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Angiography in pediatric patients

Measurement and estimation of femoral vessel diameter

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Abstract

The diameter of femoral vessels was angiographically explored in pediatric patients with congenital heart disease (CHD) and compared with anthropometric and demographic indexes.

A total of 153 pediatric patients younger than 3 years old were recruited. The sex, age, weight, and height of patients were recorded daily, and the body surface area (BSA) was calculated with the Mosteller formula.

The values of mean left-right diameters were 3.13 (0.32) mm for the femoral artery (FA) and 5.14 (0.68) mm for the femoral vein (FV). The FA diameter (FA-Dm) and FV diameter (FV-Dm) were clearly related ($R=0.84$, $P<.001$), and the FA-Dm/FV-Dm ratio ranged from 0.61 to 0.622. The diameters of femoral vessels were significantly correlated with age, height, weight and BSA ($R=0.63$ to 0.73, $P<.001$). The FA-Dm and FV-Dm were most closely associated with the height of patients (FA-Dm: $R=0.73$, $P<.001$; FV-Dm: $R=0.69$, $P<.001$).

The FV-Dm and FA-Dm were consistent with the weight, height, age and BSA in the surveyed pediatric patients. The FA-Dm and FV-Dm were closely associated with the height of pediatric patients. Furthermore, the FA-Dm/FV-Dm ratio was stable in these patients. Such estimations could help clinicians select the appropriate diameter of cannulation needles and catheters for interventional therapy pediatric patients with CHD.

Abbreviations: BSA = body surface area, CHD = congenital heart disease, CI = confidence interval, cm = centimetres, Dm = diameter, FA = femoral artery, FV = femoral vein, kg = kilograms, m = month, R = correlation coefficient, SD = standard deviation, y = year.

Keywords: angiography, CHD, estimation of vascular diameter, femoral artery, femoral vein, pediatric patients

1. Introduction

Congenital heart disease (CHD) is a congenital malformation caused by anomalous development of the heart and central vessel in foetuses and a major cause of infant death and morbidity. According to epidemiological surveys,[1] the incidence of CHD is 6 to 10 in every 1000 live births. The advantages of percutaneous interventional treatment in older patients with CHD have been confirmed.[2] Determination of the normal range of lengths and diameters of the central veins and arteries under angiography is valuable for guiding manufacturers in the production of suitable catheters and other in-vessel equipment and guiding clinicians in selecting catheters with an appropriate size during interventional treatment.[3] As temporary devices are improved and as the sizes of delivery systems gradually decrease, studies have increasingly shown that percutaneous occlusion is less invasive than surgery and may therefore be the preferred alternative in younger infants (<3 years old).[4] Currently, the central vascular diameters of infants and pediatric patients are measured by vascular ultrasound. Ultrasound examinations have been applied in the vessel trees of pediatric patients to evaluate vascular depth, internal diameters, vessel routes and regularity, closeness to other anatomical structures (e.g., arteries or nerves), and probable anomalies (i.e., haematomas, thrombus or anatomical variants).[5–8] A variety of limitations, such as the proficiency of ultrasound physicians, a lack of cooperation in subjects, and the compression of vessels by the ultrasound probe, make it difficult to use ultrasound imaging technology to accurately measure and estimate the normal range of vascular diameters in infants <3 years old. Measurements of central vascular diameters are more accurate when performed by angiography than by ultrasound. However, previous studies have not determined the normal range of vascular diameters in infants <3 years old with CHD, which makes it difficult for clinicians to select appropriate catheters and to explore many of the risks and complications associated with CHD.[9–11] To provide data from living subjects, the diameters of femoral arteries and veins should be measured in pediatric patients using angiographic images.

Angiographic detection was used in this study to compare vascular diameters with anthropometric and demographic

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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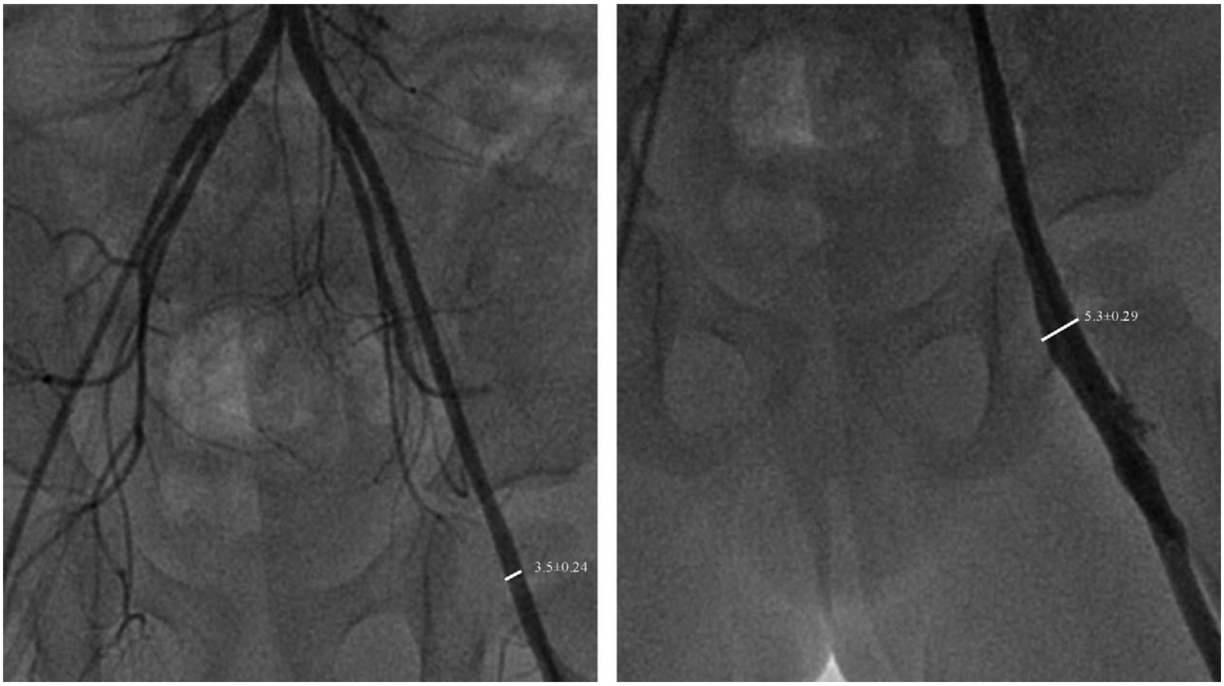

Figure 1. The diameter of the left femoral vessels in a 19-month-old pediatric patient. (A) FA-Dm; (B) FV-Dm.

variables in pediatric patients with CHD younger than 3 years old. A multiple linear regression equation related to age, weight, height and the surface area of the body was used to estimate the normal range of femoral vascular diameters in pediatric patients to facilitate device selection during radiation interventions.

2. Patients and methods

The same healthcare team calculated the weight in kilograms (kg) and height in centimetres (cm) of all patients. The weight was measured using a digital scale, and the height of the patients was measured with a regular test tape from the highest point of the head to the tarsus. Age is given in years (y) and/or months (m). The body surface area (BSA) of the patients was determined in square metres with the Mosteller formula[12,13]: $BSA=[\text{height (cm)}\times \text{weight (kg)}/3600]^{1/2}$.

After successful intubation, 5 to 8 ml of ioversol (320 mg/ml) was injected through the femoral artery sheath, and an image was obtained. We used a position 8 to 10 mm below the edge of the femur as a reference point, and we measured 3 groups of data at 5 mm above and 5 mm below the reference point. The mean value was used as the diameter of the femoral artery. The diameter of the femoral vein was measured by the same method. All measurements were performed using a GE Innova 3100-IQ digital plateau cardiovascular system.

We applied 2 techniques, covariance analysis and multiple regression models, to investigate vascular diameters and their relationships with age, weight, height and BSA.

Angiography results are displayed in clinically stable patients.

Using the Kolmogorov-Smirnov test, constant statistical variables were evaluated to explore normality. We evaluated possible associations among categorical variables using the Chi-square independence test. The means of constant variables were compared with Student's t test.

All images were analysed by Image-Pro Plus 6.0.

The significance level was set to 5%.

We acquired informed consent from the patients' parents or legal representatives. The protocol performed in this paper followed the basic principles of the World Medical Association Declaration of Helsinki[14] and was approved by the Ethical Committee of Clinical Trials of our Hospital.

3. Results

In this study, we recruited 153 pediatric patients with CHD who were younger than 3 years old. The proportion of males and the mean age of all patients were 51.4% (48.6%) and 21.5 ± 7.5 (22.2 ± 7.5) months old, respectively. The mean weight and height of the patients were 11.3 ± 2.0 (11.3 ± 2.3) kg and 83.4 ± 8.0 (84.2 ± 8.2) cm, respectively. The mean BSA was 0.51 ± 0.068 (0.52 ± 0.077) m^2.

We used the GE Innova 3100-IQ digital plateau cardiovascular system to measure the diameters of femoral vessels in the studied pediatric patients (Fig. 1 and Table 1). Based on previous studies, we selected appropriate demographic and anthropometric variables, including gender, age, height, weight, and BSA. We analysed the correlations between these variables and the diameters of femoral vessels and obtained regression equations

Table 1

Diameter measurements of pediatric femoral vessels (expressed in millimetres).

	N	Mean	SD	Range	
FA-Dm	153	3.13	0.31	2	4
FV-Dm	153	5.14	0.68	3.1	7.2

Dm = diameter, FA = femoral artery, FV = femoral vein, SD = standard deviation.

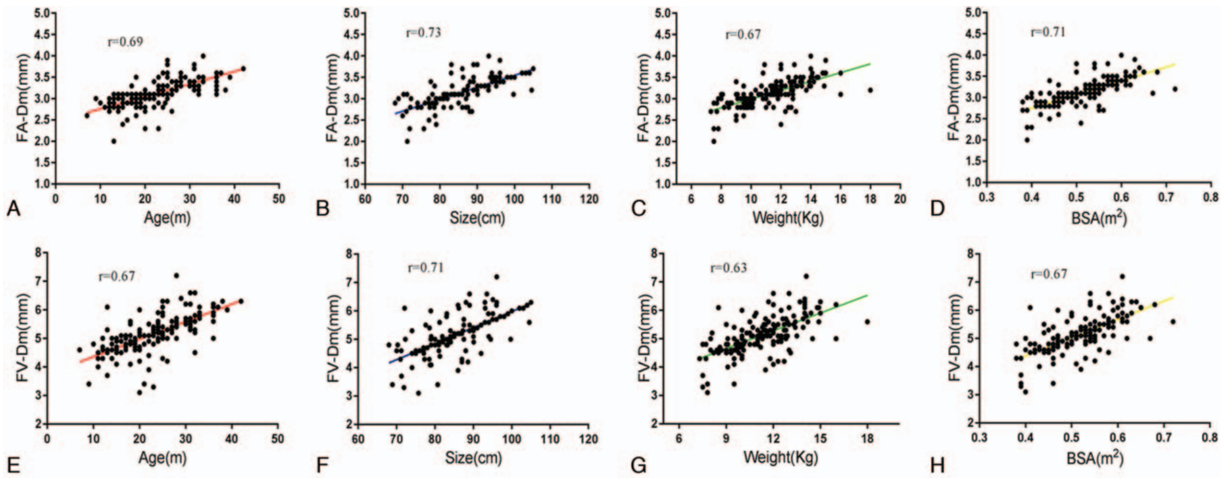

Figure 2. Correlation between vascular diameter and demographic and anthropometric variables in the included pediatric patients according to a regression equation. (A) Correlation of FA-Dm with age; (B) correlation of FA-Dm with height; (C) correlation of FA-Dm with weight; (D) correlation of FA-Dm with BSA; (E) correlation of FV-Dm with age; (F) correlation of FV-Dm with height; (G) correlation of FV-Dm with weight; (H) correlation of FV-Dm with BSA.

using the Pearson correlation analysis method. To identify associations with the diameters of femoral vessels, variables, including the age, height, weight and BSA of the included pediatric patients, were evaluated, and significant associations were investigated. There was no correlation between femoral vessel diameter and sex. Figure 2 and Table 2 show the significance level and the R correlation coefficient of Pearson's correlation and the regression equations. However, a significant association was found between the femoral artery and the femoral vein (Fig. 3), with the femoral artery diameter (FA-Dm)/ femoral vein diameter (FV-Dm) ratio ranging from 0.602 to 0.636. As the results show, the diameter of the femoral vessels and patient height showed the highest correlation coefficient values, and the FA-Dm/FV-Dm ratio was stable in the explored pediatric patients.

Next, a multiple linear regression analysis of height was performed to determine which variable would most precisely predict the mean FA-Dm ($R=0.729$) and FV-Dm ($R=0.686$) in the patients. The corresponding coefficients are shown in Table 3, which also shows the significance and 95% CI values. The following equations were found to predict the FA-Dm and FV-Dm in the studied pediatric patients: FA-Dm $=0.748+0.028\times$ height (cm); FV-Dm $=0.31+0.057\times$ height (cm).

Table 2

Correlation between vascular diameter of demography and anthropometry variables in the researched pediatric patients and regression equation.

	FA		FV	
	R	*P*	*R*	*P*
Age	0.69	<.0001	0.67	<.0001
Size	0.73	<.0001	0.71	<.0001
Weight	0.67	<.0001	0.63	<.0001
BSA	0.71	<.0001	0.67	<.0001

BSA = body surface area, FA = femoral artery, FV = femoral vein, R = correlation coefficient.

4. Discussion

Assessing vascular diameter in pediatric patients with CHD may be helpful for making decisions at the time vascular canalisation is performed. In contrast to adult patients, in pediatric patients, these variables are valuable when they fall within a stable range; however, highly variable values might be observed in pediatric patients according to their growth and development.

A reference for vascular diameter would be useful for selecting a suitable size and needle diameter for cannulation in addition to the catheter diameter that should be used to restrain an early thrombus or address issues related to distal insufficient perfusion and difficulty in venous return.

Alvarez et al[7] used ultrasound to measure the femoral arteriovenous diameter in 125 pediatric patients and found that the mean femoral vessel diameter was strongly and significantly related (correlation coefficient (R) between 0.83 and 0.89) to height, weight and age. Height was one of the best predictors of vessel diameter ($R=0.86$ for the femoral vein and $R=0.89$ for the

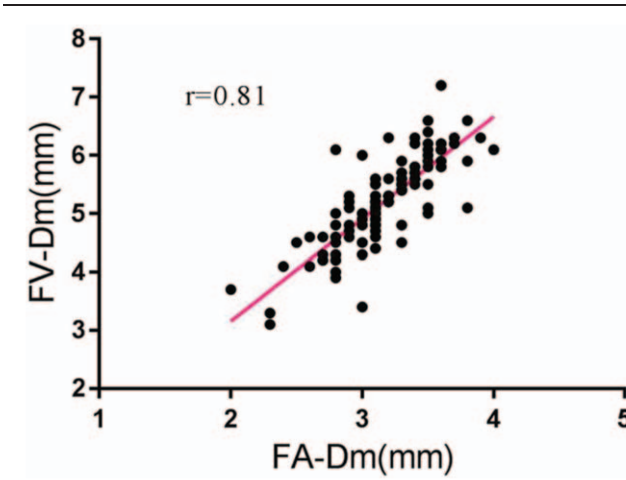

Figure 3. Correlation between FA-Dm and FV-Dm in the included pediatric patients.

Table 3

Predictive model of FA-Dm and FV-Dm in the studied pediatric patients.

	β	P	95%CI	
FA-Dm				
Coefficient	0.731	<.001	−0.033	1.496
Size	0.028	<.001	0.019	0.037
FV-Dm				
Coefficient	2.459	<.001	1.141	3.776
BSA	3.650	<.05	0.162	7.138
Age	0.035	<.05	0.001	0.069

BSA = body surface area, Dm = diameter, CI = confidence interval, FA = femoral artery, FV = femoral vein.

femoral artery) in a multiple linear regression analysis, with a 1 cm increase in a patient's height corresponding to a 0.004 to 0.005 cm increase in femoral vessel diameter. Warkentine et al[15] measured the femoral veins and discovered that correlations existed between FV-Dm and weight, height, age and BSA in 84 pediatric patients younger than 9 years. They also performed FV-Dm assessments on the basis of these variables and found that a 1-year increase corresponded to a 0.065 cm increase in FV-Dm; a 1 kg weight increase corresponded with a 0.018 cm increase in FV-Dm; and a 1 cm increase in height corresponded with a 0.007 cm increase in FV-Dm. In a series test that involving 24 pediatric patients. Akingbola et al[16] compared 2 age groups (infants of 3–16 months mean age versus newborns with a mean age of 1–3 days) and found that FV-Dm was significantly related to weight ($R = 0.80$) in infants (which decreased in relation to age; $R = 0.56$), while it failed to exhibit a significant relationship with FV-Dm and weight in newborns. In conclusion, they found that a patient's weight can predict FV-Dm in infants but not in newborns, perhaps because there is large variability in body weight during the first few days of life, and this might interfere with predictions of vessel size based on this variable.

In our study, angiography was first used to determine the diameter of femoral vessels in Chinese pediatric patients younger than 3 years old, and the mean femoral vessel diameter was strongly and significantly associated (correlation coefficient (R) between 0.62 and 0.73) with height, age, weight and BSA. The height was the best predictor of femoral vessel diameter in the multiple linear regression analysis ($R = 0.89$ for the femoral artery and $R = 0.86$ for the femoral vein), where a 1 cm increase in in height corresponded with a 0.023 cm increase in FA-Dm and a 0.057 cm increase in FA-Dm. The findings of the estimations of vascular diameter at the femoral level based on height were similar to those of Warkentine and Alvarez, J but different from Akingbola's results. We suspect that this discrepancy is primarily due to ethnic differences. In addition, our study found that the FA-Dm/FV-Dm ratio was similar to but slightly smaller than the results found in adults and was stable within a certain range.

5. Conclusion

This paper unavoidably had 3 certain limitations: (a) pediatric patients were not divided into different age groups; (b) we did not compare the angiographic findings with ultrasound results; (c) measurements were not correlated with the clinical condition of the pediatric patients (even for clinically stabile patients). However, despite these limitations, we suggest that in pediatric patients requiring femoral vessel cannulation, it can be helpful to determine the sizes of the needle and the catheter that must be implanted by angiography at the time at which the vessel is cannulated, and then the vessel diameter can be measured and estimated based of demographic and anthropometric variables.

Author contributions

Conceptualization: Xue-qi Fang.
Data curation: Xue-qi Fang, Hao Zhang.
Formal analysis: Xue-qi Fang, Hao Zhang.
Investigation: Xue-qi Fang.

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