Accuracy of echocardiography for assessing aortic root diameter¹

Gary S. Francis, Arthur D. Hagan, James Oury, and Robert A. O'Rourke²

From the Cardiology Division, Department of Medicine, the Clinical Investigation Center, and Thoracic Surgery Service, Naval Regional Medical Center, San Diego, California, and the University of California School of Medicine, San Diego, California, U.S.A.

The normal range for aortic root diameters employing the echocardiographic continuous recording technique was determined in 159 adult subjects without aortic valve disease or hypertension. In order to evaluate the accuracy of this noninvasive technique, the aortic root diameters as measured by ultrasound before operation in 31 patients with aortic valve disease were compared with their respective aortic annulus diameters as determined at the time of valve replacement.

The 159 normal subjects consisted of 78 men and 81 women whose ages ranged from 18 to 74 years (average 38). The normal range of aortic root diameters in this group was 17 to 33 mm (mean 23.7). A significant difference ($P < 0.001$) in aortic root diameters existed between men and women which could not be explained by differences in body surface area. The mean diameter among the 81 women was 22.4 ± 3.3 mm (1 SD) compared to the mean diameter in the 78 men of 25 ± 3.5 mm. These results indicate a normal range for aortic root diameters which is significantly lower than previously reported.

The aortic root diameter which was measured preoperatively by ultrasound in the 31 patients with aortic valve disease averaged 25.1 ± 1.9 mm and did not differ significantly from the actual aortic annulus diameter of 25.5 ± 2.6 mm measured at the time of surgery. The aortic root measurements by echo were within 2 mm of the corresponding annulus diameter in 25 of the 31 operated patients (80%).

Echocardiography is a well-established, reliable noninvasive technique for evaluating various types of heart disease. Evaluation of the aortic valve and measurement of the aortic root diameter are routinely included in every echocardiographic examination. Previous investigators have reported different values for the normal range of aortic root diameter with echo measurements, varying from a low of 20 mm to a high of 38 mm and mean values ranging from 27 to 34 mm (Feigenbaum, 1972; Gramiak and Shah, 1968, 1970; Goldberg, 1971). No standardized method for obtaining the aortic root diameter or for assessing the accuracy of the echocardiographic measurement have been established. Accordingly, the purpose of this study was to define better the range of normal aortic root dia-

meter and to assess the accuracy of the ultrasound continuous recording technique for making this determination.

Methods

A group of 159 normal subjects was studied. This group included 78 men and 81 women whose ages ranged from 18 to 74 years (average 38). None of these subjects had evidence of aortic valve disease, hypertension, or an enlarged aortic root on chest x-ray.

A second group of 31 patients with aortic valve disease was studied before undergoing aortic valve replacement.

All patients were examined in the supine or left lateral decubitus position. Recordings were obtained using a commercially available Picker Ultrasonoscope interfaced with a Honeywell strip chart recorder, and employing a 2.25 MHz transducer with a focal depth of 5 cm.

Echoes from the aortic root were obtained easily by first locating the mitral valve by positioning the transducer in the third or fourth intercostal space along the left sternal border. The transducer was then directed medial and superior to identify the anterior wall of the

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aortic root, the aortic valve leaflets, and the posterior wall of the aortic root. Care was taken to record distinct echoes from the inner aspect of both the anterior and the posterior walls of the aortic root in order to obtain accurate measurement of the internal diameter (Fig. 1). Only recordings in which aortic valvular tissue was visualized were included in the study. The internal aortic root diameter was measured where the best recordings of the two inner walls of the aorta were obtained. All measurements were made by two of the authors independently and obtained with calipers at both end-diastole and end-systole. The QRS complex of the electrocardiogram was used to define end-diastole, and closure of the aortic leaflets on the echocardiogram was used to determine the point of end-systole. Measurements were obtained as depicted by the arrows in the Fig.

The exact diameter of the aortic root at the level of the valve was determined in the 31 patients with aortic valve disease at the time of operation by employing a metal sizer.

Results

The aortic root diameter obtained by echo in the normal group ranged from 17 to 33 mm with a mean value of 23.7 mm. The mean aortic root size per square metre (m^2) of body surface area measured $14.1 \text{ mm}/m^2$ with a range from 9 to $19 \text{ mm}/m^2$. Correction for body surface area did not reduce the variability in normal aortic root size. There was no significant difference in measurements obtained at end-diastole or end-systole. The mean aortic root diameter in the men was $25 \pm 3.4 \text{ mm}$ (1 SD) and was significantly greater ($P < 0.001$) than the mean

diameter in the women which averaged $22.5 \pm 3.3 \text{ mm}$. This difference in aortic root size between men and women was not explained by the difference in body surface area.

The measurements obtained before operation in the 31 patients who underwent aortic valve replacement were compared to the actual aortic root size as measured directly at the time of operation. The range of aortic root diameter in this group measured by ultrasound was 18 mm to 33 mm, and the mean was $25.1 \pm 1.9 \text{ mm}$ compared to the range measured at surgery of 18 mm to 29 mm, with a mean diameter of $25.5 \pm 2.6 \text{ mm}$. No significant difference exists between these two measurements ($P > 0.5$), and the aortic root size determined by ultrasound correlated well with the actual aortic root size measured at surgery in the 31 patients ($r = +0.70$).

Discussion

Although normal and abnormal values for the aortic root diameter as measured by echocardiography have been reported (Gramiak and Shah, 1970), there has been considerable variation in the normal values obtained, and the accuracy of the ultrasound measurement has not been validated. It is important that echocardiographers use standardized methods for obtaining aortic root measurements and that the accuracy of these methods be confirmed. Since the earlier publications dealing with ultrasound measurements of aortic root size, improved equipment has become available which utilizes a continuous

FIG. Diagram on the left shows arrows at end-diastole where the internal diameter of the aortic root was measured. ECG=electrocardiogram, RV=right ventricular wall, AAR=anterior wall of the aortic root, AV=aortic valve, PAR=posterior wall of the aortic root, LA=left atrial wall.

recording technique and results in better quality recordings.

We feel that the lower range and mean values of aortic root diameters in our normal group as compared to earlier reports result from several factors. First, the improved quality of the echocardiograms with the continuous recording technique made the determination of correct measurement points easier. Second, care was taken to measure only the distance between the internal echo (inner walls) of the anterior and the posterior aortic root. And finally, measurements were made only from tracings with echoes from the aortic leaflets present in the recording in order to avoid obtaining measurements in the left ventricular outflow tract. This is important since Hagan *et al.* (1974) have demonstrated that the superior portion of the interventricular septum moves in the same manner as the anterior aortic root.

It should be pointed out that the aortic root measurements obtained by ultrasound represent the diameter at the annulus since the echo beam passes through the root at the level of the valve leaflets.

The diameter of the annulus in the group with aortic valve disease was not as large as might have been anticipated since most of these 31 patients demonstrated dilatation of the ascending aorta on x-ray. Though it is usually not possible to obtain ultrasound recordings of the ascending aorta, measurement of the internal diameter of the aortic annulus by echo is quite accurate. The preoperative measurement by echo was the same as measured at surgery in 11 of the 31 patients, and within 2 mm in an additional 14 of the 31. Cardiac surgeons may find such predictive values useful when contempla-

ting aortic valve replacement, especially in younger patients when the root size appears to be too small to accept a prosthesis or mounted heterograft.

It is of interest to note that the aortic root size was significantly smaller in women than men, but this could not be explained on the basis of body surface area.

Conclusions

This echocardiographic study using the continuous recording technique in 159 subjects revealed a smaller range and mean diameter of the normal aortic root than previously reported by other investigators who have employed the Polaroid exposure method. Preoperative measurements obtained in 31 patients who underwent aortic valve replacement confirm the accuracy for this technique for assessing root size at the level of the aortic valve leaflets.

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Requests for reprints to Dr. Gary S. Francis, Cardiology Division, Naval Regional Medical Center, San Diego, California 92134, U.S.A.