ELSEVIER

The Journal of Heart and Lung Transplantation
http://www.jhltonline.org

ORIGINAL CLINICAL SCIENCE

Outcome of unplanned right ventricular assist device support for severe right heart failure after implantable left ventricular assist device insertion

Koji Takeda, MD, PhD,[a] Yoshifumi Naka, MD, PhD,[a] Jonathan A. Yang, MD, MPH,[a] Nir Uriel, MD,[b] Paolo C. Colombo, MD,[b] Ulrich P. Jorde, MD,[b] and Hiroo Takayama, MD, PhD[a]

From the [a]Department of Surgery, Division of Cardiothora cic Surgery; and the [b]Department of Medicine, Division of Cardiology, Columbia University Medical Center, New York, New York.

KEYWORDS:
ventricular assist device;
right ventricle;
heart failure;
LVAD;
RVAD;
heart transplant

BACKGROUND: The use of a right ventricular assist device (RVAD) becomes necessary for severe right ventricular (RV) failure after left ventricular assist device (LVAD) insertion. Although temporary support could lead to successful RVAD weaning in certain patients, the data remain scarce.

METHODS: We retrospectively reviewed 398 patients who underwent implantable LVAD insertion between January 2000 and December 2012. Of these patients, 44 (11%) required unplanned RVAD support due to severe RV failure after LVAD insertion. For comparison, 37 patients who underwent planned biventricular assist device (BiVAD) insertion were identified during the same study period. We analyzed the early and late outcomes in these patients.

RESULTS: The mean duration of RVAD support was 21 ± 23 days. Of the 44 patients, 21 (49%) were weaned from the RVAD (weaning group), whereas 23 (51%) required continued biventricular support (failure group). The failure group had ongoing end-organ dysfunction after RVAD insertion. Hospital mortality was significantly lower in the weaning group (24%) and in the planned BiVAD group (30%) as compared to the failure group (74%, $p = 0.0009$). The 6-month actuarial survival rate was 75% in the weaning group, 62% in the planned BiVAD group and 13% in the failure group ($p < 0.0001$). Successful bridge to transplant was achieved in 14 patients (67%) in the weaning group as compared with 8 patients (35%) in the failure group ($p = 0.03$). On multivariate logistic regression analyses, pre-operative white blood cell (odds ratio [OR] 1.3, 95% confidence interval [CI] 1.04 to 1.50, $p = 0.016$) and creatinine (OR 0.26, 95% CI 0.079 to 0.88, $p = 0.03$) levels were significant predictors for RVAD removal.

CONCLUSIONS: Among patients who developed acute RV failure after LVAD insertion, only half could be weaned from the temporary RVAD support. An alternative strategy is necessary in patients who require continuous RVAD support.

J Heart Lung Transplant ▮▮▮▮;▮:▮▮▮–▮▮▮
Published by Elsevier Inc.

The use of left ventricular assist devices (LVADs) has become standard care among patients with end-stage heart failure.[1] However, right ventricular (RV) failure after LVAD implantation is an unresolved issue and is associated with significant peri-operative mortality and morbidity.[2–4] Approximately 20% of patients develop some form of RV failure after LVAD placement.[2] For those patients with severe RV failure, unexpected right ventricular assist device (RVAD) insertion is necessary to establish adequate end-organ support.[2–5]

Recent studies have reported the usefulness of a temporary assist device for unplanned RV support, which

Reprint requests: Hiroo Takayama, MD, PhD, Department of Surgery, Division of Cardiothoracic Surgery, Columbia University Medical Center, 177 Fort Washington Avenue, New York, NY 10032. Telephone: 212-305-6380. Fax: 212-342-3520.
E-mail address: hirofu2@hotmail.com

1053-2498/$ - see front matter Published by Elsevier Inc.
http://dx.doi.org/10.1016/j.healun.2013.06.025

may eliminate the need for a long-term biventricular assist device (BiVAD) and result in a better outcome.[6–11] This strategy may be useful for identifying patients who require only a few days or weeks of RV support, as numerous factors contribute to RV function after LVAD and some forms of RV failure may be reversible.[6–9,11] However, the data were limited to small series of patients. In this study, we reviewed our larger experience with unplanned RVADs using temporary devices after LVAD placement.

Methods

The institutional review board of our institution approved this study. We retrospectively reviewed our experience at Columbia Presbyterian Medical Center between January 2000 and December 2012. During this period, a total of 398 patients with end-stage heart failure underwent insertion of implantable LVADs (168 pulsatile-flow devices and 230 continuous-flow devices). Of these, 44 (11%) developed severe RV failure immediately or late after LVAD implantation and required unplanned RVAD insertion. These patients were included in this study. The definition of severe RV failure after LVAD insertion and the indications for implantation of an RVAD have been described elsewhere.[12] For comparison, 37 patients who underwent planned long-term BiVAD implantation were identified during the same study period. These patients were taken into the operating room in a pre-determined plan for BiVAD placement. The decision regarding device insertion was made individually for each patient according to the discretion of a surgeon and heart failure cardiologist.

Devices

As implantable LVAD support, 34 HeartMate I and 10 HeartMate II (Thoratec, Pleasanton, CA) devices were used. For unplanned RVAD support, we used the Thoratec PVAD (Thoratec) in 2 patients, the Abiomed AB 5000 (Abiomed, Danvers, MA) in 25 and the CentriMag (Levitronix, Waltham, MA) in 17. The temporary RVAD was established with cannulation of the right atrium and pulmonary artery in all cases.

As planned long-term BiVAD support, Thoratec IVADs and PVADs were used in 13 and 24 patients, respectively. In these patients, the RVAD inflow cannula was placed either in the right atrium ($n = 23$) or the right ventricle ($n = 14$).

RVAD weaning

RVAD support was continued while patients were acutely ill after surgery. In general, RVAD flow was initially set as around 3 liters/min/m^2. LVAD pump speed was also kept high in patients with the HeartMate II device. Once the decreased need for vasoactive medication and recovery of pre-existing end-organ failure were confirmed, RVAD flow was decreased by 0.5 liter/min every 12 hours and down to 3 to 3.5 liters/min. At the same time, LVAD speed was adjusted to maintain good septal positioning on echocardiography. An RVAD weaning study was then performed in the intensive care unit under monitoring with a Swan–Ganz catheter and LVAD flow. With adequate heparinization, RVAD flow was decreased by 0.5 liter every 1 minute to 1 liter/min of flow. Adding new vasoactive drugs or nitric oxide inhalation to facilitate weaning was generally not recommended. Weaning was considered successful if the central venous pressure (CVP) remained at ≤13 mm Hg with stable LVAD flow. RVAD removal was performed in the operating room under transesophageal echocardiography guidance.

Data collection

For each patient, pre- and intra-operative variables that may correlate with survival were retrospectively collected. Most of these variables were selected from previous LVAD risk scores.[13] For unplanned RVAD patients, we also collected early post-operative data, including blood urea nitrogen (BUN), creatinine, total and direct bilirubin, alanine aminotransferase (ALT) and aspartate aminotransferase (AST) levels, to assess end-organ recovery after RVAD insertion. These values were measured immediately before RVAD implantation if patients underwent delayed insertion and at Days 1 and 3 post-operatively.

In patients who could be weaned from RVAD support, to assess the time course of tricuspid regurgitation (TR) severity and RV function, the echocardiography findings were reviewed. The severity of TR was graded as none to trace, mild, moderate or severe, in addition to qualitative assessment of RV systolic function (normal, mildly, moderately or severely reduced systolic function). The data before RVAD insertion and at 1 week and 1 month after RVAD removal were collected.

Statistical analysis

Data are presented as frequency distribution and percentage. Continuous variables are expressed as mean ± standard deviation (SD), and were compared using 2-sample *t*-tests. Categorical variables were compared using the chi-square test. For all analyses, $p < 0.05$ was considered statistically significant. Kaplan–Meier analysis was used to calculate 6-month survival along with a log-rank *p*-value when comparing groups. Stepwise logistic regression analysis was performed to identify the predictive factors for successful RVAD removal. Factors with a value of $p < 0.05$ on univariate analyses were entered into a stepwise logistic regression model. All data were analyzed using SPSS software, version 11.0 (SPSS, Inc., Chicago, IL).

Results

Patients' characteristics

The baseline patients' characteristics and comparisons with the planned BiVAD group are shown in Table 1. The unplanned RVAD cohort consisted of 30 men with a mean age of 52 years. As compared with the planned BiVAD group, patients in the unplanned RVAD group were significantly older with larger body size, and more likely to have pre-operative comorbidity, including hypertension and diabetes. In terms of disease etiology, long-term BiVAD was more likely used for severe biventricular failure associated with myocarditis and allograft failure. Baseline CVP was significantly higher in patients with planned BiVAD despite an increased requirement for inotropes. For laboratory data, serum albumin and hematocrit values were significantly lower for those with unplanned RVAD compared with values for those with planned BiVAD.

Of 44 patients, 28 (64%) underwent RVAD insertion at the time of LVAD implantation. These patients could not be weaned from cardiopulmonary bypass due to severe RV failure. Sixteen patients (36%) underwent delayed RVAD