# Outcomes of contemporary mechanical circulatory support device configurations in patients with severe biventricular failure

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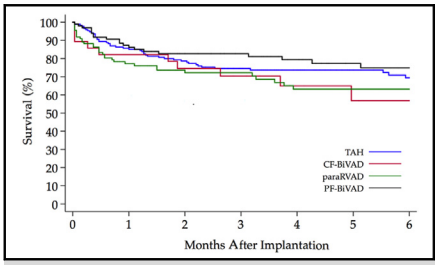
## ABSTRACT

**Objectives:** Severe right ventricular failure often is considered a contraindication for left ventricular assist device (LVAD) therapy and necessitates use of biventricular assist devices (BiVADs). Available options for BiVADs are limited, and comparative outcomes are largely unknown.

**Methods:** Heart transplant candidates who were registered on the United Network for Organ Sharing waitlist and underwent long-term contemporary LVAD (n = 3195) or BiVAD (n = 408) implantation, from January 2010 through June 2014, were retrospectively analyzed. We evaluated clinical characteristics and outcomes of patients requiring a BiVAD, as well as regional differences in utilization of this technology.

**Results:** Patients requiring a BiVAD were younger (48.9 vs 53.3 years), had a higher proportion of nonischemic disease (69.1% vs 58.2%), a higher bilirubin level (0.9 vs 0.7 mg/dL), and a lower 6-month survival rate (68.1% vs 92.7%) after device implantation (all $P < .05$). Postimplantation and posttransplantation survival was comparable for commonly used BiVAD configurations, including total artificial heart, continuous flow BiVAD, a continuous-flow LVAD coupled with a right-sided device, and pulsatile flow. Significant variation was found in regional utilization of these devices, regardless of differences in transplantation waitlist times. A large body surface area was an independent predictor of mortality on a BiVAD (hazard ratio = 2.12, $P = .017$).

**Conclusions:** Outcomes of patients requiring a BiVAD remain poor in the contemporary device era, regardless of the configuration used. Among other clinical factors, body surface area should be incorporated into decision making for device selection in these patients. (J Thorac Cardiovasc Surg 2016;151:530-5)




Postimplantation survival on BiVADS.

**Central Message**

Outcomes of patients who undergo device implantation for biventricular support remain poor, regardless of the device type.

**Perspective**

Utilization of biventricular support devices differs significantly by geographic region, independent of transplantation waitlist times. Large body size is an important risk factor for mortality on biventricular device support, and therefore should be incorporated into selection decisions regarding the appropriate device type for each candidate. Outcomes of patients who undergo device implantation for biventricular support remain poor, regardless of the device type.

See Editorial Commentary page 536.

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Supplemental material is available online.

Continuous-flow left ventricular assist device (CF-LVAD) technology has led to substantial improvements in outcomes of patients with end-stage heart failure, for bridge-to-transplantation as well as destination therapy indications.[1,2] Despite the rapidly increasing CF-LVAD implant numbers and physician experience nationwide, management of right ventricular (RV) failure before and after device insertion continues to be a major challenge in this patient population.[3] Although direct unloading of the left ventricle leads to a reduction in left-sided filling pressures, and hence RV afterload, RV function may commonly deteriorate after CF-LVAD implantation, owing to increased RV preload, changes in the septal position, and RV geometry, as well as perioperative inflammatory response. Several preoperative risk assessment tools have been developed to determine the risk of RV failure in patients after they undergo LVAD implantation.[4-8]

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**Abbreviations and Acronyms**

BiVAD = biventricular assist device
BSA = body surface area
CF = continuous-flow
LVAD = left ventricular assist device
PF = pulsatile-flow
RV = right ventricular
RVAD = right ventricular assist device
TAH = total artificial heart

Abnormal laboratory parameters (elevated bilirubin, blood urea nitrogen, aspartate aminotransferase, creatinine), echocardiographic indices (presence of RV systolic dysfunction, severe tricuspid regurgitation), and hemodynamic findings (higher central venous pressure, lower pulmonary artery pressures, higher central venous pressure/wedge ratio) have been identified as potential predictors of post-LVAD RV failure.[4-8] Moreover, intraoperative or early postoperative events, such as bleeding and/or sepsis-related vasodilatory conditions, which are not always predictable at the preoperative stage, might contribute to the development of RV failure as well. Given the poor outcomes associated with RV failure, patients who are deemed to be at high risk for this complication may not be offered CF-LVAD implantation without concomitant insertion of right-sided support devices.

Contemporary mechanical circulatory support options for patients with severe biventricular failure include total artificial hearts (TAH), CF-LVADs coupled with a contemporary paracorporeal-RVAD, fully implantable CF-biventricular assist devices (CF-BiVADs), and paracorporeal pulsatile-flow BiVADs (PF-BiVADs).[9-12] Given the limited number of these patients at any given center, and clustering due to center- or surgeon-specific device preferences, the comparative effectiveness of these device configurations remains largely unknown.[13] The United Network for Organ Sharing database recently implemented a mechanical circulatory support dataset that provides detailed information regarding device implantation/explantation dates and configurations. Using this dataset, we sought to comparatively analyze outcomes of various BiVAD configurations in patients listed for heart transplantation in the database.

## METHODS

### Data Source and Study Population

The United Network for Organ Sharing provided deidentified patient-level data from the waitlist, for the mechanical circulatory support and transplantation registries. These data included all heart transplant candidates who were registered on the waitlist between 1985 and 2014. We included adult candidates (aged ≥18 years) who were registered for single-organ, primary heart transplantation, and received a contemporary CF-LVAD or BiVAD (including TAH) as a bridge to transplantation, between January 2010 and June 2014 (Figure E1).

Patients who required temporary left-sided support, noncontemporary durable LVAD and/or RVAD combination, or RVAD insertion after LVAD, were excluded from the analysis. Candidate characteristics present at the time of waitlist registration were collected and comparatively analyzed. For geographic comparisons, The United Network for Organ Sharing Regions are numbered 1 through 11. For the purpose of this analysis, we categorized regions as follows: East (regions 1, 2, and 9); Midwest (regions 7, 8, and 10); South (regions 3, 4, and 11); and West (regions 5 and 6). Use of these data is consistent with the regulation of the Columbia University Institutional Review Board.

### Statistical Analysis

Continuous variables were summarized as mean ± SD, or median with interquartile range, and were compared using an independent *t* test and analysis of variance. The *P* values for pairwise comparisons were adjusted using the Bonferroni correction. Categorical variables were summarized as frequencies and percentages, and were compared using the Pearson $\chi^2$ test. Cumulative survival rates of ventricular assist devices were estimated using Kaplan-Meier survival analysis, and compared using the log-rank test. Patients were censored from the analysis at any of the following points: explantation of biventricular support; heart transplantation; and waitlist removal for other reasons. Univariable Cox proportional regression was performed to determine the association of patient characteristics with survival on biventricular support.

The models examined the effect of the following candidate characteristics present at registration on the heart transplantation waitlist: age, gender, body surface area (BSA), race, ABO blood type, heart failure etiology, history of diabetes mellitus, tobacco use, creatinine level, cardiac index, cardiac output, and geographic region. To determine the independent effect of multiple risk factors on waitlist mortality, a multivariable Cox proportional hazard model was utilized. Variables at the $P < .10$ level in unadjusted analyses were considered for inclusion; only variables at the $P < .05$ level, based on the likelihood ratio test, were retained in the final model. Hazard ratios, 95% confidence intervals, and *P* values were generated for both univariable and multivariable analyses as measures of strength of association and precision. All analyses were performed with STATA software, version 13 (Stata Corporation, College Station, Tex).

## RESULTS

### Characteristics of Patients

A total of 3195 contemporary CF-LVAD patients, and 408 BiVAD bridge-to-transplantation patients (including TAH) were identified in the United Network for Organ Sharing registry. The BiVAD configurations included the following: TAH in 172 patients; CF-BiVAD in 28 patients; paracorporeal-RVAD in 110 patients; and PF-BiVAD in 98 patients (Figure E1). Patients who required biventricular support had the following characteristics, compared with those who required left ventricular support only: They were significantly younger (48.9 ± 13.5 vs 53.3 ± 12.0 years, $P < .001$); they were more likely to be women (26% vs 22%, $P = .048$) and to have nonischemic etiology of heart failure (69% vs 58%, $P < .001$); they had a lower incidence of diabetes (26% vs 33%, $P = .003$) and tobacco use (39% vs 54%, $P < .001$), and a lower average body mass index (26.8 ± 5.0 vs 28.1 ± 4.9 kg/m$^2$, $P < .001$) and cardiac index (2.1 ± 0.8 vs 2.2 ± 0.6 L/minute/m$^2$, $P = .009$). They had lower albumin levels (3.4 ± 0.8 vs 3.6 ± 0.7 g/dL, $P < .001$), as well as

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