“Prophylactic” Tricuspid Repair for Functional Tricuspid Regurigitation

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Background. The optimal management of functional tricuspid regurgitation (FTR) in the setting of mitral valve operations remains controversial. The objective of this study is to compare the outcomes of congestive heart failure patients who underwent a prophylactic tricuspid operation for FTR as a component of their initial mitral valve procedure with those who underwent a redo tricuspid operation at a later date for residual FTR.

Methods. Patients with FTR repaired as a redo operation between 2004 and 2012 were identified. These patients were propensity-matched 1:2 with contemporaneous patients with FTR or tricuspid dilatation who underwent tricuspid repair at the same time as mitral valve repair. Demographic information, postoperative complications, and short-term and long-term mortality rates were compared between groups.

Results. There were 21 patients treated with redo tricuspid valve repair matched with 42 patients treated prophylactically. There were 3 deaths at 30 days in the redo group (14%), compared with zero in the prophylactic group ($p = 0.03$). Overall long-term mortality in the redo group was 29% (6 of 21), with a mean 31 months of follow-up, but was only 14% (6 of 42) in the prophylactic group, with a mean 25 months of follow-up. Kaplan-Meier long-term survival analysis did not reveal a difference between groups (log-rank $p = 0.37$) once the perioperative period was survived.

Conclusions. Redo tricuspid valve repair for residual FTR can be performed with acceptable short-term and long-term mortality. However, treatment of FTR at the time of the initial intervention should be considered, because it is safe and effective. A randomized, controlled trial of prophylactic tricuspid operation for FTR at the time of the mitral operation may be warranted.

Accepted for publication Nov 25, 2013.

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the morbidity and mortality of redo TVr in the present era compared contemporaneously with prophylactic TVr performed at the time of mitral valve repair. We hypothesized that redo TVr can be performed with a relatively acceptable mortality rate but that prophylactic repair at the time of initial operation would produce better outcomes.

Patients and Methods
This study was approved by the University of Michigan Health System Institutional Review Board (HUM00054299).

Patients and Study Design
We performed a retrospective review of all patients with New York Heart Association class II to IV heart failure and FTR who underwent TV annuloplasty between 2004 and 2012. The redo TVr group was composed of 21 patients who had previous cardiac operations with some degree of FTR at the time of their earlier operation. They were propensity matched in a 1:2 fashion with 42 patients from the same time period identified as having a TV annuloplasty at the time of an operation for functional mitral regurgitation.

Patients were identified and propensity-matched for age, smoking status, diabetes, renal failure, chronic obstructive pulmonary disease, New York Heart Association class, and right ventricular systolic pressure. These 42 identified and matched patients composed the prophylactic group. Patients with organic TV disease were not included in this study.

Surgical Technique
Our criteria for TVr at the time of mitral valve repair were more aggressive than current American guidelines and included mild to moderate or greater TR or a tricuspid annulus diameter greater than 40 mm on intraoperative or preoperative echo testing, analogous to the present European guidelines. Determination of type and size of annuloplasty rings was at the discretion of the operating surgeon. For the prophylactic group, rigid remodeling rings were used for TV annuloplasty and were matched to the same size as the mitral valve annuloplasty ring size [17]. The mitral valve rings were generally complete rigid rings. In the redo group, TV annuloplasty was generally performed with a rigid remodeling ring.

Data Collection and Statistics
A prospectively maintained database was used for data collection. Mortality data were confirmed using the Social Security Death Index. Categoric variables were compared between groups using $\chi^2$ tests. Two-sample t tests or Wilcoxon rank sum tests were used to compare continuous variables between groups. Kaplan-Meier survival analysis was used to estimate long-term survival, and the log-rank test was used to compare survival between groups. All statistics were performed with SPSS 20 software (IBM Corp, Armonk, NY). Statistical significance was defined as two-sided $p$ value of less than 0.05.

Results
Baseline patient characteristics of the prophylactic TVr and redo TVr groups are reported in Table 1. Prophylactic TVr patients were more often male, with a higher preoperative weight, but lower ejection fraction, compared with redo patients. There were no other differences in demographics and comorbidities between the matched groups.

In the redo group, TV annuloplasty was performed in 15 patients (71%), and replacement was performed in 6 (29%). All operations were performed on cardiopulmonary bypass. Redo sternotomy was performed in 5 patients (24%), and right thoracotomy was performed in 16 patients (76%). Concomitant procedures included a Maze procedure in 6 patients (29%) and coronary artery bypass grafting (CABG) in 1 patient (5%). Annuloplasty was performed with the Edwards MC3 tricuspid annuloplasty ring, size 26 to 28 mm (Edwards Lifesciences, Irvine, CA).

Previous operations performed included mitral valve annuloplasty alone in 8 patients (38%), mitral valve annuloplasty with CABG in 4 (19%), CABG alone in 4 (19%), aortic valve replacement in 2 (10%), aortic valve replacement with mitral valve repair in 1 (5%), aortic valve replacement with CABG in 1 (5%), and aortic dissection repair in 1 (5%).

In the prophylactic group, all patients underwent mitral valve and TV annuloplasty. Mean TR was moderate (3+), with a mean gradient of 1.7. Two patients had a right thoracotomy (5%), and the remainder had a median sternotomy (95%). Mitral valve annuloplasty was performed with the Geof orm ring (Edwards Lifesciences) in 33 patients (79%), the Cosgrove-Edwards Annuloplasty System (Edwards Lifesciences) in 7 (17%), the Carpentier-Edwards Physio ring (Edwards Lifesciences) in 1 (2%), and the Carpentier-Edwards Classic ring (Edwards Lifesciences) in 1 (2%). TV annuloplasty was performed with the Medtronic Contour 3D ring (Medtronic Inc, Minneapolis, MN) in 3 patients (7%) and the Edwards MC3 ring in the rest (93%). The same size ring was used in

<table>
<thead>
<tr>
<th>Variable</th>
<th>Prophylactic TVr (n = 42)</th>
<th>Redo TVr (n = 21)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y (mean ± SD)</td>
<td>64.6 ± 12.5</td>
<td>67.1 ± 10.4</td>
<td>0.421</td>
</tr>
<tr>
<td>Smoking history, No. (%)</td>
<td>8 (19.0)</td>
<td>6 (28.6)</td>
<td>0.391</td>
</tr>
<tr>
<td>Diabetes, No. (%)</td>
<td>12 (28.6)</td>
<td>4 (19.0)</td>
<td>0.544</td>
</tr>
<tr>
<td>Renal failure, No. (%)</td>
<td>5 (11.9)</td>
<td>6 (28.6)</td>
<td>0.100</td>
</tr>
<tr>
<td>COPD, No. (%)</td>
<td>7 (16.7)</td>
<td>2 (9.5)</td>
<td>0.705</td>
</tr>
<tr>
<td>RVSP, mm Hg (mean ± SD)</td>
<td>57.6 ± 19.5</td>
<td>46.8 ± 19.3</td>
<td>0.130</td>
</tr>
<tr>
<td>NYHA class (mean ± SD)</td>
<td>2.86 ± 0.47</td>
<td>2.67 ± 0.62</td>
<td>0.222</td>
</tr>
<tr>
<td>Male sex, No. (%)</td>
<td>16 (38.1)</td>
<td>2 (9.5)</td>
<td>0.020</td>
</tr>
<tr>
<td>Preoperative weight, kg</td>
<td>84.5 ± 24.3</td>
<td>70.8 ± 15.2</td>
<td>0.008</td>
</tr>
</tbody>
</table>

Ejection fraction (mean ± SD) 0.343 ± 0.170 0.498 ± 0.168 0.001

COPD = chronic obstructive pulmonary disease; NYHA = New York Heart Association; RVSP = right ventricular systolic pressure; TVr = tricuspid valve repair.
both valves: 26 mm in 35 patients (83%) and 28 mm in 7 patients (17%).

Actuarial survival between the two groups is reported in Table 2. The mean time from the previous operation in the redo TVr group was 6 years. Three patients (14.3%) died within 30 days of operation. Mortality was 19.0% (4 of 21) at 1 year and 23.8% (5 of 21) at 2 years. With a mean follow-up time of 31.4 months, the total mortality was 28.6% (6 of 21). In the prophylactic group, no patients died within 30 days of operation, 3 (7.1%) died within the first year, and 5 (11.9%) died within 2 years. Mean follow-up in the prophylactic group was 25 months, and total mortality in this group was 14.3% (6 of 42).

Postoperative complications between the two groups are reported in Table 3. Rates of arrhythmia, respiratory failure or prolonged ventilator requirement, or both, and miscellaneous complications were significantly higher in the redo TVr group. There was no difference in rates of renal failure, stroke, infection, or need for a new pacemaker. Redo patients were more likely to have more cumulative and total postoperative complications than prophylactic patients. Figure 1 shows a Kaplan-Meier estimation of long-term survival after TV annuloplasty. The log-rank test did not reveal a significant difference in late survival between groups after the postoperative period ($p = 0.367$). The curves do appear to diverge up to around 24 months from the time of the operation in favor of the prophylactic group, although the difference at that point does not quite reach statistical significance ($p = 0.149$).

**Comment**

This study demonstrates that patients with recurrent or residual TR after prior cardiac operations can undergo redo repair with acceptable morbidity and mortality. However, this redo TVr group has a significantly increased complication rate and worse 30-day survival compared with contemporaneous patients treated prophylactically with TVr at the time of mitral repair. As evidence, all patients in the prophylactic TVr group were alive 30 days after repair, and mortality at 1 and 2 years was acceptably low, even despite the prophylactic group having a significantly lower left ventricular ejection fraction.

Historically, some authors have argued that FTR does not progress after the mitral valve operation [18]. Unfortunately, even if there were no further progression, these patients would still have some degree of FTR as well as the significant morbidity and mortality associated with FTR. In fact, most studies have shown that there is actually a high incidence of early return or progression of FTR after mitral valve operations, occurring in up to half of the patients [19–22]. Furthermore, the rate of increase of recurrent/residual TR has been shown to be progressive and even worse at late follow-up from mitral valve operations, up to 74% after 3 years [22]. As further evidence, a recent study from Mayo Clinic showed a transient decrease in functional TR after mitral valve repair, but within 5 years, the degree of TR had worsened beyond what it had been preoperatively [8]. In addition, patients with moderate TR were not repaired in that series [8] and were therefore left with at least residual moderate TR, which is known to adversely affect the mortality rate [5]. Arguably all efforts should be made to prevent this residual FTR after left-sided heart operations, which is an independent risk factor for heart failure and death [23].

**Table 2. Actuarial Survival After Tricuspid Valve Repair**

<table>
<thead>
<tr>
<th>Mortality</th>
<th>Prophylactic TVr (n = 42)</th>
<th>Redo TVr (n = 21)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-day</td>
<td>0 (0)</td>
<td>3 (14.3)</td>
<td>0.033</td>
</tr>
<tr>
<td>1-year</td>
<td>3 (7.1)</td>
<td>4 (19.0)</td>
<td></td>
</tr>
<tr>
<td>2-year</td>
<td>5 (11.9)</td>
<td>5 (23.8)</td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>6 (14.3)</td>
<td>6 (28.6)</td>
<td></td>
</tr>
</tbody>
</table>

TVr = tricuspid valve repair.

**Table 3. Postoperative Complications After Tricuspid Valve Repair**

<table>
<thead>
<tr>
<th>Complication</th>
<th>Prophylactic TVr (n = 42)</th>
<th>Redo TVr (n = 21)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrhythmia</td>
<td>4 (11)</td>
<td>7 (33)</td>
<td>0.032</td>
</tr>
<tr>
<td>Respiratory failure</td>
<td>1 (2)</td>
<td>9 (43)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>3 (7)</td>
<td>10 (48)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Total patients with</td>
<td>10 (24)</td>
<td>17 (81)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>complications*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acute renal failure</td>
<td>2 (5)</td>
<td>3 (14)</td>
<td>0.323</td>
</tr>
<tr>
<td>Stroke</td>
<td>0</td>
<td>1 (5)</td>
<td>0.333</td>
</tr>
<tr>
<td>Infection</td>
<td>2 (5)</td>
<td>4 (19)</td>
<td>0.089</td>
</tr>
<tr>
<td>Need for new pacemaker</td>
<td>1 (2)</td>
<td>1 (5)</td>
<td>1.000</td>
</tr>
</tbody>
</table>

* These values represent number of patients that had complications in each group. Since some patients had more than 1 complication, the total sum of the complications in each column will be more than 10 and 17. TVr = tricuspid valve repair.
The results of our study are in agreement with a now-growing body of literature suggesting that TV operations can safely be performed and perhaps should be performed at the time of other cardiac surgical interventions, particularly mitral valve operations. A landmark study by Dreyfus and colleagues [24] demonstrated that if a dilated TV was repaired at the same time as a mitral valve repair, a 10-fold reduction in recurrent/residual TR was achieved at 2 years. In addition, Benedetto and colleagues [25] randomized 40 patients to receive or not receive TV annuloplasty at the time of mitral valve operation. The 12-month follow-up showed a decreased progression of TR as well as improvement in right ventricular remodeling and functional outcome [25].

Presently, many have shown that compared with mitral valve repair alone, the combination of mitral valve repair and TVr decreases the degree of TR and improves right ventricular remodeling, without adversely affecting operative mortality [26]. In a recent study, Desai and colleagues [27] showed that patients with mitral valve repair alone had only short-term improvements in TR and right ventricular function, with subsequent return to preoperative levels of TR. However, the result in those that had concomitant mitral and tricuspid repair was sustained improvement in function [27].

Our group described a simple approach to simultaneous repair by using identically sized annuloplasty rings for mitral and tricuspid repair [17]. This method reduced the recurrence of TR without any negative effects on right ventricular function or operative survival. Similar findings have previously been shown by Calafiore and colleagues [28], who performed a propensity score analysis that demonstrated improved survival and less progression of TR in patients who underwent tricuspid and mitral repair simultaneously. Finally, the Dreyfus study also indicated no increase in the complication or mortality rate with the addition of simultaneous tricuspid annuloplasty. Therefore, although there are known risks associated with TVr, such as atrioventricular node injury, hemolysis, and endocarditis, it appears that TVr can safely be performed prophylactically at the same time as mitral valve repair, without an increase in the complication or mortality rate [24]. On the basis of these studies, one could potentially imagine recommending criteria (similar to the present European guidelines) for TVr to include any impactful TR or TV annulus exceeding 40 mm [29].

Our study does have limitations, primarily related to its retrospective nature. This is a small study, and despite matching, unique patient technical and pathophysiologic features cannot be accounted for. Many of these redo TVr patients were referred to our center late in their course, and the exact amount and cause of TR present at that time and specific details of their initial operation were not always completely available.

In conclusion, in patients with recurrent and residual functional TR, our data question the prohibitively high mortality rate in other historically reported reoperative TVr series. Consequently, given the morbidity and mortality associated with untreated TR, these patients perhaps should be judiciously considered for TVr despite their redo status.

More important, the data in our present small study suggest that efforts to repair the TV prophylactically can be undertaken safely and effectively at the time of the initial mitral repair. The data warrant a larger scale, prospective trial of concomitant mitral and TVr in patients with TR or significant tricuspid dilatation randomized against patients left with uncorrected TR (natural history arm) at the time of mitral repair operations. With positive results from a larger trial, clinicians could confidently treat patients with FTR prophylactically and avoid both the risks of recurrent TR and the risks associated with late redo tricuspid operations.

References

committee to revise the 1998 Guidelines for the Management of Patients With Valvular Heart Disease: developed in collaboration with the Society of Cardiovascular Anesthesiologists; endorsed by the Society for Cardiovascular Angiography and Interventions and the Society of Thoracic Surgeons. Circulation 2006;114:e84–231.


INVITED COMMENTARY

Teman and colleagues [1] compared outcome after tricuspid valve repair (TVR) for functional tricuspid regurgitation (FTR) at the time of mitral valve repair (MVR) with outcome after TVR for FTR in which the patient had undergone prior open heart surgery. The authors refer to the first group as the “prophylactic” group and the second as the “redo” group. Briefly, early and 2 years’ mortality was substantially better in the prophylactic TVR group.

Despite propensity matching on age, New York Heart Association class, right ventricular systolic pressure, and a number of medical factors, the prophylactic and redo groups in the authors’ study are not comparable because, as designed, the study fails to take the redo surgery status and different threshold for tricuspid repair in the two groups into consideration. Moreover, given the history of coronary artery bypass grafts in the redo group, it is unfortunate the groups were not propensity matched for coronary artery disease.

However, the study does point out the need for a randomized clinical trial of MVR with and without TVR in patients with mitral regurgitation and moderate FTR. In that regard, the authors make a number of key points that illustrate the controversy.

First, conservative management of FTR at the time of MVR is based on studies that found improvement in FTR after MVR [2]. However, residual FTR may progress after MVR [3–6], and TVR at the time of MVR is therefore probably underused. This is important because Nath and associates [7] found that even moderate FTR is associated with a substantial reduction in survival (no FTR and moderate FTR with 78% and 47% survival at 4 years, respectively).

On the other hand, TVR clearly adds to operation time and early mortality of an MVR [8], and a recent retrospective study of MVR with and without TVR for patients with mild-to-moderate FTR found no difference in early mortality as well as no difference in a composite of congestive heart failure, reoperation, and death at 65 months of follow-up [9].

The bottom line is that this is a provocative, well-written manuscript that addresses an important issue and makes the case for a subsequent randomized trial of prophylactic FTR. We completely agree with the authors’ statement that the “data may warrant a larger scale, prospective trial of concomitant mitral and tricuspid valve repair.”

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© 2014 by The Society of Thoracic Surgeons
Published by Elsevier Inc
0003-4975/$36.00
http://dx.doi.org/10.1016/j.athoracsur.2014.01.008