Brief Report

Three-Dimensional Geometry of Aortic Valve: A new Trial of Visualization With Real-Time Three-Dimensional Echocardiography

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Aortic regurgitation (AR) may be congenital or acquired, caused by either abnormalities of the aortic root or the valve itself. Surgical management is recommended in patients with significant AR enough to reduce left ventricular function. Aortic valve (AV) replacement is a common surgical strategy for significant AR, but in some patients who have annuloaortic ectasia (AAE) without leaflets abnormalities, valve-preserving aortic replacement can be considered[1]. Therefore, the knowledge of aortic annulus and leaflets geometry is very important in considering the surgical strategy.

Recently developed real-time 3-dimensional (3-D) echocardiography can be used to provide fast and noninvasive estimates with high image resolution that is more accurate and physiologically realistic than those measured by conventional imaging techniques[2]. We have already demonstrated the geometry of the mitral leaflets and annulus in patients with ischemic functional mitral regurgitation using this system[3-5]. In the present study we evaluated the 3-D geometry of the aortic annulus and leaflets in normal subjects and in patients who had different etiologies of significant AR.

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Methods

We performed real-time 3-D echocardiographic examination in 3 normal subjects and 5 patients who had different etiologies of significant AR: AR with AAE (n=2), AR with degenerative valve (n=1), AR with leaflet prolapse (n=1), and AR with bicuspid AV (n=1). Left ventricular (LV) systolic function and degree of AR were quantified by using 2-dimensional echocardiography. Transthoracic volumetric images were acquired by the real-time 3-D echocardiography system in apical views. By utilizing our original software system for 3-D aortic valve analysis, we radially cropped the 3-D volumetric data into 18 planes to mark and trace the aortic annulus and leaflets. Then, 3-D images of the aortic leaflets and annulus were reconstructed in early diastole for the 3-D quantitative measurements. Aortic annular size was calculated by using those 3-D data sets (area, circumference). The aortic leaflets' surface area on LV side was calculated from the 3-D data as well. All subjects provided written informed consent to the study protocol, which was approved by the Committee for the Protection of Human Subjects in Research at Kawasaki Medical School.

Table 1. Clinical characteristics and 3-D measurements of aortic annulus and leaflets

	Normal 1	Normal 2	Normal 3	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5
Age (y)	65	68	57	66	64	55	58	62
Sex	Male	Male	Female	Female	Female	Female	Female	Male
AR etiology	·	·	·	AAE	AAE	Degenerative	Prolapse	Bicuspid
LV								
EDV(mL)	80	78	88	78	133	164	123	186
ESV(mL)	31	28	27	21	37	87	64	74
EF (%)	61	64	69	73	72	46	47	60
AR								
RV (mL)	·	·	·	55	81	105	81	110
ROA (cm^2)	·	·	·	0.24	0.39	0.49	0.38	0.34
Aortic annulus								
Area (mm^2)	531	516	544	990	870	553	462	663
Circumference (mm)	82.5	84.1	84.0	114.5	106.3	84.4	77.3	93.3
Aortic leaflets								
Surface area (mm^2)	604	618	639	1540	1420	720	622	845

AR, aortic regurgitation; AAE, annuloaortic ectasia; AV, aortic valve; LV, left ventricle; EDV, end-diastolic volume; ESV, end-systolic volume; EF, ejection fraction; RV, regurgitation volume; ROA, regurgitant orifice area.

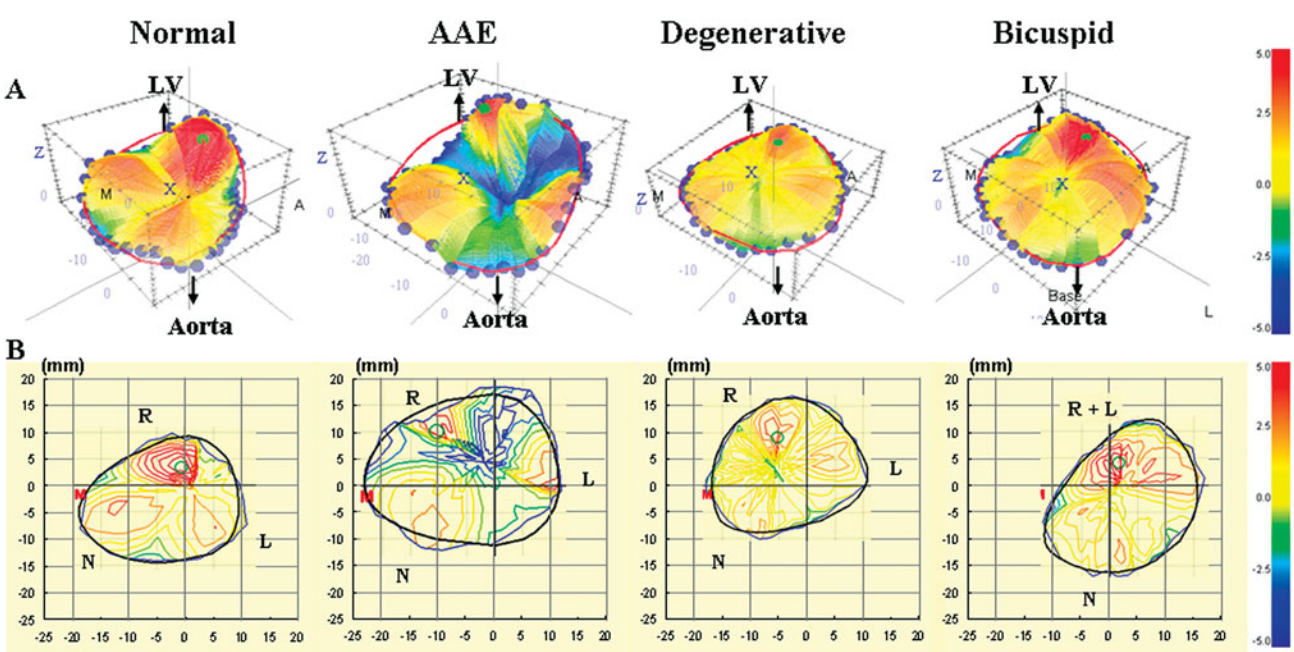

Fig. 1. Three-dimensional images of the aortic leaflets and annulus in early diastole obtained from subjects: A, Anatomic 3-D images. The anatomic 3-D images shows the actual configuration of the annulus and leaflets with surface colorations. B, 3-D surface images in the vertical view from the LV. The aortic leaflets' configuration was represented in contour. R, right coronary cusp; L, left coronary cusp; N, non coronary cusp; LV, left ventricle

Results

We could visualize and measure the AV annular and leaflets geometry and size by using novel software system for AV with 3-D transthoracic echocardiography not only in 3 normal subjects but also in 5 patients with significant AR. Table 1 shows baseline characteristics, measured 2-D parameters, and calculated 3-D parameters in each subject.

In normal subjects, we could see the three-curved, semilunar and non-planar geometry of aortic annulus and define three normal leaflets. In patients with AAE, the area and circumference of aortic annulus and the aortic leaflets' surface area were apparently large. We could find that the non-planar curvature of the annulus seemed to be blunted in a patient with degenerative AV. In a patient with bicuspid AV, the size of the aortic annulus was larger than that of normal subjects, and we could define only two leaflets on the aortic leaflets' configuration (Table 1, Figure 1).

Discussion

Although there have been many studies of the saddle-shaped mitral annulus, the geometry of aortic annulus and leaflets has not been studied with real-time 3-D echocardiography. Like the mitral annulus, the annular configuration of aortic valve also appeared curved-shaped and non-planar because aortic leaflets were attached in a semilunar fashion rather than a ring-like planar fashion[6,7]. Therefore, precise and comprehensive understanding of the 3-D geometric changes of the aortic annulus and leaflets is needed in various clinical settings, especially for preoperative evaluation before AV surgery. In this study, we successfully demonstrated the three-curved, non-planar configuration of aortic annulus and quantified their circumferences and areas in normal subjects and in patients with significant AR who had different etiologies using our novel software system with real-time 3-D echocardiography.

Even though this study was performed with a small number of subjects, it was enough to show a new possibility of the AV geometric evaluation. Further investigations are needed to clarify the geometric differences of various AV diseases.

In conclusion, this 3-D technique would be helpful to understand the 3-D geometry of AV, especially before AV surgery, and to make a proper decision for surgical strategy for each individual.

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