The Value of Three-Dimensional Echocardiography Derived Mitral Valve Parametric Maps and the Role of Experience in the Diagnosis of Pathology

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Background: Accurate segmental mitral valve (MV) analysis is essential for surgical planning. Although real-time three-dimensional (3D) transesophageal echocardiography has improved the ability to visualize the MV, accurate localization of MV pathology from 3D transesophageal echocardiographic images still remains experience dependent. Three-dimensional parametric maps of the MV obtained from these images further simplify the visualization of MV anatomy. The aims of this study were to examine whether 3D parametric maps of the MV could improve the diagnostic accuracy in localizing pathology and to determine their usefulness for readers with different levels of training.

Methods: Five novice (American Society of Echocardiography [ASE] level 2), three intermediate-level (ASE level 3; <500 MV cases), and two expert (ASE level 3; >500 MV cases) readers interpreted MV segmental anatomy in 50 patients (30 with degenerative MV disease, 20 with normal MVs). All readers reviewed two-dimensional and 3D transesophageal echocardiographic and 3D parametric maps at sequential weekly sessions. The results were compared with surgical findings.

Results: Expert readers were the most accurate irrespective of image type. Novice readers were the least accurate and commonly misinterpreted P2 and P3 scallops. Their accuracy was highest when interpreting 3D parametric maps (from 87% with two-dimensional transesophageal echocardiography to 92%). Intermediate readers' accuracy fell between the other two groups irrespective of image type and showed no change with the use of parametric maps.

Conclusions: This is the first study to show that the interpretation of 3D parametric maps improves the accuracy of localization of MV pathology by novice readers. Therefore, parametric maps should be used routinely by less experienced readers during the assessment of degenerative MV disease. (J Am Soc Echocardiogr 2011;24:860-7.)

Keywords: Three-dimensional echocardiography, Mitral valve, Mitral regurgitation

Accurate preoperative assessment of the mitral valve is critical in the surgical management of patients with severe mitral regurgitation. This information determines whether patients should undergo valve repair or replacement, which has implications in terms of timing of surgery and long-term morbidity and mortality.[1] Although two-dimensional (2D) transthoracic echocardiography and transesophageal echocardiography (TEE) are part of the standard assessment of mitral valve anatomy, three-dimensional (3D) transthoracic echocardiography and TEE have been shown to facilitate the understanding of more complex abnormalities of the mitral valve apparatus and individual scallop identification.[2-13] However, even with 3D echocardiography, accuracy in diagnosing mitral valve pathology is still not perfect.[8] Specifically, mitral valve pathology involving the posteromedial and less commonly the anterolateral commissures is often missed or erroneously interpreted.[8,9]

Although 3D echocardiography provides "realistic" images of the mitral valve, training is required to differentiate normal anatomy from dropout artifacts. The majority of studies demonstrating improvement in diagnosing mitral valve pathology using 3D echocardiography have included readers with significant 2D (and presumably 3D) echocardiographic experience. It is plausible that readers without sufficient experience may not adequately harness the information available from 3D echocardiography.

Three-dimensional parametric maps transform the 3D images of the mitral valve into color-encoded topographic displays of mitral valve anatomy, in which the color gradations indicate the distance of the leaflet from the mitral annular plane toward the left atrium. Thus, in mitral valve prolapse, the location of maximal prolapse can be easily appreciated by the presence of orange color on the affected leaflet. We hypothesized that these 3D parametric maps could improve the interpretation

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Abbreviations

ASE = American Society of Echocardiography

RT3DE = Real-time three-dimensional echocardiography

3D = Three-dimensional

2D = Two-dimensional

TEE = Transesophageal echocardiography

of mitral valve pathology even in inexperienced readers. Accordingly, the aims of this study were (1) to examine whether 3D parametric maps could improve diagnostic accuracy in localizing mitral valve pathology and (2) to determine to what extent reader's level of training affects the utility of 3D parametric maps on the sensitivity, specificity, and accuracy of the TEE-based interpretation of mitral valve pathology.

METHODS

Patient Population

We retrospectively identified 50 patients (mean age, 59 ± 15 years; 37 men) who had undergone clinically indicated TEE and had standard 2D and 3D transesophageal echocardiographic studies, of whom 20 had normal mitral valves and 30 had severe mitral regurgitation requiring surgical intervention. The localization of mitral valve pathology in the patients with mitral regurgitation was confirmed by surgical exploration. All 50 patients were in normal sinus rhythm. The institutional review board approved this study.

Image Acquisition and Formats

Two-dimensional TEE was performed according to a standard protocol using the iE33 ultrasound system (Philips Medical Systems, Andover, MA).[2,5,14-17] The following midesophageal, zoomed views of the mitral valve were obtained: four-chamber view (0°), bicommissural view (45°), two-chamber view (90°), and long-axis view (125°). These 2D images were exported for interpretation as digital cine loops.

Real-time 3D echocardiography (RT3DE) of the mitral valve was performed using a fully sampled matrix transesophageal echocardiographic transducer (X7-2t). Initially, gain settings were optimized using the narrow-angle acquisition mode, which allows imaging of a pyramidal volume of approximately 30° × 60° without the need for electrocardiographic gating. Zoomed real-time 3D echocardiographic images of the entire mitral valve were then acquired in a single cardiac cycle, resulting in frame rates between 5 and 35 Hz (mean, 9 ± 5 Hz). Acquisition of 3D data sets was repeated at least three times to ensure optimal image quality.

The 3D images were reviewed offline on an Xcelera workstation (Philips Medical Systems) by a trained echocardiographer. To improve visualization, pyramidal data sets were cropped along designated x-y-z axes or using a manually positioned cropping plane of choice. The images were then oriented from the left atrial perspective with the aortic valve at the 12-o'clock position and exported for interpretation as digital cine loops.

Parametric maps of the mitral valve were generated using commercial software (MVQ, QLAB version 8.0; Philips Medical Systems). Initially, the end-systolic frame was defined as the second-to-last frame before the initiation of mitral valve opening. Then, a long-axis view of the mitral apparatus was used to determine anterior, posterior, anterolateral, and posteromedial annular coordinates (Figure 1). The annulus was manually outlined by defining annular points in multiple planes rotated around the axis perpendicular to the mitral annular plane. The annulus was then segmented to identify leaflet geometry and coaptation points by manually tracing the leaflets in multiple parallel long-axis planes spanning the annulus from commissure to commissure. The reconstructed mitral valve was subsequently displayed as a color-encoded 3D surface-rendered image representing a topographic map of the mitral leaflets (Figure 1D). This parametric map of the mitral valve was oriented as viewed from the left atrium with the aortic annulus at the 12-o'clock position and exported as a still image.

Interpretation Definitions

We used the mitral valve nomenclature proposed by Carpentier,[18] which divides the posterior leaflet into three scallops: lateral (P1), middle (P2), and medial (P3). The anterior leaflet was divided into three segments: lateral third (A1), middle third (A2), and medial third (A3).

On 2D TEE, a scallop was considered prolapsed if any portion moved above the mitral annular plane during systole.[14] Flail scallop was defined as a free leaflet edge or chordae tendineae detected in the left atrium during systole.[14] Leaflet perforation was defined as the presence of normal coaptation of the leaflets with regurgitant jet originating from the leaflet body, in a location separate from the coaptation line.[14]

For RT3DE, a scallop was considered prolapsed if any of the following features were noted: billowing or hammock shape, coaptation gap with correspondent or adjacent scallops, straight lines from the annulus to the free border delineating the border between a prolapsing and a nonprolapsing scallop, and image of negative relief, depression, or fingerprint corresponding to one or several scallops.[9] Flail scallop on RT3DE was diagnosed as a flail shape or line between the annulus and the free border of the scallops that was directed toward the left atrium. Perforation on RT3DE was diagnosed as a discontinuity in the leaflet surface.

The definition of prolapse from the parametric maps was the presence of a coaptation gap between corresponding segments or billowing represented by color gradations on the leaflet segments (Figure 2). Because of limitations of the parametric maps, flail segments could not be identified, and consequently segmental prolapse was considered a correct answer.

Study Interpreters

Five cardiologists and five cardiology fellowship trainees blinded to the surgical findings were asked to interpret mitral valve segmental anatomy. Expertise was determined according to the American Society of Echocardiography (ASE) standards of training,[19] resulting in five novice (ASE level 2), three intermediate-level (ASE level 3; <500 mitral valve cases), and two expert (ASE level 3; >500 mitral valve cases) readers. Readers initially interpreted the 2D transesophageal echocardiographic images, then after 1 week the 3D transesophageal echocardiographic images, and then after another week the 3D parametric maps. Each mitral valve scallop or segment was classified using the above definitions.

Surgical Inspection and Validation

Intraoperatively, the surgeons described the anatomy of the mitral valve using the same Carpentier classification as the readers. The surgeons had access to the clinical echocardiography reports but were unaware of the interpretations made for this study.