Echocardiographic Criteria for Normal Newborn Infants

By Arthur D. Hagan, CDR, MC, USN, William J. Deely, CDR, MC, USN, David Sahn, M.D., and William F. Friedman, M.D.

SUMMARY

Echocardiograms were obtained from 200 normal newborn infants ranging from 6 to 10 pounds in weight and from 10 to 72 hours in age. A continuous recording technique is described employing a 5 MHz transducer. Criteria have been established for a normal echocardiographic profile in the full-term neonate. This profile consists of obtaining quantitative measurements of mitral valve excursion and velocity, tricuspid valve excursion and velocity, pulmonary artery diameter, aortic root diameter, left atrial diameter, and interventricular septal thicknesses. In addition, qualitative assessment is made of the septal contour, position of the aortic root to pulmonary artery, continuity of mitral valve with posterior aortic root, and continuity of tricuspid valve with anterior aortic root. No correlation was found between the magnitude of any one parameter and either body surface area or weight. The establishment of normal echocardiographic criteria for the newborn may be expected to significantly facilitate application of this noninvasive technique to infants born with congenital heart disease.

Additional Indexing Words:
Ultrasound Ultrasound cardiology Echocardiographic profile Echocardiography Noninvasive techniques

IT MAY be expected that echocardiography will provide progressively more information about various forms of acquired and congenital heart disease. In this regard, there is a relative paucity of anatomic and physiologic ultrasound measurements in infants and children when compared to the large body of data for normal and abnormal adult hearts. While the altered anatomy of several specific congenital cardiac malformations may be detected by ultrasound in infants, the range of normal for the dimensions and motion of all cardiac structures has not yet been defined precisely for the neonate.1-10 Most previously reported studies of normal infants have been limited by the use of 2.25 to 3.5 MHz transducers with data display on Polaroid film.4, 5, 9-12 The determinations that form the basis of this report were obtained with a 5 MHz transducer and a continuous recording technique. The present findings provide an echocardiographic profile for normal, full-term infants.

Methods

Cardiac echograms were obtained from 200 normal, full-term infants ranging in age from 10 to 72 hr (average = 37 hr). The group consisted of 100 males and 100 females and weights ranged from 6 to 10 pounds (average = 7.6 pounds).

A Picker Echoview II interfaced with a Honeywell strip chart recorder was employed. The transducer by Aerotec Corporation has a center frequency of 5.0 mHz with an active element diameter of one-fourth inch. It is a non-focused, highly damped transducer which permits more superior resolution and definition of cardiac structures in the newborn than is possible using a 2.25 or a 3.5 MHz transducer. It has a repetition rate of 1,000 impulses/sec and is a sound transmitter for 1 microsecond and a sound receiver for 999 microseconds. Airless contact between transducer and skin was achieved with a water soluble gel. All ultrasound
recordings were obtained in "slow sweep" or M-mode display along with the infant's electrocardiogram. Tracings were calibrated for 1 cm anterior-posterior distance and 0.5 sec horizontal duration. Maximum near and far gain control settings were employed and recording paper speed adjusted to provide the best quality for each infant's heart rate. Examinations were performed in the newborn nursery with the infants in a supine position in their respective bassinets. Sedation was not administered, although a bottle or pacifier nipple was occasionally required to quiet the infant.

The mitral leaflets were identified by posterior direction of the beam of the transducer placed along the left sternal border over the third or fourth intercostal space. Since the sternum and ribs are not calcified in the neonate, they offer no significant interference in recording the substernal echoes of the right ventricular wall. Occasionally the transducer was directed in a slight infero-lateral direction to record the mitral valve (fig. 1). The tricuspid valve echo was obtained by a slight medial angulation without displacing the transducer. Often both mitral and tricuspid valve echoes were recorded simultaneously.

In order to record echoes from the aortic valve and aortic root the transducer was directed superiorly and rightward at the level of the third intercostal space. Normal mitral-aortic valve continuity was identified as echoes from anterior mitral leaflet, mitral annulus, and posterior aortic root were recorded continuously at the same depth (fig. 2). Infrequently, identification of the aortic valve necessitated placement at the level of the second intercostal space. The wall of the left atrium was detected posterior to the aortic root and the left ventricle posterior to the mitral valve. The pulmonic valve was identified in most infants by directing the transducer in either the second or third intercostal spaces laterally from the left sternal border. In adults we have identified the pulmonic valve by directing the transducer in the second intercostal space in a lateral direction so that it lies anteriorly, laterally, and slightly cephalad to the aortic valve. In contrast, in occasional infants in this study, the aortic root was visualized simultaneously just posterior to the pulmonary artery (fig. 3).

The excursion or mobility of either the mitral or tricuspid valves was measured from the D to E points (fig. 1). The anterior movement encountered from the C to D points was considered to reflect motion of the mitral annulus due to left ventricular ejection, and thus C to D movement was not used to assess individual leaflet mobility.

Interventricular septal thickness and contour was identified best when recording at the level of either the mitral or tricuspid valves. Care was taken to measure thickness only where shape echoes were recorded from both right and left ventricular (LV) endocardial

![Diagram and echographic recording with the transducer directed at the level of the mitral valve.](http://circ.ahajournals.org/doi/10.1161/01.CIR.44.6.1222)
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Figure 2

Sweeping the transducer from the mitral valve to the aortic valve establishes the normal continuity of the anterior mitral leaflet and the posterior aortic root as well as the septal-anterior aortic root continuity. RV = right ventricular wall, S = septum, AM = anterior mitral leaflet, PM = posterior mitral leaflet, LV = posterior left ventricular wall, Ao = aorta, LA = left atrium.

surfaces. Since the tricuspid annulus and anterior aortic root lie at the same depth as the septum, a mixture of echoes from two sources must be avoided. Their distinction was accomplished readily by recording continuously as the transducer was directed to sweep from the full excursion of the tricuspid valve with septum to the aortic root.

Although the LV epicardial echo is prominent and easily identified, the LV endocardial echo is often less distinct. The position found best for measuring internal left ventricular dimensions was at the mitral valve level such that timing of end-systole and end-diastole could be assessed directly from the anterior mitral leaflet (fig. 1). In this manner, end-systole is more accurately recognized than is often possible using the peak anterior excursion of the LV endocardial echo. The internal dimensions of the left ventricle were measured from the LV endocardial septal surface to the corresponding LV posterior wall endocardial echo.

The internal diameters of the right ventricle (RV) were measured similarly, i.e., from the RV endocardial echo to the corresponding endocardial septal surface at end-systole and end-diastole, using the mitral valve for timing purposes (fig. 4). In newborns, the endocardial echo of the RV wall could not be recorded satisfactorily with low frequency transducers, but was well delineated with the 5 MHz transducer employed in this study.

Results

Mitral and tricuspid valve measurements are compared in table 1. Although the mean velocity and excursion of the anterior tricuspid leaflet was greater than the anterior mitral leaflet, the ranges overlapped and did not differ significantly. The posterior mitral leaflet is easily identified in 91% of the study group.

The pulmonary artery and aortic root diameters are given in table 2. The difference between end-systole and end-diastole in the external diameter of the aortic root was always less than 1 mm. In each neonate in whom the pulmonary artery could be identified (80% of the entire group), the external diameter of the latter vessel was larger than the aorta ($P < 0.005$).

Average values for left atrial diameters are provided in table 2. This dimension was measured

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The pulmonary valve is recorded anterior and slightly lateral to the aortic valve. PA = pulmonary artery, Ao = aorta.

The interventricular septum ranged in thickness from 1.8 to 4 mm (mean = 2.7 mm). Septal motion is normally posterior during systole and anterior during diastole with the best quality recording site at the level of either atrioventricular valve. On occasion, variability in septal contour was noted with a diminution in anterior-posterior excursion when echoes were recorded at a more inferior

### Table 1

<table>
<thead>
<tr>
<th></th>
<th>Velocity (mm/sec)</th>
<th>Excursion (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tricuspid Range</td>
<td>60 - 116</td>
<td>7.0 - 14.0</td>
</tr>
<tr>
<td>Mean ± se</td>
<td>93 ± 2</td>
<td>9.3 ± .2</td>
</tr>
<tr>
<td>Mitral Range</td>
<td>60 - 130</td>
<td>6.0 - 12.0</td>
</tr>
<tr>
<td>Mean ± se</td>
<td>80 ± 1</td>
<td>8.1 ± .1</td>
</tr>
</tbody>
</table>

### Table 2

| Pulmonary artery diameter (mm) | 9.4 - 13.0 |
| Aortic root diameter (mm)     | 8.1 - 12.0  |
| Left atrial diameter (mm)     | 5.0 - 10.0  |
| Interventricular septal thickness (mm) | 1.8 - 4.0 |
| Mean ± se                      | 11.1 ± .2   |
| Mean ± se                      | 10.0 ± .06  |
| Mean ± se                      | 7.0 ± .1    |
| Mean ± se                      | 2.7 ± .04   |

from the endocardial surface of the left atrium to the outer margin of the posterior aortic root at both end-systole and end-diastole. Diameters in end-systole were 2.4 ± .3 mm greater than in end-diastole. The reflected echoes from the left atrial (LA) wall were usually identified as a straight line. However, increased LA wall motion was noted often while sweeping the transducer from posterior aortic root to the mitral valve just prior to recording the transition to LV wall. This accentuated LA wall motion near the mitral annulus was anterior in diastole and posterior in systole.
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The right ventricular wall thickness and internal diameters are shown here. The arrows identify end-systolic and end-diastolic diameters utilizing the anterior mitral leaflet for timing purposes. EPI = epicardium, END = endocardium, S = septum, AM = anterior mitral leaflet, PM = posterior mitral leaflet.

Figure 4

position, below the level of the mitral or tricuspid valve. In addition, it was noted that the septal contour could erroneously be interpreted as illustrating paradoxical motion if anterior aortic root echoes were superimposed.

The internal diameters and wall thicknesses of the right and left ventricles are compared in Table 3. Posterior LV wall thickness was not significantly different from RV wall thickness at either end-systole or end-diastole. Although the RV and LV internal diameter ranges overlap, the LV diameters were always greater than the RV diameters in the same neonate.

Discussion

All valves and chambers except the right atrium can be identified in the newborn infant by employing the continuous recording technique and a 5 MHz transducer. Use of the latter transducer allows excellent resolution and more refined detail of all echographic recordings of the infant heart than is possible with lower frequency transducers. Further, the application of a continuous recording technique enables more accurate measurements of all parameters than is possible with Polaroid film display. With the latter technique, Meyer and Kaplan have described a substantially slower anterior mitral leaflet velocity in infants when compared to adults. Similar results have been obtained in our laboratory with Polaroid film recordings. However, the improved techniques employed in the present study reveal a much higher velocity of the mitral leaflet in the same infants without significant differences when compared to established adult values. The most frequent error leading to a false impression of slow mitral leaflet velocity is failure to record echoes from the tip of

Table 3

<table>
<thead>
<tr>
<th></th>
<th>Right ventricle</th>
<th>Left ventricle</th>
</tr>
</thead>
<tbody>
<tr>
<td>End-systolic wall thickness (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>3.3 - 7.3</td>
<td>2.5 - 6.0</td>
</tr>
<tr>
<td>Mean ± se</td>
<td>5.0 ± 1.1</td>
<td>4.3 ± .1</td>
</tr>
<tr>
<td>End-diastolic wall thickness (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>2.0 - 4.7</td>
<td>1.6 - 3.7</td>
</tr>
<tr>
<td>Mean ± se</td>
<td>3.0 ± .1</td>
<td>2.6 ± .1</td>
</tr>
<tr>
<td>End-systolic diameter (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>5.5 - 11.4</td>
<td>8.0 - 18.6</td>
</tr>
<tr>
<td>Mean ± se</td>
<td>9.4 ± .2</td>
<td>13.3 ± .3</td>
</tr>
<tr>
<td>End-diastolic diameter (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>6.1 - 15.0</td>
<td>12.0 - 23.3</td>
</tr>
<tr>
<td>Mean ± se</td>
<td>11.4 ± .4</td>
<td>18.7 ± .3</td>
</tr>
</tbody>
</table>
the leaflet. Thus, this same error will also result in a reduced value when the extent of excursion of the leaflet is calculated.

The pulmonary valve and artery were not as consistently recorded (80% of cases) as the aortic valve and aortic root which were identified in all the infants. Although the grouped data for the diameters of the pulmonary artery and aortic root overlapped, in each infant in whom both were measured the pulmonary artery was always larger than the aortic root.

The interventricular septum was recorded easily at the level of the tricuspid and mitral valves and the septal contour and degree of anterior-posterior excursion was found to vary slightly in the same neonate by varying the transducer angulation. Septal thickness was not significantly different from the end-diastolic wall thickness of the left ventricle (2.7 ± .04 and 2.6 ± .1 mm, respectively).

Only a few previously reported studies have defined normal right ventricular dimensions in either infants or adults, and echoes from the RV epicardium have been employed in all of these. In order to accurately obtain these measurements a well defined RV endocardial echo must be recorded. Since different sites of the RV free wall are recorded with changes in the angle of the transducer beam, the endocardial echo is often altered slightly, suggesting a change in thickness. This phenomenon would appear to result from the variation in the angles of the echo beams as they are reflected from RV trabeculations. Anterior RV and posterior LV wall thicknesses do not vary significantly at either end-systole or end-diastole. Although internal diameter ranges of the two ventricles overlap, the LV diameters always exceed the RV in each individual infant.

Attempts were made in this study to correlate each ultrasound measurement with weight and body surface area, but no significant correlations were found to exist. Thus, our findings in this regard are in contrast to those reported recently by Solinger, Elbl and Minhas.

In conclusion, the current study establishes normal echocardiographic criteria for assessment of the full-term neonate. In order to obtain a complete ultrasound profile, quantitative measurements are made of the atrioventricular valves' excursions and velocities, pulmonary artery and aortic root diameters, left atrial diameter, interventricular septal thickness, right and left ventricular diameters and wall thicknesses. In addition, qualitative assessment is made of the septal contour, position of the aortic root and pulmonary artery, continuity of mitral valve with posterior aortic root, and continuity of tricuspid valve with anterior aortic root. The establishment of normal echocardiographic criteria for the newborn will greatly facilitate the application of ultrasound to infants suspected of having congenital heart disease.

References
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