Fate of Functional Tricuspid Regurgitation After Mitral Valve Repair for Degenerative Mitral Regurgitation

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Background: The issue of whether functional tricuspid regurgitation (TR) should be repaired at the time of mitral valve surgery is controversial, and the long-term durability of tricuspid valve (TV) annuloplasty remains unknown.

Methods and Results: We retrospectively reviewed 654 patients who underwent mitral valve repair for degenerative mitral regurgitation between 1991 and 2010. Preoperative TR was classed as mild, trivial or absent in 479 (73.2%) patients, moderate in 125 (19.1%) patients and severe in 50 (7.7%) patients. Concomitant TV annuloplasty was performed in 162 patients (24.8%). The mean follow up duration was 7.5±4.9 years. Postoperative transthoracic echocardiography was performed according to a fixed schedule. The long-term survival rate and freedom from re-admission for congestive heart failure were affected by the severity of TR. Although the durability of ring annuloplasty was excellent up to 10 years after surgery, the mean TR grade started to increase after 10 years. Sixteen out of 492 patients who did not undergo TV annuloplasty (3.2%) revealed progression to severe TR. Preoperative atrial fibrillation (odds ratio (OR), 4.85; 95% confidence interval (CI), 1.38–17.1; P=0.014) and preoperative TR grade (OR, 5.16; 95% CI, 1.78–14.9; P=0.003) were predictors for progression to severe TR.

Conclusions: Aggressive treatment with concomitant TV annuloplasty should be advocated in cases with atrial fibrillation and more than moderate TR. (Circ J 2013; 77: 2288–2294)

Key Words: Follow-up study; Mitral valve; Regurgitation; Surgery; Valve

Functional tricuspid regurgitation (TR) is often associated with left-sided cardiac valve disease. Functional TR has historically been managed conservatively because it was expected to diminish or disappear after surgical correction of left-sided valve pathology.  However, residual and recurrent functional TR has been reported after isolated mitral surgery. Severe late TR is associated with increased early and mid-term morbidity and mortality, despite adequate cardiac surgery for left-sided valve disease. It is commonly accepted that concomitant tricuspid valve (TV) annuloplasty should be performed for severe functional TR at the time of mitral surgery. However, the issue of whether moderate TR should be repaired remains controversial. Few studies have addressed the progression of functional TR and its clinical impact after mitral valve repair for degenerative mitral regurgitation (MR). Yilmaz et al reported that TV surgery was unnecessary in most patients undergoing mitral valve repair for degenerative MR. Navia et al, however, reported that moderate TR should be treated by concomitant TV repair to prevent disease progression and the development of right ventricle dysfunction. Severe TR associated with degenerative MR is generally treated with concomitant TV annuloplasty in our institution, while mild and moderate TR are treated on a case-by-case basis, taking into account individual patient characteristics. We have applied TV annuloplasty even for mild and moderate TR in cases with chronic atrial fibrillation or pulmonary hypertension; however, we have no clear criteria for mild and moderate TR without atrial fibrillation or pulmonary hypertension. In this study, we retrospectively investigated the long-term outcome in terms of functional TR grade after mitral valve repair for degenerative MR, and clarified the impact of concomitant TV annuloplasty on long-term TR control.

Methods

Data analysis for this retrospective study was approved by the Institutional Review Board of Kobe City Medical Center Gen-

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ards regression analysis was used to identify predictors of late survival and freedom from events were calculated using the Kaplan-Meier method. Statistical analysis was performed with StatView (SAS Institute, Cary, NC, USA). Univariate Cox hazard method. Continuous data are expressed as mean ± standard deviation (SD) and range. Survival and freedom from events were calculated using the Kaplan-Meier method. Statistical analysis was performed with StatView (SAS Institute, Cary, NC, USA). Univariate Cox hazards regression analysis was used to identify predictors of late progression to severe TR.

### Patient Population
A total of 1,138 patients underwent mitral valve surgery (949 mitral valve repair and 169 mitral valve replacement) at Kobe City Medical Center General Hospital from January 1991 to December 2010. Among the patients who underwent mitral valve repair, 247 (26.0%) with type I or III MR were excluded. Patients with congenital MR and patients who underwent concomitant aortic valve procedures were also excluded. A total of 654 patients with type II, degenerative MR were therefore retrospectively analyzed.

### Clinical Follow up and Examinations
Patients were followed up at the outpatient clinic or by telephone survey. Follow up was completed in 647 patients (98.9%) with a mean ± standard deviation (SD) follow-up duration of 7.5±4.9 years. Postoperative transthoracic echocardiography was performed at the outpatient clinic in 562 out of 644 patients (87.3%) who survived surgery. Postoperative echocardiographic follow up was generally performed before discharge and at the outpatient clinic at 1, 5, 10 and 15 years post-operation. The mean duration of echocardiographic follow up was 5.5±4.8 years. Follow-up echocardiographic data were obtained for 558 patients at 1 year, 360 patients at 5 years, 202 patients at 10 years and 65 patients at 15 years after surgery.

### Statistical Analysis
Continuous data are expressed as mean ± SD and range. Survival and freedom from events were calculated using the Kaplan-Meier method. Statistical analysis was performed with StatView (SAS Institute, Cary, NC, USA). Univariate Cox hazards regression analysis was used to identify predictors of late progression to severe TR.

### Results

#### Preoperative Characteristics
The TR grade was scored as none or trivial (0), mild (1), moderate (2) and severe (3). Preoperative TR grade was 0 or 1 in 479 (73.2%) patients, grade 2 in 125 (19.1%) patients and grade 3 in 50 (7.7%) patients. Patient characteristics and preoperative echocardiographic data are shown in Table 1. Patients with preoperative moderate or severe TR were older, were mostly women, and had a higher New York Heart Association (NYHA) functional class. Regarding echocardiographic data, patients with preoperative moderate or severe TR had a larger left atrial diameter, higher systolic pulmonary artery pressure, and a higher incidence of atrial fibrillation. However, left ventricular diastolic and systolic diameters and left ventricular ejection fraction were similar in all 3 groups.

### Surgical Techniques
We used a median sternotomy approach and standard cardiopulmonary bypass techniques, including bicaval cannulation, in all patients. The techniques of mitral valve repair have been described previously by Carpentier and by David et al. Prolapso of the posterior leaflet was usually corrected by resection and suture of mitral leaflets. Prolapse of the anterior leaflet was usually corrected by chordal replacement with polytetrafluoroethylene (Gore-Tex; W.L. Gore and Associates Inc, Flagstaff, AZ, USA) sutures.

Concomitant TV annuloplasty was performed in 162 patients (24.8%). TV annuloplasty was performed in 63 of 479 (13.1%) patients with grade 0 or 1 TR, in 54 of 125 (43.2%) patients with grade 2 TR, and in 45 of 50 (90%) patients with grade 3 TR. With respect to TV annuloplasty procedures, ring annuloplasty was performed in 120 patients, posterior leaflet commissure plication was performed in 30 patients, and De Vega suture was performed in 12 patients. The materials used were flexible Duran annuloplasty rings (Medtronic Inc, Minneapolis, MN, USA) in 87 patients and SJM Tailor flexible annuloplasty rings (St. Jude Medical Inc, St. Paul, MN, USA) in 33 patients. We divided the patients into 2 groups according to whether they received concomitant TV annuloplasty: the TV repair (+) group and TV repair (−) group. Saline infusion tests were per-

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### Table 1. Patient Characteristics and Preoperative Echocardiographic Data

<table>
<thead>
<tr>
<th>Preoperative TR grade</th>
<th>Mild or less (n=479)</th>
<th>Moderate (n=125)</th>
<th>Severe (n=50)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>54.2±14.7</td>
<td>62.8±11.5</td>
<td>62.0±15.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Male sex (n, %)</td>
<td>295 (62)</td>
<td>67 (54)</td>
<td>23 (46)</td>
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<tr>
<td>NYHA functional class</td>
<td>2.2±0.5</td>
<td>2.3±0.6</td>
<td>2.7±0.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LV diastolic diameter (mm)</td>
<td>55.6±6.8</td>
<td>55.6±6.3</td>
<td>53.6±8.1</td>
<td>0.990</td>
</tr>
<tr>
<td>LV systolic diameter (mm)</td>
<td>33.8±6.6</td>
<td>35.0±6.6</td>
<td>33.1±7.4</td>
<td>0.071</td>
</tr>
<tr>
<td>LV ejection fraction (%)</td>
<td>66.6±7.8</td>
<td>66.0±7.9</td>
<td>66.9±9.7</td>
<td>0.449</td>
</tr>
<tr>
<td>Left atrial diameter (mm)</td>
<td>44.9±8.2</td>
<td>49.6±10.3</td>
<td>55.1±10.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Systolic PA pressure (mmHg)</td>
<td>39.2±11.2</td>
<td>51.4±19.1</td>
<td>53.4±18.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Atrial fibrillation (n, %)</td>
<td>69 (14)</td>
<td>51 (41)</td>
<td>37 (74)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

NYHA, New York Heart Association; LV, left ventricle; PA, pulmonary artery; TR, tricuspid regurgitation.

### Table 2. Details of Surgical Procedure

<table>
<thead>
<tr>
<th>Procedure</th>
<th>n=654</th>
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<tbody>
<tr>
<td>TV procedure</td>
<td></td>
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<tr>
<td>Ring annuloplasty, n (%)</td>
<td>120 (18.3)</td>
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<tr>
<td>Posterior leaflet commissure plication, n (%)</td>
<td>30 (4.6)</td>
</tr>
<tr>
<td>De Vega suture, n (%)</td>
<td>12 (1.8)</td>
</tr>
<tr>
<td>Concomitant other procedures</td>
<td></td>
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<tr>
<td>Coronary artery bypass grafting, n (%)</td>
<td>35 (5.4)</td>
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<tr>
<td>Maze procedure, n (%)</td>
<td>87 (13.3)</td>
</tr>
<tr>
<td>Closure of ASD or PFO, n (%)</td>
<td>34 (5.2)</td>
</tr>
<tr>
<td>Cardiopulmonary bypass time (min)</td>
<td>147±48</td>
</tr>
<tr>
<td>Aortic cross-clamp time (min)</td>
<td>104±36</td>
</tr>
</tbody>
</table>

TV, tricuspid valve; ASD, atrial septal defect; PFO, patent foramen ovale.
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...tion in 2 patients, arrhythmia in 1 patient, pneumonia in 1 patient, and bowel ischemia in 1 patient.

The mean preoperative TR grade in the TV repair (+) group was 1.8±0.9, which decreased to 0.6±0.5 postoperatively (P<0.001). The mean preoperative TR grade in the TV repair (–) group was 0.9±0.6, which also decreased postoperatively to 0.7±0.5 (P<0.001; Figure 1).

Details of the surgical procedures are shown in Table 2.

Early Outcomes

In-hospital mortality occurred in 6 of 479 patients with grade 0 or 1 TR (1.3%), in 3 of 125 patients with grade 2 TR (2.4%), and in 1 of 50 patients with grade 3 TR (2.0%). In-hospital mortality was not affected by preoperative TR grade. The causes of in-hospital death were low-output syndrome in 3 patients, intraoperative left ventricular rupture in 2 patients, cerebral infarction in 2 patients, arrhythmia in 1 patient, pneumonia in 1 patient, and bowel ischemia in 1 patient.

The mean preoperative TR grade in the TV repair (+) group was 1.8±0.9, which decreased to 0.6±0.5 postoperatively (P<0.001). The mean preoperative TR grade in the TV repair (–) group was 0.9±0.6, which also decreased postoperatively to 0.7±0.5 (P<0.001; Figure 1).

Long-Term Survival and Freedom From Admission for Congestive Heart Failure

The overall survival curve is shown in Figure 2. Survival
Tricuspid Regurgitation After Mitral Valve Repair

The incidence of freedom from re-admission for congestive heart failure was also related to preoperative TR severity (Figure 3). The 5-year freedom rates were 97.1±0.8% in grade 0 or 1 TR, 93.6±2.4% in grade 2 TR, and 87.7±5.8% in grade 3 TR. The corresponding 10-year freedom rates were 91.2±1.7%, 78.1±5.5%, and 83.3±7.0%, respectively. The incidences of freedom from re-admission for congestive heart failure were significantly lower in the grade 2 and 3 TR groups compared with the other 2 groups (log rank P<0.001).

Figure 3. Incidence of freedom from re-admission for congestive heart failure is shown. Mild or less indicates patients with preoperative TR grade 0 or 1. Moderate indicates patients with grade 2 preoperative TR. Severe indicates patients with grade 3 preoperative TR. TR, tricuspid regurgitation.

Figure 4. Serial changes in mean TR grade in the TV repair (+) and TV repair (−) groups. Dis, at discharge; 1-y, 1 year post-operation; 3-y, 3 years post-operation; 5-y, 5 years post-operation; 10-y, 10 years post-operation; 15-y, 15 years post-operation; TR, tricuspid regurgitation; TV, tricuspid valve.
Progression to Severe TR

Five out of 162 patients in the TV repair (+) group (3.1%) progressed to severe TR during the follow-up period. These 5 patients had undergone prior posterior leaflet commissure plication, and none of them underwent further surgery for TR because their symptoms were mild. There were no recurrences of severe TR in patients who underwent ring annuloplasty or De Vega suture.

Sixteen of 492 patients in the TV repair (−) group (3.3%) progressed to severe TR during the follow-up period. The preoperative TR grade was 0 or 1 in 6 patients and grade 2 in 10 patients, and the incidences of severe TR were 1.5% (6/413) in the grade 0 or 1 group and 14% in the grade 2 group (10/71). Five patients who did not undergo TV repair despite having severe preoperative TR showed no recurrence of severe TR.

The NYHA functional classes of patients who progressed to severe TR are shown in Figure 5. Among 21 patients, 11 (52%) were NYHA functional class I, 7 (33%) were class II, and 3 (14%) were class III. One class II patient and 2 class III patients required redo TV surgery because of severe symptoms because of right cardiac failure.

Univariate analysis revealed that TV repair (−) (Table 3), preoperative TR grade (hazard ratio (HR), 5.16) and preoperative atrial fibrillation (HR, 4.85) were associated with late recurrence of severe TR. Recurrences of severe MR were encountered in 19 cases during the follow-up period but were not associated with late recurrence of severe TR.

**Discussion**

Functional TR is often associated with left-sided valve disease, and has historically been managed conservatively.1,13 However, moderate-to-severe late functional TR has been reported after isolated mitral surgery.1,14 Because severe late TR is associated with high mortality and morbidity, concomitant TV annuloplasty is recommended at the time of mitral surgery in these patients, to prevent progression of functional TR. However, previous studies have identified various mechanisms of MR, ranging from rheumatic to ischemic disease and other cardiomyopathic processes.1,3–15 The type of MR affects the progression of TR. We therefore focused on degenerative mitral valve leaflet prolapse, which is the most frequent MR condition in the West. In this study, the severity of preoperative TR was associated with symptom progression, atrial fibrillation, and pulmonary hypertension. Although preoperative TR severity did not affect in-hospital mortality, it did affect long-term survival and freedom from re-admission for congestive cardiac failure. Correction of functional TR is therefore an important factor in improving the clinical outcome of patients after mitral valve surgery.

The need for concomitant TV annuloplasty for moderate functional TR remains controversial.9,10 Yilmaz et al concluded that TV annuloplasty was rarely necessary in patients with degenerative mitral disease because progression of TR after mitral

| Table 3. Univariate Analysis of Predictors for Recurrence of Severe TR in the TV Repair (−) Group |
|-----------------|-----------------|-----------------|-----------------|
| Age             | 0.99            | 0.95–1.04       | 0.769           |
| Male sex        | 0.31            | 0.09–1.12       | 0.748           |
| Preoperative atrial fibrillation | 4.85 | 1.38–17.1       | 0.014           |
| Preoperative RVP | 0.99           | 0.95–1.03       | 0.631           |
| Preoperative TR grade | 5.16 | 1.78–14.9       | 0.003           |
| Postoperative severe MR recurrence | 2.27 | 0.22–23.3       | 0.491 |

CI, confidence interval; HR, hazard ratio; RVP, right ventricular pressure; TR, tricuspid regurgitation; MR, mitral regurgitation.
surgery was unlikely; however, the mean TR grade increased postoperatively in a time-dependent manner. They suggested that progression of TR was clinically insignificant and was not associated with the risk of re-operation. The current study provided longer follow-up data for functional TR after mitral valve repair compared with previous studies, and found that mean TR grade increased rapidly after 10 years post-operation. To the best of our knowledge, this is the only study to provide such long-term follow-up data. Progression to severe TR was rare in patients with grade 0 or 1 preoperative TR grade (1.5%), but was more frequent in patients with grade 2 preoperative TR (14%). Moreover, TR progression was associated with the deterioration of patients’ symptoms. Approximately half of the patients in the present study were NYHA functional class II or higher, and some required redo cardiac surgery because of severe symptoms of right cardiac failure. Given that there was no progression to severe TR after ring annuloplasty, we suggest that concomitant TV annuloplasty should be performed in patients with moderate or worse preoperative TR. The addition of TV annuloplasty does not significantly increase surgical times, and is therefore unlikely to jeopardize clinical outcomes. In contrast, redo surgery for TV is more likely to be high risk because of adhesion of the right ventricle, as well as right ventricular dysfunction. We suggest that redo surgery should be considered in patients with severe symptoms of right cardiac failure.

We routinely performed a saline infusion test after ring implantation to confirm coaptation of the leaflets. No additional procedures for residual TR were required in the current study. Only 12 patients in this study underwent the De Vega procedure; because this is an older procedure, the mean follow-up time of these patients exceeded 10 years (11.8 years). Moderate late TR was revealed in some patients in this cohort, but there were no cases of severe late TR. Nevertheless, the mean TR grade after 10 years operation was higher in De Vega suture patients than in ring annuloplasty patients. Therefore, ring annuloplasty can provide better long-term durability than suture annuloplasty. Five patients did not undergo concomitant TV annuloplasty despite severe TR; they were treated under urgent or emergent situations because of the relatively acute onset of MR. Postoperative TR was not significant after correction of left-sided disease. We considered these patients differently from those patients who suffered from severe TR associated with a long history of MR.

TV ring annuloplasty is usually applied to patients with functional TR. However, high rates of residual and recurrent TR have been reported. McCarthy et al described 790 patients who underwent TV repair for functional TR. The rate of residual TR 1 month after repair was 15%. Tang et al reported a TR recurrence rate of 30% at a mean follow up of 5.9 years after TV repair in 702 patients. A variety of prosthetic rings are currently available: flexible bands, semi-rigid rings, and rigid rings. The most suitable type of ring for TV annuloplasty for functional TR is controversial, and no randomized studies have explored this issue. Ghoreishi et al and Jeong and Kim reported good outcomes of TV repair using under-sized rigid three-dimensional annuloplasty rings. Benedetto et al performed a randomized study to determine if TV annuloplasty should be performed prophylactically at the time of mitral valve surgery. They concluded that prophylactic TV annuloplasty using a flexible ring was associated with a reduced rate of TR progression in patients with dilated tricuspid annulus. Zutani et al retrospectively compared the outcomes associated with the use of flexible bands and rigid rings. They concluded that although both flexible band and rigid ring annuloplasty were associated with low rates of recurrent TR, rigid ring annuloplasty might be more effective than flexible band annuloplasty for decreasing functional TR in the immediate and mid-term postoperative periods. However, these studies only analyzed the short- and mid-term outcomes, while the current study showed the long-term outcomes of tricuspid annuloplasty, generally performed using flexible bands. Mean TR grade increased rapidly after 10 years post-operation. It is unclear if rigid rings would be more durable in the long term because no studies have so far assessed the long-term follow-up data for the use of rigid rings for tricuspid annuloplasty.

Several factors, including female sex, older age, preoperative atrial fibrillation, diabetes mellitus, and severe preoperative TR have reportedly been associated with a time-dependent increase in TR. Mutlak et al reported that pulmonary hypertension was a strong determinant of TR severity, but many patients with pulmonary hypertension did not exhibit significant TR. In this study, preoperative TR grade and atrial fibrillation were associated with progression to severe TR. However, pulmonary hypertension was not associated with the progression of TR, which is agreement with a previous study. We support the use of concomitant TV annuloplasty in patients with atrial fibrillation or pulmonary hypertension, even in those with mild preoperative TR. The results of this study suggest that aggressive treatment with TV annuloplasty is justified in patients with atrial fibrillation.

**Study Limitations**

This study was a retrospective single-institution review of collected data, and was therefore influenced by typical biases. Second, clinical and postoperative transthoracic echocardiography follow up was incomplete in some cases. Finally, the technical ability to reproducibly quantify TR might have changed over the course of the study, in line with improvements in echocardiographic technologies.

**Conclusions**

This study showed the long-term fate of functional TR after mitral valve repair for degenerative MR. Concomitant TV annuloplasty using flexible bands showed excellent durability for preventing progression of TR up to 10 years post-operation. However, the mean TR grade increased rapidly after 10 years, indicating the need for long-term follow up. Aggressive treatment with concomitant TV annuloplasty should be advocated in patients with atrial fibrillation and more than moderate preoperative TR.

**References**

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