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Normal M mode values in healthy Turkish children

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Aim: Evaluation of cardiac structures requires a large study group for accurate data on normal values. The aim of the study was to obtain normal M mode echocardiographic values in a substantial sample of healthy term neonates and children to develop centile charts.

Materials and methods: Data were obtained over 2 years from a single center in Turkey, from 1200 healthy infants and children aged 1 day to 17 years. Using echocardiographic investigation, measurements were obtained of the following: left ventricular dimension at end diastole and end systole; thickness of interventricular septum and posterior wall of the left ventricle; aortic and pulmonary root diameter; and left atrial dimension. The influence of systematic errors as statistical noise in this large sample was decreased using third-degree polynomial curves.

Results: Measurements are presented graphically as curved lines of centiles with respect to body weight for healthy term neonates and children. The values showed a good correlation with body weight and allowed the construction of percentile curves (5%, 25%, 50%, 75%, and 95%). Higher values were observed in boys during adolescence.

Conclusion: The presented charts and tables make it possible to judge the echocardiographic measurements of a particular patient as normal or abnormal.

Key words: Normal M mode values, echocardiography, reference values, neonates, children

1. Introduction

M mode echocardiography allows the noninvasive assessment of the dimensions and anatomy of the heart and its functional characteristics (1). With the beginning of the 21st century, there has been an increase in the number of echocardiography laboratories and dramatic improvements in echocardiographic equipment around the world; as a result, it is now possible to obtain reliable measurements for pediatric cardiologists (1–8). These measurements, when compared to normal data, can be used quantitatively to make judgments about normality. A centile chart shows the position of a measured parameter within a statistical distribution. The most important reason for establishing normal values and centile charts for echocardiographic dimensions in normal children is to identify quantitative abnormalities (8).

The wide range of changes during normal development of the cardiac structures requires a large study group for accurate data on normal values, even when centile charts are used (1,3). However, nearly all published normal values either date from the start of routine echocardiography in the United States (mid-1970s to mid-1980s) or consist of small samples of healthy children; thus, reevaluation was necessary to extend the normal limits (1). In addition, a study conducted by DerSimonian and Levine (9) showed that data obtained from multiple small population studies and combined by metaanalysis have a drawback in that they are overly affected by the heterogeneity of the populations examined. Kampmann et al. (1) reviewed the echocardiographic records of 2000 healthy infants and children aged 1 day to 18 years without heart disease in central Europe to develop centile charts. To the best of our knowledge, there are no studies that evaluated healthy term Turkish neonates and children to develop centile charts.

The purpose of this prospective study was to evaluate the limits of echocardiographic measurements of healthy term Turkish term neonates and children and to develop centile charts.

2. Materials and methods

This study was approved by the ethics committee; it was conducted in accordance with the latest revision of the Declaration of Helsinki. Informed consent was obtained

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from the parents. We examined 1200 normal healthy Turkish newborns and children, without cardiac heart disease or a history of cardiac involvement in infectious, hematological, neuromuscular, or metabolic disorders, in the Pediatric Cardiology Unit from 2009 to 2011. Most were outpatients referred for evaluation of a heart murmur, which was found to be innocent on clinical, radiological, and electrocardiographic grounds.

The neonates and children taking part in this study represented a homogeneous sample of the normal healthy population. Their weights were all within the normal range on standard growth charts. They were examined by 1 of the 2 pediatric cardiologists to ensure that they had normal hearts before the echocardiograms were obtained. In all cases, their chest roentgenogram and electrocardiogram recordings were within age-appropriate normal limits.

All the subjects had complete cross-sectional 2-D, M mode, and Doppler echocardiographic examinations in the supine position with the right shoulder slightly raised. A Toshiba system (Aplio 50, Toshiba, Japan, with 3.0, 5.0, and 6.5 MHz transducers) ultrasonic imager was used for echocardiographic assessments. Instantaneous measurements were made over 3 cardiac cycles and the mean values were obtained. The echocardiograms were obtained in the standard precordial positions. The measurements were obtained using the published standards recommended by the American Society of Echocardiography (10).

The following measurements were obtained from each subject: left ventricular dimension at end diastole and end systole; aortic and pulmonary root diameter; thickness of the interventricular septum at end diastole; left ventricular posterior wall thickness at end diastole; and left atrial dimension at end diastole. Left atrial diameter measurement was obtained from M-mode in the parasternal long axis image at the level of the aortic valve. Aortic root diameter measurement was performed at the sinuses of Valsalva from a 2-D parasternal long-axis image, using the inner edge to inner edge method. Measurement of the pulmonary artery diameter was performed at the pulmonic valve annulus in the parasternal short axis image (10).

Curved lines of centiles (5th, 10th, 25th, 50th, 75th, 90th, and 95th centiles) were constructed for each measurement in relation to body weight.

Statistical analyses, percentile charts, and calculations were performed using Microsoft Excel and SPSS for Windows. For clarity in the percentile charts, individual data points were omitted. The influence of systematic errors as statistical noise in this large sample was decreased using third-degree polynomial curves: $P(x) = ax^3 + bx^2 + cx + d$.

3. Results

The results are presented graphically as centile charts (Figures 1 and 2). The centile lines are not smoothed, but reflect the centiles of each body weight group. Distribution of cases against age group and body weight are shown in Tables 1 and 2. Centile values of the different variables (from the 5th to 95th centiles) are shown in Tables 3 (A–G) and 4 (A–G).

4. Discussion

The reference values of echocardiographic measurements for children that are currently used in our country are based on standards of normalcy of populations of other countries; it is important to establish national standards. The presented charts and tables make it possible to judge echocardiographic measurements of a particular patient as normal or abnormal.

There is no consensus in the literature about which anthropometric parameter presents a better correlation with the cardiac measurements assessed by echocardiography. Some studies show a better correlation with body surface area (11,12) and others with body weight (13–15). Echocardiographic measurements in all children were expressed in relation to body weight, because when body weight changes from 2 kg to 4 kg, body surface area changes only minimally in newborn and early infancy. Ebstein et al. showed that body weight could be substituted for body surface area with no loss of precision (2). Because of the dramatic changes of cardiac dimensions during the early years of child development, small increments were chosen between the smaller weight area groups (1–2 kg) and larger increments between the larger body weight groups (5–10 kg). We aimed to determine the growth rate of the human heart in relation to body weight.

It has been suggested that there might be a tendency for sex and race dependency in echocardiographic measurements (1). In our study, racial differences were excluded as only white Middle Anatolian children were examined. There were no significant differences in echocardiographic values between the sexes. However, in older children, echocardiographic measurements in the male group were found to be slightly higher compared to those of females. Kampmann et al. (1) suggested that the reason for this might be developmental differences between males and females during adolescence.

The centiles presented in the figures reflect the calculated centiles for each weight group. Some of the children without heart disease had negligible echocardiographic measurements outside of Feigenbaum's limits, because the range of suggested normal limits in our study was fairly narrow (10).

There was better resolution of cardiac structures in the younger and nonobese population. Furthermore, there

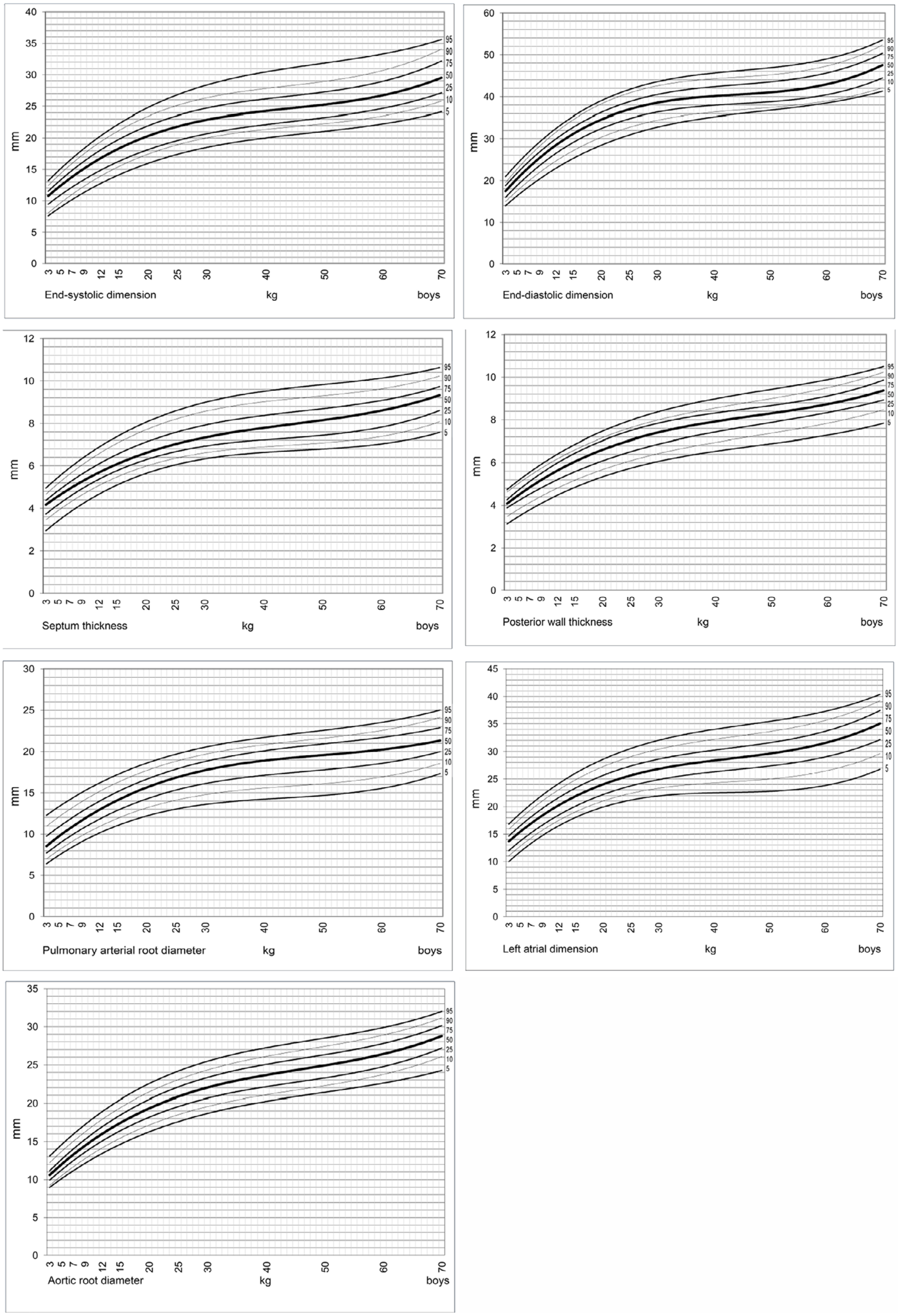

Figure 1. Percentile curves for M-mode values relative to body weight in boys.

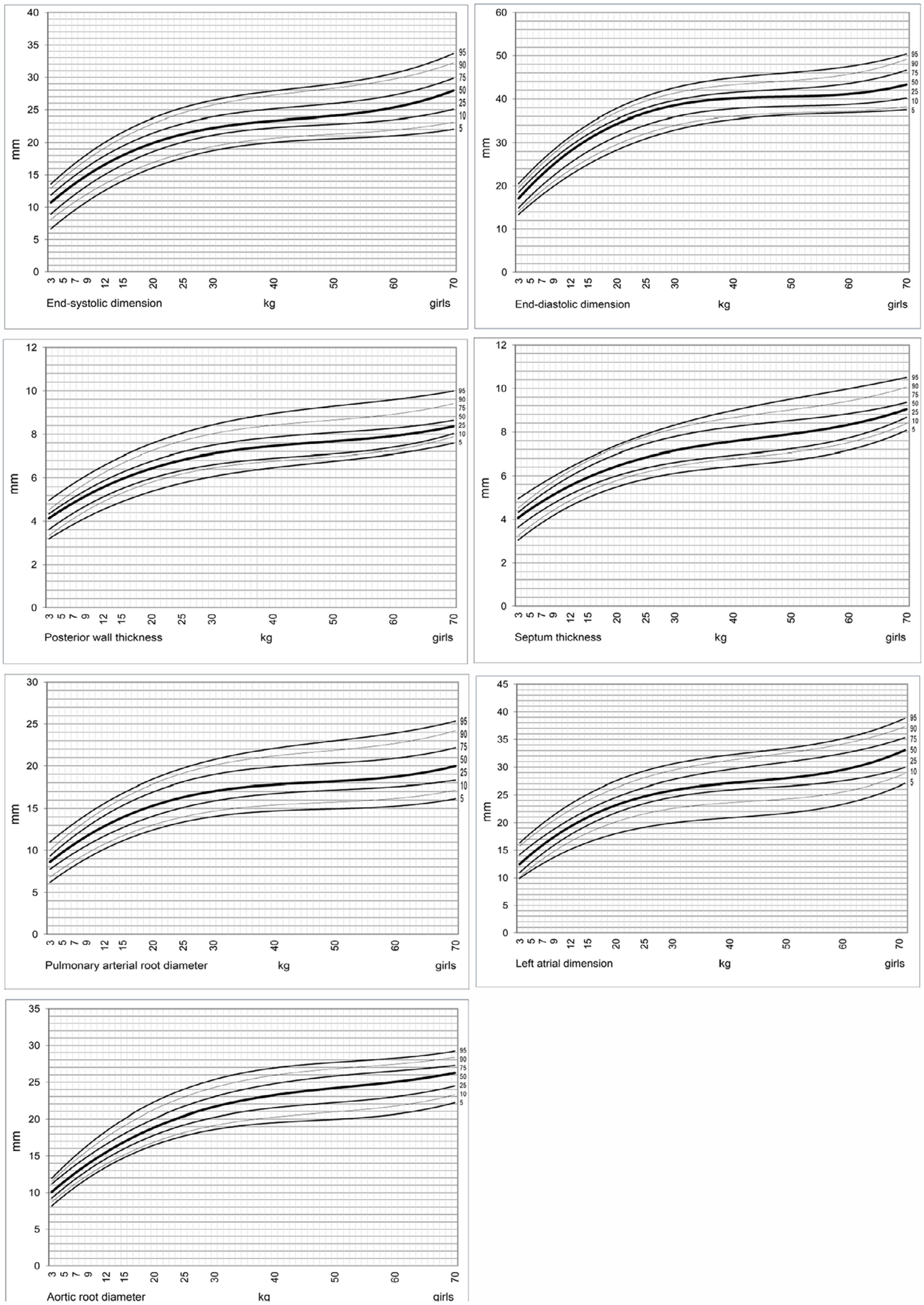

Figure 2. Percentile curves for M-mode values relative to body weight in girls.

Table 1. Distribution cases against body weight.

Weight (kg)	Boys		Girls		Total	
	n	%	n	%	n	%
≤10	106	8.8	103	8.6	209	17.4
11–20	187	15.6	171	14.3	358	29.8
21–30	140	11.7	124	10.3	264	22.0
31–40	81	6.8	72	6.0	153	12.8
41–50	51	4.3	61	5.1	112	9.3
≥51	49	4.1	55	4.6	104	8.7
Total	614	51.2	586	48.8	1200	100.0

may be a problem of lung echoes obscuring the lateral pulmonary artery wall. There was a substantial difference between aortic and pulmonary diameters, combined with a wider scatter of normal pulmonary diameter values, because the aortic root diameter was measured at end diastole, while the pulmonary diameter was measured whenever it was possible. We also concluded, like Kampmann et al. (1), that the wider confidence limits of the pulmonary artery dimension confirm that the pulmonary artery has much greater systolic widening than the aorta in childhood.

In a recent study, it was shown that data obtained from quite large population studies combined by third-degree polynomial curves do not have any homogeneity-related drawbacks. We suggest that the curve lines of these normal data may be used for quantitative echocardiography in childhood. These data on normal values should also be useful for identifying abnormalities in cardiac chamber or arterial size, and calculating its z-score (actual value minus predicted mean, divided by the standard deviation) in children who have undergone surgical therapy. It can be used also as a reference to assess children with suspected cardiomyopathy or to follow-up with those with diagnosed cardiomyopathy or under treatment with potentially cardiotoxic drugs.

Table 2. Distribution of body weight groups.

	Body weight (kg) n: 1200	
3	2.5–3.9	70
5	4.0–5.9	52
7	6.0–7.9	80
9	8.0–10.4	99
12	10.5–13.4	89
15	13.5–17.4	137
20	17.5–22.4	139
25	22.5–27.4	114
30	27.5–34.9	103
40	35.0–44.9	115
50	45.0–54.9	105
60	55.0–64.9	54
70	≥65.0	43

Table 3. Centile value of left ventricular end-diastolic dimensions (from 5th to 95th centiles) calculated against body weight in boys.

a) Left ventricular end-diastolic dimension													
3	4	5	7	10	15	20	25	30	40	50	60	70	kg (boys)
13.1	16.0	17.5	21.0	23.0	27.0	29.0	31.6	33.0	34.0	37.0	38.2	41.0	5%
17.8	19.8	21.8	24.8	28.6	32.0	34.5	36.3	37.5	39.0	41.0	44.0	47.0	50%
22.0	23.5	25.4	29.0	33.6	36.0	38.0	41.0	43.3	44.8	46.6	50.3	53.5	95%
b) Left ventricular end-systolic dimension													
3	4	5	7	10	15	20	25	30	40	50	60	70	kg (boys)
7.0	9.0	10.0	11.0	12.0	14.5	15.6	17.1	18.7	20.0	21.4	23.0	24.0	5%
11.0	12.0	13.0	15.0	16.6	19.0	20.0	21.0	23.0	24.0	25.0	27.1	29.0	50%
13.7	15.1	16.5	19.0	21.2	23.0	24.4	26.0	28.1	29.0	30.9	33.0	34.3	95%
c) Aortic root diameter													
3	4	5	7	10	15	20	25	30	40	50	60	70	kg (boys)
9.1	9.5	10.8	12.0	14.0	15.2	16.0	17.0	19.1	20.1	21.0	23.3	24.5	5%
11.0	12.0	13.0	15.0	16.0	18.0	19.0	21.0	22.0	23.0	25.0	27.0	29.0	50%
13.0	14.2	15.5	18.1	19.1	21.0	22.4	24.0	25.0	27.0	29.0	30.3	32.5	95%

Table 3. (Continued).

d) Left atrial dimension													
3	4	5	7	10	15	20	25	30	40	50	60	70	kg (boys)
11.0	11.3	12.5	15.0	17.0	19.6	19.7	21.0	21.5	22.0	23.0	24.3	25.0	5%
14.0	14.9	16.0	19.0	21.0	22.0	24.0	25.0	27.0	28.0	30.0	31.5	33.4	50%
16.7	19.5	21.0	22.6	24.1	25.8	28.3	30.0	32.3	33.0	35.6	37.3	40.2	95%
e) Septum thickness													
3	4	5	7	10	15	20	25	30	40	50	60	70	kg (boys)
3.0	3.5	3.8	4.3	5.0	5.3	5.7	6.0	6.3	6.5	6.8	7.2	7.5	5%
4.0	4.5	5.0	5.5	5.8	6.2	6.5	7.0	7.3	7.7	8.3	8.9	9.6	50%
5.0	5.5	5.9	6.4	7.0	7.5	8.0	8.5	9.0	9.4	9.8	10.5	11.2	95%
f) Posterior wall thickness													
3	4	5	7	10	15	20	25	30	40	50	60	70	kg (boys)
3.1	3.5	3.8	4.2	4.6	4.9	5.1	5.8	6.1	6.6	7.0	7.3	7.5	5%
3.7	4.4	5.0	5.5	5.7	6.0	6.3	6.7	7.0	7.5	8.0	8.5	9.5	50%
4.5	5.4	5.9	6.3	6.8	7.3	7.6	8.0	8.5	9.0	9.5	10.4	11.1	95%
g) Pulmonary arterial root diameter													
3	4	5	7	10	15	20	25	30	40	50	60	70	kg (boys)
6.2	6.5	8.0	9.5	11.0	11.5	12.0	12.5	13.0	14.0	15.0	16.0	18.0	5%
9.0	9.6	10.9	12.0	14.0	14.4	15.0	16.3	18.0	19.0	20.0	20.5	21.0	50%
12.7	13.5	13.9	15.0	16.2	17.2	18.3	19.2	20.7	21.9	22.6	24.0	25.3	95%

Table 4. Centile value of left ventricular end-diastolic dimensions (from 5th to 95th centiles) calculated against body weight in girls.

a) Left ventricular end-diastolic dimension													
3	4	5	7	10	15	20	25	30	40	50	60	70	kg (girls)
14.0	15.0	17.6	20.2	23.0	25.0	28.2	31.0	31.6	33.0	33.9	35.1	36.7	5%
17.0	20.0	22.0	25.1	27.5	31.5	34.0	36.0	38.0	40.0	41.0	41.5	42.0	50%
20.0	23.0	25.4	29.5	32.0	35.0	37.6	40.8	42.8	45.0	46.1	48.0	49.7	95%
b) Left ventricular end-systolic dimension													
3	4	5	7	10	15	20	25	30	40	50	60	70	kg (girls)
7.1	8.3	10.0	11.0	13.0	13.8	16.0	17.4	19.0	19.4	20.0	21.1	21.9	5%
10.5	12.0	14.0	15.8	17.0	18.0	20.0	21.0	22.0	23.0	24.0	26.0	27.0	50%
12.9	16.0	17.4	19.0	20.0	21.3	23.3	24.8	26.0	28.0	29.0	31.0	33.6	95%
c) Aortic root diameter													
3	4	5	7	10	15	20	25	30	40	50	60	70	kg (girls)
7.1	8.3	10.0	11.0	13.0	13.8	16.0	17.4	19.0	19.4	20.0	21.1	21.9	5%
10.5	12.0	14.0	15.8	17.0	18.0	20.0	21.0	22.0	23.0	24.0	26.0	27.0	50%
12.9	15.1	17.4	19.0	20.0	21.3	23.3	24.8	26.0	28.0	29.0	31.0	32.6	95%

Table 4. (Continued).

d) Left atrial dimension													
3	4	5	7	10	15	20	25	30	40	50	60	70	kg (girls)
9.0	10.9	13.0	14.6	15.6	17.0	17.4	18.4	19.8	21.0	22.9	24.9	27.0	5%
12.0	14.0	16.0	18.0	19.0	22.0	23.0	24.0	26.0	27.0	28.0	30.0	31.0	50%
16.0	18.6	19.4	21.9	23.0	25.6	27.3	28.0	30.5	32.4	34.2	35.9	37.6	95%
e) Septum thickness													
3	4	5	7	10	15	20	25	30	40	50	60	70	kg (girls)
3.0	3.3	4.0	4.5	4.8	5.0	5.5	5.7	6.0	6.4	6.8	7.3	8.0	5%
3.9	4.2	4.7	5.4	5.7	6.0	6.5	6.7	7.0	7.5	8.0	8.4	9.0	50%
5.0	5.4	5.8	6.3	6.7	7.0	7.4	7.9	8.5	9.0	9.5	9.8	9.9	95%
f) Posterior wall thickness													
3	4	5	7	10	15	20	25	30	40	50	60	70	kg (girls)
3.0	3.4	3.9	4.5	4.9	5.0	5.1	5.4	5.8	6.2	6.6	7.0	7.5	5%
3.9	4.2	5.0	5.5	5.7	6.0	6.3	6.5	7.0	7.3	7.7	8.0	8.3	50%
4.8	5.0	5.8	6.4	6.7	7.2	7.5	8.0	8.4	8.9	9.2	9.6	10.0	95%
g) Pulmonary arterial root diameter													
3	4	5	7	10	15	20	25	30	40	50	60	70	kg (girls)
6.0	7.0	8.1	9.0	10.3	11.1	12.0	13.0	13.8	14.2	15.0	15.5	16.0	5%
8.0	9.5	11.0	12.0	13.0	14.0	15.0	16.0	17.0	17.6	18.3	19.1	19.6	50%
10.8	11.5	13.0	15.0	16.4	17.3	18.6	20.1	21.0	22.2	23.1	23.8	24.1	95%

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