Accuracy of Matrix-Array Three-Dimensional Echocardiographic Measurements of Aortic Root Dilation and Comparison with Two-Dimensional Echocardiography in Pediatric Patients

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Background: Cardiac magnetic resonance imaging has demonstrated that the aortic root may be dilated in a dimension that two-dimensional echocardiography (2DE) is not able to interrogate. In the standard parasternal long-axis view, only a portion of the aortic root in the anteroposterior (AP) dimension can be visualized, as opposed to three-dimensional (3D) echocardiography (3DE), which can capture the entire root in an infinite number of planes. The purposes of the present study were to compare measurements of dilated aortic roots between 3DE and 2DE and to evaluate interobserver variability on 3DE.

Methods: Thirty-one patients (median age, 13 years) with aortic root dilation were identified. Two-dimensional echocardiographic images and full-volume electrocardiographically gated 3D echocardiographic (3DE) images were obtained. Two blinded observers measured six dimensions of the aortic root in the short-axis view: three in the AP dimension and three in the transverse dimensions. Two-dimensional echocardiographic measurements were made by a third blinded observer. The largest AP 3DE measurement was compared with two-dimensional echocardiographic measurements. Interobserver 3DE measurements were also compared.

Results: The median aortic root *Z* score was +2.63. Maximum 3DE measurement in any plane of the root size was significantly greater than on 2DE ($P < .0001$). The largest AP dimension by 3DE was significantly greater than on 2DE ($P = .001$). There was no significant interobserver variability for the largest dimension or those in the AP dimension, but a difference was found in the transverse dimension ($P = .02$).

Conclusions: Three-dimensional echocardiography compares favorably with 2DE in the evaluation of aortic root dilation in patients with known histories of aortic root disease. Three-dimensional echocardiography found that the largest diameter measured was significantly larger than on 2DE. The interobserver variability of 3DE is low, particularly in the AP dimension and in identifying the largest diameter. Three-dimensional echocardiography can be a useful technique in the periodic surveillance of patients with aortic root dilation. (J Am Soc Echocardiogr 2012;25:287-93.)

Keywords: Aortic root, 3D echocardiography, Congenital heart disease, Dilation

Aortic root dilation is a common manifestation found in many forms of congenital heart disease. Examples of frequently encountered diseases in which aortic root dilation is a component include Marfan's syndrome, Loeys-Dietz syndrome, and bicuspid aortic valve disease.[1-5] Aortic root dilation is also commonly found among other types of cardiac disease, such as conotruncal defects and postoperatively after the Ross procedure.[6,7] In all of the above examples, continued surveillance at regularly scheduled intervals to measure the aortic root is the recommended clinical management. Currently, two-dimensional (2D) echocardiography is the modality of choice to follow the dilation of the aortic root. A theoretical disadvantage of measuring the aortic root using 2D echocardiography is the underestimation of the largest diameter. When measuring the aortic root as typically performed in the parasternal long-axis view, 2D echocardiography interrogates the aortic root in primarily an anteroposterior (AP) dimension. However, cardiac magnetic resonance imaging (MRI), which typically measures the aortic root in the short axis, has demonstrated that actual root dilation may be in other dimensions, and thus 2D echocardiography may underestimate the actual root size and not capture the largest diameter between aortic cusps.[8]

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Abbreviations

AP = Anteroposterior

MRI = Magnetic resonance imaging

3D = Three-dimensional

3DE = Three-dimensional echocardiographic

2D = Two-dimensional

2DE = Two-dimensional echocardiographic

Three-dimensional (3D) echocardiography with the matrix-array transducer allows the reader to manipulate the image in an infinite number of planes. With this capability, the analyzer is able to delineate the largest diameter between cusps of the aortic root. However, 3D echocardiography has not been used consistently in the assessment of the aortic root in a pediatric population up to this point. The objectives of our study were to analyze dilated aortic roots in a pediatric population using 3D echocardiography and to compare these findings with those demonstrated using 2D echocardiography to assess for differences in measurement as well as the feasibility of 3D echocardiography in this clinical context. The capability of finding the largest diameter could make a difference in therapeutic options, because one of the key factors in the decision making for aortic root replacement is largest diameter.[9] Although there have been 3D echocardiographic (3DE) studies of the aortic valve in the pediatric population, these studies did not compare the results with those of 2D echocardiography but instead compared the 3DE findings with the morphology and severity of disease found at the time of surgery.[10] However, with the growing use of 3D echocardiography and its clinical applicability, this modality may be able to more feasibly measure the aortic root. The purposes of our study were to evaluate and to compare 2D echocardiographic (2DE) and 3DE measurements of dilated aortic roots and to determine differences in reproducibility.

METHODS

Study Population

The study population consisted of 33 pediatric patients identified prospectively by examining the daily echocardiography schedule for patients whose indication was aortic root dilation. The patients were aged 6 to 20 years (median, 13 years). If a patient was found to have aortic root dilation, 3D echocardiography was performed at the conclusion of 2DE image acquisition. Patients were enrolled in the study from August 2009 through September 2010. The weights and heights of all patients were recorded, and body surface areas were calculated.[11] The clinical details of the study subjects can be found in Table 1. Patients were included in the study if they were of age to cooperate for the acquisition of 3DE images and also had aortic root dilation, defined by a Z score > 2.[12] Patients were excluded if they were not able to pause their breathing for four cardiac cycles or other forms of heart disease, such as conotruncal defects, were present. Although patients with conotruncal defects or postoperative cardiac pathology such as the Ross procedure may have aortic root dilation, for the purposes of this study, we sought to evaluate a more uniform patient population. The study was undertaken using a protocol approved by the Seattle Children's Hospital Institutional Review Board. Consent and assent were obtained from all subjects and their legal guardians.

Echocardiographic Examination

Patients underwent comprehensive echocardiographic examinations while lying in the supine or left lateral semirecumbent position. No sedation was used for the examinations. The 2DE images were acquired using a Phillips iE33 ultrasound system (Philips Medical Systems, Andover, MA). At the conclusion of 2DE image acquisition, 3DE images were obtained by one of the four investigators after institutional review board–approved verbal assent was obtained. All 3DE images were obtained during the same session as 2DE image acquisition. Full-volume, electrocardiographically gated 3DE images were obtained from a parasternal view using a 1-MHz to 4-MHz matrix-array transducer. All data sets were acquired while subjects paused their breathing for a total of four cardiac cycles. The 3DE data set was then evaluated to ensure that the entire aortic root was optimally scanned with minimal spatial and temporal artifacts. Several full-volume data sets were obtained for each patient to enable the analyzer to choose the clip with the best resolution and the least amount of stitch artifact. At the conclusion of the 3DE volume acquisition, the images were downloaded to a 3DE workstation for analysis. Thirty-one patients with aortic root dilation were studied using 3D echocardiography. All of the 3DE examinations were completed without complications. We did not have to abort a 3DE examination because of patient cooperation issues. The 2DE and 3DE studies were completed during the same scanning period. The total time for the 3DE acquisition was typically <5 min. The 3DE image postprocessing time period was never more than 20 min and was typically 10 min. We attempted to image two patients who met the inclusion criteria using 3D echocardiography, but the imaging windows were poor and prevented adequate image acquisition, resulting in a success rate of 94% for possible patients meeting the inclusion criteria.

Echocardiographic Analysis

The 2DE studies were performed in the parasternal long-axis view using standard practice and protocol to obtain the largest diameter of the aortic root during systole.[12] The corresponding 3DE images were then analyzed independently by two observers (C.V.N. and B.D.S.), using Phillips 3D software (QLAB version 6.0; Philips Medical Systems). These observers were blinded to each other's results and the 2DE images. A separate observer measured aortic root dimensions using 2D echocardiography. The 3DE full-volume images were analyzed to find the image that displayed the aortic root in the short axis with the most clarity of the inner borders. Brightness and contrast were adjusted to optimize signal-to-noise ratio. The image was then manipulated in various planes to isolate the largest diameter of the aortic root during systole; Figure 1 demonstrates the multiplanar reformat mode. The multiplanar reformat mode demonstrates three orthogonal views: the long-axis, short-axis, and oblique coronal views. The multiplanar reformat is based on simultaneous slices of the 3DE full-volume data set and is not simply a compilation of various 2DE views. The reviewers were able to manipulate the plane of the long-axis and coronal view to obtain the largest aortic root dimension, and the measurement was then determined in the short-axis view. Six measurements were then made of the aortic root in an attempt to find the largest diameter; see Figure 2 for an aortic root imaged using 3D echocardiography complete with all six measurements, as well as a schematic of the aortic root in systole with the corresponding measurements. These measurements were between the various commissures and cusps to improve reproducibility by using defined landmarks. These measurements were assigned to one of two categories: AP dimensions or transverse dimensions. The measurements in the AP dimensions were from the right coronary cusp to the noncoronary cusp, the right coronary cusp to the left-non commissure, and the right coronary cusp to the left coronary cusp. The transverse dimensions were defined as measurements