## SPECIAL ARTICLE



# Impact of durable ventricular assist devices on post-transplant outcomes in adults with congenital heart disease

Ari Cedars MD<sup>1</sup> Luke Burchill MD, PhD<sup>2</sup> | S. Lucy Roche MB, ChB<sup>3</sup> | Jonathan Menachem MD<sup>4</sup> | Kelly Axsom MD<sup>5</sup> | Kristen Tecson PhD<sup>6</sup> | for the ACTION Learning Network, Adult Congenital Heart Disease Sub-Committee

## Correspondence

Ari Cedars, The University of Texas Southwestern Medical Center, 2001 Inwood Rd. Suite WC05.852, Dallas, TX 75390, USA. Email: Ari.cedars@utsouthwestern.edu

#### **Funding information**

Divisional funding from UT Soutwestern Medical School.

# **Abstract**

Background: There are no published data on post-transplant outcomes in durable ventricular assist device (VAD)-supported adult congenital heart disease (ACHD) patients. Methods: We compared post-transplant outcomes in VAD-supported vs non-VADsupported ACHD patients using the Scientific Registry of Transplant Recipients. Results: At 1 year, there was no difference in post-transplant mortality between VAD-supported (12 patients) and non-VAD-supported (671 patients) ACHD patients. Conclusions: In appropriate ACHD patients, VAD use as a bridge to transplant is a reasonable strategy.

## **KEYWORDS**

adult congenital heart disease, heart transplant, ventricular assist device

# **INTRODUCTION**

There is a need for more information on outcomes after durable ventricular assist device (VAD) implant in adults with congenital heart disease (ACHD). Heart failure (HF) is currently the leading cause of death in ACHD patients. Although transplantation is a good option for end stage heart failure in ACHD, these patients have increased mortality while listed for transplant compared to their non-ACHD counterparts<sup>2</sup> due to a combination of delayed referral, anatomic complexity, allosensitization, lower listing status, longer wait-list times and increased risk of sudden death.<sup>3</sup> The utility of VAD in clinically deteriorating patients awaiting heart transplant is well established for non-ACHD patients however it is rarely used in ACHD despite generally favorable data on post-VAD outcomes.<sup>4</sup> To further elucidate a role

for VAD as a bridge to transplant in ACHD, we investigated post-transplant outcomes in VAD-supported ACHD patients.

## 2 | METHODS

#### 2.1 | Data

We employed the Scientific Registry of Transplant Recipients (SRTR) database for the present study. The SRTR data system includes data on all donor, wait-listed candidates, and transplant recipients in the United States, submitted by the members of the Organ Procurement and Transplantation Network (OPTN). The Health Resources and Services Administration, U.S. Department of Health and Human Services provides oversight to the activities

<sup>&</sup>lt;sup>1</sup>University of Texas Southwestern Medical School, Dallas, Texas, USA

<sup>&</sup>lt;sup>2</sup>University of Melbourne, Melbourne, Australia

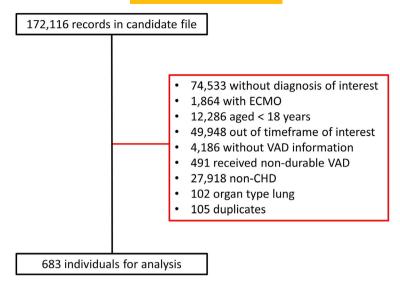
<sup>&</sup>lt;sup>3</sup>University of Toronto, Toronto, Ontario, Canada

<sup>&</sup>lt;sup>4</sup>Vanderbilt University, Nashville, Tennessee,

<sup>&</sup>lt;sup>5</sup>Columbia University, New York, New York,

<sup>&</sup>lt;sup>6</sup>Baylor University Medical Center, Dallas, Texas, USA

FIGURE 1 Inclusion diagram



for the OPTN and SRTR contractors. The analysis was approved by the University of Texas Southwestern Medical Center Institutional Review Board.

# 2.2 | Primary outcome

One-year post-transplant mortality.

#### 2.3 | Subjects

We compared adults (>18 years of age) with HF secondary to congenital heart disease who were bridged to transplant with durable VAD to ACHD patients wait-listed for transplant without VAD. To maximize relevance for the current era and to allow for one full year of follow-up, we limited the timeframe to that from 1999 to 2017. We excluded patients patients listed for multi-organ transplant, those on extracorporeal membrane oxygenation support and those with a non-durable mechanical circulatory support. The durable VAD group included only patients with information on type of VAD implanted who had one of the following types: Heartmate VE, XVE, II, Jarvik 2000, Micromed Debakey adult and child, Heartware HVAD and Ventracore ventrassist.

## 2.4 | Statistical analyses

All continuous variables were skewed and are presented as medians (quartile 1, quartile 3). Categorical variables are presented as frequency (percentage). To assess differences in patient characteristics between those with and without VAD, we performed Wilcoxon Rank Sum, Chi-Squared tests, or Fisher's exact tests, as appropriate. We tested for differences in survival rates and curves using Fisher's exact and the Logrank test, respectively. Hypothesis tests assume a two-sided alternative and a type I error rate of 5%. Analyses were performed using SAS 9.4 (Cary, NC).

# 3 | RESULTS

A total of 683 ACHD patients (Figure 1) who had undergone heart transplant during the investigated period were identified, 12 of whom had VAD as a bridge to transplant, 671 had not. There were few differences between the groups as shown in Table 1.

The median post-transplant follow-up times for this 1-year outcome analysis were 192.5 days (183, 216) and 216 days (182, 365) for VAD and non-VAD patients, respectively. At 30 days, 6 months, and 1 year after transplant, there were no deaths in the VAD group. In the non-VAD group, there were 3 (.45%), 17 (2.53%), and 32 (4.77%). There was no difference in survival at any of the three time points (P = .8166, .5769 and .5193, respectively; Figure 2).

There were 12 VAD transplant recipients with ACHD and 4188 VAD transplant recipients without ACHD. There were no post-transplant deaths among VAD transplant recipients with ACHD; however, 7 (.17%), 93 (2.22%), and 180 (4.3%) VAD transplant recipients without ACHD died within 30 days, 6 months, and 1 year of transplant, respectively. There were no differences in survival rates between ACHD and non-ACHD VAD transplant recipients (P = .8873, .5990 and .4842 at 30 days, 6 months, and 12 months, respectively).

# 4 | DISCUSSION

In this brief analysis, we investigated post-transplant outcomes in ACHD patients who underwent VAD as a bridge to transplant. We found only 12 (1.8%) mostly male ACHD patients who received VAD as a bridge to transplant. While numbers are limited, use of VAD did not appear to adversely impact post-transplant outcomes and there is no significant difference in outcomes between ACHD and non-ACHD post-VAD transplant recipients up to one year after transplant.

These data along with other recent analyses should encourage broader consideration of VAD in appropriate transplant-listed

 TABLE 1
 Characteristics of adults with congenital heart disease who received a heart-only transplant

Characteristic         IVAD (n = 471)         P value           Age         30.5 [2.2, 4.05]         34 [24.46]         .4277           Cender (male)         11 (19.47%)         30.1 (28.83%)         .03.62           Body mass index         23.5 [22.29.5]         23 [20.27]         .2646           Caucation         10 (83.33%)         298 [81.1%)         .6312           Education         T         25 (81.5%)         .75 (83.3%)         .25 (81.5%)           Attended college         7 (58.33%)         35 (99.93%)         .75 (83.3%)         .75 (99.93%)           Ver         12 (100%)         466 (69.45%)         .75 (83.3%)         .75 (99.93%)         .75 (99.93%)           Ver         12 (100%)         466 (69.45%)         .75 (99.93%)			· ·	
Gender (mile)         11 (91.67%)         401 (98.85%)         .033 (62.22.25)         22 (20.27)         .264 (62.20%)           Caucasian         10 (83.33%)         598 (89.12%)         .631 (20.20%)           Education         10 (83.33%)         598 (89.12%)         .631 (20.20%)           High school or less         5 (41.67%)         25 (38.15%)	Characteristic	LVAD (n = 12)	No LVAD (n = 671)	P value
Body mass index         23.5 (22.25.5)         23 (20.27)         .646           Caucasian         10 (83.33%)         598 (891.2%)         .631.2           Education         1 (10 (83.33%)         256 (38.15%)            If ligh school or less         5 (41.67%)         25 (38.15%)            Attended college         7 (58.33%)         33 (49.93%)            Unknown         0 (0%)         80 (11.93%)            Prior cardiac surgery         12 (100%)         46 (69.45%)            No         0 (0%)         65 (9.69%)            No         0 (0%)         10 (10.68%)            Unknown         1 (83.33%)         14 (1.64%)            Yes         1 (83.33%)         32 (4.92%)            Unknown         1 (83.33%)         32 (4.92%)            Unknown         1 (200%)         52 (39)            Yes         0 (0%)         1 (37.04.2%)            Unknown         0 (0%)         1 (37.04.2%)            Yes         0 (0%)         1 (1.49%)            Yes         0 (0%)         1 (1.49%)	Age	30.5 [22.5, 40.5]	34 [24, 46]	.4297
Body mass index         23.5 (22.25.5)         23 (20.27)         .646           Caucasian         10 (83.33%)         598 (891.2%)         .631.2           Education         1 (10 (83.33%)         256 (38.15%)            If ligh school or less         5 (41.67%)         25 (38.15%)            Attended college         7 (58.33%)         33 (49.93%)            Unknown         0 (0%)         80 (11.93%)            Prior cardiac surgery         12 (100%)         46 (69.45%)            No         0 (0%)         65 (9.69%)            No         0 (0%)         10 (10.68%)            Unknown         1 (83.33%)         14 (1.64%)            Yes         1 (83.33%)         32 (4.92%)            Unknown         1 (83.33%)         32 (4.92%)            Unknown         1 (200%)         52 (39)            Yes         0 (0%)         1 (37.04.2%)            Unknown         0 (0%)         1 (37.04.2%)            Yes         0 (0%)         1 (1.49%)            Yes         0 (0%)         1 (1.49%)	Gender (male)	11 (91.67%)	401 (59.85%)	.0336
Caucasian         10 (83.3%)         598 (99.12%)         .4312           Education         Filty action         256 (83.15%)         Filty Carbon of less         5 (41.47%)         256 (83.15%)         Filty Carbon of less         Filty Carbon of less         1 (10.0%)         305 (49.93%)         Filty Carbon of less         1 (10.0%)         466 (69.45%)         Filty Carbon of less         1 (10.0%)         466 (69.45%)         Filty Carbon of less         Filty Carbon of less </td <td>Body mass index</td> <td>23.5 [22, 29.5]</td> <td>23 [20, 27]</td> <td>.2646</td>	Body mass index	23.5 [22, 29.5]	23 [20, 27]	.2646
Education         Education         5 (1.67%)         25 (3.815%) <th< td=""><td></td><td>10 (83.33%)</td><td>598 (89.12%)</td><td>.6312</td></th<>		10 (83.33%)	598 (89.12%)	.6312
Attended college	Education			
Attended college	High school or less	5 (41.67%)	256 (38.15%)	
Unknown         0 (%)         80 (11.9%)			335 (49.93%)	
Yes         12 (100%)         466 (69.45%)           No         0 (0%)         65 (9.69%)           Unknown         0 (0%)         140 (20.86%)           Symptomatic cerebrovascular disease*				
Yes         12 (100%)         466 (69.45%)           No         0 (0%)         65 (9.69%)           Unknown         0 (0%)         140 (20.86%)           Symptomatic cerebrovascular disease*		, ,	, ,	.0801
No         0 (0%)         65 (9.6%)         Image: Composition of the compos		12 (100%)	466 (69.45%)	
Unknown         0 (0%)         140 (20.86%)           Symptomatic cerebrovascular disease*         1 (8.33%)         12 (1.64%)           Yes         1 (8.33%)         227 (93.44%)           Unknown         1 (8.33%)         33 (4.92%)           Unknown         1 (8.33%)         33 (4.92%)           Diabetes              Yes         0 (0%)         2 (30%)            No         0 (0%)         337 (20.42%)            Unknown         12 (100%)         52 (79.28%)            Dialysis				
Symptomatic cerebrovascular disease*         1.08.33%         11 (1.64%)           Yes         1 (8.33%)         627 (93.4%)           No         1 (8.33%)         627 (93.4%)           Unknown         1 (8.33%)         324.92%           Diabetes				
Yes         1 (8.33%)         11 (1.64%)           No         10 (83.33%)         627 (93.44%)           Unknown         1 (8.33%)         32 (79.24%)           Diabetes         . (83           Yes         0 (0%)         2 (.3%)           No         0 (0%)         137 (20.42%)           Unknown         12 (100%)         532 (79.28%)           Dialysis         T         1           Yes         0 (0%)         10 (1.49%)           No         12 (100%)         660 (98.36%)           Unknown         10 (0%)         1 (1.5%)           Unknown         10 (0%)         1 (1.5%)           Yes         0 (0%)         1 (1.5%)           Yes         5 (41.67%)         138 (20.57%)         1 (1.5%)           Yes         5 (41.67%)         138 (20.57%)         1 (1.5%)           Yes         5 (41.67%)         115 (17.14%)         1 (1.5%)           No         5 (41.67%)         125 (23.756%)         1 (1.5%)           Some         3 (25%)         252 (37.56%)         1 (2.25%)           Some         3 (25%)         252 (37.56%)         1 (2.25%)           Yes         4 (50%)         27 (8.49%)         1 (2.25%) </td <td></td> <td>- ()</td> <td></td> <td>.1095</td>		- ()		.1095
No         10 (83.3%)         627 (93.4%)           Unknown         1 (8.3%)         33 (4.92%)           Diabetes		1 (8.33%)	11 (1.64%)	12070
Unknown         1 (8.33%)         33 (4.92%)           Diabetes         .683           Yes         0 (0%)         2 (.3%)           No         0 (0%)         137 (20.42%)           Unknown         12 (100%)         52 (79.28%)           Dialysis         1         1 (1.4%)           Yes         0 (0%)         10 (1.4%)         1 (1.4%)           No         12 (100%)         60 (98.3%)         1 (1.4%)           Unknown         10 (0%)         1 (1.5%)         1 (1.5%)           Unknown         1 (2 (1.67%)         1 (1.65%)         1 (1.5%)           Yes         5 (41.67%)         1 (1.60,23%)         1 (1.4%)           Yes         5 (41.67%)         1 (1.60,23%)         1 (1.4%)           No         5 (41.67%)         1 (1.60,23%)         1 (1.4%)           Ver         5 (41.67%)         1 (1.60,23%)         1 (1.4%)           None         3 (25%)         2 (25 (3.55%)         1 (1.4%)           Sower         3 (25%)         1 (1.50,23%)         1 (1.50,23%)           Yes         3 (25%)         1 (1.50,23%)         1 (1.50,23%)           Yes         3 (25%)         1 (2.50,25%)         1 (1.50,25%)           Yes </td <td></td> <td></td> <td></td> <td></td>				
Diabetes         0 (0%)         2 (3%)           Yes         0 (0%)         137 (20.42%)           No         12 (10%)         532 (79.28%)           Dialysis         1           Yes         0 (0%)         10 (1.49%)           No         12 (10%)         660 (98.36%)           Unknown         12 (10%)         660 (98.36%)           Tyes         0 (0%)         1 (1.5%)           Tyes         5 (41.67%)         138 (20.57%)           No         5 (41.67%)         138 (20.57%)           No         5 (41.67%)         138 (20.57%)           No         5 (41.67%)         148 (62.3%)           Unknown         2 (56.67%)         150 (23.7%)           Some         3 (25%)         252 (37.56%)           Some         3 (25%)         252 (37.56%)           Severe         6 (50%)         203 (30.25%)           Unknown         0 (0%)         57 (8.49%)           No         9 (75%)         437 (65.13%)           Yes         3 (25%)         102 (15.2%)           Implantable defibrillator         2 (8.5%)         28 (42.2%)           No         9 (50%)         288 (42.2%)           No         2 (3.				
Yes         0 (0%)         2 (.3%)           No         0 (0%)         137 (20.42%)           Unknown         12 (100%)         532 (79.28%)           Dialysis         T         1           Yes         0 (0%)         10 (1.4%)           No         12 (100%)         660 (98.36%)         1           Unknown         1 (2 (100%)         660 (98.36%)         1           Unknown         1 (2 (100%)         660 (98.36%)         1           Unknown         0 (0%)         1 (1.5%)         1           Prog treated hypertension         5 (41.67%)         1 38 (20.57%)         1           No         5 (41.67%)         418 (62.3%)         1           Unknown         5 (41.67%)         418 (62.3%)         1           Unknown         3 (25%)         415 (71.4%)         488           None         3 (25%)         252 (37.56%)         488           Some         3 (25%)         259 (23.76%)         1           Sowere         6 (50%)         203 (30.25%)         1           Yes         3 (25%)         437 (65.13%)         1           Yes         3 (25%)         437 (65.13%)         1           Unknown         <		1 (0.0070)	00 (4.7270)	1683
No         0 (0%)         137 (20.42%)           Unknown         12 (100%)         532 (79.28%)           Dialysis         T         1           Yes         0 (0%)         10 (1.49%)         1           No         12 (100%)         660 (98.36%)         1           Unknown         10 (10%)         660 (98.36%)         1           Proug treated hypertension         T         1,745           Yes         5 (41.67%)         138 (20.57%)         1           No         5 (41.67%)         418 (62.3%)         1           Unknown         2 (16.67%)         115 (17.14%)         1           Functional limitations*         3 (25%)         252 (37.56%)         3           None         3 (25%)         252 (37.56%)         4           Sowere         6 (50%)         203 (30.25%)         1           Unknown         0 (0%)         5 (8.49%)         1           Yes         3 (25%)         102 (15.2%)         1           No         9 (75%)         437 (65.13%)         1           Unknown         0 (0%)         32 (19.67%)         1           Ves         6 (50%)         288 (42.22%)         1           Ves <td></td> <td>0 (0%)</td> <td>2 ( 3%)</td> <td>.1000</td>		0 (0%)	2 ( 3%)	.1000
Unknown         12 (100%)         532 (79,28%)           Dialysis         1           Yes         0 (0%)         10 (1,49%)           No         12 (100%)         660 (98,36%)           Unknown         0 (0%)         1 (1,5%)           Unknown         0 (0%)         1 (1,5%)           Drug treated hypertension         5 (41,67%)         138 (20,57%)           No         5 (41,67%)         418 (62,3%)           Unknown         2 (16,67%)         115 (17,14%)           Functional limitations*         2 (16,67%)         115 (17,14%)           Some         3 (25%)         252 (37,56%)           Some         3 (25%)         159 (23,7%)           Severe         6 (50%)         203 (30,25%)           Unknown         0 (0%)         37 (8,49%)           Yes         3 (25%)         102 (15,2%)           No         9 (75%)         437 (65,13%)           Unknown         0 (0%)         132 (19,67%)           Implantable defibrillator         5 (41,67%)         328 (42,2%)           No         5 (41,67%)         37 (55,29%)           No         5 (41,67%)         37 (55,29%)           Unknown         1 (8,33%)         12 (1,79%)<				
Dialysis         1           Yes         0 (0%)         10 (1.4%)           No         12 (100%)         660 (98.36%)           Unknown         0 (0%)         1 (15%)           Drug treated hypertension				
Yes         0 (0%)         10 (1.49%)           No         12 (100%)         660 (98.36%)           Unknown         0 (0%)         1 (15%)           Drug treated hypertension		12 (100%)	332 (77.26%)	1
No       12 (100%)       660 (98.3%)         Unknown       0 (0%)       1 (15%)         Drug treated hypertension		0 (0%)	10 (1 100/)	1
Unknown       0 (0%)       1 (15%)         Drug treated hypertension       .1745         Yes       5 (41.67%)       138 (20.57%)         No       5 (41.67%)       418 (62.3%)         Unknown       2 (16.67%)       115 (17.14%)         Functional limitations*       .838         None       3 (25%)       252 (37.56%)         Some       3 (25%)       159 (23.7%)         Severe       6 (50%)       203 (30.25%)         Unknown       0 (0%)       57 (8.49%)         Yes       3 (25%)       102 (15.2%)         No       9 (75%)       437 (65.13%)         Unknown       0 (0%)       132 (19.67%)         Implantable defibrillator       2 (650%)       288 (42.92%)         No       5 (41.67%)       371 (55.29%)         Unknown       1 (8.33%)       12 (1.79%)         Pulmonary artery mean pressure       5 (41.67%)       257 (38.30%)         25       5 (41.67%)       257 (38.30%)				
Drug treated hypertension         .1745           Yes         5 (41.67%)         138 (20.57%)           No         5 (41.67%)         418 (62.3%)           Unknown         2 (16.67%)         115 (17.14%)           Functional limitations*         .4838           None         3 (25%)         252 (37.56%)           Some         3 (25%)         159 (23.7%)           Severe         6 (50%)         203 (30.25%)           Unknown         0 (0%)         57 (8.49%)           Yes         3 (25%)         102 (15.2%)           No         9 (75%)         437 (65.13%)           Unknown         0 (0%)         132 (19.67%)           Implantable defibrillator         2 (50%)         288 (42.92%)           No         5 (41.67%)         371 (55.29%)           Unknown         1 (8.33%)         12 (1.79%)           Pulmonary artery mean pressure         5 (41.67%)         257 (38.30%)           25         5 (41.67%)         257 (38.30%)				
Yes         5 (41.67%)         138 (20.57%)           No         5 (41.67%)         418 (62.3%)           Unknown         2 (16.67%)         115 (17.14%)           Functional limitations*         .4838           None         3 (25%)         252 (37.56%)           Some         3 (25%)         159 (23.7%)           Severe         6 (50%)         203 (30.25%)           Unknown         0 (0%)         57 (8.49%)           Smoking history         .1526           Yes         3 (25%)         402 (15.2%)           No         9 (75%)         437 (65.13%)           Unknown         0 (0%)         132 (19.67%)           Implantable defibrillator         .1833           Yes         6 (50%)         288 (42.92%)           No         5 (41.67%)         371 (55.29%)           Unknown         1 (8.33%)         12 (1.79%)           Pulmonary artery mean pressure         .6951           25         5 (41.67%)         257 (38.30%)           425         6 (50.00%)         276 (41.13%)		0 (0%)	1 (.15%)	4745
No       5 (41.67%)       418 (62.3%)         Unknown       2 (16.67%)       115 (17.14%)         Functional limitations*       . 4838         None       3 (25%)       252 (37.56%)         Some       3 (25%)       159 (23.7%)         Severe       6 (50%)       203 (30.25%)         Unknown       0 (0%)       57 (8.49%)         Smoking history       3 (25%)       102 (15.2%)         No       9 (75%)       437 (65.13%)         Unknown       0 (0%)       132 (19.67%)         Implantable defibrillator       288 (42.92%)         No       5 (41.67%)       371 (55.29%)         Unknown       1 (8.33%)       12 (1.79%)         Pulmonary artery mean pressure       .6951         25       5 (41.67%)       257 (38.30%)         425       6 (50.00%)       276 (41.13%)		F (44 (70/)	400 (00 570)	.1745
Unknown       2 (16.67%)       115 (17.14%)         Functional limitations*       .4838         None       3 (25%)       252 (37.56%)         Some       3 (25%)       159 (23.7%)         Severe       6 (50%)       203 (30.25%)         Unknown       0 (0%)       57 (8.49%)         Smoking history       .1526         Yes       3 (25%)       102 (15.2%)         No       9 (75%)       437 (65.13%)         Unknown       0 (0%)       132 (19.67%)         Implantable defibrillator       .00%)       132 (19.67%)         No       5 (41.67%)       371 (55.29%)         Unknown       1 (8.33%)       12 (1.79%)         Pulmonary artery mean pressure       .6951         ≥25       5 (41.67%)       257 (38.30%)         <25       6 (50.00%)       276 (41.13%)				
Functional limitations*       .4838         None       3 (25%)       252 (37.56%)         Some       3 (25%)       159 (23.7%)         Severe       6 (50%)       203 (30.25%)         Unknown       0 (0%)       57 (8.49%)         Smoking history       .1526         Yes       3 (25%)       102 (15.2%)         No       9 (75%)       437 (65.13%)         Unknown       0 (0%)       132 (19.67%)         Implantable defibrillator       .00%)       288 (42.92%)         No       5 (41.67%)       371 (55.29%)         Unknown       1 (8.33%)       12 (1.79%)         Pulmonary artery mean pressure       .6951         ≥25       5 (41.67%)       257 (38.30%)         <25				
None       3 (25%)       252 (37.56%)         Some       3 (25%)       159 (23.7%)         Severe       6 (50%)       203 (30.25%)         Unknown       0 (0%)       57 (8.49%)         Smoking history		2 (16.6/%)	115 (17.14%)	
Some       3 (25%)       159 (23.7%)         Severe       6 (50%)       203 (30.25%)         Unknown       0 (0%)       57 (8.49%)         Smoking history      1526         Yes       3 (25%)       102 (15.2%)         No       9 (75%)       437 (65.13%)         Unknown       0 (0%)       132 (19.67%)         Implantable defibrillator      1833         Yes       6 (50%)       288 (42.92%)         No       5 (41.67%)       371 (55.29%)         Unknown       1 (8.33%)       12 (1.79%)         Pulmonary artery mean pressure      6951         ≥25       5 (41.67%)       257 (38.30%)         <25       6 (50.00%)       276 (41.13%)		- / //	/ /	.4838
Severe       6 (50%)       203 (30.25%)         Unknown       0 (0%)       57 (8.49%)         Smoking history       .1526         Yes       3 (25%)       102 (15.2%)         No       9 (75%)       437 (65.13%)         Unknown       0 (0%)       132 (19.67%)         Implantable defibrillator       .1833         Yes       6 (50%)       288 (42.92%)         No       5 (41.67%)       371 (55.29%)         Unknown       1 (8.33%)       12 (1.79%)         Pulmonary artery mean pressure       .6951         ≥25       5 (41.67%)       257 (38.30%)         <25       6 (50.00%)       276 (41.13%)				
Unknown       0 (0%)       57 (8.49%)         Smoking history       .1526         Yes       3 (25%)       102 (15.2%)         No       9 (75%)       437 (65.13%)         Unknown       0 (0%)       132 (19.67%)         Implantable defibrillator       .1833         Yes       6 (50%)       288 (42.92%)         No       5 (41.67%)       371 (55.29%)         Unknown       1 (8.33%)       12 (1.79%)         Pulmonary artery mean pressure       .6951         ≥25       5 (41.67%)       257 (38.30%)         <25       6 (50.00%)       276 (41.13%)				
Smoking history       .1526         Yes       3 (25%)       102 (15.2%)         No       9 (75%)       437 (65.13%)         Unknown       0 (0%)       132 (19.67%)         Implantable defibrillator       .1833         Yes       6 (50%)       288 (42.92%)         No       5 (41.67%)       371 (55.29%)         Unknown       1 (8.33%)       12 (1.79%)         Pulmonary artery mean pressure       .6951         ≥25       5 (41.67%)       257 (38.30%)         <25				
Yes       3 (25%)       102 (15.2%)         No       9 (75%)       437 (65.13%)         Unknown       0 (0%)       132 (19.67%)         Implantable defibrillator       .1833         Yes       6 (50%)       288 (42.92%)         No       5 (41.67%)       371 (55.29%)         Unknown       1 (8.33%)       12 (1.79%)         Pulmonary artery mean pressure       .6951         ≥25       5 (41.67%)       257 (38.30%)         <25       6 (50.00%)       276 (41.13%)		0 (0%)	57 (8.49%)	
No       9 (75%)       437 (65.13%)         Unknown       0 (0%)       132 (19.67%)         Implantable defibrillator       .1833         Yes       6 (50%)       288 (42.92%)         No       5 (41.67%)       371 (55.29%)         Unknown       1 (8.33%)       12 (1.79%)         Pulmonary artery mean pressure       .6951         ≥25       5 (41.67%)       257 (38.30%)         <25       6 (50.00%)       276 (41.13%)				.1526
Unknown       0 (0%)       132 (19.67%)         Implantable defibrillator       .1833         Yes       6 (50%)       288 (42.92%)         No       5 (41.67%)       371 (55.29%)         Unknown       1 (8.33%)       12 (1.79%)         Pulmonary artery mean pressure       .6951         ≥25       5 (41.67%)       257 (38.30%)         <25       6 (50.00%)       276 (41.13%)				
Implantable defibrillator         Yes       6 (50%)       288 (42.92%)         No       5 (41.67%)       371 (55.29%)         Unknown       1 (8.33%)       12 (1.79%)         Pulmonary artery mean pressure       .6951         ≥25       5 (41.67%)       257 (38.30%)         <25	No			
Yes       6 (50%)       288 (42.92%)         No       5 (41.67%)       371 (55.29%)         Unknown       1 (8.33%)       12 (1.79%)         Pulmonary artery mean pressure       .6951         ≥25       5 (41.67%)       257 (38.30%)         <25       6 (50.00%)       276 (41.13%)		0 (0%)	132 (19.67%)	
No       5 (41.67%)       371 (55.29%)         Unknown       1 (8.33%)       12 (1.79%)         Pulmonary artery mean pressure       .6951         ≥25       5 (41.67%)       257 (38.30%)         <25       6 (50.00%)       276 (41.13%)	Implantable defibrillator			.1833
Unknown     1 (8.33%)     12 (1.79%)       Pulmonary artery mean pressure     .6951       ≥25     5 (41.67%)     257 (38.30%)       <25			288 (42.92%)	
Pulmonary artery mean pressure       .6951         ≥25       5 (41.67%)       257 (38.30%)         <25		5 (41.67%)		
≥25 5 (41.67%) 257 (38.30%) <25 6 (50.00%) 276 (41.13%)	Unknown	1 (8.33%)	12 (1.79%)	
<25 6 (50.00%) 276 (41.13%)	Pulmonary artery mean pressure			.6951
	≥25	5 (41.67%)	257 (38.30%)	
Unknown 1 (8.33%) 138 (20.57%)	<25	6 (50.00%)	276 (41.13%)	
	Unknown	1 (8.33%)	138 (20.57%)	

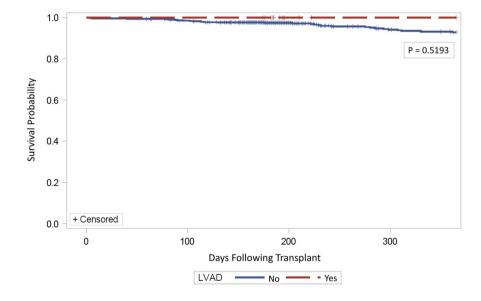
(Continues)

TABLE 1 (Continued)

Characteristic	LVAD (n = 12)	No LVAD (n = 671)	P value
Albumin			1
≥3.2	1 (8.33%)	73 (10.88%)	
<3.2	8 (66.67%)	434 (64.68%)	
Unknown	3 (25%)	164 (24.44%)	
Drug treated COPD			1
Yes	0 (0%)	10 (1.49%)	
No	10 (83.33%)	523 (77.94%)	
Unknown	2 (16.67%)	138 (20.57%)	
IV inotropes			.0785
Yes	0 (0%)	159 (23.70%)	
No	12 (100%)	511 (76.16%)	
Unknown	0 (0%)	1 (.15%)	
Life support*			.0436
Yes	0 (0%)	173 (25.82%)	
No	12 (100.0%)	497 (74.07%)	
Unknown	0 (0%)	1 (.15%)	
Type of LVAD			-
Heartmate II	11 (91.67%)	-	
Heartware HVAD	1 (8.33%)	-	

Note: Variables assessed at the time of heart transplant.

**FIGURE 2** Post transplant survival in ACHD patients bridged to transplant with VAD (red) and transplanted without bridge (blue)



ACHD patients. Despite the potential to beneficially impact waiting list outcomes, VAD remains infrequently used in ACHD patients. A.5 The arguments against VAD use in this population have broadly been two. First, concern that VAD might not be safe and efficacious in anatomy for which it was not designed. Second, that VAD implant might adversely impact post-transplant outcomes due to additional surgical scarring, exposure to blood products with consequent allosensitization and augmented operative difficulty associated with VAD explant at the time of transplant in patients with already complex anatomy. Previous INTERMACS

analyses have addressed the first of these questions. <sup>4,6</sup> Maxwell et al addressed the second among ACHD patients supported by all types of mechanical circulatory support in aggregate. <sup>7</sup> The present analysis, although limited, adds to these data by specifically investigating outcomes after durable VAD.

# 4.1 | Limitations

In addition to all of the limitations inherit to retrospective research using SRTR, the test group in the present analysis is very small. With a

<sup>\*</sup>Based on SRTR definitions.8

larger sample, we expect that adverse events would be detected in the ACHD VAD group. Nevertheless, anecdotal experience suggests that VAD has been used predominantly in severely deteriorating ACHD patients without other options. Following this logic, these patients are likelt at higher risk of adverse outcomes than the average transplant-listed ACHD patient, and one might therefore anticipate fewer rather than more events with expanded use in lower risk individuals. Nevertheless, given limited patient numbers and follow-up, the impact of VAD on long-term post-transplant outcomes cannot be definitively concluded based on the present analysis.

In conclusion, post-transplant outcomes in VAD-supported ACHD patients are not worse than in non-VAD-supported patients. VAD is a reasonable option in transplant-listed ACHD patients.

## 5 | DISCLAIMER

The data reported here have been supplied by the Hennepin Health Research Institute (HHRI) as the contractor for the Scientific Registry of Transplant Recipients (SRTR). The interpretation and reporting of these data are the responsibility of the authors and in no way should be seen as an official policy of, or interpretation by the SRTR or the U.S. Government.

#### **CONFLICT OF INTEREST**

The authors declare that they have no conflicts of interest with the contents of this article.

## **AUTHOR CONTRIBUTION**

All authors have read and approved the final manuscript.

Drafting manuscript, study design: Cedars

Drafting manuscript, critical reading: Burchill, Roche, Menachem,

Data analysis, database search: Tecson

#### ORCID

Ari Cedars https://orcid.org/0000-0002-9975-5301

#### REFERENCES

- Engelings CC, Helm PC, Abdul-Khaliq H, et al. Cause of death in adults with congenital heart disease—An analysis of the German National Register for Congenital Heart Defects. *Int J Cardiol.* 2016;211:31-36. https://doi.org/10.1016/j.ijcard.2016.02.133.
- Alshawabkeh LI, Hu N, Carter KD, et al. Wait-list outcomes for adults with congenital heart disease listed for heart transplantation in the U.S. J Am Coll Cardiol. 2016;68(9):908-917. https://doi.org/10.1016/j. jacc.2016.05.082.
- Everitt MD, Donaldson AE, Stehlik J, et al. Would access to device therapies improve transplant outcomes for adults with congenital heart disease? Analysis of the United Network for Organ Sharing (UNOS). J Heart Lung Transplant. 2011;30(4):395-401. https://doi. org/10.1016/j.healun.2010.09.008.
- Cedars A, Vanderpluym C, Koehl D, Cantor R, Kutty S, Kirklin JK. An Interagency Registry for Mechanically Assisted Circulatory Support (INTERMACS) analysis of hospitalization, functional status, and mortality after mechanical circulatory support in adults with congenital heart disease. *J Hear Lung Transplant*. 2018;37(5):619-630. https:// doi.org/10.1016/j.healun.2017.11.010.
- Davies RR, Russo MJ, Yang J, Quaegebeur JM, Mosca RS, Chen JM. Listing and transplanting adults with congenital heart disease. *Circulation*. 2011;123(7):759-767. https://doi.org/10.1161/CIRCU LATIONAHA.110.960260.
- VanderPluym CJ, Cedars A, Eghtesady P, et al. Outcomes following implantation of mechanical circulatory support in adults with congenital heart disease: an analysis of the Interagency Registry for Mechanically Assisted Circulatory Support (INTERMACS). J Hear Lung Transplant. 2018;37(1):89-99. https://doi.org/10.1016/j. healun.2017.03.005.
- 7. Maxwell BG, Wong JK, Sheikh AY, Lee P, Lobato RL. Heart transplantation with or without prior mechanical circulatory support in adults with congenital heart disease. *Eur J Cardiothorac Surg.* 2014;45(5):842-846. https://doi.org/10.1093/ejcts/ezt498.
- Scientific Registry of Transplant Recipients. https://www.srtr.org/. Accessed November 11, 2018.

How to cite this article: Cedars A, Burchill L, Roche SL, Menachem J, Axsom K, Tecson K; for the ACTION Learning Network, Adult Congenital Heart Disease Sub-Committee. Impact of durable ventricular assist devices on post-transplant outcomes in adults with congenital heart disease. *Congenital Heart Disease*. 2019;14:958–962. https://doi.org/10.1111/chd.12851