Risk Factors for Prolonged Mechanical Ventilation for Children on Ventricular Assist Device Support

Parthak Prodhan, MD, Giridhar Kalikivenkata, MD, Xinyu Tang, PhD, Kassandra Thomas, MD, Jonathan Byrnes, MD, Michiaki Imamura, MD, PhD, Robert D. B. Jaquiss, MD, Xiomara Garcia, MD, Elizabeth A. Frazier, MD, Adnan T. Bhutta, MD, and Umesh Dyamenahalli, MD

Divisions of Pediatric Critical Care and Pediatric Cardiology, Department of Pediatrics, College of Medicine, University of Arkansas Medical Sciences, Arkansas Children Hospital, Little Rock, Arkansas; Division of Pediatric Cardiology, Department of Pediatrics, University of Florida Hospitals, Gainesville, Florida; Division of Biostatistics, Department of Pediatrics, College of Medicine, University of Arkansas Medical Sciences, Arkansas Children Hospital, Little Rock, Arkansas; Division of Pediatric Cardiology, Department of Pediatrics, Cincinnati Childrens Hospital, Cincinnati, Ohio; Division of Cardiovascular Surgery, Department of Pediatrics, College of Medicine, University of Arkansas Medical Sciences, Arkansas Children Hospital, Little Rock, Arkansas; Division of Pediatric Cardiothoracic Surgery, Department of Surgery, Duke Medical Center, Durham, North Carolina; Division of Pediatric Critical Care, Department of Pediatrics, University of Maryland, Baltimore, Maryland; Division of Pediatric Cardiology, Department of Pediatrics, University of Chicago, Chicago, Illinois

Background. **Patients with end-stage heart failure possess many attributes that place them at risk for prolonged mechanical ventilation (MV). However, there are only limited data on MV support among children after ventricular assist device (VAD) implantation. We report the duration of MV after VAD placement, indications for respiratory support in the postimplantation period, and associated patient factors.**

Methods. **This single-center retrospective study included 43 consecutive children (aged <18 years) with end-stage heart failure who were supported with a VAD as a bridge to transplantation from January 2005 to December 2011. Multivariable analysis was performed using the multiple Poisson regression model for the duration of MV.**

Results. **Overall, 33% (n = 14) remained on MV until heart transplant or death. Of those requiring pre-VAD extracorporeal membrane oxygenation (ECMO) support, 63% (n = 12 of 19) remained on MV until heart transplant or death compared with 8% (n = 2 of 24) among those not on ECMO before VAD ($p < 0.001$). Patients with moderate or severe mitral regurgitation while on VAD support had 1.7-times more MV days compared with those with none or trivial on-VAD mitral regurgitation. In addition, previous support on ECMO, those with moderate or severe tricuspid regurgitation, and those with only left VAD implants had an increased risk of prolonged MV.**

Conclusions. **Our results suggest that VAD recipients previously supported on ECMO, those with moderate or severe mitral regurgitation, moderate or severe tricuspid regurgitation, and those with only left VAD implants had an increased risk of prolonged MV. Future studies in larger cohorts are necessary to confirm the findings from this single-institutional experience.**

(Ann Thorac Surg 2015;■:■–■)

Ventricular assist devices (VADs) are being implanted more frequently in children with end-stage heart failure as a bridge to orthotopic heart transplantation (OHT) or recovery [1, 2]. The use of VADs has dramatically reduced waiting list deaths among these patients. Nearly 73% of these children who receive VAD implantation for end-stage heart failure require mechanical ventilation (MV) [3]. These patients with end-stage heart failure have attributes, such as deconditioned respiratory musculature, pulmonary edema, and a history of chronic ventilation, that may impair their ability to wean early from MV support. Furthermore, the need for ongoing MV during VAD support is also a risk factor for death while receiving VAD support [4].

There are currently scant data relating to the extent of the MV requirement in children after VAD implantation. This information is of critical importance for prognostication, resource utilization, and family counseling in the intensive care unit. Therefore, the objectives of this study were to describe the characteristics of MV after VAD implantation and identify the risk factors for prolonged

Accepted for publication Dec 16, 2014.

Address correspondence to Dr Prodhan, Division of Pediatric Cardiology and Critical Care Medicine, College of Medicine, University of Arkansas Medical Sciences, Arkansas Children Hospital, 1 Children's Way, Slot 512-3, Little Rock, AR 72205; e-mail: prodhanparthak@uams.edu.

The Appendix can be viewed in the online version of this article [http://dx.doi.org/10.1016/j.athoracsur.2014.12.068] on http://www.annalsthoracicsurgery.org.

0003-4975/$36.00
http://dx.doi.org/10.1016/j.athoracsur.2014.12.068

MV after VAD implantation. We hypothesized that the presence of moderate or severe mitral regurgitation after VAD implantation would be associated with prolonged duration of MV support.

Material and Methods

The University of Arkansas Medical Sciences Institutional Review Board approved the study protocol.

Study Population

This retrospective study included 43 consecutive children (aged <18 years) with advanced heart failure who were supported on pediatric mechanical cardiac support (Berlin Heart EXCOR Pediatric VAD [Berlin Heart, Berlin Heart GmbH, Berlin, Germany] only or extracorporeal membrane oxygenation [ECMO], followed by Berlin Heart EXCOR Pediatric VAD), as a bridge to OHT from January 2005 to December 2011 at Arkansas Children's Hospital, a large tertiary care academic children's hospital. The study excluded children supported on other types of VADs. Pertinent medical information was abstracted from the institutional medical records.

VAD Support

During the study period, the Berlin Heart EXCOR Pediatric VAD, a paracorporeal volume-displacement VAD specifically designed for placement in young patients (neonates to adolescents), was the predominant type of VAD used. VAD implantation was considered in patients with decompensated heart failure who were candidates for OHT as direct mechanical cardiac support or in those who were on prior ECMO used on qualitative right ventricular (RV) support according to previously published inclusion and exclusion criteria [1]. The decision to place a left VAD (LVAD) only vs a biventricular assist device (BiVAD) was based on preoperative clinical characteristics, including echocardiographic findings as well as intraoperative assessment of RV function after LVAD implantation.

Variables

Data on patient demographics, presupport characteristics, characteristics while receiving VAD support, and clinical outcomes were collected. Data collected on variables specific to MV support included pre-VAD implantation MV support, support on ECMO, positive bronchioalveolar lavage cultures, and on-VAD–MV characteristics.

Statistical Analysis

Descriptive statistics are expressed as median (25^{th} percentile, 75^{th} percentile [interquartile range; IQR]) for continuous variables and as percentage (frequency) for categoric variables. The distributions of continuous variables were compared between groups (eg, VAD vs VAD+ECMO) using Mann-Whitney U tests. The proportions of categoric variables were compared using χ^2 tests. The association between paired categoric variables was evaluated using the McNemar test. Univariate analysis was performed to investigate the association between duration of MV and each clinical variable (eg, ECMO yes/no, pre-MR) using Poisson regression models. Multivariable analysis was further performed by fitting multiple Poisson regression model for the duration of MV using all the variables with univariate p of less than 0.10 simultaneously. Redundancy analysis was performed for all of the variables included in the multiple Poisson regression model, and no redundant variable was detected. A p value of less than 0.05 was considered to indicate statistical significance. All data were analyzed using R 3.0.1 statistical software (R Foundation for Statistical Computing, Vienna, Austria).

Results

Baseline Characteristics

The demographic and VAD-related characteristics of the 43 patients included in the study are reported in Table 1. The temporal distribution of study patients were as follows: from 2005 to 2006 there were six VAD implantations (four LVADs only), from 2007 to 2009 there were 21 VAD implantations (14 LVADs only), and from 2010 to 2012 there were 16 VAD implantations (three LVADs only).

BiVAD support was instituted on 51% (n = 22 of 43) of all cases, of which 68% (n = 15 of 22) of patients supported with a BiVAD were on pre-VAD ECMO vs 19% (n = 4 of 21) for those with only LVAD support. In the BiVAD group (n = 22), all patients on pre-VAD ECMO (n = 15) were on MV, the rest were not on any MV before VAD implantation. In the BiVAD-only group (excluding the 3 patients who were converted from LVAD to BiVAD), 6 of 19 patients were not on pre-VAD MV. In the LVAD-only group (n = 21), 4 patients were on pre-VAD ECMO support and 7 were on no pre-VAD MV. The median duration of VAD support was 21 days.

MV Characteristics

The median duration of MV before VAD implantation was 5 days. Between 2005 and 2010, 72% (n = 23 of 32) of patients required pre-VAD MV compared with only 58% (n = 7 of 12) from 2011 to 2012. Those supported on ECMO before VAD implantation had longer pre-VAD MV days (8 days) compared with those not on pre-VAD ECMO support (0 days; $p < 0.001$). Pre-VAD MV was noted in 67% (n = 29 of 43) of patients, of which 66% (n = 19 of 29) were also on pre-VAD ECMO support. Pre-VAD MV exceeded 10 days in 12 patients, of whom 75% (n = 9 of 12) were supported on pre-VAD ECMO. The MV days on VAD for these 3 patients were 16, 9, and 1 days, respectively. The median was 9 days (IQR, 4.5, 12.5 days).

Overall, the median duration of MV while on VAD support for the study group was 9 days. Overall, 33% (n = 14) remained intubated till OHT or death. Among these patients, 63% (n = 12 of 19) of those requiring pre-VAD ECMO support remained intubated till OHT or death compared with 8% (n = 2 of 24) among those on VAD support only ($p < 0.001$).

The median duration of MV after OHT was only 2.5 days for the overall study group. Of the 43 patients, 38 patients received a transplant, of which 61% (23 patients)