Magnetic resonance imaging assessment of reverse left ventricular remodeling late after restrictive mitral annuloplasty in early stages of dilated cardiomyopathy

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Objective: Magnetic resonance imaging was used to evaluate left ventricular reverse remodeling at long-term follow-up (3–4 years) after restrictive mitral annuloplasty in patients with early stages of nonischemic, dilated cardiomyopathy, and severe mitral regurgitation.

Methods: Twenty-two selected patients (eligible to undergo magnetic resonance imaging) with mild to moderate heart failure (mean New York Heart Association class 2.2 ± 0.4), dilated cardiomyopathy (left ventricular ejection fraction 37% ± 5%, left ventricular end-diastolic volume 215 ± 34 mL), and severe mitral regurgitation (grade 3–4+) underwent restrictive mitral annuloplasty. Magnetic resonance imaging was performed 1 week before surgery and repeated after 3 to 4 years.

Results: There was no hospital mortality or major morbidity. Two patients died during follow-up (9%), and 2 patients could not undergo repeat magnetic resonance imaging because of comorbidity. New York Heart Association class improved from 2.2 ± 0.4 to 1.2 ± 0.4 ($P < .05$). Mitral regurgitation was minimal at late echocardiographic follow-up. There were significant decreases in indexed (to body surface area) left atrial end-systolic volume (from 84 ± 20 mL/m^2 to 68 ± 12 mL/m^2, $P < .01$), left ventricular end-systolic volume (from 42 ± 14 mL/m^2 to 31 ± 12 mL/m^2, $P < .01$), left ventricular end-diastolic volume (from 110 ± 18 mL/m^2 to 80 ± 17 mL/m^2, $P < .01$), and left ventricular mass (from 76 ± 21 g/m^2 to 66 ± 12 g/m^2, $P = .03$). Forward left ventricular ejection fraction improved from 37% ± 5% to 55% ± 10% ($P < .01$). Indexed left atrial end-diastolic volume did not show a significant decrease (from 48 ± 16 mL/m^2 to 44 ± 10 mL/m^2, $P = .15$).

Conclusion: Magnetic resonance imaging confirms sustained significant reverse left atrial and ventricular remodeling at late (3–4 years) follow-up in patients with nonischemic, dilated cardiomyopathy, and mild to moderate heart failure after restrictive mitral annuloplasty.

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Received for publication May 1, 2007; revisions received Sept 20, 2007; accepted for publication Oct 4, 2007.

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J Thorac Cardiovasc Surg 2008;135:1247-53

0022-5223/$34.00

doi:10.1016/j.jtcvs.2007.10.021

Magnetic resonance imaging (MRI) is currently considered the gold standard for the assessment of left ventricular (LV) function and volumes.[1] Advantages of MRI over echocardiography are the superior image quality and the 3-dimensional quantification possibilities with high reproducibility, implying that smaller sample sizes are needed to prove statistical significance of changes in LV volumes after therapy.[2] MRI may therefore be the most appropriate imaging technique for the evaluation of surgical treatments for heart failure. In a previous study, we presented MRI data on short-term follow-up after restrictive annuloplasty in patients with nonischemic, dilated cardiomyopathy, and severe mitral regurgitation (MR).[3] Significant left atrial (LA) and LV reverse remodeling were noted 2 months after surgery. Moreover, LV ejection fraction (LVEF) improved significantly. However, whether these beneficial effects are sustained at long-term follow-up is not clear.[4] In the current study, the persistence of reverse remodeling at long-term follow-up after restrictive mitral annuloplasty is

Abbreviations and Acronyms

"i"	= indexation to body surface area
LA	= left atrial
LAEDV	= left atrial end-diastolic volume
LAESV	= left atrial end-systolic volume
LV	= left ventricular
LVEDV	= left ventricular end-diastolic volume
LVEF	= left ventricular ejection fraction
LVESV	= left ventricular end-systolic volume
MR	= mitral regurgitation
MRI	= magnetic resonance imaging
NYHA	= New York Heart Association

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evaluated with MRI. Twenty-two selected patients with nonischemic, dilated cardiomyopathy, mild to moderate heart failure, and severe MR were evaluated by MRI within 1 week before restrictive mitral annuloplasty, and repeat imaging with MRI was performed at 3 to 4 years after surgery.

Materials and Methods

Patients

Twenty-two selected patients (18 male, 4 female, mean age 57 ± 15 years) with mild to moderate heart failure and dilated cardiomyopathy (New York Heart Association [NYHA] class 2.2 ± 0.4, LV end-diastolic dimension 61 ± 5 mm, forward LVEF 37% ± 5%, LV end-diastolic volume [LVEDV] 215 ± 34 mL) who were scheduled for isolated restrictive mitral annuloplasty were included. All patients presented with nonischemic, dilated cardiomyopathy (coronary artery disease excluded on coronary angiography) and severe functional MR on echocardiography. The patients had 3 to 4+ MR (central jet) secondary to LV and annular dilatation and systolic restrictive motion of mitral leaflets (Carpentier type IIIb). All patients were receiving optimized medical therapy and kept on an optimal regimen during the study period.

Patients selected for this study had to be eligible to undergo repeat MRI examination. Therefore, in addition to general MRI exclusion criteria (ie, pacemakers/defibrillators, intracranial clips, pregnancy, claustrophobia), disease-related specific criteria were applied. These included the presence of (supra)ventricular arrhythmias or an existing indication for postoperative (biventricular) pacemaker/defibrillator implantation. To maintain uniformity of surgical intervention in this small patient group, additional valve surgery, including tricuspid valve repair, was another exclusion criterion. These factors inevitably limited the patient selection to those with relatively mild heart failure, a group of patients representing the better part of our heart failure program. None of the patients had pulmonary hypertension, and all patients had preserved right ventricular function. MRI was performed within 1 week before surgery and repeated 3 to 4 years later (43 ± 8 months). At follow-up, a routine transthoracic echocardiographic examination was performed.

Surgery

All surgical procedures were performed via a midline sternotomy under normothermic cardiopulmonary bypass with intermittent antegrade warm blood cardioplegia. The mitral valve was exposed through a vertical transseptal approach along the right border of the foramen ovale, leaving the roof of the left atrium untouched. Ring size (Carpentier-Edwards Physio ring, Edwards Lifesciences, Irving, Calif) was determined after careful measurement of the intercommissural distance and height of the anterior leaflet, and then downsizing by 2 ring sizes (ie, size 26 when measuring 30). All patients had intraoperative transesophageal echocardiographic assessment of valve function. Mitral valve repair was considered successful if there was no residual MR and a leaflet coaptation height of at least 8 mm at the A2-P2 level was achieved on intraoperative echocardiography.

Magnetic Resonance Imaging

MRI was performed using a 1.5 T MRI scanner (ACS-NT15 Gyroscan with the Powertrack 6000 gradient system; Philips Medical Systems, Best, The Netherlands). The body coil was used for transmission, and a 5-element phased-array synergy cardiac-coil was placed on the chest for signal reception. Standard 2- and 4-chamber long-axis series and a complete set of short-axis cine acquisitions were performed (conform standard cardiac MRI protocols[5] using steady-state free precession[6]) with the patient performing a breath hold in end expiration. Imaging parameters of the 2- and 4-chamber long-axis series and for the short-axis series were as follows: TE/TR = 1.52/3.0, flip angle = 50 degrees, field of view = 350 mm, scan matrix = 192 × 153, slice thickness = 8 mm, and gated cardiac triggering with retrospective reconstruction of 30 phases. For the short-axis series, 10 to 12 parallel oriented slices were acquired with a 2-mm slice gap, 1 slice during each breath hold. LVEDV and LV end-systolic volume (LVESV) (from short-axis MRI[7]) and LAEDV and LAESV (from measuring biplane area-length in orthogonal long-axis 2- and 4-chamber views[3]) were obtained by manual segmentation. Image analysis was performed blinded with respect to echocardiographic data.

In the presence of significant MR, LVEF does not represent the true forward blood flow (through the aortic valve) because a substantial part of the blood volume leaks back into the left atrium. To correct for this effect, we have recently used the "forward LVEF," which was derived by calculating the ratio of the forward stroke volume and the EDV.[3] The forward stroke volume was obtained from aortic flow measurements derived from velocity-encoded MRI.[8] QMass and QFlow software (Medis, Leiden, The Netherlands) were used for image analysis. MRI examination was repeated at 3 to 4 years follow-up, and similar parameters were assessed. Significant reverse remodeling was defined as a volume reduction exceeding 15%. An increase in forward LVEF of 5% or more and a decrease in LV mass 10 g or more were considered significant.[3] The medical ethics committee of our institute approved all examinations. All patients gave informed consent.

Statistical Analysis

Continuous data were expressed as mean ± standard deviation and compared using the Student *t* test for paired data.

Results

Clinical Outcome

All patients underwent successful mitral valve repair. The median annuloplasty ring size was 26. Intraoperative transesophageal echocardiography showed a mean coaptation