Ring or Suture Annuloplasty for Tricuspid Regurgitation? A Meta-Analysis Review

Alessandro Parolari, MD, PhD,* Fabio Barili, MD, PhD,* Alberto Pilozzi, MD, and Davide Pacini, MD

Department of Cardiovascular Sciences, University of Milan, Milan; Department of Cardiac Surgery, S. Croce Hospital, Cuneo; and Department of Cardiac Surgery, University of Bologna, Italy

We performed a meta-analysis of early and long-term outcomes after tricuspid repair to compare the results of suture-based and prosthetic ring annuloplasty with the employment of an algorithm that derives the original patient time-to-event data. There was an advantage in early but not in long-term survival with the use of the annuloplasty ring. The freedom from moderate tricuspid regurgitation was significantly better in patients with ring annuloplasty (78.9% ± 5.0% at 15 years vs 60.0% ± 4.2%, log-rank p = 0.0107). The ring annuloplasty is associated to better outcomes, being a protective factor for early mortality and long-term recurrence of tricuspid regurgitation after surgery.

© 2014 by The Society of Thoracic Surgeons

Material and Methods

Different methodologies were employed to meta-analyze short-term and long-term outcomes after tricuspid repair for TR with prosthetic ring or suture annuloplasty. It was undertaken mainly to compare the impact of these 2 different surgical approaches on short-term outcomes and mortality and TR recurrence at follow-up.

Data Extraction

In both cases, a systematic review and meta-analysis were performed after Meta-analysis Of Observational Studies in Epidemiology [14] and Standards for Reporting of Diagnostic Accuracy [15] guidelines. From October 7 to 15, 2013, 3 reviewers searched Medline (1950 through October 15, 2013) and PubMed (up to October 15, 2013), including electronic links to related articles. The text strings used were (formatted for PubMed): ["tricuspid valve repair" OR "tricuspid valve plasty" OR "tricuspid valvuloplasty"]'). To further reduce the probability of losing any major related study, an electronic search was performed of 4 major cardiothoracic surgery journals in the electronic format; Interactive CardioVascular and Thoracic Surgery, The Annals of Thoracic Surgery, The European Journal of Cardiothoracic Surgery, and The Journal of Thoracic and Cardiovascular Surgery. Tangential electronic exploration of related articles and manual

*Drs Parolari and Barili contributed equally to this paper.

Address correspondence to Dr Barili, Department of Cardiac Surgery, S. Croce Hospital, Via M. Coppino 26, 12100 Cuneo, Italy; e-mail: fabarili@libero.it.
searches of bibliographies, related journals, and reference lists of reviews was also used. Non-English articles were excluded. The title of every article was considered first, then selected abstracts were searched to identify the peer-reviewed studies reporting the outcomes after tricuspid repair for TR.

The surgical techniques were classified as originally reported and then categorized as the following: (1) techniques foreseeing the use of a ring (eg, when an artificial or pericardial ring was used, partial or complete) (RING); (2) suture-based annuloplasties (eg, De Vega technique and bicuspidalization) (NO RING). Hence, all the papers reporting techniques that could not be easily attributed at one of the two previously mentioned surgical strategies, or papers reporting combination of different techniques were excluded.

Summarizing, the following exclusion criteria were employed to select the final articles for the short-term outcomes: (1) no direct comparison between TR repair with prosthetic ring or suture annuloplasty; (2) surgical techniques that could not be easily attributed at 1 of the 2 previously mentioned surgical strategies; (3) combination of different techniques for TR repair; (4) no data on early mortality (30-day or in-hospital mortality); and (5) non-English articles. For the outcomes at follow-up, the exclusion criteria were the following: (1) surgical techniques that could not be easily attributed at 1 of the 2 previously mentioned surgical strategies; (2) combination of different techniques for TR repair; (3) no KM curves of survival, freedom from recurrent moderate TR, freedom from reoperation, reoperation for recurrent TR; (4) non-English articles. In the meta-analysis of late outcomes the lack of a direct comparison between TR repair with prosthetic ring or suture annuloplasty was not considered an exclusion criteria, and also papers reporting the KM graphs of a single surgical technique were included in the study as the methodology permits to handle time-to-event data accounting for the duration of the follow-up.

The full texts of these articles were retrieved and searched for in-hospital mortality data and for Kaplan-Meier graphs of survival, freedom from recurrence of moderate tricuspid regurgitation, and freedom from reoperation due to recurrent tricuspid regurgitation. Several strategies were employed to avoid duplication of data. If the same institution produced several studies and there was sample overlap, only the most updated study was included. Data were abstracted and analyzed by the 4 authors and disagreements were resolved by consensus.

Meta-Analysis of Early Outcomes

Once papers were identified, the selection criteria for early mortality meta-analysis inclusion for each study were: (1) comparison of tricuspid repair techniques with (RING) and without (NO RING) ring use in patients affected by TR; (2) report of 30-day or in-hospital mortality in patients submitted to tricuspid valve repair for TR. Data were analyzed by the random-effects model with RevMan 5 (RevMan 5.1.4, Cochrane Collaboration, Oxford, UK) and Comprehensive Meta-analysis Version 2 (Biostat, Englewood, NJ). Effects on in-hospital mortality were expressed as risk ratio (RR) with 95% confidence intervals (CI). Heterogeneity was assessed with the χ² test; in addition, the I² (Index of Inconsistency) was calculated to quantify the degree of heterogeneity across trials that could not be attributable to chance alone [16]. Publication bias was explored through visual inspection of funnel plots and by 1-tailed Egger’s test. Statistical significance was set at a p value of 0.05 or less.

Meta-Analysis of Late Outcomes

The long-term outcomes evaluated in the meta-analysis were survival and freedom from long-term recurrence of TR or surgery for recurrent TR at follow-up. Data extraction from each available Kaplan-Meier curve was performed as described by Guyot and colleagues [13]. In the first step, KM curves reproduced in each paper were digitized using a dedicated software (Plot Digitized 2.6.2 for Macintosh). The PDF. files are read into the software, the axes are defined, and then the analyst uses mouse-clicks to select points to read off from the curve, resulting in a text file with KM coordinates. The KM data reconstruction algorithm developed in R language (R 2.15.1; R Development Core Team (2011). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900954-07-0, URL http://www.R-project.org/) was employed to derive the individual patient data. A further step with derived censored information was performed where censoring marks were present on the KM graph. Derived KM curves were graphically checked with the original ones and the same comparisons of the original studies were performed. The KM data from different studies were stored together in the study database. Statistical methods for time-to-event data were employed to analyze outcomes at follow-up, including the KM estimator with the log-rank test for comparisons and a class of fully parametric models, the accelerated failure time models.

Results

Meta-Analysis of Short-Term Outcomes

The literature searches identified 969 studies identified by the literature searches and 26 candidate trials were checked for further assessment [4, 6–8, 10, 11, 17–36]. Nine [7, 8, 10, 17–19, 21, 22, 24] fulfilled the inclusion criteria (Table 1); of these, 2 were randomized studies [19, 24], whereas the remaining 7 were retrospective, non-randomized studies [7, 8, 10, 17, 18, 21, 22]. The remaining 17 studies were discarded either because they did not report any extractable data, the type of repairs performed were not homogeneous, or because the comparison of techniques did not include a technique foreseeing annular stabilization and another technique not foreseeing annular stabilization.

Figure 1 reports the forest plot of the meta-analysis on early mortality for patients undergoing TR with or without ring use that were analyzed based on prospective and retrospective study design. Patients receiving a ring
<table>
<thead>
<tr>
<th>Author</th>
<th>Journal</th>
<th>Year</th>
<th>Technique</th>
<th>Number of Patients</th>
<th>Age (Years)</th>
<th>Sex (Male)</th>
<th>EF</th>
<th>PASP (mm Hg)</th>
<th>Functional TR</th>
<th>Mitral Surgery</th>
<th>Aortic Valve Surgery</th>
<th>CABG</th>
<th>Other</th>
<th>In-hospital Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrier [21]a,b</td>
<td>J Heart Valve Dis</td>
<td>2001</td>
<td>De Vega</td>
<td>107</td>
<td>52±11</td>
<td>22 (21%)</td>
<td></td>
<td>100%</td>
<td>104 (97%)</td>
<td>29 (27%)</td>
<td>9 (8%)</td>
<td>22 (21%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CE rigid ring</td>
<td></td>
<td>267</td>
<td>61±10</td>
<td>58 (22%)</td>
<td>255 (96%)</td>
<td>63 (24%)</td>
<td>28 (11%)</td>
<td>38 (14%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chang [17]a,b</td>
<td>Ann Thorac Surg</td>
<td>2008</td>
<td>De Vega Kay</td>
<td>117</td>
<td>50±12</td>
<td>86 (73%)</td>
<td>60±0.10</td>
<td>30±12</td>
<td>100%</td>
<td>344 (100%)</td>
<td>73 (22%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pericardial ring</td>
<td></td>
<td>217</td>
<td>54±12</td>
<td>161 (74%)</td>
<td>81 (91%)</td>
<td>29 (33%)</td>
<td>19 (23%)</td>
<td>2 (2.2%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ghanta [18]a,b</td>
<td>J Thorac Cardiovasc Surg</td>
<td>2007</td>
<td>Suture bicuspidization</td>
<td></td>
<td>157</td>
<td>66±14</td>
<td>75 (48%)</td>
<td>50±0.15</td>
<td>51±17</td>
<td>100%</td>
<td>133 (85%)</td>
<td>48 (31%)</td>
<td>47 (30%)</td>
<td>5 (3.2%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ring</td>
<td></td>
<td>80</td>
<td>68±14</td>
<td>36 (45%)</td>
<td>43±0.18</td>
<td>52±15</td>
<td>100%</td>
<td>62 (78%)</td>
<td>21 (26%)</td>
<td>29 (36%)</td>
<td>8 (10%)</td>
</tr>
<tr>
<td>Ghoreishi [26]b</td>
<td>Ann Thorac Surg</td>
<td>2011</td>
<td>Edwards ring</td>
<td></td>
<td>101</td>
<td>63±14</td>
<td>42 (42%)</td>
<td>50±0.14</td>
<td>56±22</td>
<td>100%</td>
<td>93 (93%)</td>
<td>17 (17%)</td>
<td>21 (21%)</td>
<td>3 (3%)</td>
</tr>
<tr>
<td>Guenther [22]a,b</td>
<td>Eur J Cardiothorac Surg</td>
<td>2013</td>
<td>Flexible ring</td>
<td></td>
<td>255</td>
<td>60±13</td>
<td>86 (34%)</td>
<td>69%</td>
<td>226 (89%)</td>
<td>54 (21%)</td>
<td>34 (13%)</td>
<td>40 (16%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ring</td>
<td></td>
<td>433</td>
<td>67±13</td>
<td>185 (43%)</td>
<td>306 (71%)</td>
<td>101 (23%)</td>
<td>90 (21%)</td>
<td>58 (13%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Izutani [28]b</td>
<td>Heart Int</td>
<td>2010</td>
<td>Flexible ring</td>
<td></td>
<td>35</td>
<td>73±11</td>
<td>17 (49%)</td>
<td>0.56±0.08</td>
<td>100%</td>
<td>32 (91%)</td>
<td>6 (17%)</td>
<td>5 (14%)</td>
<td>4 (11%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ring</td>
<td></td>
<td>82</td>
<td>72±10</td>
<td>29 (35%)</td>
<td>0.58±0.12</td>
<td>100%</td>
<td>70 (85%)</td>
<td>18 (22%)</td>
<td>12 (15%)</td>
<td>2 (2.4%)</td>
<td></td>
</tr>
<tr>
<td>Matsuyama [19]a,b</td>
<td>J Heart Valve Dis</td>
<td>2001</td>
<td>De Vega</td>
<td></td>
<td>28</td>
<td>62±10</td>
<td>13 (48%)</td>
<td>41±15</td>
<td>100%</td>
<td>22 (79%)</td>
<td>9 (32%)</td>
<td>1 (3.6%)</td>
<td>4 (14%)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CE rigid ring</td>
<td></td>
<td>17</td>
<td>64±9</td>
<td>6 (35%)</td>
<td>14 (82%)</td>
<td>6 (35%)</td>
<td>1 (5.9%)</td>
<td>2 (12%)</td>
<td>1 (5.9%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naqband [30]b</td>
<td>Ann Thorac Cardiov Surg</td>
<td>2010</td>
<td>Suture bicuspidization</td>
<td></td>
<td>47</td>
<td>27±8</td>
<td>24 (51%)</td>
<td>100%</td>
<td>47 (100%)</td>
<td>17 (20%)</td>
<td>1 (0.2%)</td>
<td>2 (5.6%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pericardial ring</td>
<td></td>
<td>36</td>
<td>27±9</td>
<td>16 (44%)</td>
<td>36 (100%)</td>
<td>1 (2.8%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naval [8]a</td>
<td>J Thorac Cardiov Surg</td>
<td>2010</td>
<td>De Vega Kay</td>
<td></td>
<td>129</td>
<td>68±12</td>
<td>40%</td>
<td>47±14</td>
<td>100%</td>
<td>92%</td>
<td>33%</td>
<td>34%</td>
<td>18 (14%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pericardial ring</td>
<td></td>
<td>248</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12 (4.8%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Flexible ring</td>
<td></td>
<td>185</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>52 (4.9%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rigid ring</td>
<td></td>
<td>1052</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>584</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rivera [24]a</td>
<td>J Thorac Cardiov Surg</td>
<td>1985</td>
<td>De Vega</td>
<td></td>
<td>83</td>
<td>43±9</td>
<td>14 (17%)</td>
<td>64±23</td>
<td>100%</td>
<td>83 (100%)</td>
<td>22 (27%)</td>
<td>12 (14%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CE rigid ring</td>
<td></td>
<td>76</td>
<td>44±10</td>
<td>17 (22%)</td>
<td>59±19</td>
<td>100%</td>
<td>76 (100%)</td>
<td>20 (26%)</td>
<td>9 (12%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roshanali [19]a</td>
<td>J Thorac Cardiov Surg</td>
<td>2010</td>
<td>De Vega</td>
<td></td>
<td>52</td>
<td>55±11</td>
<td>20 (38%)</td>
<td>40±7</td>
<td>100%</td>
<td>44 (85%)</td>
<td>12 (23%)</td>
<td>2 (3.8%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ring</td>
<td></td>
<td>53</td>
<td>56±10</td>
<td>18 (34%)</td>
<td>44±10</td>
<td>100%</td>
<td>47 (89%)</td>
<td>11 (21%)</td>
<td>3 (5.7%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tang [7]a,b</td>
<td>Circulation</td>
<td>2006</td>
<td>De Vega</td>
<td></td>
<td>493</td>
<td>59±14</td>
<td>173 (35%)</td>
<td>74%</td>
<td>399 (81%)</td>
<td>173 (35%)</td>
<td>84 (17%)</td>
<td>34 (7%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ring</td>
<td></td>
<td>209</td>
<td>55±14</td>
<td>52 (25%)</td>
<td>165 (79%)</td>
<td>54 (26%)</td>
<td>21 (10%)</td>
<td>8 (4%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yoda [36]b</td>
<td>Interact Cardiovasc Thorac Surg</td>
<td>2011</td>
<td>Edwards ring</td>
<td></td>
<td>136</td>
<td>65±12</td>
<td>80 (59%)</td>
<td>54±8</td>
<td>100%</td>
<td>115 (85%)</td>
<td>29 (21%)</td>
<td>12 (9%)</td>
<td>35 (26%)</td>
<td>5 (3.7%)</td>
</tr>
</tbody>
</table>

* Study included in meta-analysis of early outcomes.  b Study included in meta-analysis of late outcomes.  c Data measured on only part of patients, for this reason the dispersion parameter (SD) may be higher than expected.

3D = three-dimensional;  CE = Carpentier-Edwards;  EF = echocardiographic ejection fraction;  PASP = pulmonary artery systolic pressure.
had lower early mortality rates (RR 0.76, 95% CI 0.60 to 0.95). This result was, however, mainly driven by observational studies, whereas the subanalysis of the 2 randomized studies, albeit a very limited number of patients were studied, suggested no differences between treatments. No significant heterogeneity was underscored. The analysis of the funnel plot gave no hint of publication bias.

Meta-Analysis of Late Outcomes
Among the 26 candidate trials identified for further assessment [4, 6–8, 10, 11, 17–36], 10 [7, 10, 17, 18, 21, 22, 26, 28, 30, 36] fulfilled the inclusion criteria for the follow-up meta-analysis (Table 1). All were retrospective and non-randomized. The remaining studies were discarded as they did not report any extractable KM curves or the type of repairs performed was not homogeneous.

Long-Term Survival
Seven studies were included in the survival meta-analysis [7, 10, 17, 21, 22, 26, 36]. Three papers did not report the KM curves of survival and were excluded [18, 28, 30]. Moreover, some studies included all patients in the KM analysis while others excluded the 30-day mortality, generating a potential bias. In order to homogenize our study group and avoid biases we removed the 30-day mortality and the final dataset included 1,370 patients; 584 with a ring annuloplasty and 786 with a suture-based annuloplasty (bicuspidalization and De Vega techniques).

Figure 2(A) shows the survival function obtained by the KM nonparametric method with Greenwood confidence bands. The number of patients included in the follow-up was 1,370 and there were 319 deaths at follow-up. The median of the survival function was 14.0 years (95% CI 12.7 to 14.5 years). The KM estimates of survival at 10 and 15 years were, respectively, 66.3% ± 2.0% [95% CI 62.4% to 70.3%] and 41.2% ± 3.2% [95% CI 35.3% to 48.1%].

There was no difference in long-term survival (Fig 2B) between patients after tricuspid repair for TR with a ring (RING group, survival at 15 years 48.0% ± 4.6%, 95% CI 39.8% to 57.8%) or suture annuloplasty (NO RING group, survival at 15 years 34.6% ± 4.7%, 95% CI 26.5% to 45.2%) as demonstrated by log-rank test ($p = 0.441$) and Gehan test ($p = 0.781$).

Freedom From Moderate TR and Freedom From Recurrent Moderate TR/Reoperation for Recurrent TR
The studies included in the meta-analysis of freedom from moderate recurrent TR and surgery for recurrent TR were 10 [7, 10, 17, 18, 21, 22, 26, 28, 30, 36]. In order to avoid the bias described above, even in this analysis we removed 30-day events, and the final dataset included 1,991 patients.

Figure 3(A) shows the freedom from recurrent moderate TR (9 studies) [7, 10, 17, 18, 21, 26, 28, 30, 36]. The number of patients included in the follow-up was 1,483 and there were 171 events at follow-up. Overall, the freedom from recurrent moderate (or greater) TR at 8 and 15 years was, respectively, 83.6% ± 1.5% [95% CI 80.6% to 86.7%] and 60.0% ± 4.2% [95% CI 52.3% to 68.9%]. The events occurring in RING and NO RING groups were, respectively, 59 and 112 (Fig 3B). The freedom from recurrent moderate (or greater) TR at 8 and 15 years in patients who underwent TR repair with prosthetic ring was 88.5% ± 2.0% [95% CI 84.57 to 92.5] and 78.9% ± 5.0% [95% CI 69.7 to 89.3]. The freedom from recurrent moderate (or greater) TR at 8 and 15 years in patients who underwent TR repair without a prosthetic ring was 81.8% ± 2.0% [95% CI 78.0 to 85.8] and 50.5% ± 5.9% [95% CI 40.2 to 63.6]. There was a significant difference between the 2 groups (log-rank test $p = 0.0107$; Gehan test $p = 0.0177$).
Figure 4(A) shows the freedom from the composite recurrent moderate TR or repeated surgery for recurrent TR (10 studies) [7, 10, 17, 18, 21, 22, 26, 28, 30, 36]. The number of patients included in the follow-up was 2107 and there were 199 events at follow-up. Overall, the freedom from recurrent moderate TR or surgery for recurrent TR at 8 and 15 years was, respectively, 88.0% ± 1.0% [95% CI 85.9% to 90.1%] and 57.3% ± 7.8% [95% CI 43.9% to 74.9%]. The events occurring in RING and NO RING groups were, respectively, 64 and 135. The freedom from recurrent moderate TR at 8 and 15 years in patients who underwent TR repair with a prosthetic ring was 93.1% ± 1.0% [95% CI 91.2 to 95.1] and 83.4% ± 4.8% [95% CI 74.5 to 93.3]. The freedom from recurrent moderate TR at 8 and 15 years in patients who underwent TR repair without a prosthetic ring was 84.9% ± 1.5% [95% CI 81.9 to 87.9] and 52.8% ± 7.4% [95% CI 40.0 to 69.7]. There was a significant difference between the 2 groups (log-rank test \( p = 0.0001 \); Gehan test \( p = 0.0002 \); Fig 4B).

In order to quantify the hazard risk linked with the 2 types of surgical techniques, data were fitted to accelerated failure time models and the log-logistic distribution was selected for the time-to-event regression. The regression modeling demonstrated that the employment
of a prosthetic ring significantly increases the freedom from recurrent moderate TR ($p < 0.0001$). The OR was 2.0, meaning that the odds of freedom for recurrent TR among subjects with prosthetic ring is 2 times higher than that of subject without it. Moreover, the median freedom from recurrent TR is 2.6 higher in the RING group.

Comment

The number of studies describing the outcomes of surgery for TR is relatively low if compared with the extensive literature on aortic or mitral valve disease. Moreover, most of the studies have focused on functional TR as organic etiology is rare and the lack of a shared consensus on the optimal timing and treatment generally refers to functional TR [6, 7, 22]. For several years secondary TR has been ignored and surgery for primary left heart pathology was considered sufficient to lead to TR regression [1, 37]. The nonsurgical management was first advised and then reconsidered when it was demonstrated that untreated TR could persist or even worsen despite correction of the associated left-side lesions [3, 38]. Moderate or severe TR has been associated with poor short-term and long-term outcomes; reoperation is at high risk and an aggressive approach to TR is now warranted [5, 6, 39]. Our study group reflects the prevalence of TR etiology as more than 95% of the patients included in the meta-analysis have secondary regurgitation, and consequently the inference on the meta-results can be referred to functional TR [7, 10, 17, 18, 21, 22, 26, 28, 30, 36].

Tricuspid regurgitation is primarily treated with valve reconstruction, which carries a lower operative risk than valve replacement [6, 7]. Different techniques for repairing tricuspid valve have been proposed according to the anatomic level of surgery [8]. In the majority of patients the valve leaflets are normal and a coaptation defect due to annular dilatation is the common finding. Hence, the surgical repair has been mostly addressed to the annular or commissural level, although there is an ongoing debate on tricuspid valve repair using either a suture-based or a prosthetic ring annuloplasty [22]. Among the suture-based annuloplasties, the De Vega technique [40] is the most commonly employed as it preserves the anatomy and flexibility of the annulus; in addition, it is easy, fast, and cost effective [4, 9], while suture bicuspidalization initially described by Kay [41] is presently less performed. Some series have demonstrated good short-term and long-term outcomes of both De Vega and Kay annuloplasties [9, 10]. However, other authors have questioned these results as high incidence of recurrent postoperative TR has been pointed out at follow-up, especially when pulmonary hypertension and severe tricuspid annular dilatation were evident [6, 24]. The annuloplasty with a prosthetic ring has been proposed as a solution to recurrent TR of suture-based techniques. The first comparisons between annuloplasty with or without prosthetic ring demonstrated a better mid-term performance of the ring, with a significant higher freedom from moderate and severe TR [24]. These results have been confirmed by other studies [7, 21, 22] and hence these findings seem to recommend an annuloplasty ring in patients undergoing TR repair in order to prevent recurrence and adverse long-term sequelae, particularly in those with more severe TR and pulmonary hypertension. The results of our meta-analysis support the protective effect of prosthetic ring on recurrence of postoperative TR. The performance of prosthetic rings and suture-based annuloplasty appeared initially similar but the 2 KM curves separated after 5 years with a constant increase of events in the NO RING group. This
difference is particularly marked in the composite outcome (Fig 4) that is more representative as the sample size is higher, and it also underestimates the significance being the incidence of reoperation for recurrent TR lower than incidence of moderate recurrent TR.

Studies that analyzed the effect of surgery for TR most often grouped both suture-based and prosthetic ring techniques and a final conclusion on the superiority of 1 repair technique is far in the future. Modified De Vega has been found to be superior to bicuspidalization in a small series [30], while Navia and colleagues [8] reported better outcomes of Kay techniques compared with De Vega annuloplasty. Even the choice of the prosthetic ring has not reached a shared consensus. The rigid ring has been reported to achieve the best freedom from recurrent TR if compared with the flexible rings [8] but these data have not been confirmed by Guenther and colleagues, who did not find significant differences in term of reoperations [22]. In a subanalysis of our study group, excluding grouped techniques and hence reducing the sample size, we aimed to check a potential benefit of a technique over the others. We selected 3 main groups; De Vega annuloplasty, bicuspidalization, and annuloplasty with a rigid ring. The analysis of composite endpoint (freedom from moderate TR and freedom from surgery for recurrent TR in the study where there is no KM curve of freedom from TR) showed a superiority of the rigid ring over both suture-based techniques and also a better outcome of De Vega annuloplasty versus bicuspidalization, which leads to early recurrent TR (p < 0.0001, Fig 5). Our data seem to confirm the improved performance of rigid ring; nonetheless, we should underscore that this analysis reduces the sample size and gives only a partial vision (especially for the bicuspidalization techniques) which is reported by a single study. Interestingly, focusing on the rigid rings our meta-analysis results did not agree with the high incidence of moderate TR showed by Navia and colleagues in their experience [8].

The other main aim of the present meta-analysis was the comparison of survival between suture-based and prosthetic ring annuloplasties. The meta-analyses showed possibly improved outcomes for the RING group in terms of early mortality (but this result was mainly driven by observational, retrospective studies included in the analysis), although no significant difference between the 2 groups could be demonstrated in late mortality, confirming the large part of the existing studies. Among studies that reported a long-term survival advantage of ring annuloplasty, Tang and colleagues related it to prevention of annular dilatation, right ventricular volume overload and right ventricular failure [7]. Nonetheless, the study groups differed with respect to age, gender, previous cardiac surgery, and concomitant procedures, and the same heterogeneity is common in other studies. Therefore, it is difficult to relate a potential survival advantage to the surgical technique.

Limitations of the Study
This study has some intrinsic limitations. The main limitation of the study is the lack of large randomized trials as most of the publications were relatively small observational studies with the inherent biases of retrospective reviews. Potential selection bias linked to the diverse risk profiles of the studies’ groups cannot be evaluated and no adjustment for confounders can be performed in a meta-analysis context. Hence, both short-term and long-term outcomes represent univariate unadjusted effects of surgical techniques for TR repair on mortality and freedom from TR recurrence or surgery for TR and should be confirmed by large randomized trials. The choice of the surgical technique is often based on individual surgeon’s preference and judgment and includes clinical data that cannot be extrapolated from the studies. Even the same

![Graph showing freedom from recurrent moderate tricuspid regurgitation or surgery for recurrent tricuspid regurgitation (in the paper that did not report freedom from moderate TR) patients who underwent De Vega annuloplasty, bicuspidization annuloplasty, and rigid ring annuloplasty.](image)
described technique can be performed in different ways by different surgeons and, also, this source of variability cannot be eliminated. Moreover, the grading of TR regurgitation can vary among studies and hence moderate TR could be defined non-homogeneously.

Conclusions

Our meta-analysis demonstrates that the prosthetic ring’s annuloplasty for TR is associated to better outcomes if compared with suture-based techniques, being a protective factor for long-term recurrence of TR after surgery. From available data, rigid rings appear to confer a better protection against recurrent TR at follow-up and improved early survival.

References

2. Song ZZ. Does tricuspid annular plane systolic excursion or systolic velocity allow a precise determination of right ventricular function after heart transplantation? J Heart Lung Transplant 2007;26:868.