Echocardiographic Assessment of Left Ventricular Performance in Normal Newborns

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SUMMARY

Left ventricular function was assessed in 72 normal neonates (age 5-15 days, weight 6-10 lbs) using the echocardiographically determined mean velocity of circumferential fiber shortening (VCF). Comparison between mean VCF determined echocardiographically and angiographically in nine infants with congenital heart disease yielded a correlation coefficient of +0.97 (P < 0.001). For the group of normal newborns, mean VCF averaged 1.51 ± 0.04 (se) circumferences/sec with a range of 0.92 to 2.2 circ/sec. Sub-group values were: <12 hrs (N = 13) 1.48 ± 0.05 circ/sec; 12-24 hrs (N = 16) 1.46 ± 0.05 circ/sec; 24-48 hrs (N = 26) 1.44 ± 0.06 circ/sec; 48-72 hrs (N = 19) 1.57 ± 0.06 circ/sec; 72-150 hrs (N = 8) 1.61 ± 0.11 circ/sec. The differences between age groups were not significant statistically. In contrast, VCF was noted to be depressed significantly in the first hour of life when normal infants were evaluated serially. These studies validate ultrasound determinations of internal shortening velocity in the neonatal period, provide normal values, and attest to the reproducibility of the method. The technique will be especially valuable for the serial, noninvasive assessment of left ventricular performance in newborn infants.

Additional Indexing Words:
Cardiac performance Mean VCF Ultrasound Noninvasive

EMPLOYING CONTINUOUS RECORDING techniques and high frequency transducers, cardiac ultrasound is particularly well suited for the noninvasive evaluation of cardiac anatomy and function in the newborn period. Nonetheless, compared to the substantial data that exist for normal and abnormal adult hearts, there is a relative paucity of echocardiographic criteria for the evaluation of infants. Accordingly, past studies from this laboratory have defined the range of normal for the dimensions and motion of great vessels and cardiac structures in the early newborn period. The purpose of the present report is to evaluate the range of normal for the mean velocity of circumferential fiber shortening (mean VCF) in this age group, since this index offers a simplified measure of alterations in left ventricular performance.

Methods

Seventy-two normal, full-term newborns ranging in weight from 6 to 10 pounds (average 7.3 lbs) were studied in the supine position during quiet rest or sleep. Visualization of left ventricular structures was obtained using a commercially available ultrasonoscope (Picker #103) interfaced with a Honeywell fiberoptic strip chart recorder. A 5 MHz, ¾ inch nonfocused transducer was employed. The site of maximal mitral excursion was identified (fig. 1) by sweeping the left ventricle from body to outflow tract. Preliminary studies using a phased multiple crystal technique for cross-sectional imaging have suggested to us that the mitral valve leaflet in newborns hangs further into the left ventricle than in adults and older children. Therefore, we consider that appropriate measurements of left ventricular posterior wall and septal motion are obtained in the plane of maximal mitral excursion. Recordings were considered adequate for analysis if there was good visualization of the endocardial surfaces of the posterior left ventricular wall and septum, posterior motion of the septum in systole, and maximal excursion of the anterior mitral leaflet. These criteria were met by careful
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Figure 1

An M-mode scan of the left ventricle from body (left) to outflow tract and aortic root (right). The anterior (AM) and posterior (PM) mitral valve leaflets are labeled at the site of maximum excursion. The ECG lead is at the bottom of the tracing. RV = right ventricle; S = septum; Ao = aorta; LA = left atrium.

Figure 2

Structures traversed by the ultrasonic beam, from the area overlying the third rib in an infant. Mitral valve motion defines end systole and end diastole. The diameters at these times are measured as shown by the arrows. The ECG is shown at the bottom of the tracing. RV = right ventricle; T = tricuspid annulus; S = septum; A = anterior mitral; P = posterior mitral; End = left ventricular endocardium.

Recording in each infant in this study. The mean velocity of left ventricular circumferential fiber shortening was calculated as [end-diastolic dimension − end-systolic dimension] / end-diastolic dimension × ejection time] and expressed in circumferences per second. Using mitral valve motion for timing purposes, end-diastolic and end-systolic dimensions were measured as illustrated in figure 2. Ejection time was also measured from the point of complete mitral valve closure to the onset of mitral valve opening. These points corresponded closely with the onset and termination of left ventricular systolic wall motion and yet could be more easily identified. As the values for ejection time were almost identical to those reported in normal infants by Levy, Leaman and Hanson (measured from axillary artery tracings) no correction was applied for the pre-ejection period.

Data were collected from infants grouped in the following manner: (1) 72 infants who had a single mean VCF determination performed between the ages of five and 150 hours; (2) ten infants who had initial studies at less than twelve hours and repeat evaluations beyond forty-eight hours of age; (3) seven infants born by elective Caesarian section with Apgar ratings of 9 or 10 at one minute who were studied continuously during the first hour of age and examined repeatedly during their first twenty-four hours of life.

In order to assess the validity of the ultrasound derived mean VCF, nine infants with a variety of congenital cardiac malformations who underwent cardiac catheterization and selective left ventricular angiography in our laboratory had echocardiographic studies performed immediately prior to injection of contrast material. The angiographic method for the calculation of mean VCF has been described in detail previously.3 Left ventricular dimensions were determined from a mid-ventricular chord in these babies since this site most closely corresponds to the area of maximal mitral excursion detected echocardiographically. The Student's t-test was employed to assess statistical significance.

Results

Ultrasound vs Angiography: A comparison of mean VCF determinations obtained by sequential ultrasound and cineangiographic methods in babies with congenital heart disease is shown in figure 3. The correlation coefficient was + 0.97 and attests to the reliability of the ultrasound derived index.

Normal Infants: Mean VCF data for the total study group is depicted graphically in figure 4. The average for the entire group was 1.51 ± 0.04 (se) cm/sec with a range of 0.92 to 2.2 cm/sec.
Important early change was noted (fig. 6). The mean VCF was significantly reduced in the first minutes of life ($P < 0.001$), and it was not until thirty minutes that sustained normal values were observed.

Discussion

A variety of noninvasive techniques are now available for assessing cardiac performance in man.\cite{7} Interest in echocardiographic imaging of the left ventricle has led to a number of attempts to assess both pump and muscle function.\cite{8-14} In this regard, the mean velocity of circumferential fiber shortening (mean VCF) has been viewed recently as the simplest and most empirically useful index of cardiac contractility.\cite{2,15} Using cineangiographic methods, Fisher, Dubrow and Hastreiter\cite{16} were able to detect altered left ventricular performance in pediatric patients with this index, and excellent correlations have been shown to exist in adults between angiographically and echocardiographically determined values.\cite{17}

At this institution diverse efforts have been expended using cardiac ultrasound to evaluate normal neonatal cardiac function. Our initial experience suggested that difficulties in spatial orientation and the angular errors involved in studying left ventricular dimensions in the small

**Figure 3**

Angiographically determined mean VCF in circumferences per second is shown on the abscissa. Echocardiographically determined mean VCF is shown on the ordinate.

Statistical differences were sought but not found between age subgroups.

**Serial Studies:** Values for mean VCF in ten patients studied at less than ten and greater than forty-eight hours of age are shown in figure 5. In this group, five infants showed substantial increases, three infants a small decrease, and no change was noted in two infants. The average values at these two ages did not differ statistically.

Finally, in the group of seven infants studied continuously during the first hour of age (from age four minutes) and sequentially thereafter, an

**Figure 4**

Mean circumferential fiber shortening rates of 72 normal full term infants subdivided into the age groups shown on the abscissa. No statistically significant differences existed between values of the age subgroups. Each point and the vertical bars represent the mean ± SE. The numbers in brackets are the numbers of infants in each age subgroup.

**Figure 5**

Serial determinations of mean VCF in ten full term normal infants at less than ten and greater than forty-eight hours of age. The triangles and vertical bars represent the mean ± SE at these different ages. Differences were not statistically significant.

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Results in seven infants studied from age four minutes continuously during the first hour of life and repeatedly thereafter. A marked rise was noted in the first twenty minutes of life (P < 0.001) and stable values were not obtained until thirty minutes. All of these infants were born by elective Caesarian section and had one minute Apgar scores of 9 or 10.

The newborn heart led to prohibitively large errors in volume calculations. However, since the mean VCF is normalized for end diastolic diameter and involves no cube function it is significantly less sensitive to minor dimensional discrepancies. Values for mean VCF obtained from slightly different areas of the mid-portion of the same ventricle were essentially identical and suggested to us that this parameter might be reliably and reproducibly determined in newborn infants. Accordingly, the present study was undertaken to establish the reliability in newborns of the ultrasound determination of mean VCF when compared to angiographic techniques and to establish normal values of mean VCF in the early postnatal period in normal full-term infants.

The excellent correlation of angiographic and echocardiographic determinations of mean velocity of circumferential fiber shortening found in infants in this study establishes the reliability of the noninvasive determination and confirms the work done by Cooper et al. in adults. The normal mean values obtained in this study (1.51 ± 0.04) lie between those obtained in adults by Cooper et al. (1.29 ± 0.23) and Paraskos et al. (1.45 ± 0.08), and those derived angiographically in children by Fisher et al. (1.84 ± 0.63).

The observation that infants studied within the first hour of life show a significant increase in the mean VCF is of particular interest. All of these infants were judged clinically to be vigorous and in excellent health immediately after Caesarian section although stable values were not achieved until thirty minutes of life. The early increase that was observed in mean VCF most likely reflects the alterations in cardiac loading that result from the increase in pulmonary blood flow attendant to the onset of pulmonary ventilation. It would appear less likely that initial values of mean VCF are truly depressed, either because of intra-partum hypoxia or the rise in systemic vascular resistance associated with clamping the umbilical cord.

Mean VCF is easy to measure noninvasively after the attainment of adequate skill in echocardiographic technique. In our series appropriate quality recordings could be obtained in 90% of infants studied. The examination has no risk, and can be repeated as necessary. Only in patients with markedly atypical chamber position or orientation secondary to cardiac rotation is the geometry altered in such a way as to make the index unreliable.

The normal data obtained in the present study provide a framework for the assessment of left ventricular contractile state in sick newborns with or without abnormal cardiac anatomy, since questions arise so frequently at this age concerning the degree of cardiac compensation in various disease states.

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References


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