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Assessment of mitral valve geometric deformity in patients with ischemic heart disease using three-dimensional echocardiography

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KEYWORDS

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Abstract *Background:* A full understanding of the geometry of the nonplanar saddle-shaped mitral annulus can provide valuable information regarding the pathophysiology of mitral regurgitation (MR).

Aim of the work: To investigate mitral annular geometric deformities using three-dimensional echocardiography among patients with ischemic coronary illness with and without mitral regurgitation.

Methods: Three-dimensional transesophageal echocardiographic data were acquired intraoperatively from patients with ischemic heart disease with or without associated mitral regurgitation who experienced coronary artery bypass grafting and normal control subjects. The mitral annulus was analyzed for differences in geometry using QLAB software.

Results: Left ventricular ejection fraction was reduced in patients with ischemic heart disease and MR ($n = 21$; Group 1) and without MR ($n = 7$; Group 2) compared with that in normal subjects ($n = 14$; Group 3) (43.4% ± 11.8% and 35.9% ± 13.6% vs. 52.6% ± 9.3%, respectively; $p = 0.015$). Mitral annular height and mitral annular saddle-shaped nonplanarity were significantly lower in Group 1 compared to Group 2 and Group 3 (6.00 ± 1.07 mm, 7.96 ± 0.93 mm and 8.31 ± 1.12 mm; $p < 0.0001$) and (0.19 ± 0.04, 0.26 ± 0.04 and 0.26 ± 0.03; $p < 0.0001$) respectively while mitral annular ellipsicity and Mitral valve tenting volume were significantly higher in the same group (1) (114.82% ± 22.47%, 100.21% ± 9.87% and 97.29% ± 14.37%; $p = 0.0421$) and (2.73 ± 1.11, 2.20 ± 1.39 and 0.87 ± 0.67) respectively. Vena contracta diameter was inversely correlated with the mitral annular height ($r = -0.82$; $p < 0.0001$) and saddle-shaped nonplanarity of the annulus ($r = -0.68$; $p < 0.0001$).

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Conclusion: Among patients with ischemic heart disease, there are significant increases in mitral valve tenting volume and height, and those with mitral regurgitation exhibited a reduced mitral annular height, a shallower saddle shape annulus and losses of ellipsicity of the annulus.

1. Introduction

After myocardial infarction, mitral regurgitation occurs roughly in ten to twenty percent of patients.[1] The mechanisms underlying ischemic mitral regurgitation are multiple and complex and are yet to be fully elucidated; they remain the subject of considerable debate. However, surgical procedures for the mitral valve demand the precise analysis of its anatomy.

The normal mitral annulus has a nonplanar saddle shape[2–5] that is higher at its anterior and posterior points and lower at the anterolateral and posteromedial commissures.[6] Normal annular motion throughout the cardiac cycle helps in leaflet coaptation and valve competence[7], and it has been suggested that this is valuable for reducing mechanical stress on the chordae tendineae and mitral leaflets.[8]

Recent data show that restrictive annuloplasty for the treatment of mitral regurgitation during a coronary artery bypass graft is associated with persistent mitral regurgitation early after the operation in 10–20% of cases and with a higher rate of recurrent mitral regurgitation in 50–70% of cases at the 5-year follow-up.[9,10] These imperfect results highlight the need to create options or concomitant surgical procedures that specifically focus on the causal mechanisms of the condition. Any tool that can potentially help in the development of annuloplasty rings to restore a diseased mitral valve annulus back to a truly normal geometry will be highly beneficial.

Recent advances in technology resulted in high temporal and spatial resolution of the three-dimensional (3D) echocardiography that aids in the quantitative analysis of mitral valve geometry.[11] The aim of this study was to use 3D echocardiographic analysis to investigate mitral annular geometric deformities in patients with ischemic heart disease with and without mitral regurgitation.

2. Subjects and methods

2.1. Study population

This study was conducted between March 2014 and August 2015 (as prospective observational study). We screened 32 consecutive patients who underwent coronary artery bypass grafting. As a control group, we also screened 19 subjects who were referred for a transesophageal echocardiographic study for various etiologies but were found to have no underlying structural cardiac disease. We excluded nine of the screened patients because of the presence of a stitching artifact, aortic valve disease, structural mitral valve disease (flail leaflets or torn chordae), mitral prolapse, atrial fibrillation, or technically inadequate studies; this left 28 patients ischemic heart disease and 14 healthy control subjects, who were enrolled in the study. The study was approved by our institutional review board. Informed written consent was obtained from all the subjects.

2.2. Procedure

Transesophageal echocardiographic images were obtained for all the enrolled subjects, and static mitral annular parameters were accordingly measured at end-systole. Mitral regurgitation was assessed through the measurement of the diameter of the vena contracta which was taken from long-axis at mid-esophageal view and defined as the narrowest part of the mitral regurgitation jet. Vena contracta was defined as severe, moderate, or mild for vena contracta diameters $\geqslant 0.7$ cm, 0.3–0.69 cm, and < 0.3 cm, respectively.[12] The measured annular parameters were compared between patients with ischemic heart disease with mitral regurgitation, patients with ischemic heart disease with no mitral regurgitation, and control subjects. Left ventricular internal dimensions and ejection fraction, were acquired preoperatively within one week of the study by 2 D echocardiographic examination.

2.3. Image acquisition

Complete (two and three dimensional) transesophageal echocardiographic examinations were performed according to recommendations of the American Society of Echocardiography[13] after the induction of general anesthesia, using a Philips iE33 Ultrasound Machine (Philips Healthcare, USA) equipped with a fully sampled 3D X7-2t xMATRIX array transducer (Philips Healthcare).

3D images of the mitral valve were acquired using the full-volume acquisition method. Images were acquired with R-wave gating over four beats; the images covered the entire mitral complex, including the annulus, leaflets, papillary muscles, and aortic valve. An adequate image was defined as en face surgical views of the mitral valve without artifacts.[14]

2.4. Image analysis

Offline quantitative mitral valve analysis was performed on an Xcelera Workstation (Philips Healthcare) equipped with custom software (QLAB MVQ, version 10.3, Philips).

To build a model of the mitral valve annulus, mitral valve images were presented on a quad screen, including three orthogonal planes representing the orthogonal anatomic planes derived from the 3D dataset. To start the analysis, end-systole was tagged on the cine-loop (the end-systolic frame defined as the frame just before aortic valve closure). Image alignment was achieved and a multiplanar projection model was produced by rotating the image on orthogonal planes and aligning the red, blue, and green lines to adjust the mitral valve where it was bisected by the two long-axis planes. The four major annulus reference points were tagged on the appropriate planes to define the anterolateral, posteromedial, anterior, and posterior reference points in the two- and four-chamber views. With regard to editing the nadir and aortic