Standard versus bicaval techniques for orthotopic heart transplantation: An analysis of the United Network for Organ Sharing database

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Objective: Most studies of anastomotic technique have been underpowered to detect subtle differences in survival. We analyzed the United Network for Organ Sharing database for trends in use and outcomes after either bicaval or traditional (biatrial) anastomoses for heart implantation.

Methods: Review of United Network for Organ Sharing data identified 20,999 recipients of heart transplants from 1997 to 2007. Patients were stratified based on the technique of atrial anastomosis: standard biatrial (atrial group, n = 11,919, 59.3%), bicaval (caval group, n = 7661, 38.1%), or total orthotopic (total group, n = 519, 2.6%).

Results: The use of the bicaval anastomosis is increasing, but many transplantations continue to use a biatrial anastomosis (1997, 0.2% vs 97.6%; 2007, 62.0% vs 34.7%; $P < .0001$). Atrial group patients required permanent pacemaker implantation more often (odds ratio, 2.6; 95% confidence interval, 2.2–3.1). Caval group patients had a significant advantage in 30-day mortality (odds ratio, 0.83; 95% confidence interval, 0.75–0.93), and Cox regression analysis confirmed the decreased long-term survival in the atrial group (hazard ratio, 1.11; 95% confidence interval, 1.04–1.19).

Conclusions: Heart transplantations performed with bicaval anastomoses require postoperative permanent pacemaker implantation at lower frequency and have a small but significant survival advantage compared with biatrial anastomoses. We recommend that except where technical considerations require a biatrial technique, bicaval anastomoses should be performed for heart transplantation. (J Thorac Cardiovasc Surg 2010;140:700-8)

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After a fitful start in the late 1960s,[1] cardiac transplantation has become the treatment of choice for end-stage heart failure. Over the ensuing 40 years, significant advances have been made in both the perioperative management of donors and recipients and in long-term management to prevent and treat rejection; however, the most commonly performed technique of cardiac allograft implantation, the standard, or biatrial, technique, has remained little changed since its initial description by Lower and Shumway in 1960.[2]

The primary advantage of the biatrial technique is its relative simplicity. By performing only 2 anastomoses to the donor atria (rather than 6 to the 2 cavae and the 4 pulmonary veins), the technical challenge of cardiac implantation is lessened, and allograft ischemic times are reduced. However, the biatrial anastomosis puts the sinoatrial node at risk of injury, and redundant atrial tissue might worsen atrial hemodynamics and contribute to an increased risk of atrial arrhythmias in the postoperative period.[3,4]

Attempts to solve these downsides resulted in the development of 2 alternative techniques: bicaval and total heterotopic cardiac transplantation.[5-7] The bicaval anastomosis consists of a single left atrial anastomosis with separate caval suture lines, whereas total heterotopic transplantation divides the left atrial anastomosis into 2 portions (left and right pulmonary veins). These techniques are progressively more complicated and might require longer operative times, but they should result in a lower incidence of sinoatrial node dysfunction and improved hemodynamic and physiologic cardiac performance. Unfortunately, studies performed to date to assess the results of these techniques have generally been insufficiently powered (because of either small sample

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Abbreviations and Acronyms

CI = confidence interval
PPM = permanent pacemaker
UNOS = United Network for Organ Sharing

sizes[8-14] or high frequency of missing data[15]) to detect important differences.

This report uses data from the United Network for Organ Sharing (UNOS) database to assess posttransplantation outcomes in patients stratified by the technique used for allograft implantation. Our goals were (1) to assess the current use of these techniques and (2) to identify which techniques resulted in better short- and long-term outcomes.

MATERIALS AND METHODS

Data Collection

UNOS provided deidentified patient-level, encrypted center–specific data from the Thoracic Registry (data source no. 092707-15). The UNOS Standard Transplant and Research Dataset contains information from the UNOS forms, including the Transplant Candidate Registration form, the Transplant Recipient Registration form, and the Transplant Recipient Follow-up form. Use of these data is consistent with the regulations of our university's institutional review board.

Study Population

The study population consisted of 20,999 transplantations performed on adult patients without congenital heart disease between 1997 and 2007 for whom UNOS data included the type of anastomosis performed. Patients were stratified based on the technique of atrial anastomosis: standard biatrial (atrial group, n = 11,919 [59.3%]), bicaval (caval group, n = 7661 [38.1%]), or total orthotopic (total group, n = 519 [2.6%])

Data Analysis

Statistical analysis was performed with SAS 9.13 software for Windows (SAS Institute, Inc, Cary, NC). Primary outcomes were (1) the need for a permanent pacemaker (PPM) before hospital discharge after transplantation and (2) 30-day mortality. Other outcomes included length of stay, the incidence of in-hospital complications, long-term survival, graft survival, transplant coronary artery disease–free survival, and renal failure–free survival. Continuous variables are reported as means ± standard deviations and were compared by using the Student's *t* test.

Ordinal variables were compared by using the χ^2 test. Body surface area, weight, and age were used as both continuous variables and stratified into subgroups; the most predictive method was used. *P* values are all 2-sided. Risk ratios and 95% confidence intervals (CIs) are also reported. Kaplan–Meier analysis and Cox proportional hazards regression (PROC PHREG, stepwise, $P < .05$) were used for time-to-event analysis. Survival function estimates for strata of the explanatory variables were calculated with the BASELINE statement of PROC PHREG. Multivariate regression (PROC LOGISTIC, stepwise, $P < .05$) was also performed to evaluate the incidence of peritransplantation death and the incidence of morbidity; all variables reaching statistical significance in univariate analysis were included in multivariate analyses.

Missing Variables

Missing variables are a significant problem in analyses of large multi-institutional databases in general and the UNOS database in particular (see Table 1 for the proportion of missing data for each variable in our dataset). For multivariate analyses, missing variables were imputed by using the technique of multiple imputation, as implemented by using the MI and MI-ANALYZE procedures (SAS 9.13 for Windows; see the Materials and Methods section of this article's Online Repository for full details of analysis). Multiple imputation has been shown to produce efficient and unbiased estimates if the data are missing at random and even in the rarer situation of information missing not at random.[16-19] In circumstances with a high proportion of missing variables, as is the case with the UNOS dataset (see again), it provides more accurate estimates of true relationships than the more commonly used method of listwise deletion. A full list of evaluated variables is given in Table E2 in the Materials and Methods section of this article's Online Repository.

The authors had full access to the data and take full responsibility for its integrity. All authors have read and agree with the manuscript as written.

RESULTS

Anastomotic Technique

Baseline demographics and clinical status at the time of transplantation in patients undergoing each anastomotic technique are shown in Table 2. Since 1997, the use of bicaval techniques has been steadily increasing, whereas the number of total orthotopic transplantations has been decreasing ($P = .0001$, Figure 1). However, 644 (34.5%) transplantations in 2006 were still performed with a biatrial anastomosis. The percentage of transplantations performed with the bicaval technique was higher at higher-volume transplant centers ($P = .0344$, Figure 2).

Short-Term Outcomes

Patients in the atrial group (n = 576, 5.1%) required a PPM before discharge more often (odds ratio [vs the caval group], 2.6; 95% CI, 2.2–3.1) than those in the caval group (n = 146, 2.0%) or the total group (n = 11, 1.9%; odds ratio [vs the caval group], 1.0, 95% CI, 0.6–1.7). Multivariate predictors of the need for PPM implantation included biatrial anastomosis (odds ratio, 3.1; 95% CI, 2.5–3.9), donor age of 60 to 69 years (odds ratio, 2.9; 95% CI, 1.5–5.3), donor age of 50 to 59 years (odds ratio, 2.0; 95% CI, 1.6–2.5), donor age of 40 to 49 years (odds ratio, 1.3; 95% CI, 1.0–1.6), recipient inotropic support at transplantation (odds ratio, 1.5; 95% CI, 1.2–1.7), donor history of hypertension (odds ratio, 1.2; 95% CI, 1.0–1.4), and transplantation year (odds ratio, 1.04; 95% CI 1.01–1.07 [per year]); use of T4 before organ retrieval (odds ratio, 0.8; 95% CI, 0.6–0.9) was protective. Length of stay was similar between patients requiring and not requiring PPM implantation (21.8 vs 20.0 days, $P = .1360$). Despite this, patients in the atrial group had longer posttransplantation lengths of-stay (21.1 days) than those in the caval group (19.3 days, $P < .0001$).

In univariate analysis atrial group patients had a higher incidence of postoperative death (8.9%; odds ratio, 1.17; 95% CI, 1.05–1.30) than those in the caval group (7.6%; odds ratio, 0.83; 95% CI, 0.75–0.93); postoperative mortality in the total group (9.5%; odds ratio, 1.14; 95% CI, 0.86–1.53) was not significantly different from that seen in either of the other

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