Is “Four Stage Management” the Future of Univentricular Hearts? – Destination Therapy in the Young

RDB Jaquiss
Duke University
Disclosures

• None
Current Paradigm for Palliation

• Stage I – shunt/band PROTECT PVR
• Stage II – superior CPC RELIEVE VOLUME LOAD
• Stage III – Fontan completion RELIEVE CYANOSIS

• If (when?) palliation fails - transplant
Normal
Single Ventricle
Fontan Circulation
Fontan Circulation
How Well and How Long Does It Work?

Long-Term Survival, Modes of Death, and Predictors of Mortality in Patients With Fontan Surgery

Paul Khairy, MD, PhD; Susan M. Fernandes, MHP, PA-C; John E. Mayer Jr, MD; John K. Triedman, MD; Edward P. Walsh, MD; James E. Lock, MD; Michael J. Landzberg, MD

Background—To better define determinants of mortality in patients with univentricular physiology, a database registry was created of patients born in 1985 or earlier with Fontan surgery who were followed up at Children’s Hospital Boston.

Methods and Results—A total of 261 patients, 121 of whom (46.4%) were women, had a first Fontan surgery at a median age of 7.9 years: right atrium–to–pulmonary artery connection in 135 (51.7%); right atrium to right ventricle in 25 (9.6%); and total cavopulmonary connection in 101 (38.7%). Over a median of 12.2 years, 76 (29.1%) died, 5 (1.9%) had cardiac transplantation, 5 (1.9%) had Fontan revision, and 21 (8.0%) had Fontan conversion. Perioperative mortality decreased steadily over time and accounted for 68.4% of all deaths. In early survivors, actuarial freedom from death or transplantation was 93.7%, 89.9%, 87.3%, and 82.6% at 5, 10, 15, and 20 years, respectively, with no significant difference between right atrium to pulmonary artery versus total cavopulmonary connection. Late deaths were classified as sudden in 7 patients (9.2%), thromboembolic in 6 (7.9%), heart failure–related in 5 (6.7%), sepsis in 2 (2.6%), and other in 4 (5.2%). Most sudden deaths were of presumed arrhythmic origin with no identifiable predictor. Independent risk factors for thromboembolic death were lack of antiplatelet or anticoagulant therapy (hazard ratio [HR], 9.16; P=0.0041) and clinically diagnosed intracardiac thrombus (HR, 22.7; P=0.0002). Independent predictors of heart failure death were protein–losing enteropathy (HR, 7.1; P=0.0043), single morphologically right ventricle (HR, 10.5; P=0.0429), and higher right atrial pressure (HR, 1.3 per 1 mm Hg; P=0.0016).

Conclusion—In perioperative survivors of Fontan surgery, gradual attrition occurs predominantly from thromboembolic, heart failure–related, and sudden deaths. (Circulation. 2006;117:95-92.)

Conditional Freedom from Death or Transplant

<table>
<thead>
<tr>
<th>Time (years)</th>
<th>Freedom</th>
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<tr>
<td>5</td>
<td>94%</td>
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<tr>
<td>10</td>
<td>90%</td>
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<tr>
<td>15</td>
<td>87%</td>
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<tr>
<td>20</td>
<td>83%</td>
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<table>
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<th>Time from Fontan surgery (years)</th>
<th>Number at risk</th>
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<td>RA-RV</td>
<td>25 25 20 14 10 6</td>
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<tr>
<td>TCPC</td>
<td>122 77 57 27 1 0</td>
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<tr>
<td>RA-PA</td>
<td>135 85 77 61 23 3</td>
</tr>
<tr>
<td>TOTAL</td>
<td>282 187 154 102 34 9</td>
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</table>

Logrank P=0.0018
A Very Large and Excellent Experience

Redefining Expectations of Long-Term Survival After the Fontan Procedure
Twenty-Five Years of Follow-Up From the Entire Population of Australia and New Zealand

Yves d’Udekem, MD, PhD; Ajay J. Jyngear, MBBS(BiHons, BMedSci, GCAMIT); John C. Galati, BSc, PhD; Victoria Foekidick, MBBS;
Robert G. Wentzrab, MBBS, FRACP; Gavin R. Wheaton, MBBS, FRACP;
Andrew Bullock, MBBS, FRACP; Robert J. Justo, MBBS, FRACP;
Laetare E. Grigg, MBBS, FRACP; Gary F. Stiller, MBBS, FRACP;
Sarah Hope, BSc, BMedSci(Hons); MICBCh, FRACP; PhD;
Dorothy J. Raikoff, MBBS, MD, FRACP, Thomas L. Gentili, MICBCh, FRACP;
David S. Celermejer, MBBS, PhD, DSc, FRACP; David S. Wintle, MBBS(Hons), MD, FRACS

Background...The life expectancy of patients undergoing a Fontan procedure is unknown.
Methods and Results...Follow-up of all 160 survivors of the 189 patients who underwent a Fontan procedure in Australia and New Zealand was obtained from a bimetalldisc population-based registry that includes all pediatric and adult cardiac cases. There were 203 atrioventricular connections (AP, 1973-1995), 271 lateral tunnels (1998-2006), and 332 extracardiac conduits (1997-2018). The proportion with hypoplastic left heart syndrome increased from 11% (4%) before 1990 to 30% to 69% after 2000. Survival at 10 years was 89% (84% to 95% for AP, 69% to 95% for lateral tunnels and extracardiac conduits). The longest survival estimate was 90% (95% CI, 67% to 96%) at 25 years for AP. AP independently predicted worse survival compared with extracardiac conduits (hazard ratio, 6.2; 95% CI, 1.9 to 21.4; P=0.001). Freedom from death (single, transplantation, takeover, conversion to extracardiac conduits, New York Heart Association II, or postoperative events) was 53% for AP and 68% for lateral tunnels and extracardiac conduits, respectively. The 10-year freedom from death was 79% (95% CI, 63% to 92%) for AP and 82% (95% CI, 75% to 89%) for lateral tunnels and extracardiac conduits, respectively.

Conclusions...The long-term survival of the Australian and New Zealand Fontan population is excellent. Patients with AP Fontan experience survival of 74% at 25 years. Technical modifications have further improved survival. Patients with hypoplastic left heart syndrome are at higher risk of failure. Large, comprehensive registries such as this will further improve our understanding of late outcomes after the Fontan procedure. (Circulation. 2014;130[ suppl 1]:S32-S38.)

Conditional Survival

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Years</th>
<th>Survival</th>
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<tbody>
<tr>
<td>Atriopulmonary</td>
<td>25 years</td>
<td>76%</td>
</tr>
<tr>
<td>Lateral Tunnel</td>
<td>20 years</td>
<td>90%</td>
</tr>
<tr>
<td>Extracardiac</td>
<td>13 years</td>
<td>97%</td>
</tr>
</tbody>
</table>

![Graph showing survival rates over time]
A Closer Look
Survival Isn’t Everything
Problems with Fontan Circulation

- Low Cardiac Output (70% of Normal at Rest)
  - Impaired Exercise Capacity
  - pre-load (PVR) determined
- Thromboembolism
- Arrythmias
- Hepatopathy
- Nephropathy
- Death
Developments in Fontan Surgery

• Description by Fontan and Baudet
• Ten Commandments
• Lateral Tunnel
• Extracardiac
• Staging
• Fenestration
• Fontan conversion
• Intra/Extra
• “Y” Grafts
...pattern of endothelial dysfunction-induced remodeling due to chronic, non-pulsatile flow with in situ thrombotic lesions.
Fontan Circulation
Modes of Fontan Failure

• Pump failure (LV<RV)
  – Intrinsic, iatrogenic, arrhythmic, valvular

• Concept failure
  – “high”PVR leading to high Fontan pressure
    • PLE, plastic bronchitis
    • Cyanosis (V-V collaterals)
Scope of Problem

• STS Congenital Database 7/2010 to 6/2014
  – 3245 “Fontan” operation (excluding conversions)
    • 810/year entering pipeline

• Scientific Registry of Transplant Recipients
Total Heart Transplants – U.S.
Status 2 – 10% waitlist mortality
Status 1 (inotropes) – 40% waitlist mortality
Status 1 (ventilator) – 70% waitlist mortality
## Changing Profile of Adult Heart Transplant 2002 and 2012

<table>
<thead>
<tr>
<th>Urgency Status</th>
<th>2002</th>
<th>2012</th>
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<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
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<tr>
<td>Urgency Status</td>
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</tr>
<tr>
<td>1A</td>
<td>660</td>
<td>34.8</td>
</tr>
<tr>
<td>1B</td>
<td>723</td>
<td>38.2</td>
</tr>
<tr>
<td>2</td>
<td>509</td>
<td>26.9</td>
</tr>
<tr>
<td>Bridge</td>
<td></td>
<td></td>
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<tr>
<td>No VAD</td>
<td>1454</td>
<td>76.8</td>
</tr>
<tr>
<td>VAD</td>
<td>440</td>
<td>23.2</td>
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</table>
Use of a HeartWare Ventricular Assist Device in a Patient With Failed Fontan Circulation

Robert A. Niebler, MD, Nancy S. Ghanayem, MD, Tejas K. Shah, MD, Andrea De La Rosa Bobke, CPNP, Steven Zangwill, MD, Cheryl Brosig, PhD, Michelle A. Frommelt, MD, Michael E. Mitchell, MD, James S. Tweddell, MD, and Ronald K. Woods, MD

Herma Heart Center, Children's Hospital of Wisconsin; Department of Pediatrics, Section of Critical Care, Medical College of Wisconsin; Department of Pediatrics, Section of Cardiology, Medical College of Wisconsin; and Department of Cardiothoracic Surgery, Medical College of Wisconsin, Milwaukee, Wisconsin

We present a successful case of the use of a HeartWare ventricular assist device as a bridge to transplantation in an 11-year-old with a hypoplastic left heart and failed Fontan circulation.

Application of LVAD

• Pump failure (LV<RV)
  – Intrinsic, iatrogenic, arrhythmic, valvular

• Concept failure
  – “high” PVR leading to high Fontan pressure
    • PLE, plastic bronchitis
    • Cyanosis (V-V collaterals)
“As many as two thirds of adult Fontan patients who die or require transplantation do so with preserved ventricular function.”
LVAD for Concept Failure – “Pulling”

A new era: Use of an intracorporeal systemic ventricular assist device to support a patient with a failing Fontan circulation

David L. S. Morales, MD, Ik I Adachi, MD, Jeffrey S. Heinle, MD, and Charles D. Fraser, Jr, MD, Houston, Tex

Worldwide experience with ventricular assist device (VAD) support in patients with univentricular physiology has been very limited. In particular, the use of a long-term continuous-flow implantable VAD has never been described. We report the successful application of an intracorporeal systemic ventricular assist device (SVAD), the HeartMate II (Thoratec Corporation, Pleasanton, Calif), in an adolescent with a failing Fontan circulation and protein-losing enteropathy (PLE).

CLINICAL SUMMARY
The patient is a 15-year-old boy (body surface area, 1.5 m²) with double-outlet right ventricle, mitral atresia, and a systemic right ventricle. He underwent staged palliation culminating in a fenestrated lateral Fontan operation at 3 years old. Although he did well for many years, his condition began to deteriorate with increasing dyspnea on exertion, peripheral pitting edema, and hepatomegaly with ascites. PLE was diagnosed (serum albumin, 2.6 g/dL; prealbumin, 9.7 mg/dL). Echocardiogram revealed severely depressed systolic ventricular function with significant tricuspid regurgitation. In preparation for cardiac transplantation, a cardiac catheterization was performed. After induction of positive-pressure ventilation, he had several periods of cardiac arrest necessitating resuscitation. The abbreviated catheterization demonstrated a severely elevated Fontan pressure of 30 mm Hg, a pulmonary vascular resistance of 1.9 Wood units, normal caliber pulmonary arteries, and a wedge pressure of 22 mm Hg. Because his circulatory failure was primarily the result of systemic ventricular dysfunction and his condition was hemodynamically unstable, he underwent urgent VAD placement.
Because the patient had levocardiopathy with normally related great arteries, a HeartMate II SVAD was implanted in the usual manner (Figure 1) on cardiopulmonary bypass without cardiac arrest. The only atypical aspect was the...
Concept Failure – “Pushing”

“Fontan patients are doomed to a circulatory failure and many of them will require a circulatory assistance as a bridge to transplantation.”
## RVAD vs. LVAD
### Pushing vs. Pulling

<table>
<thead>
<tr>
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<th>LVAD</th>
<th>RVAD</th>
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<tr>
<td><strong>Power Requirements</strong></td>
<td>X</td>
<td>0.25 X</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>Small</td>
<td>Smaller</td>
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<tr>
<td><strong>Embolic Consequences</strong></td>
<td>Very Bad</td>
<td>Bad</td>
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<tr>
<td><strong>Durability</strong></td>
<td>Unknown</td>
<td>Unknown+++</td>
</tr>
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</table>
Performance evaluation of a pediatric viscous impeller pump for Fontan cavopulmonary assist

Guruprasad A. Giridharan, PhD, a Steven C. Koenig, PhD, a Jeffrey Kennington, BS, a Michael A. Sobieski, RN, CCP, a Jun Chen, PhD, a Steven H. Frankel, PhD, a and Mark D. Rodefeld, MD a

Objective: The anatomic and physiologic constraints for pediatric cavopulmonary assist differ markedly from adult Fontan circulations owing to smaller vessel sizes and risk of elevated pulmonary resistance. In this study, hemodynamic and hemolysis performance of a catheter-based viscous impeller pump (VIP) to power the Fontan circulation is assessed at a pediatric scale (~15 kg) and performance range (0-30 mm Hg).

Methods: Computer simulation and mock circulation studies were conducted to assess the hydraulic performance, acute hemodynamic response to different levels VIP support, and the potential for vena caval collapse. Computational fluid dynamics simulations were used to estimate VIP hydraulic performance, shear rates, and potential for hemolysis. Hemolysis was quantified in a mock loop with fresh bovine blood.

Results: AVIP augmented 4-way total cavopulmonary connection flow at pediatric scales and restored systemic pressures and flows to biventricular values, without causing flow obstruction or suction. VIP generated flows up to 4.1 L/min and pressure heads of up to 38 mm Hg at 11,000 rpm. Maximal shear rate was 160 Pa, predicting low hemolysis risk. Observed hemolysis was low with plasma free hemoglobin of 11.4 mg · dL⁻¹ · h⁻¹.

Conclusions: A VIP will augment Fontan cavopulmonary flow in the proper pressure and flow ranges, with low hemolysis risk under more stringent pediatric scale and physiology compared with adult scale. This technology may be developed to simultaneously reduce systemic venous pressure and improve cardiac output after stage 2 or 3 Fontan repair. It may serve to compress surgical staging, lessening the pathophysiologic burden of repair. (J Thorac Cardiovasc Surg 2013;145:249-57)
Novel techniques of mechanical circulatory support for the right heart
and Fontan circulation

Gwendolyn Derk, Hillel Laks, Reshma Biniwale, Sanjeev Patel, Kim DeLCruz, Einat Mazor, Ryan Williams, John Valdivinos, Daniel S. Levi, Leigh Reardon, Jamil Aboulhosn

ABSTRACT

Background: Currently available ventricular assist devices are designed primarily for use in patients with left sided heart failure. This study evaluated the efficacy of the Jarvik 2000 ventricular assist device (VAD) as a pulmonary pump to power a Fontan circuit in a large animal model.

Methods: Without the use of cardiopulmonary bypass, Fontan circulations were surgically created in 4 pigs (50 kg) using synthetic grafts from the inferior and superior vena cava to the main pulmonary artery. Subsequently, the VAD was implanted within the common Fontan graft to provide a pulmonary pump. Direct chamber pressures and echocardiographic Doppler images were taken during the various phases of the experiment. Heart rate, femoral artery blood pressure, oxygen saturation, and aortic flow rate were continuously recorded. The outflow cannula of the VAD was then partially occluded by 50% and then 75% to mimic increased afterload.

Results: Fontan and VAD implantation was successfully performed in all 4 animals. Arterial pressure and aortic flow decreased dramatically with institution of the Fontan but were restored to baseline upon activation of the VAD. The pressure within the systemic venous circulation rose precipitously with institution of the Fontan circulation and improved appropriately with activation of the VAD. Adequate perfusion was maintained during increased afterload.

Conclusions: A novel flow VAD can restore normal hemodynamics and cardiac output when used as a pulmonary pump in a Fontan circulation. A VAD can rescue a failing Fontan as a bridge to transplant or recovery, even in the setting of high pulmonary resistance.

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Fig. 2 Aortic flow and superior vena cava (SVC) pressure at various phases of the experiment (mean flow and pressure of all 4 animals). Aortic flow decreased with institution of the Fontan circulation and was restored upon activation of the VAD. SVC pressure...
An Artificial Right Ventricle for Failing Fontan: In Vitro and Computational Study
François G. Lacour-Gayet, MD, Craig J. Lanning, BS, Serban Stoica, MD, Rui Wang, PhD, Bryan A. Rech, BS, Steven Goldberg, MD, and Robin Shandas, PhD
Department of Pediatric Cardiac Surgery, University of Colorado Health Sciences Center, Denver, Center for Bioengineering, University of Colorado Denver, Denver, and Department of Mechanical Engineering, University of Colorado Boulder, Boulder, Colorado

Background. The aim of this study is to develop a destination low-pressure artificial right ventricle (ARV) to correct the impaired hemodynamics in the failing Fontan circulation.

Methods. An in vitro model circuit of the Fontan circulation was created to reproduce the hemodynamics of the failing Fontan and test ARV performance under various central venous pressures (CVP) and flows. A novel geometry of the extracardiac conduit was designed to adapt to the need of the pump. The ARV was a low-pressure axial flow pump designed to produce a low suction inflow pressure and moderate outflow increase. With the power off, the passive forward gradient across the pump is 2 mm Hg at 4.5 L/min. The ARV would require 4 watts at a rotation of 5000 rpm. To examine the shear loading on the red blood cells, virtual particles were injected upstream of the ARV inducer and tracked by computerized modeling.

Results. The effect of the ARV on the failing Fontan was studied at various CVP pressures and flows, and under constant values of lung resistances and left atrial pressure set respectively to 2.5 Woods Units and 7 mm Hg. The CVP pressures decreased respectively from 25, 22.5, 20, 17.5, 15, and 10 mm Hg, to a minimal value of 2 to 5 mm Hg with a pump speed varying from 2000 to 4500 rpm. The pulmonary artery pressures increased moderately between 12.5 and 25 mm Hg at 4500 rpm. Cardiac output at 4500 rpm was increased by an average gain of 2 L/min. The average blood damage index was 0.92%, far below the 5% value considered to cause hemolysis. The flow structure produced by the pump was suitable.

Conclusions. The performance of this novel low-pressure ARV was satisfactory, showing good decrease of CVP pressures, a moderate increase of pulmonary artery pressures, adequate increase of cardiac output, and minimal hemolysis. The use of a mock Fontan model circuit facilitates device prototyping and design in a far greater extent than can be achieved using animal studies, and is an essential first step for rapid design iteration of a novel ARV device. The next steps are the manufacturing of this device, including an electromagnetic engine, a regulatory system, and further testing the device in a survival animal experiment.

(Am Thorac Surg 2009;86:170–4) © 2009 by The Society of Thoracic Surgeons
Effect of mechanical assistance of the systemic ventricle in single ventricle circulation with cavopulmonary connection

Pranava Sinha, MD,a Nina Deutsch, MD,b Kanishka Ratnayaka, MD,c,d Robert Lederman, MD,d
Dingchao He, MD,d Mark Nuszkowski, MD,a Erin Montague, CCP,b Gerald Mikesell, CCP,a
Nobuyuki Ishibashi, MD, David Zurakowski, PhD, and Richard Jonas, MD

Background: Previous attempts to support single ventricle circulation mechanically have suggested that a custom-built assist device is needed to push, rather than pull, through the pulmonary circulation. We hypothesized that using a conventional biventricular assist device, with or without conversion of a total cavopulmonary connection to a bidirectional Glenn cavopulmonary connection, would allow assistance by pulling blood through the circuit and improve the cardiac index (CI).

Methods: Cavopulmonary connections were established in each of 5 Yorkshire pigs (25 kg) using ePTFE conduits in a Y configuration with appropriate clamping of the limbs of the Y to achieve a total cavopulmonary Fontan connection (TCPC), superior vena cava cavopulmonary connection (SVC Glenn), and inferior vena cava cavopulmonary connection (IVC Glenn). A common atrium had been established previously by balloon septostomy. Mechanical circulatory assistance of the single systemic ventricle was achieved using a centrifugal pump with common atrial inflow and proximal ascending aortic outflow. The CI was calculated using an ultrasonic flow meter placed on the distal ascending aorta and compared between the assisted and nonassisted circulation for 3 conditions: TCPC, SVC Glenn, and IVC Glenn. The mean pulmonary artery pressure, common atrial pressure, arterial oxygen saturation, partial pressure of arterial oxygen, and oxygen delivery were calculated.

Results: The unassisted SVC Glenn CI tended to be greater than the TCPC or IVC Glenn CI. Significant augmentation of total CI was achieved with mechanical assistance for SVC Glenn (109% ± 24%, P = .04) and TCPC (130% ± 109%, P = .01). The assisted CI achieved at least a mean baseline biventricular CI for all 3 support modes. Oxygen delivery was greatest for assisted SVC Glenn (1786 ± 1307 mL/L/min) and lowest for TCPC (1146 ± 386 mL/L/min), with a trend toward lower common atrial and pulmonary artery pressures for SVCGlenn.

Conclusions: SVC bidirectional Glenn circulation might allow optimal augmentation of the CI and oxygen delivery in a failing single ventricle using a conventional pediatric ventricular assist device. The results from our model also suggest that the Fontan circulation itself can be supported with systemic ventricular assistance of the single ventricle. (J Thorac Cardiovasc Surg 2014;147:1271-5)
Factors Which Will Impact Future
Implants for Destination Therapy: June 2006 – December 2013, n = 3516

- Continuous Flow Intracorporeal Pump
- Pulsatile Flow Intracorporeal Pump

<table>
<thead>
<tr>
<th>Year</th>
<th>Cont Intra Pump</th>
<th>Puls Intra Pump</th>
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<tr>
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<td>1</td>
<td>15</td>
</tr>
<tr>
<td>2007</td>
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<td>48</td>
</tr>
<tr>
<td>2008</td>
<td>8</td>
<td>46</td>
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<td>2009</td>
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<td>2010</td>
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<tr>
<td>2013</td>
<td>1052</td>
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</tbody>
</table>
Right heart failure and “failure to thrive” after left ventricular assist device: Clinical predictors and outcomes

Jay Baumwol, FRACP, a Peter S. Macdonald, MD, PhD, a,b Anne M. Keogh, MD, a,b Eugene Kotlyar, MD, a Phillip Spratt, FRACS, a Paul Jansz, PhD, FRACS, a and Christopher S. Hayward, MD, a,b

From the *Heart Failure and Transplant Unit, St. Vincent’s Hospital, Victoria St, Darlinghurst: and the *Victor Chang Cardiac Research Institute, Liverpool St, Darlinghurst, New South Wales, Australia.

BACKGROUND: This study determined predictors of early post-operative right heart failure (RHF) and its consequences, as well as predictors of those who clinically thrive longer term after insertion of a continuous-flow left ventricular assist device (LVAD).

METHODS: Pre-operative and latest follow-up data were analyzed for 40 consecutive patients who received third-generation centrifugal-flow LVADs. RHF was defined using previously described criteria, including post-operative inotropes, pulmonary vasodilator use, or right-sided mechanical support. Patients were also categorized according to clinical outcomes after LVAD insertion.

RESULTS: LVADs were implanted as a bridge to transplantation (BTT) in 33 patients and as destination therapy in 7. Before LVAD implant, 22 patients were in Interagency Registry for Mechanically Assisted Circulatory Support (INTERMACS) level 1 and 17 were at level 2. Temporary mechanical assistance was present in 50% of the cohort at LVAD implantation. The 6-month survival/progression to transplant was 92.5%. Average LVAD support time was 385 days (range, 21–1011 days). RHF developed postoperatively in 13 of 40 patients (32.5%). RHF patients had more severe pulmonary hypertension than non-RHF patients. The BTT patients with evidence of RHF had poorer survival to transplant (6 of 11 [54.5%] than those without RHF [20 of 22 [90.9%], p = 0.027]. There were no other hemodynamic or echocardiographic predictors of short-term RHF. After LVAD, 22 of the 40 patients (55%) thrived clinically. For BTT patients, 20 of 21 (95%) of those who thrived progressed to transplant or were alive at latest follow-up vs 6 of 12 (50%) of those who failed to thrive (ITT, p < 0.005). The patients who failed to thrive New York Heart Association class (1.5 vs 2.9, p < 0.001), spent less time in the hospital, and had less ventricular tachycardia than the BTT patients. However, no differences were noted in pre-operative INTERMACS level, echocardiographic, hemodynamic, and biochemical indices, or in early post-operative RHF. Age was the only significant predictor: the patients were significantly younger (43.7 ± 13.9 vs 60.3 ± 12.6 years; p < 0.001). This age difference was unchanged after exclusion of destination strategy patients. RV function deteriorated in the BTT patients and remained stable in those who thrived.

CONCLUSIONS: Early post-operative RHF results in poorer survival/progression to transplantation for BTT patients and is predicted by greater pre-operative tricuspid incompetence. The most important predictor for those who will clinically thrive longer-term after LVAD insertion is younger age.

J Heart Lung Transplant 2011;30:888–95
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- Right Heart Failure after LVAD
  - ~10-15% temporary RVAD
  - ~20-30% moderate RVF
- Worse survival DT
- Worse outcome BTT
- Worse QOL
Continuous Flow LVAD/BiVAD implants: 2008 – 2013, n = 9372

EQ5D Dimension: Usual Activities

By Era
2008-2010
2011-2013

% with Problems

Pre-Implant < .0001
3 mths .14
6 mths .86
12 mths .75
18 mths .78
24 mths .35
“It's tough to make predictions, especially about the future.”

Yogi Berra
## Transplant vs. Fontan-RVAD

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<th>Transplant</th>
<th>Fontan + RVAD</th>
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<tbody>
<tr>
<td>Resting Cardiac Output</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td>Exercise Cardiac Output</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td>Hepatic Venous Pressure</td>
<td>Normal to Slightly Elevated</td>
<td>Normal</td>
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<tr>
<td>Chronic Anticoagulation</td>
<td>No</td>
<td>Yes</td>
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<td>Power Cord</td>
<td>No</td>
<td>Probably</td>
</tr>
<tr>
<td>Immunosuppression Risks</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Diabetes, Hypertension, Renal Failure</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Additional Surgery Needed</td>
<td>Yes (Redo Tx)</td>
<td>Yes (Redo VAD or Tx)</td>
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Future Paradigm for Palliation

- Stage I – shunt/band **PROTECT PVR**
- Stage II – superior CPC **RELIEVE VOLUME LOAD**
- Stage III – Fontan completion **RELIEVE CYANOSIS**
  - **SET UP STAGE IV**

- Stage IV
  - A. Pump Failure leads to transplant
  - B. Concept Failure leads to RVAD (timing?)