Multiplanar Reconstruction of Three-Dimensional Transthoracic Echocardiography Improves the Presurgical Assessment of Mitral Prolapse

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Background: The aim of this study was to evaluate the value and accuracy of multiplanar reconstruction (MPR) of three-dimensional (3D) transthoracic echocardiographic data sets in assessing mitral valve pathology in patients with surgical mitral valve prolapse (MVP).

Methods: Sixty-four patients with surgical MVP and preoperative two-dimensional (2D) and 3D transthoracic echocardiography were analyzed. The descriptions obtained by 3D MPR and 2D were compared in the context of the surgical findings.

Results: Two-dimensional echocardiography correctly identified the prolapsing leaflets in 32 of 64 patients and 3D MPR in 46 of 64 patients (P = .016). Among the 27 patients with complex pathology (ie, more than isolated middle scallop of the posterior leaflet prolapse), 3D MPR identified 20 correctly, as opposed to 6 with 2D imaging (P < .001).

Conclusion: Interpretation of 3D transthoracic echocardiographic images with MPR improved the accuracy of the description of the MVP compared with 2D interpretation. This added value of 3D MPR was most important in extensive and/or commissural prolapse. (J Am Soc Echocardiogr 2009;22:907-13.)

Keywords: 3D transthoracic echocardiography, Mitral valve prolapse, 3D multiplanar reconstruction

Three-dimensional (3D) echocardiography has become an invaluable tool in the understanding of normal and abnormal mitral valve (MV) geometry[1,2] and in the determination of the mechanism and quantification of mitral regurgitation.[3,4] It is of special interest in the management of patients with MV prolapse (MVP), because the predictability of MV repair depends on the anatomy and mechanism of the prolapse. Indeed, early MV repair in asymptomatic patients restores their survival to normal[5] but should be considered only if the operative risk is low and if there is a high likelihood of valve repair.[6] In commissural and complex prolapse, the description of the MV with two-dimensional (2D) transthoracic echocardiography (TTE) is still challenging and occasionally misleading. Real-time 3D TTE allows an accurate description of the MV,[7,8] but the interpretation of 3D volume-rendered images requires experience and a careful choice of rendering angles and settings. Up to 30% of patients[8-11] were excluded from studies evaluating 3D transthoracic echocardiographic volume-rendered images for the definition of MVP because of inadequate image quality. Multiplanar reconstruction (MPR) of a 3D transthoracic echocardiographic dataset, however, presents the data in familiar 2D tomographic images and is therefore not subject to the problems that arise from volumetric rendering of noisy images. It is thus broadly accessible, even to echocardiographers without extensive experience with 3D TTE.

The aim of our study was to assess the additive value of real-time 3D MPR TTE with 2D TTE compared with 2D TTE alone in the description of the MVP in patients with MV surgery. We studied the ease and accuracy of 3D MPR TTE compared with 2D TTE, with the surgical description of the valve as a reference.

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METHODS

Patient Selection

Sixty-four patients were included in the study from September 2005 to October 2008. From September 2005 to December 2006, we retrospectively included 19 patients, who had underwent 2D TTE and 3D TTE prior to MV surgery for MVP. From December 2006 to October 2008, we prospectively included 45 patients who were scheduled for MV surgery and performed 2D and 3D TTE. We did not exclude patients in atrial fibrillation or patients with other valvular disease or coronary artery disease, nor was there any exclusion on the basis of echocardiographic image quality.

Echocardiographic Examination

Two-Dimensional Echocardiography. Prior to surgery, 2D TTE was performed using a Philips Sonos 7500 ultrasound system and S3 transducer or a Philips iE33 ultrasound system with an S5-1 transducer (Philips Medical Systems, Andover, MA). Two-dimensional echocardiography included standard parasternal and apical views. Left ventricular dimensions and function were measured as recommended by the American Society of Echocardiography.[12] Two-dimensional color Doppler was used to determine the direction of the regurgitant jet. Three to 5 beats were analyzed and averaged. Mitral regurgitation was semiquantitatively graded as 0+ to 4+.

Three-Dimensional Echocardiography and MPR Mode Analysis. Three-dimensional TTE was performed during the same examination as 2D TTE, with a technique using an X3-1 matrix array transducer and Philips iE33 system. During a breath-hold period, a gated full-volume acquisition of an 80° × 80° pyramid over 4 heartbeats was obtained from the parasternal and apical windows. Offline analysis was performed on the recorded images using Philips Q-lab version 4.0 software with the 3D-Q plug-in.

The 3D full-volume dataset was displayed in the MPR mode, which provided 3 planar views and a fourth view showing the orientation of the planes relative to the volume. Within each of the planar views, the location of the intersection with the other imaging planes was shown by reference lines. On each image, the reference lines could be moved to change the orientation and the intersection with the other planes.

To evaluate the MVP, the 3D volume data set was preferentially acquired from a parasternal window (Figure 1). From the parasternal long-axis view, the reference lines were oriented to obtain a parasternal short-axis view of the left ventricle, parallel to the mitral annulus and cutting through the plane of coaptation of the MV during systole. The third view was a horizontal plane of the MV from above. The short-axis view allowed us to determine precisely the location of the longitudinal plane. The prolapse was identified on the longitudinal plane. On the short-axis view, the location of the longitudinal plane, where the prolapse was identified was moved across the MV from the anterolateral to the posteromedial commissure. The coaptation of the leaflets was examined scallop by scallop on the longitudinal plane. For each scallop, the orientation of the longitudinal plane was readjusted to cut perpendicularly the plane of the leaflets' coaptation.

If it was not possible to analyze the MV from the parasternal window, we analyzed it from the apical window (Figure 2). Two perpendicular imaging planes were oriented such that they intersected the major axis of the left ventricle, to obtain one 4-chamber apical view and one 2-chamber apical view. The third plane intersected the short axis of the left ventricle, parallel to the mitral annulus, cutting through the plane of coaptation of the MV during systole. This plane provided the reference image to determine precisely where the longitudinal plane crossed the MV. The leaflets' coaptation was examined in the longitudinal plane (ie, approximately in an apical 2-chamber view).

An example of the diagnosis of A1 prolapse is illustrated in Movie 1.

Description of the MV. The Carpentier nomenclature[13] was used to describe the mitral leaflets (ie, A1, A2, and A3 = lateral, middle, and medial scallops of the anterior leaflet; P1, P2, and P3 = lateral, middle, and medial scallops of the posterior leaflet). The function of each scallop was studied on 2D and 3D TTE. Each scallop was classified as normal (normal coaptation), flail (eversion of leaflet tip into left atrium during systole due to chordal rupture), or prolapsing.

MVP was defined according to the American College of Cardiology and American Heart Association 2006 guidelines[6]: prolapse of ≥2 mm superior to the mitral annulus in the long-axis parasternal view.

Analysis

To assess the quality of 3D MPR images, semiquantitative grading[9] was used: 1 = poor image quality, 2 = fair image quality, 3 = good image quality, and 4 = excellent image quality.

All cases were analyzed blinded to the surgical results. The 2D data sets were analyzed first, and their interpretation was noted. The 3D data sets were analyzed a second time by the same observer who was aware of the 2D results. Twenty-four cases were analyzed separately by two independent observers (A.-S.B. and I.S.) who were mutually blinded and blinded to the surgical results to determine interobserver variability. The remaining 40 cases were analyzed by the same observer (A.-S.B.). After both observers had analyzed the images, the surgical reports were retrieved and compared with the echocardiographic findings. The 2D data sets were analyzed first, and their interpretation was noted. The 3D data sets were analyzed a second time by the same observer who was aware of the 2D results.

Quantitative variables are expressed as mean ± SD. Each scallop (A1, A2, A3, P1, P2, and P3) was assessed individually for each patient.

Differences in diagnostic accuracy between the two methods were assessed with McNemar's test. A 2-tailed P value < .05 was considered statistically significant. Interobserver agreement was assessed using the κ test.

Surgical Assessment

Two-dimensional intraoperative transesophageal echocardiography was performed by the anesthesiology team in patients who underwent MV repair. The surgeons and the anesthesiologists had access only to the preoperative 2D transthoracic echocardiographic images and report, which mentioned only the 2D description of the MV. They were both blinded to the 3D MPR images and interpretation. The prolapsing segment or scallop was identified by visual inspection. All MV surgeries were performed by the same surgical team. The surgical reports were considered as the reference for the assessment of MV disease. The accuracy of 2D and 3D findings was determined in comparison with surgical findings.

RESULTS

Population Characteristics

Sixteen female patients (25%) and 48 male patients (75%) were included, with ages ranging from 11 to 82 years (mean, 55.6 ± 15.2 years). Fifty-five patients (86%) were in normal sinus rhythm, and 9 patients (14%) were in atrial fibrillation. Two-dimensional and 3D TEE were performed during the same examination, 1 day to 3 months prior to surgery.

The mean end-systolic left ventricular diameter was 36.2 ± 5.7 mm. The mean end-diastolic left ventricular diameter was 59.4 ± 6.2 mm. The ejection fraction was normal in all patients (mean, 66 ± 8%). Mitral regurgitation was graded as 3+ to 4+ in all patients.

Acquisition and Analysis of 3D MPR Images

Acquisition of 3D full-volume images required a few seconds of breath hold. The mean interpretation time of 3D MPR images was 4.1 ± 1.9 minutes per patient.

The average overall quality of the 3D MPR images was good. The quality was lower for patients with irregular heart rhythm (9 patients).