Impact of Preoperative Anterior Leaflet Tethering on the Recurrence of Ischemic Mitral Regurgitation and the Lack of Left Ventricular Reverse Remodeling after Restrictive Annuloplasty

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Background: The aim of this multicenter study was to investigate the impact of the preoperative anterior mitral leaflet tethering angle, α', on the recurrence of mitral regurgitation (MR) and left ventricular (LV) reverse remodeling (LVRR) after undersized mitral ring annuloplasty.

Methods: The study population consisted of 362 patients, who were divided into two groups by baseline α': group 1, $\alpha' < 39.5^\circ$ (n = 196), and group 2, $\alpha' \geq 39.5^\circ$ (n = 166). End points were recurrent MR ≥ 2+; LVRR, defined as a reduction in end-systolic volume index > 15%; and LV geometric reverse remodeling, defined as a reduction in systolic sphericity index to a normal value of <0.72 in patients with altered baseline geometry.

Results: MR occurred in 9.6% (n = 19) and 43.3% (n = 72) of the patients in groups 1 and 2, respectively ($P < .001$). LVRR (85.7% vs 22.2%) at follow-up was higher in group 1 ($P < .001$). On multivariate regression analysis, $\alpha' \geq 39.5^\circ$ was a strong predictor of MR recurrence, lack of LV reverse remodeling and lack of LV geometric reverse remodeling (all P values < .001). In contrast, the posterior mitral leaflet tethering angle, β', was not significant (all P values > .05). When we allowed for interactions between α' and other risk factors, this effect occurred also in low-risk subgroups, and it was equivalent or generally attenuated in higher risk patients. There were no significant interactions between α' and any of the covariates (all P values > .05).

Conclusions: Anterior mitral leaflet tethering is a powerful predictor of MR recurrence and lack of LVRR after undersized mitral ring annuloplasty. Evaluation of leaflet tethering should be incorporated into clinical risk assessment and prediction models. (J Am Soc Echocardiogr 2011;24:1365-75.)

Keywords: Mitral valve, Myocardial infarction, Coronary artery bypass grafts

Undersized mitral ring annuloplasty (UMRA) has long been considered an effective approach to relieve chronic ischemic mitral regurgitation (CIMR). Nonetheless, although a few groups have reported encouraging results after UMRA,[1] residual or recurrent mitral regurgitation (MR) is seen in up to 30% of patients at other centers.[2] These disappointing results have created the need for a better understanding and preoperative assessment of mitral valve configuration and left ventricular (LV) geometry and function to improve risk stratification and to allow the identification of patient subgroups that are likely to benefit from this procedure.

Recently, great attention has been paid to baseline leaflet configuration. Nonetheless, few data are available, and published studies show conflicting results[3-6] regarding a correlation of specific leaflet patterns with unfavorable postoperative outcomes.

Therefore, in this multicenter study, we investigated the impact of anterior mitral leaflet (AML) tethering on the recurrence of MR, LV reverse remodeling (LVRR) and decreased global LV sphericity (LV geometric reverse remodeling [LVGRR]).

METHODS

Ethical Issues

Ethics committee approval was waived because of the retrospective analysis of the study according to national laws regulating observational retrospective studies. However, all patients provided informed consent to access their data for scientific purposes.

Subjects

The study population consisted of 391 consecutive patients with CIMR who survived combined coronary artery bypass grafting and

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Abbreviations

α' = Anterior mitral leaflet tethering angle

ALPM = Anterolateral papillary muscle

AML = Anterior mitral leaflet

β' = Posterior mitral leaflet tethering angle

CIMR = Chronic ischemic mitral regurgitation

ESVI = End-systolic volume index

LV = Left ventricular

LVGRR = Left ventricular geometric reverse remodeling

LVRR = Left ventricular reverse remodeling

MR = Mitral regurgitation

PISA = Proximal isovelocity surface area

PM = Papillary muscle

PML = Posterior mitral leaflet

PMPM = Posteromedial papillary muscle

UMRA = Undersized mitral ring annuloplasty

UMRA performed at three institutions (Careggi Hospital, Florence, Italy; Civic Hospital, Brescia, Italy; and University Hospital, Maastricht, The Netherlands) between October 2008 and April 2010. CIMR was defined as the association of mild to severe MR with all the following features: (1) prior myocardial infarction > 16 days, (2) ≥75% stenosis of at least one coronary vessel, (3) a corresponding regional wall motion abnormality, and (4) type IIIb leaflet dysfunction following Carpentier's classification,[7] with or without annular dilatation.

Twenty-nine patients were excluded: two had intraoperative annuloplasty failure, 12 showed residual MR (≥2+ at discharge), and 15 had incomplete echocardiographic studies. Therefore, the final study population consisted of 362 patients. Other exclusion criteria were 1) degenerative or other nonischemic etiology, (2) ischemic isolated type I or type II dysfunction,[7] (3) additional mitral valve repair procedures, (4) other valvular or congenital heart diseases, (5) previous cardiac surgery or percutaneous transluminal coronary angioplasty, (6) atrial fibrillation, and (7) sinus rhythm with heart rate at rest 100 beats/min.

One-hundred normal healthy subjects with no histories of cardiovascular disease, with normal Doppler echocardiographic findings and a gender distribution, ages, and average body surface areas similar to the study patients, served as controls. The median follow-up time was 14.3 months (interquartile range, 9.3–19.1).

Surgery

Patients with moderate or severe CIMR (effective regurgitant orifice area > 20 mm^2 and regurgitant volume > 30 mL) were scheduled for operation. When MR was 2/4, surgery was indicated (1) in the presence of a dilated left ventricle (end-diastolic volume > 110 mL/m^2) or a low LV ejection fraction (<0.35), as in the case of dilated cardiomyopathy; (2) in patients with increases in effective regurgitant orifice area > 13 mm^2 on transthoracic echocardiographic exercise testing; and (3) in ischemic patients with fluctuating MR of grade ≥ 3 after intraoperative loading testing.

All patients underwent associated coronary artery bypass grafting. For the purposes of this study, complete revascularization was accomplished when at least one graft was placed distal to an approximately 50% diameter narrowing in each of the three major vascular system in which arterial narrowing of this severity was noted in a vessel ≥1.5 mm in diameter. It was not considered necessary to bypass all obstructed diagonal branches of the anterior descending or marginal branches of the circumflex coronary arteries for a classification of complete revascularization. Following this definition, 100% of patients underwent complete revascularization. The ring size was determined by standard measurements of the intertrigonal distance and anterior leaflet height. Downsizing by two ring sizes was performed in all patients.

Table 1 Bland-Altman limits of agreement for intraobserver and interobserver variability

Variable	Mean difference	SD	95% limits of agreement
α' (°)			
Intraobserver (F.L.)	1.2	0.9	−2.2 to 3.1
Intraobserver (C.M.R.)	1.2	1.0	−1.8 to 3.2
Interobserver	1.6	1.2	−2.3 to 4.0
β' (°)			
Intraobserver (F.L.)	1.5	0.9	−2.0 to 4.4
Intraobserver (C.M.R.)	1.5	1.1	−2.8 to 4.9
Interobserver	1.9	1.5	−3.5 to 5.3
Coaptation height (mm)			
Intraobserver (F.L.)	0.1	0.3	−0.2 to 0.5
Intraobserver (C.M.R.)	0.2	0.1	−0.4 to 0.8
Interobserver	0.2	0.1	−0.3 to 0.7

Intraobserver and interobserver relative differences were <5% for all parameters. The Bland-Altman method showed excellent agreement between intraobserver and interobserver measurements for both low and high values of echocardiographic parameters.

Echocardiographic Measurements

Echocardiographic examinations were performed using a commercially available system (iE33; Philips Medical Systems, Best, The Netherlands). The clinical echocardiographic evaluation was as follows: transthoracic echocardiography and transesophageal echocardiography were performed <5 days before surgery, and serial transthoracic echocardiography was performed annually thereafter. Echocardiographic examinations were carried out by experienced echocardiographers (S.C., E.V., and E.C.) and stored on a magneto-optical disk for offline analysis. Measurements and calculations were made offline by two cardiologists (F.L. and C.M.R.) blinded to the aims of the study. The reliability of echocardiographic measurements was assessed by calculating interobserver and intraobserver intervals of agreement of main direct measures used in this study in 20 subjects randomly chosen among the study patients (Table 1).

MR Assessment

The following quantitative measurements were simultaneously used to grade the severity of MR: (1) pulsed-wave Doppler and (2) proximal isovelocity surface area (PISA). When the evidence from different parameters was congruent, the measurements were averaged, allowing the calculation of effective regurgitant orifice area, regurgitant volume, and regurgitant fraction.[8]

When different parameters were contradictory, PISA was chosen in case of a central jet or in the presence of a calcific mitral valve or mitral annulus, whereas pulsed-wave Doppler was preferred when the jet was eccentric or multiple.[8] For each measurement, a minimum of three cardiac cycles were averaged. In patients with no or trivial MR by color Doppler, regurgitant volume and regurgitant fraction were used as calculated, and effective regurgitant orifice area was assumed as null. The respective thresholds for mild, moderate, and severe MR followed American Society of Echocardiography recommendations.