerical data that did not fit the normal distribution were evaluated by Spearman correlation test. Correlation coefficient (r) results were interpreted as follows:

- $R < 0.2$ , weak correlation or no correlation
- $R = 0.2-0.4$ , weak correlation
- $R = 0.4-0.6$ , moderate correlation
- $R = 0.6-0.8$ , high correlation
- $R > 0.8$ , very high correlation



**Figure 4.** Anatomical variations of the FA and FV  
 FA: Femoral artery, FV: Femoral vein

## Results

Seventy-eight patients were included in the study. The patients were divided into five groups based on age: 0-1 months (n=15), 1-6 months (n=14), 6-12 months (n=22), 12-24 months (n=13), and >24 months (n=14). Table 1 shows the demographic and clinical features of the patients.

Table 2 displays the internal Dm and distance to the skin of the vessels examined anatomically by USG. A statistically significant difference was found between the groups in all measurements. By including all patients (n=78), when the right and left measurements were compared, there was no statistically significant difference between the mean Dm (p values were 0.751 for IJV, 0.480 for CA, 0.793 for FV, and 0.720 for FA).

In the analysis that included all measurements, the rate of anatomical variation observed in patients was 25.6% in IJV and 23.7% in FV. These rates were 23.1% in the right IJV, 28.2% in the left IJV, 19.2% in the right FV, and 28.2% in the left FV. Table 3 displays the anatomical variations of the vessels examined with USG. When all measurements were included (n=78), there was no statistically significant difference in the right and left anatomic positions (p=0.461 for IJV-CA, p=0.207 for FV-FA). In addition, the right FA could not be visualized in one patient, who was excluded from the study.

## Correlation

After demographic data and measurements were analyzed, correlations were determined to estimate the Dm and Dp of the vessels. The Dm and Dp of the major central vessels were

significantly associated with age, height, weight, and BSA (p<0.001). There was no statistically significant relationship between the right and left FA Dp and BMI (p=0.078, 0.102, respectively).

A high or very high correlation was detected between the vessel Dm and age, height, weight, and BSA. Moderate correlations were detected between vascular Dp, age, height, weight, and BSA. A moderate correlation was detected between the Dm of the vessels and the BMI, and a weak correlation was found between the Dp of the vessels and BMI. The highest correlation coefficient values were between the vessel Dm and height. Pearson R correlation coefficients are shown in Table 4.

## Regression

Separate simple linear regressions were performed to evaluate the relationships between the IJV, CA, FV, and FA Dm and Dp, and age, height, weight, BSA, and BMI. When we examined the results for the right IJV (RIJV) Dm, the regression coefficient indicated that the 1 year age increase was associated with an increase in the RIJV Dm of 0.414 mm. It was shown that each 1 kg increase in weight was associated with an increase of 0.169 mm in RIJV Dm. Our results also showed that the DM of RIJV increased by 0.073 mm for every 1 cm increase in height (Table 5).

Multiple linear regressions of the RIJVs-left IJVs, the most used vessels for central venous catheter administration, and right-left FAs, which were frequently used in arterial catheterization, were performed.

**Table 1. Demographic data and clinical features**

	0-1 months (n=15) Mean ± SD	1-6 months (n=14) Mean ± SD	6-12 months (n=22) Mean ± SD	12-24 months (n=13) Mean ± SD	>24 months (n=14) Mean ± SD	p
Age (month)	0.38±0.16	2.78±1.26	7.27±1.31	17.07±3.49	81.97±68.65	≤0.01*
Height (cm)	51.5±1.8	58.5±5.5	67.1±4.5	76.5±6.4	109.0±28.7	≤0.01*
Body weight (kg)	3.35±0.37	4.32±0.9	6.25±1.1	8.61±1.0	20.9±14.3	≤0.01*
BMI	12.64±1.28	12.64±2.15	13.84±1.97	14.84±2.25	15.90±2.17	≤0.01*
Gender (male/female)	13/2	12/2	11/11	6/7	4/10	0.004*
ASA (2-3-4)	0-3-12	1-10-3	0-18-4	1-11-1	0-13-1	≤0.01*
Diagnosis						
Hypoplastic left heart	7	2	2	2	-	
TGA	6	1	-	-	-	
Pulmonary atresia/stenosis	2	-	-	-	1	
Aortic coarctation	-	3	2	-	-	
VSD	-	5	10	4	2	
ASD	-	-	-	-	7	
AVSD	-	-	5	1	1	
TOF	-	1	2	6	1	
Other	-	2	1	-	2	

SD: Standard deviation, BSA: Body surface area, BMI: Body mass index, ASA: American Society of Anesthesiologists, TGA: Transposition of the great arteries, VSD: Ventricular septal defect, ASD: Atrial septal defect, AVSD: Atrioventricular septal defect, TOF: Tetralogy of Fallot

\*Statistically significant

**Table 2.** Major vein/artery diameters and distance to the skin by group

	0-1 months (n=15) Mean (SD)	1-6 months (n=14) Mean (SD)	6-12 months (n=22) Mean (SD)	12-24 months (n=13) Mean (SD)	>24 months (n=14) Mean (SD)	P
RIJV Dm (mm)	4.03 (0.55)	3.95 (0.84)	5.81 (0.97)	5.93 (1.28)	9.00 (1.47)	>.001*
RCA Dm (mm)	2.78 (0.37)	3.16 (0.60)	3.85 (0.57)	4.57 (0.86)	6.10 (1.21)	>.001*
RIJV Dp (mm)	5.10 (1.10)	5.70 (1.63)	6.61 (0.96)	6.73 (1.48)	8.35 (1.56)	>.001*
LIJV Dm (mm)	3.46 (0.58)	4.13 (1.01)	5.85 (0.95)	6.16 (1.82)	8.50 (1.57)	>.001*
LCA Dm (mm)	2.78 (0.64)	2.90 (0.71)	3.63 (0.49)	4.43 (0.87)	6.00 (1.08)	>.001*
LIJV Dp (mm)	5.00 (1.60)	5.42 (1.41)	6.66 (1.06)	6.03 (1.71)	8.17 (1.75)	>.001*
RFV Dm (mm)	2.40 (0.44)	2.74 (0.79)	3.06 (0.47)	3.54 (0.93)	5.58 (0.85)	>.001*
RFA Dm (mm)	1.82 (0.34)	2.00 (0.26)	2.07 (0.26)	2.90 (0.60)	4.73 (1.07)	>.001*
RFA Dp (mm)	3.90 (1.69)	4.92 (2.22)	4.90 (2.59)	4.67 (1.36)	7.54 (2.77)	.001*
LFV Dm (mm)	2.55 (0.64)	2.45 (0.73)	3.05 (0.53)	3.66 (0.93)	5.47 (0.86)	>.001*
LFA Dm (mm)	1.71 (0.22)	1.94 (0.36)	2.13 (0.34)	2.70 (0.51)	4.72 (0.99)	>.001*
LFA Dp (mm)	3.42 (1.33)	4.80 (2.74)	4.88 (2.47)	4.66 (1.03)	7.48 (2.72)	>.001*

SD: Standard deviation, RIJV: Right internal jugular vein, RCA: Right carotid artery, LIJV: Left internal jugular vein, LCA: Left carotid artery, RFV: Right femoral vein, RFA: Right femoral artery, LFV: Left femoral vein, LFA: Left femoral artery, Dm: Diameter, Dp: Depth

\*Statistically significant

**Table 3.** Anatomical variations between groups

	0-1 months (n=15)	1-6 months (n=14)	6-12 months (n=22)	12-24 months (n=13)	>24 months n=14)	Total n=78	P
<b>Right IJV-CA</b>							0.832
Lateral	2 (13.3%)	3 (21.4%)	3 (13.6%)	2 (15.4%)	2 (14.3%)	12 (15.4%)	
Anterolateral	12 (80.0%)	9 (64.3%)	18 (81.8%)	10 (76.9%)	11 (78.6%)	60 (76.9%)	
Anterior	1 (6.7%)	2 (14.3%)	1 (4.54%)	1 (7.7%)	1 (7.1%)	6 (7.7%)	
<b>Left IJV-CA</b>							0.573
Lateral	3 (20.0%)	5 (35.8%)	3 (13.6%)	3 (23.1%)	1 (7.1%)	15 (19.2%)	
Anterolateral	10 (66.7%)	8 (57.1%)	17 (77.3%)	10 (76.9%)	11 (78.6%)	56 (71.8%)	
Anterior	2 (13.3%)	1 (7.1%)	2 (9.1%)	0 (0%)	2 (14.3%)	7 (9.0%)	
<b>Right FA-FV</b>							0.563
Lateral	0 (0%)	2 (14.3%)	4 (18.2%)	2 (15.4%)	3 (21.4%)	11 (14.1%)	
Anterolateral	14 (93.3%)	12 (85.7%)	17 (77.3%)	10 (76.9%)	10 (71.4%)	63 (80.8%)	
Anterior	1 (6.7%)	0 (0%)	1 (4.54%)	1 (7.7%)	1 (7.1%)	4 (5.1%)	
<b>Left FA-FV</b>							0.325
Lateral	3 (20.0%)	5 (35.7%)	4 (18.2%)	2 (15.4%)	1 (7.1%)	15 (19.2%)	
Anterolateral	11 (73.3%)	7 (50.0%)	16 (72.7%)	11 (84.6%)	11 (78.6%)	56 (71.8%)	
Anterior	1 (6.7%)	2 (14.3%)	2 (9.1%)	0 (0%)	2 (14.3%)	7 (9.0%)	

IJV: Internal jugular vein, CA: Carotid artery, FV: Femoral vein, FA: Femoral artery

**Multiple linear regression RIJV Dm:**

$y=0.159 \times \text{BMI} + 0.01 \times \text{age} + 2,920$   
 $R^2=0.490$ ;  $p [\text{BMI}] = 0.066$ ;  $p [\text{age}] \leq 0.01$

**Multiple linear regression LIJV Dm:**

$y=0.178 \times \text{BMI} + 0.01 \times \text{age} + 2,627$   
 $R^2=0.372$ ;  $p [\text{BMI}] = 0.068$ ;  $p [\text{age}] \leq 0.01$

**Multiple linear regression RFA Dm:**

$y=0.040 \times \text{BMI} + 0.01 \times \text{age} + 1,620$

$R^2=0.657$ ;  $p [\text{BMI}] = 0.326$ ;  $p [\text{age}] \leq 0.01$

**Multiple linear regression LFA Dm:**

$y=0.061 \times \text{BMI} + 0.01 \times \text{age} + 1,286$   
 $R^2=0.667$ ;  $p [\text{BMI}] = 0.127$ ;  $p [\text{age}] \leq 0.01$

**Discussion**

The results of this study provide important information for the treatment of pediatric CVS patients who are likely to have various vascular anatomical variations, as they provide

**Table 4.** Correlations between RIJV, LIJV, RCA, LCA, RFV, RFA, LFV, and LFA diameters, and depths and age, weight, height, BSA, and BMI (r)

	Age (year)	Height (cm)	Weight (kg)	BSA (m <sup>2</sup> )	BMI
RIJV Dm (mm)	0.683*	0.823*	0.708*	0.775*	0.478*
RCA Dm (mm)	0.738*	0.860*	0.755*	0.815*	0.464*
RIJV Dp (mm)	0.546*	0.655*	0.575*	0.622*	0.338*
LIJV Dm (mm)	0.585*	0.724*	0.592*	0.667*	0.442*
LCA Dm (mm)	0.715*	0.813*	0.724*	0.780*	0.501*
LIJV Dp (mm)	0.503*	0.563*	0.506*	0.546*	0.365*
RFV Dm (mm)	0.718*	0.810*	0.727*	0.783*	0.479*
RFA Dm (mm)	0.808*	0.881*	0.797*	0.850*	0.466*
RFA Dp (mm)	0.420*	0.448*	0.385*	0.424*	0.201
LFV Dm (mm)	0.702*	0.803*	0.715*	0.770*	0.453*
LFA Dm (mm)	0.810*	0.897*	0.819*	0.870*	0.498*
LFA Dp (mm)	0.453*	0.504*	0.425*	0.469*	0.187

BSA: Body surface area, BMI: Body mass index, RIJV: Right internal jugular vein, RCA: Right carotid artery, LIJV: Left internal jugular vein, LCA: Left carotid artery, RFV: Right femoral vein, RFA: Right femoral artery, LFV: Left femoral vein, LFA: Left femoral artery, Dm: Diameter, Dp: Depth  
\*Statistically significant

clinical practice guidance for the anatomical examination of the vessels to be performed before CVC and/or FA catheter administration with USG. At the same time, this study examines the correlation-regression relationship between age, height, weight, BSA, and BMI and major vessels and provides an idea to clinicians on appropriate vessel selection and catheter size during catheterization.

### Internal Jugular Vein-carotid Artery

Barone et al. (9) measured IJVs of 100 newborns undergoing noncardiac surgery and found a strong correlation between the IJV Dm and body weight. Alderson et al. (15) evaluated 50 children younger than 6 years undergoing cardiac surgery and found a strong correlation between IJV Dp and age and body weight; they reported a weak correlation between IJV Dm and age and body weight. Sayin et al. (16), in a study involving 135 patients who had undergone noncardiac surgery, reported a weak correlation of IJV Dm and Dp with age, height, and weight. In our study, we determined that the mean Dm of the IJV varied between 3.46 and 9.00 mm and its Dp between 5.10 and 8.35 mm; the Dm of the CA was found to vary between 2.78 and 6.10 mm. A high or very high correlation was detected between the Dms of bilateral IJVs and CAs and age, height, weight, and BSA, whereas a moderate correlation was detected with BMI. The strongest correlation was found between vessel Dm and height. There was a moderate or high correlation between IJV Dp and age, height, weight, and BSA and a weak correlation with BMI. Therefore, we realized that the calculation of vessel Dm and Dp with BMI in children with congenital heart disease might not provide accurate results.

There was no significant difference between the Dms of right and left IJVs and between the Dms of right and left CAs in our study. This result was parallel with the findings of Karazincir et al. (13), who found similar results between the Dms of right and left IJVs in healthy children aged 0-6 years. In their study evaluating healthy children aged 7-12 years, Yildirim et al. (17) reported that the RIJV Dm was larger than the LIJV Dm.

Vascular malformations and variations may be more common in children with congenital heart disease. This can lead to accidental risk of arterial puncture and many complications. In the healthy population, IJV is the most common anterolateral

**Table 5.** Linear regression models

	BMI		Age		Height		Weight		BSA	
	R2	Coefficient	R2	Coefficient	R2	Coefficient	R2	Coefficient	R2	Coefficient
RIJV Dm (mm)	0.466	0.414	0.678	0.073	0.501	0.169	0.601	6.410	0.228	0.426
RCA Dm (mm)	0.545	0.297	0.740	0.050	0.570	0.119	0.665	4.473	0.215	0.275
RIJV Dp (mm)	0.299	0.273	0.428	0.048	0.330	0.113	0.386	4.238	0.114	0.249
LIJV Dm (mm)	0.343	0.361	0.524	0.065	0.350	0.143	0.445	5.607	0.196	0.401
LCA Dm (mm)	0.511	0.289	0.661	0.048	0.524	0.115	0.608	4.296	0.251	0.298
LIJV Dp (mm)	0.253	0.270	0.317	0.044	0.256	0.106	0.298	3.992	0.133	0.288
RFV Dm (mm)	0.516	0.274	0.656	0.045	0.529	0.109	0.613	4.068	0.229	0.268
RFA Dm (mm)	0.652	0.285	0.777	0.045	0.636	0.110	0.723	4.093	0.217	0.242
RFA Dp (mm)	0.176	0.311	0.201	0.048	0.148	0.112	0.180	4.276	0.040	0.219
LFV Dm (mm)	0.492	0.267	0.645	0.045	0.511	0.107	0.594	4.002	0.205	0.254
LFA Dm (mm)	0.657	0.284	0.805	0.046	0.670	0.113	0.756	4.159	0.248	0.257
LFA Dp (mm)	0.205	0.339	0.254	0.055	0.181	0.125	0.220	4.780	0.035	0.206

BSA: Body surface area, BMI: Body mass index, RIJV: Right internal jugular vein, RCA: Right carotid artery, LIJV: Left internal jugular vein, LCA: Left carotid artery, RFV: Right femoral vein, RFA: right femoral artery, LFV: Left femoral vein, LFA: Left femoral artery, Dm: Diameter, Dp: Depth

location compared with CA (18). However, variations that will complicate catheter interventions may be more frequent in children with congenital heart disease. It has been reported in the literature that IJV is in the anterolateral position at a rate of 54.4-87.8% compared to CA (18,19). Uzumcugil et al. (20) found that in 84% of neonatal patients weighing less than 4000 g, the IJV was in the lateral position compared with CA. Souza et al. (21) found that there was an anatomical variation between the IJV and CA in 7.7% of 142 patients they examined. They reported that the highest variation rate was in children between the age of 1 month and 2 years (21). We determined the position of the IJV relative to the CA on the right side as 76.9% anterolateral. This rate was 71.8% on the left. In our study, the rate of anatomical variation between the left-side IJV and CA was higher than that of the right side (28.2% and 23.1%). The anatomical variation rate on the left side in the newborn group and in the 1- to 6-month age group was more pronounced than the right side. We found that the most common variation type was IJV located lateral to CA.

### Femoral Artery/Vein

Keiler et al. (22) found that the FV Dm in adults was strongly correlated with gender, age, weight, and BMI but did not correlate with height. López Álvarez et al. (23) found that there was a significant correlation between FA and FV Dm and age, height, weight, and BSA in pediatric patients followed up for non-cardiac reasons, and the highest correlation was found with height. In addition, they reported that there was a significant correlation between FA and FV Dp and age, height, weight, and BSA, but the highest correlation was with weight. In our study, the average FV Dm was between 2.40 and 5.58 mm; we determined that the average FA Dm ranged between 1.71 and 4.73 mm, and the average FA Dp ranged between 3.42 and 7.54 mm. A high or very high correlation was found between the Dms of bilateral FVs and FAs and age, height, weight, and BSA, and a moderate correlation with BMI was detected. The strongest correlation was seen between vessel Dm and height. There was a moderate correlation between the Dp of FA and age, height, weight, and BSA and a weak correlation with BMI. Our correlation results between FV and FA Dm and age, height, weight, and BSA were in line with previous studies. Therefore, we concluded that the calculation of the FV-FA Dm and FA Dp with BMI might not provide accurate results in children with congenital heart disease.

In our study, we found no significant difference between the Dm of right and left FVs or between the Dm of right and left FAs. This result was similar to the study of Keiler et al. (22), who detected significant bilateral asymmetry between the Dm of right and left FVs. However, in our study, the FV Dm was larger on both sides than the FA Dm in all age groups.

In their study of pediatric patients, Souza et al. (21) stated that there was an anatomic variation of 9.8% between FA and FV and this was most common in children between 1 month and 2 years of age (24.4%). They also reported that the most common

variation type was FA with anterolateral location to FV (21). Warkentine et al. (2) stated that FA was 88% laterally located compared with FV. We determined the anterolateral position of FA according to FV on the right side in 80.8% of the patients. This rate was 71.8% on the left. The variation between the FA and FV on the left was greater than on the right (28.2% and 19.2%). We determined that the most common variation type was FV located medial to FA.

### Effects on Clinical Practice

The relationship between vessel Dm and catheter size in terms of development of thrombosis is well known. Therefore, studies have reported that the ideal catheter Dm is approximately one-third of the vessel Dm (9,20). Based on the data from our study, for IJV cannulation, 3 French (1 mm) catheters can be used in newborns, 3-4 French (1 mm) in children aged 1-6 months, 4-5 French (1.3-1.6 mm) for children 6-12 months, 5-6 French (1.6-2.0 mm) for children 12-24 months, and 5-7 (1.6-2.4 mm) French for children >24 months. For FA cannulation, 2 French catheters can be used for newborns, 2 French for children aged 1-6 months, 2 French for children 6-12 months, 2-3 French for children 12-24 months, and 3 French for children >24 months. However, instead of estimating, it would be more accurate to determine the catheter Dm by measuring with USG by experienced people.

### Study Limitations

1. Because USG evaluation is subjective and depends on clinical experience, measurements using computed tomography or angiography can provide more accurate results in children with congenital heart disease. To minimize this error, two anesthesiologists with at least 5 years of clinical USG experience and experience in pediatric cardiac surgery performed all measurements.
2. We did not measure the SV used in central venous catheter administrations.
3. Only the anterior and posterior Dms of the vessels were measured. The transverse Dm or cross-sectional area of the vessel was not measured. Long-axis anatomical evaluations of the vessels were absent in our study.
4. The investigation was made with the patient only in the supine position. No measurement was made in the Trendelenburg position, which could lead to a change in vessel Dm.
5. The Dms and anatomic variations of femoral vessels were not evaluated according to some leg positions.
6. Measurements were made with patients on mechanical ventilation. Therefore, the extent to which mechanical ventilation affected vessel Dm could not be evaluated.
7. Due to the low number of patients, we could not make a separate formulation that would determine the vessel Dm in all age groups. This may be the subject of larger series studies.

## Conclusion

In this study, we found a high correlation between vascular Dms and age, weight, height, and BSA in children with congenital heart disease. However, we believe that determining the vessel Dm with BMI in children with congenital heart disease may not lead to the correct result. We found an anatomical variation rate of 28.2% on the left and 23.1% on the right between IJV and CA. We found that the most common variation type was IJV located lateral to CA. We established that the rate of anatomical variation between FA and FV was 28.2% on the left and 19.2% on the right.

Our study provides important data for clinicians in terms of USG evaluation for appropriate vessel selection, determination of anatomical variations, and determination of catheter size and needle length before catheterization in pediatric patients undergoing cardiac surgery, which is a special patient population. Therefore, the routine use of USG in venous catheter and/or arterial catheter interventions in pediatric patients undergoing cardiac surgery will benefit in terms of increased interference success and reduced complications.

## Ethics

**Ethics Committee Approval:** This study was approved by the Local Ethics Committee University of Health Sciences Turkey Gazi Yaşargil Training and Research Hospital (approval date and number: 20.12.2019-402).

**Informed Consent:** Retrospective study

**Peer-review:** Externally peer reviewed.

## Authorship Contributions

Concept: F.S., Design: F.S., M.B., E.A.B., C.K.K., O.D., Analysis or Interpretation: H.A., S.K., A.E., Writing: F.S., M.B., E.A.B., C.K.K., O.D., H.A., S.K., A.E.

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