ELSEVIER

The Journal of Heart and Lung Transplantation

http://www.jhltonline.org

The influence of institutional volume on the incidence of complications and their effect on mortality after heart transplantation

Joshua C. Grimm, MD,[a] Arman Kilic, MD,[a] Ashish S. Shah, MD,[a] J. Trent Magruder, MD,[a] Vicente Valero III, MD,[a] Samuel P. Dungan, BA,[a] Stuart D. Russell, MD,[b] Ryan J. Tedford, MD,[b] Glenn J.R. Whitman, MD,[a] and Christopher M. Sciortino, MD, PhD[a]

From the [a]Division of Cardiac Surgery; and the [b]The Division of Cardiology, The Johns Hopkins Hospital, Baltimore, Maryland.

KEYWORDS:
failure to rescue;
institutional volume;
orthotopic heart transplantation;
heart transplantation survival;
morbidity after heart transplantation

BACKGROUND: The aim of this study was to determine whether institutional volume influenced the effect of postoperative complications on short-term and long-term survival after orthotopic heart transplantation (OHT).

METHODS: The United Network for Organ Sharing database was queried for adult patients (aged ≥18 years) undergoing OHT between 2000 and 2010. Average institutional volume was calculated during the study period and modeled as a categoric and as a continuous variable. Postoperative complications included rejection, dialysis dependence, infection, stroke, reoperation, and a composite event. Kaplan-Meier estimates and Cox regression modeling were performed for each complication to categorize the unadjusted and adjusted influence of institutional volume on survival.

RESULTS: The analysis included 19,849 OHT recipients who were stratified into low-volume (≤14.5 per year), intermediate-volume (14.5–26.5 per year), and high-volume (>26.5 per year) tertiles. The overall incidences of postoperative complications were 10.2% for rejection, 7.8% for dialysis dependence, 12.0% for reoperation, 24.1% for infection, and 2.3% for stroke. Recipients in low-volume institutions experienced more complications after OHT than high-volume institutions (43.4% vs 36.2%; $p < 0.001$). Survival after the composite complication outcome was significantly worse at 90 days, 1 year, and 5 years in the low-volume cohort. After risk adjustment, low institutional volume (when modeled as a continuous and as a categoric variable) was also independently predictive of mortality at each time point. As expected, survival at 5 years in patients without a postoperative complication (81%; 95 confidence interval [CI], 80.0%–82.8%) was statistically greater ($p < 0.001$) than those with 1 (72.8%; 95% CI, 69.9%–75.5%), 2 (59.8%; 95% CI, 54.4%–64.8%), or 3 (39.9%; 95% CI, 31.6%–48.2%) complications.

CONCLUSIONS: Postoperative complications after OHT have a greater incidence and effect on short-term and long-term survival at low-volume institutions. Accordingly, best practice guidelines established at high-volume institutions could better equip lower-volume hospitals to manage these events in hopes of optimizing transplant outcomes.

J Heart Lung Transplant 2015;34:1390–1397

Reprint requests: Christopher M. Sciortino, MD, PhD, 1800 Orleans, Zayed 7107, Baltimore, MD 21287, Telephone: 443-287-5438. Fax: 443-287-4226.

E-mail address: csciort2@jhmi.edu

The relationship between institutional volume and outcomes in cardiothoracic surgery has been previously established.[1–3] Increased mortality in low-volume institutions

1053-2498/$ - see front matter
http://dx.doi.org/10.1016/j.healun.2015.05.014

has been attributed to their higher rate of post-operative complications.[4] More recently, procedural volume has been postulated to correlate to an institution's ability to respond favorably to complications, regardless of their incidence, and avoid a resultant death.[4,5]

The beneficial effect of high-volume institutions performing complex cardiac operations extends into the realm of orthotopic heart transplantation (OHT).[6] Although it can be assumed that this survival advantage is due to a similar mechanism, this association has not been previously investigated. Accordingly, we sought to determine whether institutional volume influenced the effect of post-operative complications on short-term and long-term survival after OHT.

Methods

This study was exempt from Institutional Review Board approval due to the deidentified nature of the data set. Permission was obtained from the United Network for Organ Sharing (UNOS) to use this information for its intended purpose.

Patient population

The UNOS database was queried for all adult patients (aged ≥ 18 years) undergoing OHT from January 1, 2000, to December 31, 2010. The analysis excluded patients undergoing simultaneous thoracic or abdominal solid-organ transplantation.

Institutional volume and post-operative complications

The average heart transplant volume was determined for each institution during the study period. Relatively equally sized low-volume, intermediate-volume, and high-volume cohorts were then generated based on tertile stratification. To improve clinical utility, volume cutoffs were established in 0.5 case-per-year increments.

Post-operative complications, as collected in the UNOS data set, were defined as occurring after OHT and before discharge. Therefore, any complication occurring after discharge was not available for analysis. Rejection, which was defined as occurring at any point during the first post-operative year, was the exception. Complications investigated included renal failure requiring hemodialysis, reoperation, stroke, rejection, and infection. A composite complication outcome was also generated that identified patients who had any post-operative complication. The complications studied were not uniformly collected by UNOS throughout the study period. Renal failure and stroke were available from 2000 to 2010, with data missing in 3.9% and 2.8% of patients, respectively. Similarly, infection and operation were available from 2000 to 2006, with data missing in 4.0% and 3.7% of patients, respectively. Lastly, acute rejection was only available from 2004 onward, with data missing in 6.0% of patients. The rates of complications analyzed in this study represent data from these specific time intervals.

Statistical analysis

The rates of post-operative complications were compared among the institutional volume cohorts. The effect of institutional volume on short-term and long-term survival in patients with each complication was then estimated with the Kaplan-Meier method, and differences were established by the log-rank test. Risk-adjusted Cox proportional hazard regression models were constructed with a series of recipient-specific, donor-specific, and transplant-specific variables identified on univariate analysis ($p < 0.20$) to determine the effect of institutional volume (when modeled as a continuous and as a categoric variable) on mortality in patients with the composite outcome. End points included 90-day, 1-year, and 5-year mortality, as well as conditional 1-year and 5-year deaths on 90-day and 1-year survivals, respectively. Logistic regression analysis was performed to determine the ability of institutional volume to independently predict each post-operative complication.

Parametric variables are reported as mean $\pm$ standard deviation and were compared with analysis of variance, and categoric variables are reported as incidence (number) and were compared with chi-square analysis. Lowess smoother plots were used to convert continuous data into stratified categoric variables based on graphically interpreted inflection points. Significance was established at a p-value of <0.05. Stata 12.1 software (Stata Corp LP, College Station, TX) was used for statistical analysis.

Results

Recipient, donor, and transplant characteristics stratified by institutional volume

A total of 19,849 patients who underwent OHT from 2000 to 2010 met criteria for eligibility in this study. After stratification into tertiles, low-volume (0–14.5 transplants per year), intermediate-volume (14.6–26.5 transplants per year), and high-volume (>26.5 transplants per year) cohorts were generated. The average transplant volume for the 144 institutions (99 low-volume, 32 intermediate-volume, and 13 high-volume institutions) was 26.4 $\pm$ 19.3 transplants per year.

There were several important differences in baseline recipient characteristics amongst the institutional volume cohorts. Notably, patients in the high-volume cohort were more likely to have a history of a previous thoracic transplantation, be supported with extracorporeal membrane oxygenation (ECMO), and managed in the intensive care unit. Similarly, low-volume institutions performed transplants in a greater percentage of patients bridged with a left ventricular assist device (LVAD) or who were mechanically ventilated before OHT. Intermediate-volume institutions had a greater incidence of recipients with pulmonary hypertension (mean pulmonary artery pressure $>$ 25 mm Hg). In regard to donor characteristics, the high-volume institutions used a greater percentage of grafts from diabetic donors. Lastly, high-volume institutions performed the bicaval technique more commonly than intermediate-volume or low-volume institutions (Table 1).

Complications

The overall rates of post-operative complications were renal failure, 7.8%; stroke, 2.3%; rejection, 10.2%; infection, 24.3%; reoperation, 12.0%; and composite outcome, 41.8%. The composite complication outcome is hard to characterize because any combination of complications could have been