

Isolated Undersized Mitral Annuloplasty for Functional Mitral Regurgitation in Non-Ischemic Dilated Cardiomyopathy

— Reconsideration of the Relationship Between Preoperative Coaptation Depth and Persistent Mitral Regurgitation —

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Background A preoperative coaptation depth (CD) ≥ 11 mm is apparently a predictive factor for persistent mitral regurgitation (MR) after undersized mitral annuloplasty for functional MR. The results of studies of isolated undersized mitral annuloplasty in non-ischemic dilated cardiomyopathy (DCM) are reported, including the relationship between the preoperative CD and recurrent MR.

Methods and Results Six patients (mean age, 61 years) with severe functional MR in non-ischemic DCM underwent isolated undersized mitral annuloplasty. There were no hospital deaths. At intermediate follow-up of 2.2 ± 1.9 years, New York Heart Association functional class improved significantly from 3.3 ± 0.5 before surgery to 2.2 ± 0.4 after surgery ($p=0.0016$). At a mean echocardiographic follow-up of 1.9 ± 1.7 years, MR grade improved significantly from 4.0 ± 0.0 before surgery to 1.0 ± 0.6 after surgery ($p<0.001$). In 4 of 5 patients with a preoperative CD ≥ 11 mm, functional MR improved to mild or less than mild after surgery.

Conclusions Isolated undersized mitral annuloplasty improved clinical symptoms and functional MR in non-ischemic DCM. These results suggest that preoperative CD ≥ 11 mm does not always predict recurrent MR after isolated undersized mitral annuloplasty for functional MR in cases of non-ischemic DCM. (Circ J 2008; 72: 1744–1750)

Key Words: Functional mitral regurgitation; LV remodeling; Non-ischemic dilated cardiomyopathy; Tethering; Undersized mitral annuloplasty

The appearance of functional mitral regurgitation (MR) predicts poor survival for patients with non-ischemic dilated cardiomyopathy (DCM). Therefore, surgical treatment is recognized as crucial for improving life expectancy. Regarding mitral reconstruction in DCM, Bolling et al reported the clinical usefulness of the undersized mitral annuloplasty (MAP) in 1995;¹ however, recurrent or persistent MR after annuloplasty has been reported.^{2–4} Regarding recurrence of MR, Calafiore et al reported that DCM patients with a coaptation depth (CD) ≥ 11 mm were likely to have persistent MR after mitral valve (MV) repair.²

We have consistently performed isolated undersized MAP to control functional MR in patients with non-ischemic DCM, regardless of the degree of CD, so in the present study we retrospectively reviewed our data to ex-

amine the relationship between persistent MR and preoperative echocardiographic parameters, especially CD.

Methods

Clinical Experience

From October 2000 to August 2007, 5 patients (2 males, 3 females) with idiopathic DCM and 1 patient (male) with dilated hypertrophic cardiomyopathy (DHCM) underwent isolated undersized MAP. Table 1 shows the patients' profiles. None of the patients had organic MV disease. Mean age was 61 ± 14 years (range, 40–77). Mean body surface area was 1.54 ± 0.12 cm² (range, 1.35–1.67). Mean preoperative number of medical admissions for congestive heart failure (CHF) was 2.7 ± 0.8 (range, 2–4). Two patients had New York Heart Association (NYHA) functional class IV and 4 had class III (mean, 3.3 ± 0.5). Two patients with NYHA functional class IV were dependent on inotropic support and continuous infusion of furosemide. One of them needed an intra-aortic balloon pump (IABP) because of low cardiac output syndrome. All patients had severe MR before surgery. One patient had severe tricuspid regurgitation. Five patients had sinus rhythm and 1 patient had atrial fibrillation (AF). Four patients had a history of ventricular tachycardia (VT). None of them had an implantable cardioverter-defibrillator (ICD). Two of the 6 patients had

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Table 1 Patients' Profiles

Etiology	Age (years)	Sex	Rhythm	NHYA			Degree of MR			MR jet direction			CD (mm)			Recur-rence of CHF	Alive or Dead
				Preop	Perdis	Inter-mediate	Preop	Perdis	Inter-mediate	Preop	Perdis	Inter-mediate	Preop	Perdis	Inter-mediate		
Idiopathic DCM	40	M	SR	III	II	II	4	0.5	0.5	Posterior	Central	Central	13.8	5.8	6.1	No	Dead
Dilated HCM	64	M	SR	III	II	II	4	1	1	Central	Central	Central	12.3	7.0	7.2	No	Dead
Idiopathic DCM	77	F	SR	III	II	II	4	1	0.5	Central	Central	Central	18.0	11.2	10.8	No	Alive
Idiopathic DCM	64	M	SR	III	II	II	4	0	0.5	Posterior	–	Central	10.2	5.2	5.1	No	Alive
Idiopathic DCM	72	F	AF	IV	II	III	4	1	2	Posterior	Anterior	Anterior	12.0	8.7	9.5	Yes	Alive
Idiopathic DCM	49	F	SR	IV	II	II	4	1	1	Posterior	Posterior	Posterior	12.1	6.0	5.8	No	Alive

NHYA, New York Heart Association; Preop, preoperative; Predis, predischARGE; MR, mitral regurgitation; CD, coaptation depth; CHF, congestive heart failure; DCM, dilated cardiomyopathy; SR, sinus rhythm; HCM, hypertrophic cardiomyopathy; –, MR jet direction was not detected; AF, atrial fibrillation.

coronary artery lesions with 75% stenosis. One patient (idiopathic DCM) had triple-vessel disease and had been diagnosed with idiopathic DCM 20 years ago at the current hospital. The other patient (DHCM) had 1-vessel disease involving the left anterior descending artery (LAD) and had also been diagnosed with HCM 19 years ago at the same institution. Previous coronary angiograms in these 2 patients had not shown any coronary artery lesions. The patients have had strict clinical follow-up and have not had myocardial ischemic findings since they diagnosed with idiopathic DCM and HCM, respectively. The coronary artery stenoses in the 2 patients did not play a major part in the left ventricle (LV) dysfunction and functional MR, so we included them in this study. Written informed consent was given by all patients.

Echocardiographic Measurement

Two-dimensional and Doppler echocardiographic studies were performed in all patients using 2.5-MHZ transducers (Toshiba, Tokyo, Japan) 7.0±5.6 days (range, 2–14) before surgery, 21±15 days (range, 8–46) after surgery at the time of predischARGE examination, and 1.9±1.7 years (range, 0.4–4.7) after surgery at intermediate follow-up.

LV Geometry and Function

The LV end-diastolic and end-systolic diameters and the left atrial (LA) diameter were measured using M-mode in the parasternal long-axis view. LV end-diastolic and end-systolic volumes and LV ejection fraction (LVEF) were determined by the modified biplane Simpson's method. The pressure gradient between the right atrium (RA) and right ventricle (RV) was determined by the tricuspid regurgitation.

MV Configuration

The mitral ring diameters were measured in the end-diastolic phase using the parasternal long-axis and 4-chamber apical views. The CD was defined as the distance between the annular line and the leaflet's coaptation point as described previously by Magne et al.⁵ The posterior leaflet (PL) angle was defined as the angle measured between the annular and PL lines in mid-systole using the parasternal long-axis view.

MR Assessment

The presence and quantity of MR was evaluated by the colored areas of jet regurgitation. MR severity was graded as none (0/4, if regurgitant area was not detected), trace (0.5/4, ≤2 cm²), mild (1/4, from 2 to 4 cm²), mild to moderate (2/4, from 4 to 8 cm²), moderate (3/4, from 8 to 12 cm²), and severe (4/4, >12 cm²).

Surgical Technique

Two patients needed scheduled IABP before anesthesia induction. Intermittent cold cardioplegia was used for myocardial protection in all patients. Mild hypothermic cardiopulmonary bypass (CPB) was initiated with cannulation of the ascending aortic and bicaval cannulation of the superior and inferior venae cava. After cross-clamping of the ascending aorta, a single dose of cold cardioplegia was injected into the aortic root. The MV was accessed by a right-sided left atriotomy and 9 or 10 U-shaped sutures using 2/0 Ticron (TI-CRON, Sherwood Medical, St Louis, MO, USA) were placed along the entire circumference of the mitral annulus. A complete annuloplasty was performed using Carpentier-Edwards Physio rings (Edwards Lifescience, Irvine, CA, USA)⁶ Briefly, a 24-mm Physio ring was applied to the female end, and a 26-mm Physio ring was applied to the male end. Four patients had 24-mm Physio rings and 2 patients had 26-mm Physio rings. Before unclamping the aorta, all patients electively received 5 μg·kg⁻¹·min⁻¹ dopamine. If necessary, dobutamine was used. At the time of weaning off CPB, transesophageal echocardiography was performed to evaluate residual MR. None of the patients had more than 2.0 cm² of regurgitant area. Concomitant coronary artery bypass grafting was performed in the 2 patients noted above. One patient had 3 coronary revascularizations. The left internal thoracic artery (LITA) was applied to the LAD, a segment of the great saphenous vein was applied to the posterolateral branch, and another segment to the posterodescending branches. The other patient had 1 coronary revascularization in which the LITA was applied to the LAD. Tricuspid annuloplasty using a 26-mm MC-3 ring (Edwards Lifescience) was performed in 1 patient. Pulmonary vein isolation was performed in 1 patient with AF. Weaning from CPB was uneventful in all patients. Mean operation time was 216±76 min (range, 175–348). Mean CPB times and mean aortic cross clamp times were 92±39 min (range, 55–166) and 51±25 min (range, 32–100), respectively.

Postoperative Course

Patients remained in the intensive care unit until the inotropic support was limited to doses of dopamine (5 μg·kg⁻¹·min⁻¹) and dobutamine (5 μg·kg⁻¹·min⁻¹), after which they were transferred to the surgical ward. All patients were followed up in the outpatient clinic for at least 3 months after the operation. At every 6-monthly follow-up visit, if possible, transthoracic echocardiography (TTE) was performed by a cardiologist (S.Y.). Chronic medical treatment included angiotensin-converting enzyme inhibitors, digoxin, diuretics, angiotensin II antagonist, and β-blockers such

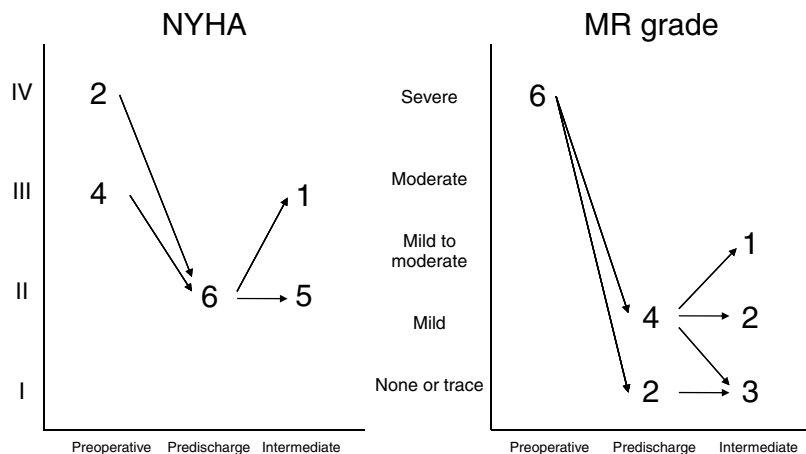


Fig 1. Comparison of New York Heart Association (NYHA) functional classification and mitral regurgitation (MR) grade before and after surgery. At a mean follow-up of 2.2 ± 1.9 years, NYHA functional class improved significantly from 3.3 ± 0.5 before surgery to 2.2 ± 0.4 after surgery ($p = 0.0016$). All patients had mild or less than mild MR at predischarge. Five have had mild or less than mild MR during the follow-up period. However, 1 patient had recurrent mild to moderate MR (regurgitant area, 6.0 cm^2) during the follow-up periods.

Table 2 Preop, Predis and Intermediate Echocardiographic Data

	Preop	Predis	Intermediate
<i>LV geometry and function</i>			
LVDd, mm	67 ± 4	65 ± 6	66 ± 6
LVDs, mm	56 ± 6	58 ± 6	60 ± 6
LVEDV, ml	165 ± 22	152 ± 18	157 ± 22
LVEDVI, ml/m ²	108 ± 14	100 ± 14	102 ± 14
LVESV, ml	106 ± 19	105 ± 18	115 ± 17
LVESVI, ml/m ²	69 ± 13	69 ± 13	75 ± 10
LVEF, %	36 ± 5	25 ± 4	27 ± 3
Annulus, parasternal, mm	39 ± 2	21 ± 1	–
Annulus, apical 4-chamber, mm	39 ± 4	24 ± 2	–
CD, mm	13.1 ± 2.7	7.3 ± 2.3	7.3 ± 2.3
PL angle, parasternal, degrees	64 ± 5	89 ± 8	88 ± 11
PL angle, apical 4-chamber, degrees	60 ± 6	87 ± 5	83 ± 3
<i>LA geometry</i>			
LA diameter, mm	47 ± 3	42 ± 4	45 ± 2
<i>MR</i>			
Jet area, cm ²	12.9 ± 1.1	2.0 ± 1.5	2.5 ± 2.0
Grade	4.0 ± 0.0	0.8 ± 0.4	0.9 ± 0.7
<i>Jet direction</i>			
Anterior	–	1	1
Central	2	2	4
Posterior	4	1	1
<i>Pressure gradient</i>			
Between RA and RV, mmHg	52 ± 11	33 ± 16	28 ± 11

Value are mean \pm SD.

LV, left ventricle; LVDd, LV end-diastolic diameter; LVDs, LV end-systolic diameter; LVEDV, LV end-diastolic volume; LVEDVI, LVEDV index; LVESV, LV end-systolic volume; LVESVI, LVESV index; LVEF, LV ejection fraction; PL, posterior leaflet; LA, left atrium; RA, right atrium; RV, right ventricle. Other abbreviations see in Table 1.

as carvedilol. Antiarrhythmia drugs, such as amiodarone, were used if there was ventricular arrhythmia. All patients completed the follow-up.

Statistical Analysis

Results are expressed as mean \pm standard deviation unless otherwise specified. Preoperative and postoperative data were compared with paired 2-tailed Student's t-test. A 2-tailed $p < 0.05$ was considered statistically significant. Statistical analyses were performed using Stat-View (Version 5.0) statistical analysis software package (Abacus Concepts, Berkeley, CA, USA).

Results

Mean duration of stay in the intensive care unit was 5.3 ± 3.8 days (range, 2–12). No patient died during the first 30

postoperative days. Mean duration of hospitalization was 75 ± 61 days (range, 23–169). Mean duration of inotropic support was 25 ± 36 days (range, 2–97). There were 2 cardiac deaths in the follow-up period; both patients had VT before the operation and died of ventricular arrhythmia: 1 patient died 0.8 years after surgery even though he was prescribed an antiarrhythmic drug, sotalolol; the other died 5.4 years after surgery even though he was prescribed amiodarone.

NYHA Functional Class

At the intermediate follow-up of 2.2 ± 1.9 years (range, 0.1–5.4), NYHA functional class significantly improved from 3.3 ± 0.5 years (range, 3–4) before the operation to 2.2 ± 0.4 years (range, 2–3) ($p = 0.0016$) (Fig 1). CHF recurred in 1 patient with mild to moderate MR 1.2 years after surgery. Postoperative CHF was managed with increased diuretics and administration of pimobentan. At 1.6 years post

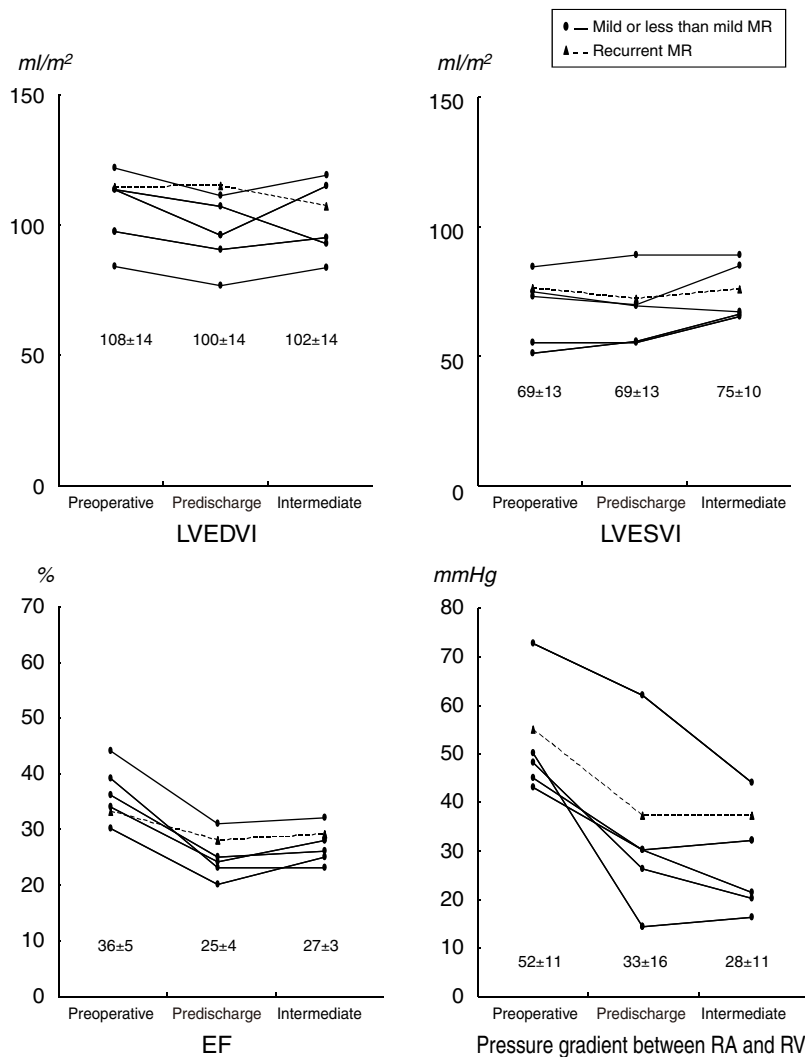


Fig 2. Individual changes in the left ventricle end-diastolic volume index (LVEDVI), end-systolic volume index (LVESVI), ejection fraction (EF), and pressure gradient between the right atrium (RA) and right ventricle (RV). (▲) Patient with recurrent mitral regurgitation (MR).

operation, this patient was in NYHA functional class III with oral medication without recurrence of CHF.

Arrhythmia

In the follow-up period, 3 patients had episodes of VT and all were managed with antiarrhythmic drugs (amiodarone, sotalolol, or mexiletine hydrochloride) without ICD. However, 2 died of ventricular arrhythmia.

Echocardiographic Measurements

Table 2 shows the preoperative, predischarge, and intermediate echocardiographic data.

MR

All patients had severe MR before the operation and all had mild or less than mild MR at predischarge. Five patients in total had mild or less than mild MR during the follow-up period and 1 patient had recurrent mild to moderate MR (regurgitant area, 6.0 cm²); that patient had recurrence of CHF 1.2 years after surgery (Fig 1, Table 1).

MR Jet Direction

Before surgery, the MR jet direction was central in 2 patients and posterior in 4 patients. At intermediate follow-up, jet direction was central in 4 patients, anterior in 1 patient,

and posterior in 1 patient. The patient with anterior jet direction after surgery had recurrent mild to moderate MR (Tables 1,2).

LV Geometry and Function (Fig 2)

The LV end-diastolic diameter (LVDd) changed from 67±4 mm (range, 62–73) before surgery, to 65±6 mm (range, 61–77) at predischarge, and to 66±6 mm (range, 60–78) in the intermediate postoperative period. The LV end-systolic diameter (LVDs) changed from 56±6 mm (range, 48–63) before surgery, to 58±6 mm (range, 48–64) at predischarge, and to 60±6 mm (range, 54–71) in intermediate postoperative period. The LV end-diastolic volume index (LVEDVI) changed from 108±14 ml/m² (range, 84–122) before surgery to 100±14 ml/m² (range, 77–115) at predischarge, and to 102±14 ml/m² (range, 84–119) in the intermediate postoperative period. The LV end-systolic volume index (LVESVI) changed from 69±13 ml/m² (range, 55–89) before surgery to 69±13 ml/m² (range, 55–89) at predischarge, and to 75±10 ml/m² (range, 65–89) in the intermediate postoperative period. LVEF changed from 36±5% (range, 30–44) before surgery to 25±4% (range, 20–31) at predischarge, and to 27±3% (range, 23–32) in the intermediate postoperative period. None of the patients had an improvement in the intermediate LVEF compared with the preoperative LVEF.

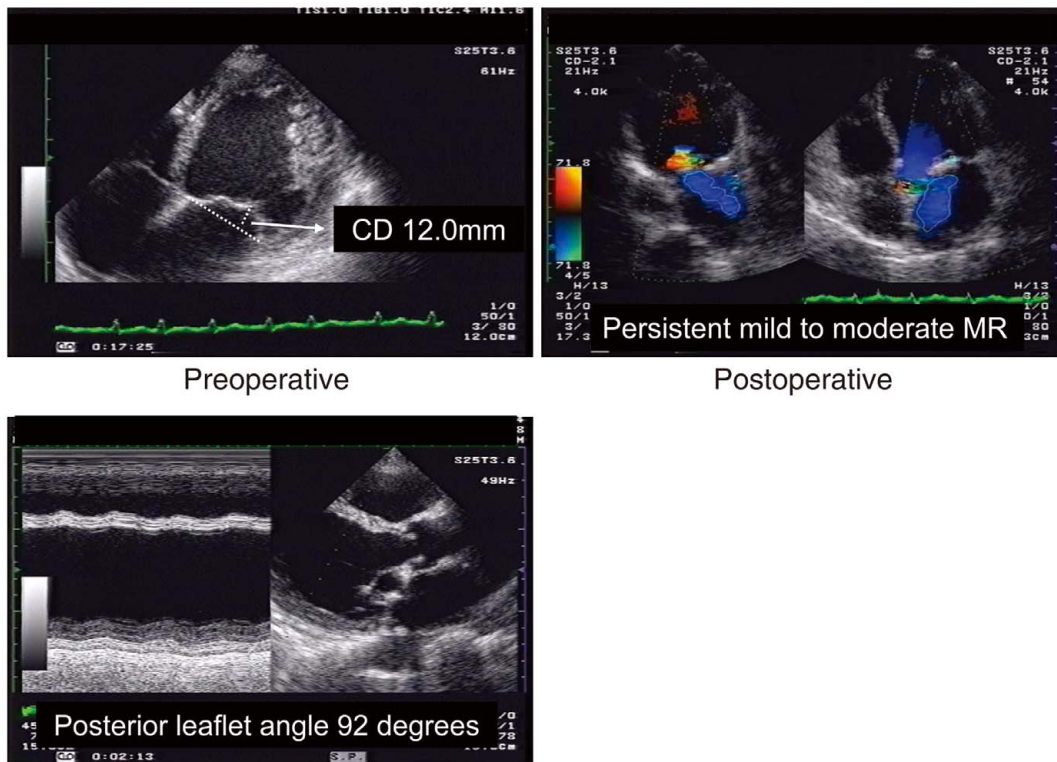


Fig 3. Persistent mild to moderate mitral regurgitation (MR) after isolated undersized mitral annuloplasty (MAP) with a 24-mm Physio ring in a 72-year-old female patient with preoperative 12-mm coaptation depth (CD) and in New York Heart Association functional class IV with inotropic support, continuous infusion of furosemide, and intra-aortic balloon pump to control low cardiac output syndrome. Mild to moderate MR persisted postoperatively. The anterior leaflet of the mitral valve was pulled toward the papillary muscle by the anterior leaflet second-order chordate.

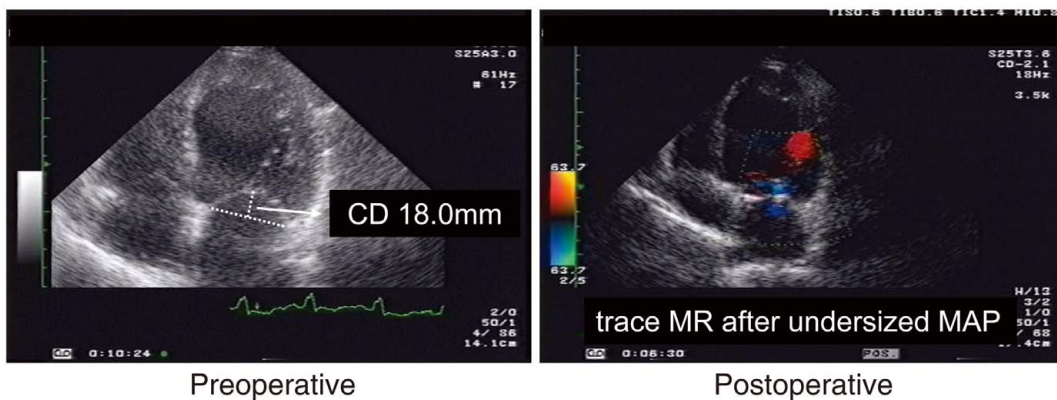


Fig 4. Improvement in functional mitral regurgitation (MR) after undersized mitral annuloplasty (MAP) using a 24-mm Physio ring in a 77-year-old female with New York Heart Association functional class III and 18-mm of coaptation depth (CD) before surgery. MR grade improved from severe before surgery to trace after surgery.

LA diameter changed from 47 ± 3 mm (range, 43–51) before surgery, to 42 ± 4 mm (range, 35–49) at predischarge, and to 45 ± 2 mm (range, 43–49) in the intermediate postoperative period. The pressure gradient between RA and RV decreased from 52 ± 11 mmHg (range, 43–73) before surgery, to 33 ± 16 mmHg (range, 14–62) at predischarge, and to 28 ± 11 mmHg (range, 16–44) in the intermediate postoperative period. All patients showed improvement of pressure gradient between RA and RV during the follow-up periods compared with the preoperative pressure gradient between RA and RV.

MV Configuration

CD decreased from 13.1 ± 2.7 mm (range, 10.2–18.0) before surgery, to 7.3 ± 2.3 mm (range, 5.2–11.2) at predischarge, and to 7.3 ± 2.3 mm (range, 5.1–10.8) in the intermediate postoperative period (Table 2). Five patients had CD ≥ 11 mm before the operation (Table 1). The preoperative CD in the 5 patients was 12.0, 12.1, 12.3, 13.8, and 18.0 mm, respectively, and all 5 patients had mild or less than mild MR at predischarge. The patient with a preoperative CD of 12.0 mm had worsening of MR in the follow-up period (Fig 3). Fig 4 shows the improvement of functional

MR after isolated undersized MAP in the patient with CD of 18.0 mm. The PL angle increased from 52 ± 7 degrees (range, 40–60) before surgery, to 81 ± 7 degrees (range, 75–92) at predischarge, and 81 ± 7 degrees (range, 75–92) at the intermediate postoperative period. The mean PL angle in 5 patients without persistent MR was 79 ± 4 degrees (range, 75–86) at predischarge. On the other hand, the PL angle in the patient with persistent MR (92 degrees) was larger than that in the 5 patients without persistent MR. A morphological characteristic (the anterior leaflet of the MV was pulled toward the papillary muscle by the anterior leaflet second-order chordate) was also noted in the patient with persistent MR (Fig 3).

Regarding the Patient With Mild to Moderate MR

The patient was a 72-year-old female with NYHA functional class IV on inotropic support, continuous infusion of furosemide and IABP to control low cardiac output syndrome before surgery. Preoperative ECG revealed AF. Preoperative TTE showed LVDd of 65 mm, LVDs of 51 mm, LVEDVI of 115 ml/m², LVESVI of 77 ml/m², LVEF of 33%, and pressure gradient between RA and RV of 55 mmHg with severe functional MR. MR jet direction was posterior and the CD was 12.0 mm. Undersized MAP using a Carpentier-Edwards Physio ring of 24 mm and PV isolation were performed. Echocardiography at predischarge showed an improvement of MR from severe to mild (regurgitant area, 4.0 cm²). Isolated undersized MAP improved the clinical symptoms leading to cessation of inotropic support, continuous infusion of diuretics and the use of IABP. At 1.2 years post operation, CHF recurred and the recurrent MR deteriorated to moderate (regurgitant area, 6.0 cm²) (Fig 3). The recurrence of CHF was managed with increasing doses of oral medication and the administration of pimobentan. At 1.6 years post operation, the patient was in NYHA functional class III with oral medication and TTE showed LVDd of 60 mm, LVDs of 54 mm, LVEDVI of 107 ml/m², LVESVI of 76 ml/m², LVEF of 22%, and a pressure gradient between RA and RV of 37 mmHg with mild to moderate MR. Brain natriuretic peptide decreased from 1,580 pg/ml before to 453 pg/ml at 1.6 years after surgery.

Discussion

The current study showed that 5 of 6 patients had an improvement of functional MR and NYHA functional class after isolated undersized MAP. Even in the patient with recurrent mild to moderate MR, isolated undersized MAP was effective in the improvement of clinical symptoms. Briefly, undersized MAP in this patient provided freedom from preoperative inotropic support, continuous infusion of diuretics, and IABP. Therefore, we reaffirmed the significance of isolated undersized MAP for functional MR in non-ischemic DCM. However, we must note that recurrent MR leads to the recurrence of CHF, as was the case with the patient with persistent MR. Szalay et al reported that preoperative NYHA functional class IV was the only risk factor of recurrent MR after MAP in idiopathic DCM.⁷ In the current study, the patient with recurrent MR was in NYHA functional class IV and had the most severe CHF before surgery among all the patients. The severity of preoperative functional status might be a sign of recurrent MR.

We reviewed the relationship between preoperative CD and postoperative MR in all patients with reference to Calafiore's report: 5 patients had CD ≥ 11 mm before sur-

gery. Postoperative TTE showed that 4 of them had mild or less than mild MR, and the other had recurrent mild to moderate MR. Our result suggests that preoperative CD ≥ 11 mm does not always predict persistent MR after isolated undersized MAP for functional MR in non-ischemic DCM.

The mechanism of regulation of functional MR by isolated undersized MAP is to reduce the anteroposterior diameter of the native annulus, as described previously.^{1,2,8} There is no other way to reestablish adequate leaflet coaptation. Green et al⁹ reported the effects of complete ring annuloplasty with both a flexible ring and a semi-rigid ring on mitral leaflet motion in normal bovine hearts. They showed that complete MAP with either ring type markedly reduced the mobility of the central PL. And they reported that, as a result, MV closure became a single anterior leaflet process with the frozen PL serving only as a buttress for closing. This frozen PL may be related to recurrent MR after isolated undersized MAP, described next.

Calafiore et al suggested that the mechanism of recurrent MR after undersized MAP in patients with DCM may be an increase in the distance between the papillary muscles and the posterior annulus.² In other words, in patients with global remodeling of the LV, which leads to displacement of both papillary muscles bilaterally and symmetrically, isolated undersized MAP may worsen the PL tethering. This might be the mechanism of recurrent MR. In the current study, we did not measure the leaflet-tethering distance between the papillary muscle tips and the contralateral anterior mitral annulus,¹⁰ which is a measure of the degree of LV remodeling and leaflet tethering. Therefore, we cannot comment on any changes regarding LV remodeling and leaflet tethering after isolated undersized MAP. The PL angle in the patient with persistent MR (92 degrees) was larger than in the 5 patients with MR remission. This result suggests that regional remodeling of the heart muscle around the papillary muscles was more severe in the patient with persistent MR compared with the 5 patients showing MR improvement. This is an important finding, indicating that close coaptation of the anterior and PLs was not ensured, and so MR remained.

Regarding the discrepancy between our results and Calafiore's, 3 factors may be considered. First is the difference in the patients. Idiopathic DCM is a heterogeneous disease, so the degree of LV remodeling varies greatly between individuals and may be related to the occurrence of residual MR after undersized MAP. Second is the method of undersized MAP. Our technique involved a complete remodeling annuloplasty using a semi-rigid Physio ring⁶ whereas Calafiore's annuloplasty involved plication of the posterior mitral annulus using autopericardium or 2/0 Ticron sutures. Calafiore et al did not treat the anterior mitral annulus. Patients with idiopathic DCM who have functional MR have significantly greater mitral leaflet orifice area and significantly larger dimensions of the anterior and posterior MV annuli.¹¹ Recently, Hueb et al reported dilatation of the fibrous annulus in humans with cardiomyopathy of idiopathic etiologies.¹² The anterior mitral annulus is involved in annular dilatation. Considering the anatomic structure of the mitral annulus in idiopathic DCM, we believe that the mitral anterior annulus should be treated. Therefore, we performed a complete remodeling annuloplasty using a Physio-ring to prevent further lengthening of the intertrigonal distance and to reduce the anteroposterior diameter in order to reestablish adequate coaptation. To treat or not to treat the anterior mitral annulus may explain the discrepancy be-

tween the results. The third difference is the measurement of CD. We measured it using transthoracic cardiography under conscious conditions, whereas Calafiore et al measured it using transesophageal echocardiography. In their cases, it is unclear if the measurement was performed under fully conscious or sedated conditions. Generally, the severity of functional MR and the CD is underestimated under sedation.¹³ If Calafiore et al measured the CD under sedation, it would be underestimated. These are important limitations of the discussion on the efficacy of undersized MAP for patients with CD ≥ 11 mm.

Arrhythmias, such as VT or ventricular fibrillation, in idiopathic DCM reduce the patient's life expectancy.¹⁴ In this study, 2 patients died of ventricular arrhythmia even though they were taking antiarrhythmia drugs. Therefore, an ICD should be considered for patients with ventricular arrhythmia that is refractory to medical treatment.

Study Limitations

The first limitation is the small number of patients. Further investigation with a larger population is required. The second limitation is the assessments of the grade of MR, which should be evaluated using quantitative methods, such as regurgitant volume (ml/beat), regurgitant fraction (%), and/or regurgitant orifice area (cm²) as per recommendations of the American and European cardiac societies,¹⁵ because regurgitant jet area (cm²) has several limitations.^{16–18} We evaluated the grade of MR using the semi-quantitative method of regurgitant jet area. Preoperative TTE showed severe MR in all patients; however, preoperative LV angiography showed an MR grade of III in 4 patients and grade IV in 2 patients. After surgery, 4 of the 6 patients had mild or less than mild MR with a central jet; 1 patient had mild MR (regurgitant jet area 2.8 cm²) with a posterior jet and 1 patient had mild to moderate MR (regurgitant jet area 6.0 cm²) with an anterior jet. Small, non-eccentric jets with an area <4.0 cm², or 20% of LA area, are usually trace or mild MR, and eccentric jets may be underestimated.²³ Therefore, the 4 patients with a central jet may have had trace or mild MR and the MR grade for the 2 patients with eccentric jets might have been underestimated. Nonetheless, the 2 patients with eccentric jets had an improvement in their clinical symptoms. The third limitation is the statistical analysis. The echocardiographic parameters were not measured at the same point in time for all patients. In particular, the intermediate echocardiographic data were not measured at the same point in time. For example, 1 patient had the echocardiographic examination 0.4 years after surgery and another patient had it 4.7 years after surgery. Therefore, statistical analysis of the echocardiographic parameters of the 3 points of time (before surgery, pre-discharge, and the intermediate follow-up periods) is inappropriate. The current study shows the change in the echocardiographic parameters during the follow-up periods. Comparing the preoperative and postoperative echocardiographic parameters, there were no major changes in the LV size; however, there were major changes in the pressure gradient between the RA and RV after isolated undersized MAP.

Conclusions

Isolated undersized MAP improved functional MR and clinical symptoms in non-ischemic DCM, although it did not reduce LV size and improve LV function. Our results suggest that preoperative CD ≥ 11 mm does not always pre-

dict persistence of MR after isolated undersized MAP for functional MR in non-ischemic DCM. Although we will continue to perform isolated undersized MAP for patients with functional MR in non-ischemic DCM, further investigation to identify patients who are at risk of persistent MR is required.

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