Over Ten Years of Experience with a Modified Right Atrial Anastomosis in Orthotopic Heart Transplantation: Follow-up and Comparison with the Biatrial and Bicaval Technique

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Abstract

Background In 1997, a modified right atrial anastomosis (cavoatrial technique) for orthotopic heart transplantation (oHTx) was first developed in our institution. The purpose of this study is to report our long-term experience with this technique compared with biatrial and bicaval technique.

Methods Retrospectively, 202 consecutive oHTx between 1997 and 2013 were analyzed. The applied transplantation techniques were biatrial (n = 108), bicaval (n = 22), and cavoatrial (n = 72).

Results Demographic data were similar in all groups. The cardiopulmonary bypass and cross-clamp time were significantly shorter in the biatrial group. Follow-up echocardiographic examination showed excellent results in all groups with no relevant differences. After 1 year, occurrence of severe tricuspid regurgitation (biatrial 1.9% vs bicaval 0.0% vs cavoatrial 1.4%) was low in all groups. Rate of permanent pacemaker implantations was also low (12.0% vs 5.0% vs 11.1%). There were no significant differences in survival between the groups.

Conclusion The cavoatrial technique can be a safe and simple alternative for heart transplantation. Easy handling and similar reduced postoperative complications encourage the use of this technique.

Keywords
► heart failure
► transplantation heart
► cardiac

Introduction

Though many advances treating end-stage heart insufficiency have been made in the past years, orthotopic heart transplantation (oHTx) is still considered as gold standard. Since the first-performed heart transplantation in 1967,1 several varieties of the surgical implantation technique, primarily focused on optimizing transplantation results, have been published.2–6 In the past, the biatrial technique of Lower and Shumway2 was widely used for oHTx. Known disadvantages of this technique include loss of the normal right atrial (RA) and left atrial (LA) anatomy resulting in severe biatrial dilatation and consecutive regurgitation of the atrioventricular (AV) valves. In the early 1990s, the bicaval implantation technique was introduced. By preserving the RA anatomy, the risk for tricuspid valvular regurgitation was supposed to be reduced.4 In worldwide heart transplantation practice, bicaval technique

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is nowadays the most commonly used technique.\textsuperscript{7} Beside the risk of caval vein stenosis, the technique is associated with prolonging ischemic time.\textsuperscript{8} Another transplantation technique is the total orthotopic heart transplantation technique described by Dreyfus et al.,\textsuperscript{3} wherein a complete recipient atrial excision and total donor heart transplantation is accomplished.

In 1997, a modified RA anastomosis (cavoatrial technique) was first developed in our institution.\textsuperscript{9} The cavoatrial technique is surgically less challenging than bialtral anastomosis and can be apprehended as a combination of the two traditional techniques. The cavoatrial anastomosis technique allows a more anatomical reconstruction of the RA and the sinus node is more likely preserved.

The hypothesis is a lower rate of rhythm disturbances which should therefore lead to a lower rate of permanent pacemaker implantation. The occurrence of tricuspid valvular regurgitation is expected to be less than in the bialtral transplantation technique.

In this study, over ten years of experience with the cavoatrial technique and the follow-up results of 72 adult patients transplanted in this technique are presented and compared with the patients transplanted at our department in the bialtral or bicaval technique during the same period.

\textbf{Methods}

\textbf{Data Collection}

Retrospectively, the data of 202 adult patients who underwent oHTx between January 1997 and December 2013 at our transplant center were analyzed. Three different transplantation techniques were applied, bialtral technique (n = 108 patients), bicaval technique (n = 22), and cavoatrial technique (n = 72). Only oHTx in adult patients (>18 y) was analyzed. The study was approved by our local institutional ethics committee.

\textbf{Technique}

In the recipient, cardiopulmonary bypass (CPB) was commenced with bicaval and aortic cannulation in the standard manner. Cardiectomy was performed leaving the LA and RA cuffs in the usual fashion. The donor heart is excised with an intact right atrium and long venae cavae. The left atrium of the donated heart is prepared by excising the tissue between the four orifices of the pulmonary veins. The donor left atrium is sutured to the recipient’s left atrium with continuous suture using a 3/0 prolene. The standard bialtral surgical technique was modified as follows: the donor right atrium is opened posterior along the inferior vena cava extended to the superior vena cava, avoiding damage of the sinus node and preserving the donor atrial appendage. Under inclusion of the LA septum, the donor right atrium is anastomosed to the recipient’s tailored cavo-atrial cuff using a running suture of 4/0 prolene (\textsuperscript{\textbullet} Fig. 1).\textsuperscript{9}

\textbf{Transplantation}

Preservation of the heart donors was performed with 3 L of ice-cold histidine-tryptophan-ketoglutarate (HTK)-Bretschneider solution. Donors’ hearts with severe hemodynamic instability, palpable coronary artery or valve sclerosis, or signs of myocardial damage ascertained by echocardiography, electrocardiography, or visual examination were rejected for transplantation. Postoperatively, immunosuppressive therapy was based on a triple-drug regimen with cyclosporine, mycophenolate mofetil, and corticoids according to our institutional protocol. Graft rejection was monitored by echocardiography and routine endomyocardial biopsy from the right ventricle.

\textbf{Follow-up}

Main focus of this study was tricuspid regurgitation (TR), heart function, and permanent pacemaker rate between the three different implantation techniques. The intraoperative data was based on the type of applied transplantation technique, cross-clamp time, CPB time, and ischemic time for the donor heart. Direct postoperative evaluation was focused on the necessity of inotropic or mechanical circulatory support (MCS), re-exploration due to bleeding complications, postoperative temporary dialysis, prolonged ventilation (>72 h), first rejection episode diagnosed by endomyocardial biopsy or echocardiographic parameters, and length of intensive care necessity and the total in-hospital stay until discharge.

The follow-up was analyzed up to five years post transplantation. Data was evaluated at defined time points: intraoperative, at month one, three and six as well as year one, three and five after date of transplantation. Echocardiography was performed to evaluate the heart function, systolic left ventricular (LV)-function and signs for right ventricular (RV)-dysfunction, as well as to assess valve performance (mitral or tricuspid valvular regurgitation). Echocardiographic evaluation and grading followed the standard guidelines. Twelve-lead electrocardiogram analysis focused on rhythm (sinus rhythm and atrial fibrillation), AV block, and occurrence of bradycardia as a result of sinus node or other cardiac conductive system lesions. The rate of permanent pacemaker implantation was compared between the implantation techniques, as well as assessment of the mortality.
Statistical Analysis

Unless otherwise indicated, continuous data are described as mean and standard deviation or, if appropriate as mean and range. Categorical data are presented as total number (n) and as percentage (%). Statistical analysis was accomplished by using SPSS 21 (IBM, SPSS Software, Germany). Missing data was excluded case-by-case wise. Shapiro–Wilk test was used to ascertain normal distribution. For categorical data, chi-square test or Fisher’s exact test was used. For analyzing intergroup comparison, one-way analysis of variances (ANOVA) was performed for normal distributed data. Homogeneity of variances was identified by Levene’s test. For Bonferroni post hoc test, respectively in inhomogeneity of variances Dunnet T3 was applied. The survival curves were estimated on right-censored data by Kaplan–Meier analysis. The survival of the three transplantation techniques was compared by log-rank (Mantel–Cox) test. Statistical significance was assumed when the p-value was < 0.05.

Results

Patient’s characteristics are outlined in Table 1 and were comparable in all groups, including age, gender, and cause of heart failure (ischemic, dilated, hypertrophic, or other). Three patients of the cavoatrial group had to be bridged to transplanted heart via MCS (Table 1).

The analysis of the intraoperative data showed that the CPB time (biatrial vs bicaval vs cavoatrial; 128 ± 34 min vs 153 ± 41 min vs 148 ± 32 min; p < 0.001) and the crossclamp time (60 ± 13 min vs 81 ± 37 min vs 80 ± 21 min; p < 0.001) were significantly shorter in the biatrial group than in the bicaval and cavoatrial group. The allograft cold ischemic time was also significantly shorter in the biatrial group than in the cavoatrial group (biatrial 189 ± 35 vs cavoatrial 213 ± 45 minutes; p < 0.001). Table 2 showed comparable postoperative findings for all three groups, including intensive care unit (ICU) stay (17 ± 38 days vs 16 ± 12 days vs 14 ± 13 days, p = 0.91) and 30-day survival (88.9% vs 86.0% vs 90.3%, p = 0.87). Higher rates of postoperative MCS (2.8% vs 9.0% vs 2.8%) or incidences of acute kidney injury requiring temporary dialysis (34.3% vs 50.0% vs 30.6%) were found in the bicaval group. Postoperatively, patients in the cavoatrial group had higher incidences of prolonged mechanical ventilation with tracheotomy (12.0% vs 18.0% vs 25.0%; p = 0.08). In the postoperative course, the rate of permanent pacemaker implantation and occurrence of atrial fibrillation also were similar in the biatrial and cavoatrial groups, and lower in the bicaval group (Table 2). In direct postoperative course, the rate of permanent pacemaker implantation was highest in the biatrial group with 10.2% (n = 11) and with 6.9% (n = 5) lower in the cavoatrial group and lowest in the bicaval group with 5% (n = 1). Regular sinus rhythm was present in over 80% of the patients in every group at all follow-up points.

Increased postoperative rate of bradycardia (38% vs 28% vs 25%, p = 0.18) was normalized in the longer follow-up and occurred only in one individual of the cavoatrial group respectively two individuals of the biatrial group. The appearance of AV block immediately postoperatively was 17% in biatrial, 23% in bicaval, and 18% in cavoatrial group, showing a drastic reduction already in the 1-month follow-up to 1% in biatrial, 5% in bicaval, and 3% in cavoatrial group.

The 30-days survival was without statistical significance between the groups (88.9% vs 86.0% vs 90.3%, p = 0.87). The Kaplan–Meier survival curves showed acceptable results with a 5-year survival rate of 70% (Fig. 2). Furthermore, there were no significant differences in survival at 1 year (78% vs 82% vs 81%), 3 years (74% vs 77% vs 75%), or 5 years (70% vs 77% vs 70%) between the groups (Fig. 2).

Follow-up echocardiographic results distributed to the three implantation technique groups are represented in Table 3. The postoperative echocardiography showed good systolic LV function of the donor’s heart in all groups. The left ventricular ejection fraction was highest in the biatrial group in comparison to the bicaval and cavoatrial group, but with no clinical relevant difference between the transplantation techniques. Early postoperative signs for RV dysfunction were higher in the biatrial and bicaval group (25.0% vs 32.0% vs 15.3%, p = 0.18). Drastic RV function improvement could be seen in all groups in the further follow-up and dysfunction occurred only in individual cases.

Table 1 Pretransplantation demographic parameters

<table>
<thead>
<tr>
<th></th>
<th>Biatrial technique (n = 108)</th>
<th>Bicaval technique (n = 22)</th>
<th>Cavoatrial technique (n = 72)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y; range)</td>
<td>53 ± 9 (20–69)</td>
<td>58 ± 8 (37–67)</td>
<td>55 ± 10 (19–70)</td>
<td>0.15</td>
</tr>
<tr>
<td>Gender (M; %)</td>
<td>89 (82.4%)</td>
<td>21 (96.0%)</td>
<td>54 (75.0%)</td>
<td>0.09</td>
</tr>
<tr>
<td>Cause for heart failure (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ischemic CM</td>
<td>49 (45.4%)</td>
<td>9 (40.0%)</td>
<td>30 (41.7%)</td>
<td>0.86</td>
</tr>
<tr>
<td>Dilated CM</td>
<td>53 (49.1%)</td>
<td>12 (55%)</td>
<td>36 (50.0%)</td>
<td>0.90</td>
</tr>
<tr>
<td>Hypertrophic CM</td>
<td>4 (3.7%)</td>
<td>0 (0.0%)</td>
<td>2 (2.8%)</td>
<td>0.65</td>
</tr>
<tr>
<td>Others</td>
<td>2 (1.9%)</td>
<td>1 (5.0%)</td>
<td>4 (5.6%)</td>
<td>0.40</td>
</tr>
<tr>
<td>MCS (%)</td>
<td>0 (0%)</td>
<td>0 (0.0%)</td>
<td>3 (4.2%)</td>
<td>0.06</td>
</tr>
<tr>
<td>LVEF (%)</td>
<td>19 ± 7%</td>
<td>20 ± 12%</td>
<td>22 ± 8%</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Abbreviations: CM, cardiomyopathy; LVEF, left ventricular ejection fraction; MCS, mechanical circulatory support.
Modified Right Atrial Anastomosis in Orthotopic Heart Transplantation  
Huenges et al.  

Table 2 Intraoperative parameters and outcome

<table>
<thead>
<tr>
<th></th>
<th>Biatrial technique (n = 108)</th>
<th>Bicaval technique (n = 22)</th>
<th>Cavoatrial technique (n = 72)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPB time (min)</td>
<td>128 ± 34 (84–242)</td>
<td>153 ± 41 (94–262)</td>
<td>148 ± 32 (96–266)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Cross-clamp time (min)</td>
<td>60 ± 13 (23–98)</td>
<td>81 ± 37 (52–237)</td>
<td>80 ± 21 (47–197)</td>
<td>&lt;0.001b</td>
</tr>
<tr>
<td>Ischemic time (min)</td>
<td>189 ± 35 (122–299)</td>
<td>208 ± 33 (149–258)</td>
<td>213 ± 45 (109–327)</td>
<td>&lt;0.001c</td>
</tr>
<tr>
<td>Rethoracotomy (n; %)</td>
<td>42 (38.9%)</td>
<td>7 (32.0%)</td>
<td>23 (31.9%)</td>
<td>0.59</td>
</tr>
<tr>
<td>Postoperative MCS (n; %)</td>
<td>3 (2.8%)</td>
<td>2 (9.0%)</td>
<td>2 (2.8%)</td>
<td>0.31</td>
</tr>
<tr>
<td>Renal replacement therapy (n; %)</td>
<td>37 (34.3%)</td>
<td>11 (50.0%)</td>
<td>22 (30.6%)</td>
<td>0.25</td>
</tr>
<tr>
<td>Tracheotomy (n; %)</td>
<td>13 (12.0%)</td>
<td>4 (18.0%)</td>
<td>18 (25.0%)</td>
<td>0.08</td>
</tr>
<tr>
<td>Pacemaker (n; %)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postoperative</td>
<td>11 (10.2%)</td>
<td>1 (5.0%)</td>
<td>5 (6.9%)</td>
<td>0.59</td>
</tr>
<tr>
<td>1 mo</td>
<td>11 (10.2%)</td>
<td>1 (5.0%)</td>
<td>5 (6.9%)</td>
<td>0.61</td>
</tr>
<tr>
<td>3 mo</td>
<td>13 (12.0%)</td>
<td>1 (5.0%)</td>
<td>6 (8.3%)</td>
<td>0.52</td>
</tr>
<tr>
<td>6 mo</td>
<td>13 (12.0%)</td>
<td>1 (5.0%)</td>
<td>6 (8.3%)</td>
<td>0.61</td>
</tr>
<tr>
<td>1 y</td>
<td>13 (12.0%)</td>
<td>1 (5.0%)</td>
<td>8 (11.1%)</td>
<td>0.72</td>
</tr>
<tr>
<td>Atrial fibrillation (n; %)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postoperative</td>
<td>22 (20.4%)</td>
<td>3 (14.0%)</td>
<td>10 (13.9%)</td>
<td>0.49</td>
</tr>
<tr>
<td>1 mo</td>
<td>13 (12.0%)</td>
<td>1 (5.0%)</td>
<td>6 (8.3%)</td>
<td>0.49</td>
</tr>
<tr>
<td>3 mo</td>
<td>10 (9.3%)</td>
<td>1 (5.0%)</td>
<td>6 (8.3%)</td>
<td>0.77</td>
</tr>
<tr>
<td>6 mo</td>
<td>4 (3.7%)</td>
<td>0 (0.0%)</td>
<td>4 (5.6%)</td>
<td>0.53</td>
</tr>
<tr>
<td>1 y</td>
<td>6 (5.6%)</td>
<td>1 (5.0%)</td>
<td>5 (6.9%)</td>
<td>0.94</td>
</tr>
<tr>
<td>Intensive care unit (d; range)</td>
<td>17 ± 38 (2–327)</td>
<td>16 ± 12 (3–42)</td>
<td>14 ± 13 (2–54)</td>
<td>0.91</td>
</tr>
<tr>
<td>Hospital stay (d; range)</td>
<td>33 ± 41 (2–327)</td>
<td>37 ± 24 (10–87)</td>
<td>40 ± 36 (5–204)</td>
<td>0.47</td>
</tr>
<tr>
<td>30 days survival (n; %)</td>
<td>96 (88.9%)</td>
<td>19 (86.0%)</td>
<td>65 (90.3%)</td>
<td>0.87</td>
</tr>
</tbody>
</table>

Abbreviations: CPB, cardiopulmonary bypass; MCS, mechanical circulatory support.  
*a*Biatrial versus bicaval, p = 0.009; biatrial versus cavoatrial, p < 0.001.  
*b*Biatrial versus bicaval, p < 0.001; biatrial versus cavoatrial, p < 0.001.  
*c*Biatrial versus cavoatrial, p < 0.001.

Over >85% of all patients at all follow-up points had no severe TR, beside trace regurgitation only in individual cases mild or moderate insufficiency was detectable in echocardiographic examination. After 1 year, occurrence of mild TR (24.0% vs 19.0% vs 26.4%, p = 0.47) or severe TR (1.9% vs 0.0% vs 1.4%, p = 0.81) was low in all groups.

**Discussion**

In the past 50 years of cardiac transplantation history, a variety of different surgical techniques have been established; the majority of those based on the most traditional one, the biatrial technique; as well as on bicaval or total orthotopic technique. All techniques and their modification have their advantages and disadvantages. Even though bicaval transplantation technique is currently the most commonly used technique, biatrial technique is still one of the most accepted transplantation techniques. With the modified RA anastomosis cavoatrial technique, a combination of the two traditional techniques was developed. Our study presented an over ten years of experience with the cavoatrial technique and to compare the follow-up results of 72 adult patients transplanted in this technique to the patients transplanted at our department in the biatrial or bicaval technique during the same period. This study showed that the technique can be a safe and simple alternative for heart transplantation with excellent findings.

Since its first presentation, bicaval technique turned out to be the more preferred technique in the United States. The biatrial technique creates an hourglass-shaped atrium, with suture lines protruding into an enlarged atrial cavity and can lead to asynchronous contraction which might impair valvular regurgitation. Bicaval technique may reduce AV regurgitation as well as asynchronous atrial contraction. A meta-analysis of 41 papers by Schnoor and colleagues also provided beneficial effects of the bicaval technique compared with biatrial technique. Maintaining the native cardiac anatomy is claimed by the Dreyfus total orthotopic technique.

Besides the risk of caval vein stenosis, transection of superior and inferior caval vein as preparation for the bicaval implantation can lead to distortion and retraction which may aggravate correct anatomical, tension-free anastomosis.
Hence this is distinctly reduced by cavoatrial technique whereat right atrium and caval veins is longitudinal opened. Likewise, another modification of the bicaval technique has been given by Kitamura et al.\textsuperscript{5}

Kara et al also reported, in a short postoperative follow-up analysis, lower rate of mitral or tricuspid valvular regurgitation and permanent pacemaker implantation by using bicaval technique compared with biatrial technique.\textsuperscript{12} Another modification of the bicaval technique to reduce tricuspid valve regurgitation by modifying inferior vena caval anastomosis presented by Marelli et al also focuses on the influence of RA anterior wall stress through traditional bicaval technique.\textsuperscript{6}

Our modified RA anastomosis (cavoatrial technique) can be apprehended as a combination of the two traditional techniques. The cavoatrial anastomosis technique allows preservation of the natural RA geometry with normal diameters to reduce the rate of tricuspid valve regurgitation. In our technique, sinus node is not endangered by starting the incision and suture line on the backside of the donor atrium. Hypotheses are a lower rate of rhythm disturbances and it should therefore lead to a lower rate of permanent pacemaker implantation. At our department the three different techniques are currently applied depending on the preference of the individual transplant surgeon. Since the development of the cavoatrial technique it became the more preferred technique in our department. Even though statistically significant effects regarding reduction of tricuspid valve regurgitation and reduction of rhythm disturbances could not been seen comparing the cavoatrial with the standard established techniques, the results obtained with this technique are still very promising. Remarkable in the cavoatrial group are the lower rates of intra- and direct postoperative RV dysfunction, which might also be one of the reasons for the shorter ICU time and quick recovery of the patients in this group, even in absence of statistical significance.\textsuperscript{9} The occurrence of mild and moderate tricuspid valve regurgitation is slightly reduced by this technique which lowers the need for right heart failure-preventive drug therapy. The pacemaker rate in the early follow-up period was and remained low.

Overall posttransplantation LV function was normal, even though there was a significant difference between the biatrial, the bicaval, and the cavoatrial group in the direct postoperative course, the systolic LV function was in comparable excellent extent. Mitral regurgitation occurred in comparable frequencies. Sinus rhythm was present in >80\% of all patients at all follow-up investigations. In the long follow-up, no bradycardia and low rate of AV block were present.

Aziz et al depicted a 5-year survival of 62\% in patients transplanted in the biaatrial technique and 81\% of patients transplanted in the bicaval technique.\textsuperscript{13} In our observation, 5-year survival rate was similar between the groups.

Enhanced LV filling in patients undergoing bicaval approach compared with biatrial implantation technique was published by Markowicz-Pawlus et al.\textsuperscript{14} In our study, focus of echocardiographic evaluation was limited to basal assessment of LV and RV function, and valvular performance detailed analysis of, for instance, diastolic function have to be made to clearly demonstrate possible cavoatrial superiority over bicaval or biatrial technique.

In conclusion, the encouraging results of our patients proved this technique to be equally applicable like common used techniques. Cavoatrial technique can be considered as a safe and alternative technique for heart transplantation, which may improve surgical and clinical outcome of heart transplanted patients.

\textbf{Fig. 2} Kaplan–Meier survival curve of the biastral, bicaval, and cavoatrial group.
Our study has some limitations. One limitation of this study is that the data were collected retrospectively and subject to incomplete, missing, or inaccurate reporting of events. This report is a single-center experience and the sample size remains small and unequal between the three applied techniques.

In conclusion, the encouraging long-term results of our patients proved the cavoatrial technique to be equally applicable like commonly used techniques. The technique can be considered as a safe and alternative technique for heart transplantation, which may improve surgical and clinical outcome of heart transplanted patients.

**Table 3** Follow-up echocardiographic parameters

<table>
<thead>
<tr>
<th></th>
<th>Biatrial technique (n = 108)</th>
<th>Bicaval technique (n = 22)</th>
<th>Cavoatrial technique (n = 72)</th>
<th>p-value</th>
</tr>
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<tbody>
<tr>
<td>LVEF (%; range)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postoperative</td>
<td>67 ± 8% (40–81%)</td>
<td>66 ± 6% (55–80%)</td>
<td>63 ± 9% (30–87%)</td>
<td>0.038a</td>
</tr>
<tr>
<td>1 mo</td>
<td>67 ± 8% (30–83%)</td>
<td>64 ± 7% (50–75%)</td>
<td>65 ± 8% (48–85%)</td>
<td>0.13</td>
</tr>
<tr>
<td>3 mo</td>
<td>67 ± 7% (45–84%)</td>
<td>63 ± 9% (44–78%)</td>
<td>64 ± 11% (19–84%)</td>
<td>0.05</td>
</tr>
<tr>
<td>6 mo</td>
<td>67 ± 8% (38–83%)</td>
<td>63 ± 10% (41–84%)</td>
<td>63 ± 7% (39–77%)</td>
<td>0.05</td>
</tr>
<tr>
<td>1 y</td>
<td>67 ± 7% (49–81%)</td>
<td>62 ± 11% (36–75%)</td>
<td>66 ± 8% (40–80%)</td>
<td>0.06</td>
</tr>
<tr>
<td>RV dysfunction (n; %)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postoperative</td>
<td>27 (25.0%)</td>
<td>7 (32.0%)</td>
<td>11 (15.3%)</td>
<td>0.18</td>
</tr>
<tr>
<td>1 mo</td>
<td>3 (2.8%)</td>
<td>3 (14.0%)</td>
<td>1 (1.4%)</td>
<td>0.63</td>
</tr>
<tr>
<td>3 mo</td>
<td>2 (1.9%)</td>
<td>3 (14.0%)</td>
<td>3 (4.2%)</td>
<td>0.46</td>
</tr>
<tr>
<td>6 mo</td>
<td>1 (0.9%)</td>
<td>0 (0.0%)</td>
<td>1 (1.4%)</td>
<td>0.86</td>
</tr>
<tr>
<td>1 y</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>1 (1.4%)</td>
<td>0.44</td>
</tr>
<tr>
<td>Tricuspid regurgitation (n; %)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postoperative</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>0</td>
<td>65 (60.2%)</td>
<td>15 (75%)</td>
<td>43 (59.7%)</td>
<td>0.76</td>
</tr>
<tr>
<td>I–II°</td>
<td>31 (28.7%)</td>
<td>2 (10%)</td>
<td>20 (28.7%)</td>
<td>0.15</td>
</tr>
<tr>
<td>III–IV°</td>
<td>3 (2.8%)</td>
<td>3 (15%)</td>
<td>1 (1.4%)</td>
<td>0.019b</td>
</tr>
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<td>0</td>
<td>57 (52.8%)</td>
<td>12 (63%)</td>
<td>39 (54.2%)</td>
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</tr>
<tr>
<td>I–II°</td>
<td>32 (29.6%)</td>
<td>6 (32%)</td>
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<td>0.95</td>
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<tr>
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<td>5 (4.6%)</td>
<td>1 (5%)</td>
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<td>49 (45.4%)</td>
<td>12 (63%)</td>
<td>33 (45.8%)</td>
<td>0.73</td>
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<tr>
<td>I–II°</td>
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<td>6 (32%)</td>
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<td>0.72</td>
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<tr>
<td>III–IV°</td>
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<td>1 (5%)</td>
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</tr>
<tr>
<td>6 mo</td>
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</tr>
<tr>
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<td>49 (45.4%)</td>
<td>13 (76%)</td>
<td>42 (58.3%)</td>
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</tr>
<tr>
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<td>34 (31.5%)</td>
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<td>1 (1.4%)</td>
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<td>I–II°</td>
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<td>2 (1.9%)</td>
<td>0 (0%)</td>
<td>1 (1.4%)</td>
<td>0.81</td>
</tr>
</tbody>
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Abbreviations: LVEF, left ventricular ejection fraction; RV, right ventricle.

*a*Biatrial versus cavoatrial, p = 0.035.

*b*Biatrial versus bicaval, p = 0.033; bicaval versus cavoatrial, p = 0.018.
Note
Parts of this manuscript were presented (Scientific poster) at the Annual Meeting of the German Transplantation Society (DTG) in Dresden, Germany on October 22, 2015.

References