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Original articles

Anatomical features of the right internal jugular vein in infants and young children undergoing heart surgery for congenital disease: comparison between cyanotic and noncyanotic patients

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Abstract
Purpose. It has been reported that children with cyanotic heart disease have elevated systemic levels of vascular endothelial growth factor, which may be related to the development of vessels. However, it is unknown whether the anatomical features of the internal jugular vein (IJV) differ between cyanotic and noncyanotic children. In this study, we compared anatomical information about the IJV of these two groups of patients.
Methods. We measured the distance between the right IJV and the right carotid artery (distance), the diameter of the IJV (diameter), and the depth of the IJV from the skin (depth), using an ultrasound device, in 100 children (0–34 months) undergoing heart surgery for congenital disease. First, we evaluated the relationship of these measurement values with patient demographic data (age, height, and body weight). Next, we evaluated the effect of the 15° Trendelenburg position on these measurement values.
Results. There were 62 cyanotic and 38 noncyanotic patients. Distance and diameter, but not depth, were well correlated with the demographic data in both patient groups. Diameter in cyanotic patients was highly correlated with the demographic data. Clinically significant changes in the measurement values were not observed in the 15° Trendelenburg position compared with the horizontal position in either patient group.
Conclusion. The anatomical features of the right IJV in infants and young children with congenital heart disease were not different in cyanotic and noncyanotic patients, except for the relationship between diameter and the demographic data. In the small patients examined in our study (72% of them were infants), the diameter of the IJV was not sufficiently enlarged by the Trendelenburg position, regardless of whether the patients were cyanotic or noncyanotic.

Key words Internal jugular vein · Children · Infant · Cannulation · Cyanosis

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Introduction

Cannulation of the internal jugular vein (IJV) in infants and small children remains difficult, although ultrasound-guided techniques are becoming standard even in these patients [1–3]. Accordingly, we believe that it is still important for anesthesiologists to understand the anatomical features of the IJV in such patients. Nakayama et al. [4] reported that the diameter of the IJV tended to increase with the patient's age, body weight, and height, whereas the depth from the skin to the IJV did not significantly correlate with these parameters in infants and small children scheduled for cardiac catheterization. Recently, it has been reported that cyanotic children have elevated systemic levels of vascular endothelial growth factor (VEGF) [5,6], which may be related to the development of vessels, including abnormal ones. However, it is not known whether the IJVs in cyanotic and noncyanotic patients have any different anatomical features. Accordingly, in this study, we compared anatomical information about the IJV in cyanotic and noncyanotic patients by ultrasound imaging.

Patients and methods

After obtaining institutional approval and parental informed consent, 100 pediatric patients, whose body weight was less than 12 kg and who consecutively underwent heart surgery for congenital disease were studied prospectively. The patients were divided into two groups based on whether their condition was cyanotic or noncyanotic. Patients with O_2 treatment before surgery or with peripheral oxygen saturation (S_{pO_2}) of less than 95% under room air before induction of anesthesia were defined as cyanotic.

Anesthesia was induced and maintained with sevoflurane and fentanyl. After the trachea was intubated, the lungs were ventilated with pressure control (15 ±

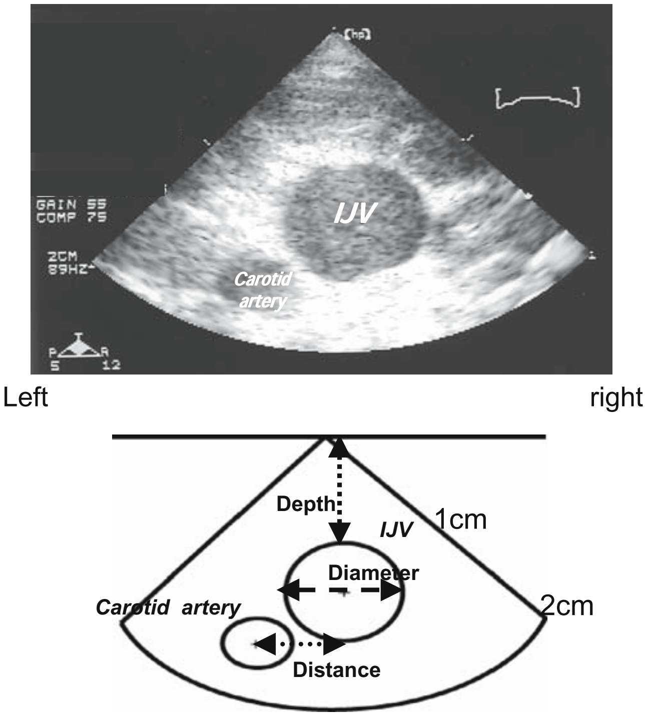

Fig. 1. Ultrasound imaging of pediatric right internal jugular vein (IJV). The diagram *at the bottom* shows the items measured to determine the quantitative anatomical features of the IJV

1 cmH_2O). The head was tilted to the left at a 30° angle with a rolled towel placed under the shoulders to extend the neck.

Ultrasound assessment was performed using a 12-MHz transducer with a SONOS 5500 ultrasound system (Philips Medical Systems, Andover, MA, USA). The probe was put on the neck skin gently so that the IJV was not compressed. Assessment was performed in the end-inspiratory period at the level of the cricoid ring. We measured the distance between the center of the IJV and the center of the carotid artery (distance), the diameter of the IJV (diameter), and the depth of the IJV from the skin (depth; Fig. 1). The measurements were done twice in the horizontal position and the measured values were averaged. Demographic (age, body weight, and height) and measurement data for the cyanotic and noncyanotic patients were compared by the unpaired *t*-test. Within each patient group, correlation coefficients were obtained between demographic data and measurement values.

Next, the head end of the operating room table was tilted down to a 15° angle (Trendelenburg position), and measurements were done again twice and the measured values were averaged. Differences in measurement values between the two positions were compared by the paired *t*-test.

Data values are expressed as means ± SD. $P < 0.05$ was assumed to indicate statistical significance in all the comparisons. A correlation coefficient of more than 0.40 was regarded as a positive correlation and when the value was over 0.70, we judged that there was a high correlation.

Results

The demographic and measurement data of the 62 cyanotic and 38 noncyanotic patients are listed in Tables 1 and 2. There were no significant differences in these data between the patient groups. Disproportionately small vessels (defined as <0.3-cm-diameter for neonates and infants and <0.5-cm for children in the horizontal position) were seen in only 2 (3.2%) cyanotic patients, and such vessels were not detected in noncyanotic patients. The carotid artery was entirely overlaid by the IJV in 1 cyanotic (1.6%) and 2 noncyanotic (5.3%) patients.

Correlations between the demographic and measurement data are shown in Fig. 2 (cyanotic patients) and Fig. 3 (noncyanotic patients). Distance and diameter, but not depth, were correlated with the demographic data in both patient groups. Diameter in cyanotic patients was highly correlated with the demographic data compared to findings in noncyanotic patients—each correlation coefficient in cyanotic patients was over 0.75, and each was greater than that in noncyanotic patients by 0.1 or more.

Comparisons of the measurement data between the horizontal and the Trendelenburg positions are shown in Table 2. Although there was a significant difference in distance in noncyanotic patients, clinically significant changes were not observed in the other measurement data, including diameter.

Discussion

Recently, it has gradually become accepted that an ultrasound-guided technique is useful for IJV cannulation [7]. This technique has also been reported to be useful in infants and small children [1–3]. However, cannulation of the IJV in such patients is sometimes difficult, even under ultrasound imaging. For example, inability to insert a Seldinger wire is sometimes encountered, especially in a small IJV even if puncture of the IJV has been successful under ultrasound imaging. Indeed, a recent report denied the higher efficacy of the ultrasound-guided cannulation technique compared to the landmark technique in children [8]. Accordingly, we believe that it is still important for anesthesiologists to

Table 1. Patient demographic data

	Cyanotic	Noncyanotic	*P* value
Number of patients (male/female)	62 (31/31)	38 (16/22)	
Age (months)	8.7 ± 9.4	8.0 ± 8.7	0.91
Height (cm)	62.3 ± 13.2	62.9 ± 10.5	0.81
Weight (kg)	5.9 ± 2.9	6.0 ± 2.3	0.71
Diagnoses			
ASD	0	3	
VSD	0	29	
PDA	0	2	
AV canal	9	0	
Tetralogy of Fallot	12	0	
Pulmonary atresia	7	0	
Transposition of great arteries	7	0	
Tricuspid atresia	3	0	
Anomalous venous return	4	0	
Univentricular heart	8	0	
Double-outlet right ventricle	5	0	
Interrupted aortic arch	3	1	
Aortic stenosis	1	2	
Ebstein's anomaly	2	0	
Others	1	1	

P values were obtained by unpaired *t*-tests comparing cyanotic and noncyanotic patients. Data values are expressed as means ± SD

Table 2. Measurement data in cyanotic and noncyanotic patients

	Cyanotic	Noncyanotic	*P*1 value
Horizontal position			
Distance (cm)	0.52 ± 0.18	0.54 ± 0.18	0.60
Diameter (cm)	0.68 ± 0.32	0.71 ± 0.26	0.68
Depth (cm)	0.66 ± 0.15	0.63 ± 0.18	0.35
Trendelenburg position			
Distance (cm) (*P*2 value)	0.52 ± 0.18 (0.67)	0.51 ± 0.17 (0.03)	0.78
Diameter (cm) (*P*2 value)	0.70 ± 0.32 (0.09)	0.72 ± 0.26 (0.32)	0.78
Depth (cm) (*P*2 value)	0.66 ± 0.15 (0.79)	0.62 ± 0.16 (0.65)	0.27

*P*1 values were obtained by unpaired *t*-tests comparing cyanotic and noncyanotic patients. *P*2 values were obtained by paired *t*-test comparing horizontal and Trendelenburg positions. Data values are expressed as means ± SD

understand the anatomical features of the IJV in children.

We had the personal clinical impression that difficulty in accessing the IJV was different in cyanotic and noncyanotic children. As far as we know, however, there have been no reports comparing the anatomical features of the IJV between such patients groups. Recent reports have indicated that children with cyanotic congenital heart disease have elevated systemic levels of VEGF [5,6]. These children usually experience the development of abnormal vessels, including systemic-to-pulmonary collateral arteries, systemic-to-pulmonary venous collaterals, and systemic venous collateral channels [5]. Therefore, the development of the IJV in cyanotic patients may be different from that in noncyanotic patients, although it is not known whether VEGF affects the development of such a large vessel as the IJV. In this study, accordingly, we compared anatomical information about the IJV in cyanotic and noncyanotic patients, by ultrasound imaging.

Diameter was correlated with age, height, and body weight in both of our groups, with the correlation being high in the cyanotic patients. The positive correlation between diameter and the demographic data was similar to the findings of Nakayama et al. [4]. In their report, the diameter of the right IJV obtained by venogram was correlated with age, height, and body weight (correlation coefficients were 0.61, 0.70, and 0.70, respectively) in 105 infants and children with congenital heart disease [4]. The reason why a higher correlation was obtained in our cyanotic patients is unknown. However, in cyanotic patients, the development of vessels may be related to the patient's growth under the influence of a higher VEGF level.

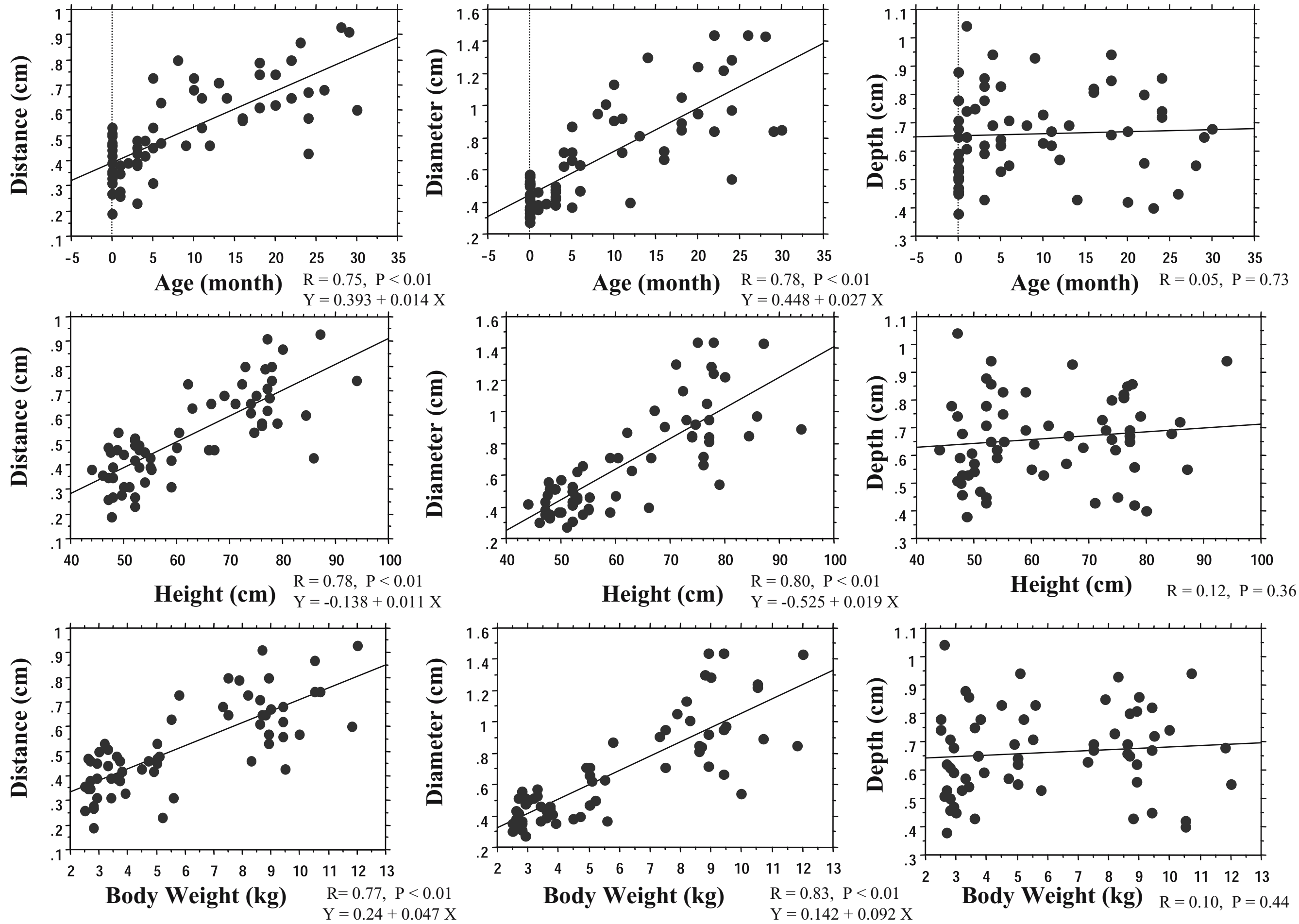

Fig. 2. Regression graphs for demographic data and measurement values in cyanotic patients. The correlation coefficient value (*R*) and the *P* value for the significance of *R* are listed *below each graph*. When the *P* value is below 0.05, the regression formula is also listed. *X*, horizontal axis; *Y*, vertical axis

In our study, a disproportionately small IJV was detected in very few patients. In the study of Nakayama et al. [4], such a small IJV was observed in 10%. In that study, some patients breathed spontaneously, whereas the lung was mechanically ventilated in all our patients. It has been reported that the IJV is significantly enlarged by positive inspiratory pressure in children [9,10]. The assessment in our study was performed in the end-inspiratory period of pressure control. Accordingly, the high rate of disproportionately small IJV seen in Nakayama's study can be attributed to the differences in the respiratory patterns between our study and theirs.

Distance was also correlated with age, height, and body weight in both of our patient groups. Moreover, there were very few patients in whom the carotid artery was entirely overlaid by the IJV. A previous study reported that the IJV overlaid more than 75% of the carotid artery in 54% of patients overall (almost all were adults.) [11]. Alderson et al. [3] reported that the IJV entirely overlaid the carotid artery in 10% of children aged up to 6 years. It was suggested that older patients were more likely to have this positional relation [11]. In our study, 72% of the patients were infants. Accordingly, such a positional relation between the IJV and the carotid artery was seen in fewer patients in our study.

Depth was not correlated with the demographic data in either of our patient groups. This result is also similar to that in the study of Nakayama et al. [4]. The reason for the poor correlation is not clear; however, one possible explanation is that we used five or six different sizes of rolled towels to extend the neck. However, this was not sufficient to fit all the patients, so different degrees of neck extension might have occurred.

No clinically significant increase in diameter was seen in the 15° Trendelenburg position in either of our patient groups. It was reported that the 20° Trendelenburg position produced a 16% increase in the cross-sectional area of the IJV in 45 children undergoing general anesthesia and mechanical ventilation (age, 6 months to 8 years)

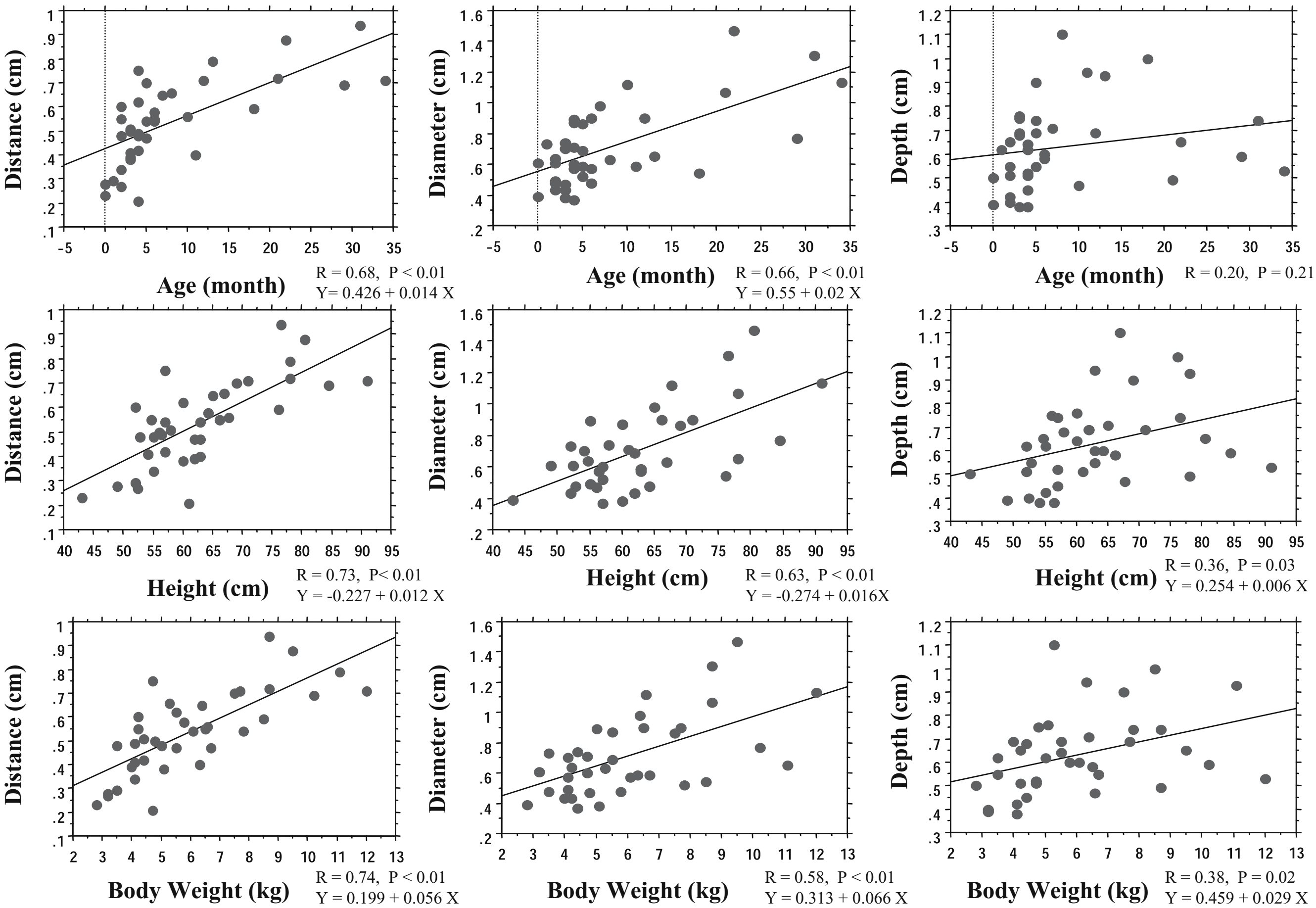

Fig. 3. Regression graphs for demographic data and measurement values in noncyanotic patients. The correlation coefficient value (*R*) and the *P* value for the significance of *R* are listed *below each graph*. When the *P* value is below 0.05, the regression formula is also listed. *X*, horizontal axis; *Y*, vertical axis

[9]. Another study, by Verghese et al. [10], found only a 5.3% increase in the cross-sectional area of the IJV in 38 infants undergoing routine surgery in the 15° Trendelenburg position. However, that study showed that in 46 children (aged 1–6 years), the IJV was enlarged by 24.3% in the 15° Trendelenburg position. Verghese et al. [10] speculated that the small IJV in infants did not have as much elasticity or compliance as that in adults. Accordingly, the increase in blood flow to the neck vessels in the Trendelenburg position may be negligible in infants. In contrast, some studies have reported that the IJV was significantly enlarged by the Trendelenburg position in adults [12,13]. As mentioned above, 72% of the patients in our study were infants; therefore, clinically significant enlargement might not have been obtained.

In conclusion, contrary to our expectation, the anatomical features of the right IJV in infants and young children with congenital heart disease were not different in cyanotic and noncyanotic patients, except for the relation of diameter to the demographic data. In the small patients seen in our study (72% of them were infants), the diameter of the IJV was not sufficiently enlarged by the Trendelenburg position, regardless of whether the patients were cyanotic or noncyanotic.

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