# Determination of normal echocardiographic values for right ventricular volume in children with two-dimensional transthoracic echocardiography

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**SUMMARY: Süleymanoğlu S, Okutan V, Yozgat Y, Lenk MK. Determination of normal echocardiographic values for right ventricular volume in children with two-dimensional transthoracic echocardiography. Turk J Pediatr 2007; 49: 141-147.**

**Assessment of right ventricular volume and functions is needed during the decision-making process in a number of cardiological disease states. We aimed to study these variables with conventional transthoracic two-dimensional echocardiography in 213 healthy cases, aged 15 days-15 years. Left ventricular systolic and diastolic volumes were measured from the apical five-chamber view and the right ventricular systolic and diastolic diameters, areas and volumes were measured from the subcostal coronal view, using the Simpson equation. Results were analyzed statistically to derive their relationship with age, height, body weight and body surface area. We conclude that right ventricular volumes measured with two-dimensional echocardiography in the subcostal coronal view using the Simpson equation are in accordance with data derived with other more complex methods reported in the literature; average values derived with this method in larger patient groups can be used as nomograms.**

***Key words: echocardiography, ventricular volume, children.***

Assessment of right ventricular volume and functions is needed during the decision-making process for repair of pathologies like tetralogy of Fallot, corrected transposition of the great arteries, and atrial switch procedures or for demonstration of volume load in cardiac defects with left-to-right shunting.

Measurement of the volume of the right ventricle is difficult due to its complex, half-moon shaped geometry, irregular trabeculation and infundibulum and a structure changing with the right ventricular afterload. As it is possible to view a broader aspect and also the contraction pattern of the right ventricle with two-dimensional echocardiography, volume and functions can be measured with this technique. However, normative data with correction of these measurements for age and body weight, height and surface area have not been published before.

In our study, we assessed right ventricular area, volume and functions in healthy children using two-dimensional echocardiographic views in the subcostal coronal plane, where it is also possible to visualize the right ventricular outflow tract. We aimed to derive normal right ventricular values corrected for age, height, body weight and surface area.

## Material and Methods

The study was performed on 213 children, 114 males (53.5%) and 99 females (46.5%), aged 15 days to 15 years, with body weights averaging 24.5±15.0 kg (range 3.9-76), height 115.2±35.7 cm (range 52-178) and body surface area 0.87±0.4 m$^2$ (range 0.23-1.85), who were referred to the pediatric cardiology outpatient clinic for evaluation of a murmur and proven to be healthy with physical and echocardiographic examinations. Children with structural or functional cardiac disease states, fever, tachycardia, and body weight and height below 3$^{rd}$ centile or above 97$^{th}$ centile were excluded.

All cases underwent echocardiographic examination after the age, body weight, height and surface area values and physical examination findings were recorded on a standard form.

Echocardiography was performed with an Acuson Sequioa C256 system using 3V2c, 5V2c and 7V3c MHz sector transducers. The left ventricular end-systolic and end-diastolic diameters, aortic and left atrial dimensions and left ventricular ejection fraction and fractional shortening were measured with M-mode echocardiography using the parasternal long-axis view. Then, using the Simpson equation, left ventricular end-systolic and end-diastolic volumes were calculated in the apical five-chamber view, and right ventricular end-systolic and end-diastolic volumes were calculated in the subcostal coronal plane (Figs. 1, 2). The calculations were performed with analysis of the area and volume, using the Simpson equation already included in the software, of the area traced on the two-dimensional echocardiographic picture. The tracings were made on the line of color transition between the ventricular line and the blood pool. The diastolic volume was calculated from a tracing where the aortic, pulmonic, mitral and tricuspid valves could best be visualized, the ventricular diameter was maximal and the mitral and tricuspid valves were closed; and the systolic volume where the ventricular diameter was minimal and the pulmonic and aortic valves were closed. Papillary muscles and smaller trabeculations were not taken into consideration. ECG correlation was also sought in the determination of end-systole and end-diastole, which was strictly correlated with data derived from valve motions and changes in ventricular dimensions.

Informed consent was obtained from the parents of study subjects. The statistical analyses were done using the SPSS and Excel for Windows software package programs. The one-way ANOVA test was utilized to analyze the differences between age groups, the t test for effects of gender difference and the Pearson test for correlations between all parameters. A p value of less than 0.05 was considered statistically significant.

## Results

When the study group was evaluated as a whole, right ventricular systolic and diastolic volumes showed a statistically significant positive correlation with age (Fig. 3). The right and left ventricular measurements showed no difference according to gender in the same age group.

There was a significant relationship between right ventricular volumes and body weight and height (Figs. 4-6). The average normal values of right ventricular volumes, upper and lower values and 95% confidence intervals are depicted in Table I. The right ventricular volumes also correlated with body surface areas in all age groups (Fig. 7).

In all age groups, as was observed with right ventricular measurements, left ventricular end-systolic and end-diastolic diameters and volumes increased in positive correlation with age.

## Discussion

Two-dimensional echocardiography has limited value in determination of right ventricular volume for a number of reasons. Improper

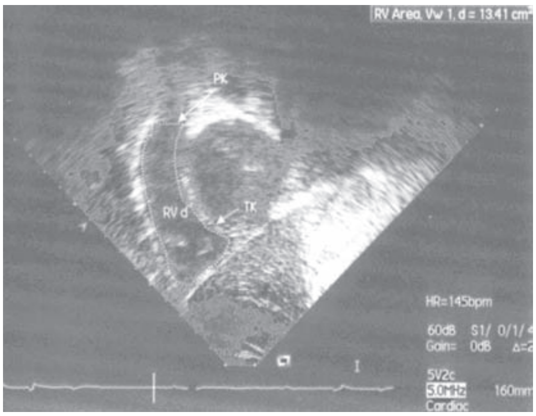


**Fig. 1.** The subcostal coronal axis view and the tracing made for measurement of right ventricular end-diastolic volume. RVd: right ventricular cavity in diastole. TK: Tricuspid valve. PK: Pulmonic valve.

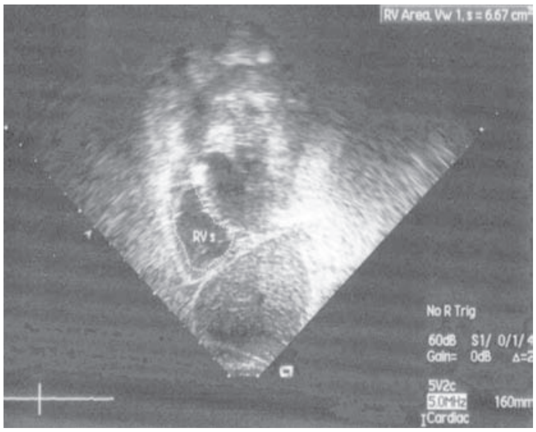


**Fig. 2.** The subcostal coronal axis view and the tracing made for measurement of right ventricular end-systolic volume. RVs: Right ventricular cavity in systole.

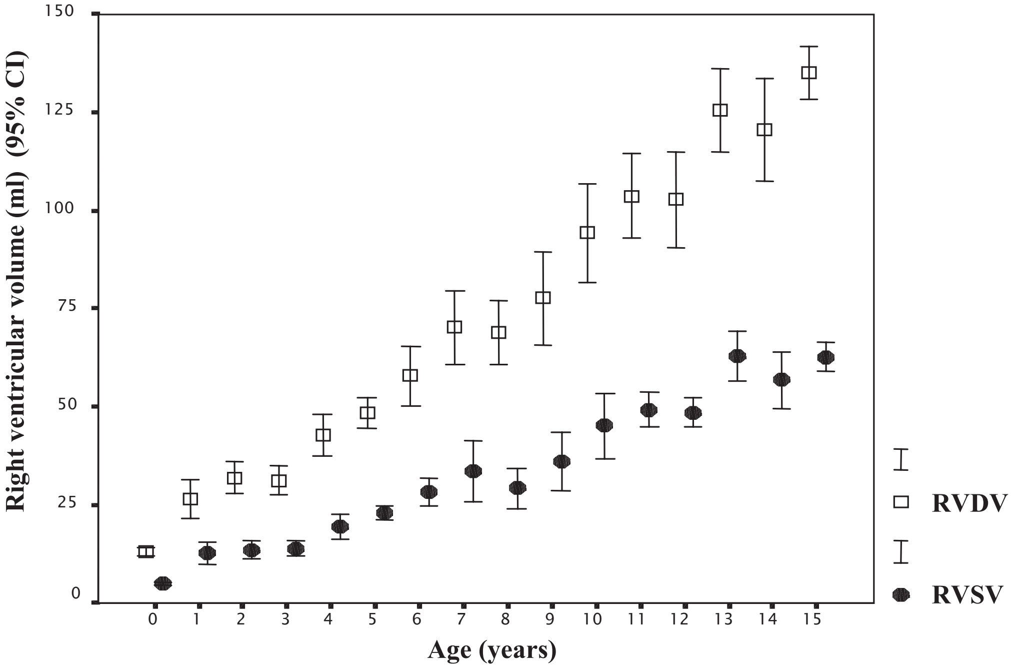


**Fig. 3.** The ages and right ventricular diastolic and systolic volumes of cases are depicted with 95% confidence intervals. RVDV: Right ventricular end-diastolic volume.
RVSV: Right ventricular end-systolic volume.

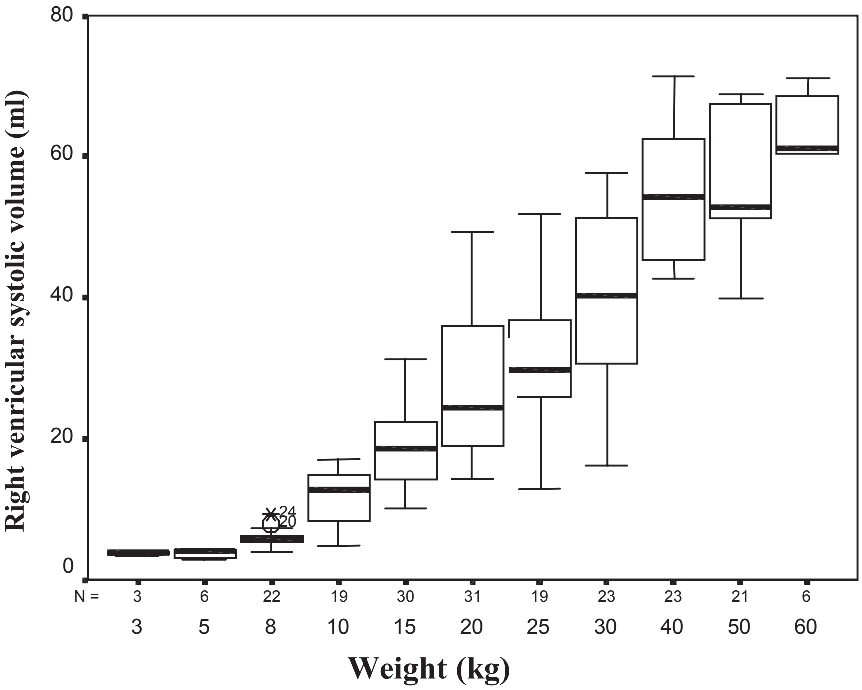


**Fig. 4.** The relationship between right ventricular systolic volume and body weight is shown with 95% confidence interval.

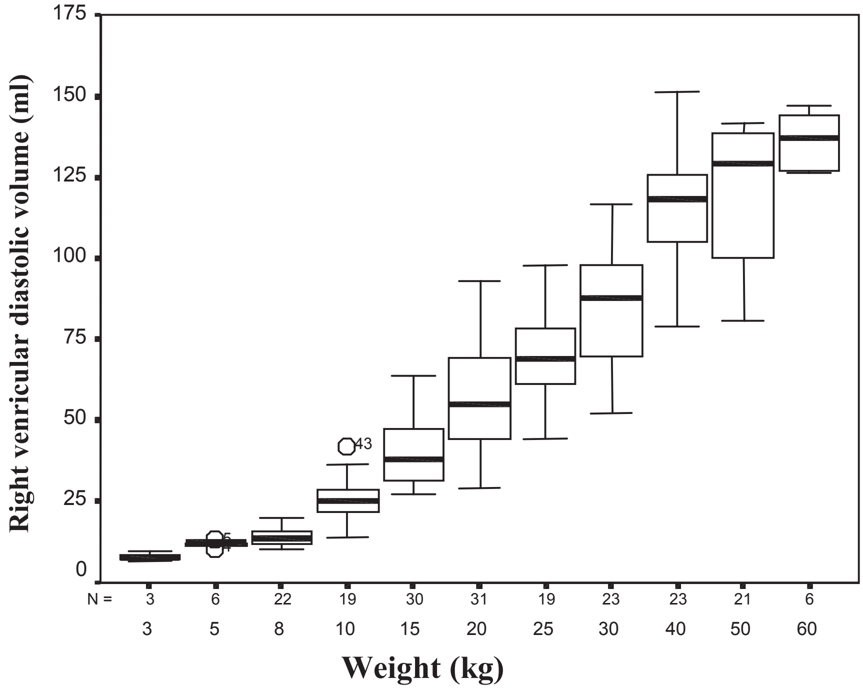


**Fig. 5.** The relationship between right ventricular diastolic volume and body weight is shown with 95% confidence interval.

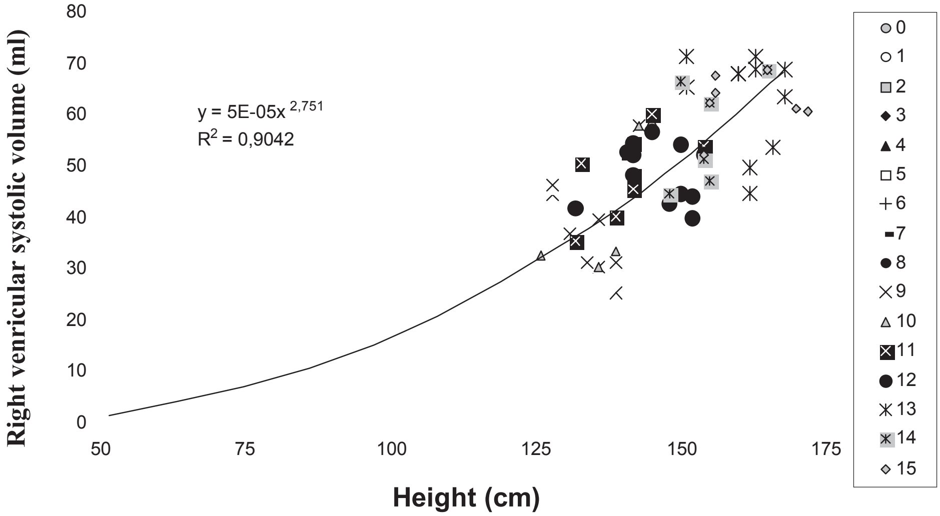


**Fig. 6.** The relationship between right ventricular systolic volume and height is shown with 95% confidence interval.

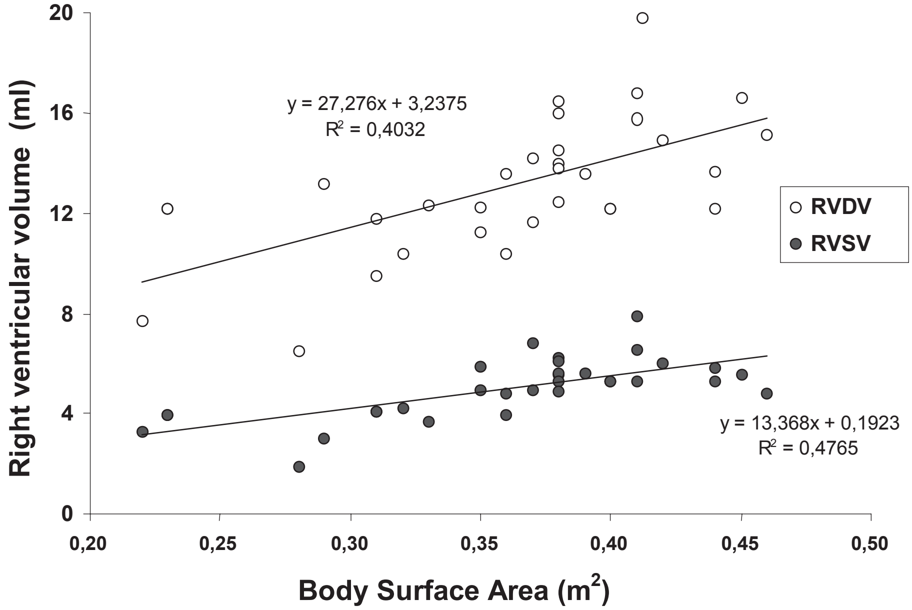


**Fig. 7.** The relationship between right ventricular volumes and body surface area is shown with 95% confidence interval.

visualization due to its half-moon shape, poor definition of the interface between the ventricular wall and blood pool, position in the thoracic cage and structural irregularity are some of the factors limiting determination of the right ventricular volume with two-dimensional echocardiography[1].

Watanabe[2] calculated right ventricular volume from pictures obtained by 90° angulation in the apical four-chamber view in the supine position, using modified Simpson rules. The resulting values were comparable to only half the values obtained with angiocardiography. The discrepancy was thought to result from not including the right ventricular outflow tract in the calculation process.

Hiraishi et al.[3] examined the right ventricular volume with regression equation using the apical four-chamber and parasternal long-axis views and reported that their results were correlated with angiocardiographic values.

Starling[4], on the other hand, measured right ventricular volume in the subcostal four-chamber and subcostal sagittal axis, and his results showed significant correlation with radionuclide angiocardiography (r: 0.76 for end-diastolic volume; r: 0.82 for end-systolic volume). In the same study, measurements were repeated using subcostal sagittal views including the right ventricular outflow tract, and results were similarly correlated with angiocardiography; however, it was not possible to obtain this view in every patient.

The results of Silverman and Hudson[5], obtained in the parasternal short-axis and apical four-chamber views using single-plane area-length equation, showed high correlation with angiocardiographic results (r: 0.81 for end-diastolic volume; r: 0.85 for end-systolic volume).

Levine and colleagues[6] studied right ventricular volume in the apical four-chamber and parasternal short-axis views using the ellipsoid model and reported results that were highly correlated with angiocardiographic calculations (r: 0.94 for end-diastolic volume; r: 0.91).

An alternative approach for measurement of right ventricular volume is the single-plane area-length method using the parasternal short-axis and apical four-chamber views and segmental analysis[7]. In that study, measurements were made in the same subcostal position as the lateral angiocardiographic view, and the results showed high correlation with measurements obtained by angiocardiography.

In our study, we tried to measure the right ventricular volume in the subcostal coronal view, because it is possible in this position to visualize the right ventricular outflow tract, simulate the lateral angiocardiographic view and delineate the interface between right ventricular wall and the blood pool.

We analyzed the relationship of our data of right ventricular diastolic and systolic volumes and areas with age and body weight, height and surface area. We found positive correlation between age and volume data ($p<0.001$, $r=0.95$ for end-diastolic volume; $p<0.001$, $r=0.93$ for end-systolic volume). We noted that the relationship between age and right ventricular volume is no longer linear after the age of eight years. The reasons for this could be the relatively small number of cases in our study or unequal distribution of body measurements in the various age groups.

To the best of our knowledge, there are no studies in the literature reporting normal values of right ventricular volume in children derived with two-dimensional echocardiography. However, results of studies done on adult age groups with two-dimensional echocardiography[2] reported results similar to ours in cases over 12 years of age. The results obtained in children with magnetic resonance imaging[8], computed tomography, radionuclide angiocardiography and three-dimensional echocardiography[11] are compatible with results of our study[8-12].

Failure to determine the normal values for cardiac structures in children continues to be an important problem. Many authors have argued that cardiac structures can be evaluated through standardization with a number of other body measurements. One of the simplest approaches is indexing the measured variable to the body surface area. While some measurements, such as cardiac output, can be made in this manner, many variables do not bear linear relationship with body surface area, and hence cannot be studied with this approach. The method of calculation of body surface area, as well, influences this relationship[13,14]. Gutgesell and Rembold[15] have pooled the relationships between body surface area and a number of cardiac structures and reported that there is a linear relationship between some parameters, such as the left ventricular end-diastolic diameter. In our study, too, there was a statistically significant positive relationship between body surface area and right ventricular end-diastolic and end-systolic volumes ($p\leq0.001$, $r=0.94$; $p\leq0.001$, $r=0.928$, respectively). The relationships observed in our study are in accordance with those in similar groups in other studies in the literature[12,15,16].

In our study, there was a statistically significant positive relationship between body weight and height and right ventricular end-diastolic and end-systolic volumes. Our results are in accordance with those of other similar studies in the literature, although study groups were not the same[9,10,17].

The left ventricular end-diastolic and end-systolic volumes in our study are comparable to those reported in the literature[18].

In conclusion, it is possible to obtain normative data of right ventricular end-diastolic and end-systolic volumes in children with conventional transthoracic two-dimensional echocardiography (Table I). Our results should be supported with further studies done on larger groups to derive nomograms for age, body weight, height and body surface area.

Assessment of right ventricular volume and functions is needed during the decision-making process in a number of cardiological disease states. Right ventricular volumes measured with conventional two-dimensional transthoracic echocardiography are in accordance with data derived with other more complex methods. Further studies are needed to obtain data with this method in larger patient groups to be used as nomograms.

As the purpose of this study was to determine the relationship of right ventricular volumes derived by transthoracic two-dimensional echocardiography with age, gender, weight, height and body surface area, correlation with other methods such as radionuclide angiography or magnetic resonance imaging was not attempted. This could be the subject of other studies.

## REFERENCES

1. Snider AR, Serwer GA. Methods for obtaining quantitative information from the echocardiographic examination. In: Snider AR, Serwer GA, Ritter SB, Gersony RA (eds). Echocardiography in Pediatric Heart Disease. St. Louis: Mosby Yearbook; 1990: 78-133.
2. Watanabe T, Katsume H, Matsukubo H, Furukawa K, Ijichi H. Estimation of right ventricular volume by two-dimensional echocardiography. Am J Cardiol 1982; 49: 1946-1953.

**Table I.** Right Ventricular End-Diastolic and End-Systolic Volumes (With Upper and Lower Limits)

| Body weight (kg) (n) | RVDV mean (ml) | 95% confidence interval (ml) | RVSV mean (ml) | 95% confidence interval (ml) |
|---|---|---|---|---|
| 3 (7) | 7.90 | 4.14-11.65 | 3.64 | 2.84-4.44 |
| 5 (9) | 12.02 | 11.05-12.99 | 3.67 | 2.99-4.35 |
| 8 (22) | 14.20 | 13.17-15.23 | 5.87 | 5.35-6.39 |
| 10 (19) | 25.78 | 22.18-29.38 | 11.22 | 9.31-13.13 |
| 15 (33) | 40.14 | 36.60-40.14 | 18.61 | 16.70-20.52 |
| 20 (31) | 57.66 | 51.39-63.93 | 27.03 | 23.71-30.90 |
| 25 (19) | 69.23 | 62.28-76.17 | 31.15 | 26.89-35.41 |
| 30 (23) | 86.57 | 78.03-95.11 | 40.56 | 35.01-46.11 |
| 40 (23) | 114.65 | 106.99-122.31 | 55.24 | 51.40-59.07 |
| 50 (21) | 119.03 | 109.42-128.63 | 57.01 | 52.53-61.48 |
| 60 (6) | 136.45 | 126.77-146.13 | 63.88 | 63.65-68.88 |

RVDV: Right ventricular end-diastolic volume. RVSV: Right ventricular end-systolic volume.


3. Hiraishi S, DiSessa TG, Jarmakani JM, Nakanishi T, Isabel-Jones JB, Friedman WF. Two-dimensional echocardiographic assessment of right ventricular volume in children with congenital heart disease. Am J Cardiol 1982; 50: 1368-1375.
4. Starling MR, Crawford MH, Sorensen SG, O'Rourke RA. A new two-dimensional echocardiographic technique for evaluating right ventricular size and performance in patients with obstructive lung disease. Circulation 1982; 66: 612-620.
5. Silverman NH, Hudson S. Evaluation of right ventricular volume and ejection fraction in children by two-dimensional echocardiography. Pediatr Cardiol 1983; 4: 197-203.
6. Levine RA, Gibson TC, Aretz T, et al. Echocardiographic measurement of right ventricular volume. Circulation 1984; 69: 497-505.
7. Silverman NH, Schiller NB. Cross sectional echocardiographic assessment of cardiac chamber size and ejection fraction in children. Ultrasound Med Biol 1984; 10: 757-769.
8. Aebischer N, Meuli R, Jeanrenaud X, Koerfer J, Kappenberger L. An echocardiographic and magnetic resonance imaging comparative study of right ventricular volume determination. Int J Card Imaging 1998; 14: 271-278.
9. Foale R, Nihoyannopoulos P, McKenna W, et al. Echocardiographic measurement of the normal adult right ventricle. Br Heart J 1986; 56: 33-44.
10. Graham TP Jr, Jarmakani JM, Atwood GF, Canent RV Jr. Right ventricular volume determinations in children. Normal values and observations with volume or pressure overload. Circulation 1973; 47: 144-153.
11. Jiang L, Handschumacher MD, Hibberd MG, et al. Three-dimensional echocardiographic reconstruction of right ventricular volume: in vitro comparison with two-dimensional methods. J Am Soc Echocardiogr 1994; 7: 150-158.
12. Wessel A. Normal values of two-dimensional echocardiographic evaluation of left and right ventricular geometry in children. Herz 1985; 10: 248-254.
13. Brion L, Fleischman AR, Schwartz GJ. Evaluation of four length-weight formulas for estimating body surface area in newborn infants. J Pediatr 1985; 107: 801-803.
14. Haycock GB, Schwartz GJ, Wisotsky DH. Geometric method for measuring body surface area: a height-weight formula validated in infants, children, and adults. J Pediatr 1978; 93: 62-66.
15. Gutgesell HP, Rembold CM. Growth of the human heart relative to body surface area. Am J Cardiol 1990; 65: 662-668.
16. Epstein ML, Goldberg SJ, Allen HD, Konecke L, Wood J. Great vessel, cardiac chamber, and wall growth patterns in normal children. Circulation 1975; 51: 1124-1129.
17. Heusch A, Rubo J, Krogmann ON, Bourgeois M. Volumetric analysis of the right ventricle in children with congenital heart defects: comparison of biplane angiography and transthoracic 3-dimensional echocardiography. Cardiol Young 1999; 9: 577-584.
18. Schiller NB. Two-dimensional echocardiographic determination of left ventricular volume, systolic function, and mass. Summary and discussion of the 1989 recommendations of the American Society of Echocardiography. Circulation 1991; 84: 1280-1287.