Mechanical Circulatory Support Strategies in Children

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Disclosure Statement

I DO NOT HAVE ANY RELEVANT FINANCIAL RELATIONSHIPS WITH ANY COMMERCIAL INTERESTS TO DISCLOSE

I would like to disclose that I am NOT a surgeon
Why?
Pediatric Heart Transplants
% of Patients Bridged with Mechanical Circulatory Support*
by Year (Transplants: January 2005 – December 2012)

* LVAD, RVAD, TAH, ECMO
### Duke Surgical Volumes FY ‘11-15

<table>
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</table>

- Duke started ECMO transport in 2013, having now completed over 50 adult transports, ~15 pediatric transports (ground and fixed wing)
Pediatric heart transplant waiting list mortality in the era of ventricular assist devices

Farhan Zafar, MD, Chesney Castleberry, MD, Muhammad S. Khan, MD, Vivek Mehta, BS, Roosevelt Bryant III, MD, Angela Lorts, MD, Ivan Wilmot, MD, John L. Jefferies, MD, MPH, Clifford Chin, MD, and David L.S. Morales, MD

From the Heart Institute, Cincinnati Children’s Hospital Medical Center, University of Cincinnati, Cincinnati, Ohio.

BACKGROUND: Earlier reviews have reported unacceptably high incidence of pediatric heart transplant (PHT) waiting list mortality. An increase in ventricular assist devices (VAD) suggests a potential positive effect. This study evaluated PHT waiting list mortality in the era of pediatric VADs.

METHODS: United Network of Organ Sharing (UNOS) database from 1999 to 2012 showed 5,532 pediatric candidates (aged ≤ 18 years) actively listed for PHT: 2,191 were listed in 1999 to 2004 (Era 1) and 3,341 were listed in 2005 to 2012 (Era 2).

RESULTS: Waiting list mortality was lower in Era 2 (8%) vs Era 1 (16%; p < 0.001). VAD therapy was used more frequently in Era 2 (16%) than in Era 1 (6%; p < 0.001) and was associated with better waiting list survival (p < 0.001). There were more UNOS Status 1A patients in Era 2 (80%) vs Era 1 (68%; p < 0.001). Independent predictors of waiting list mortality included weight < 10 kg (odds ratio [OR], 2.7 95% confidence interval [CI], 1.1–6.9), congenital heart disease diagnosis (OR, 2.4; 95% CI, 1.9–3.0), blood type O (OR, 2.2; 95% CI, 1.8–2.8), extracorporeal membrane oxygenation (OR, 1.5; 95% CI, 1.1–2.2), mechanical ventilation (OR, 1.8; 95% CI, 1.4–2.3), and renal dysfunction (OR 1.6; 95% CI, 1.2–2.0). Independent predictors of survival on the waiting list included VAD therapy (OR 4.2; 95% CI, 2.4–7.6), cardiomyopathy diagnosis (OR 3.3; 95% CI, 2.4–4.6), blood type A (OR, 2.2; 95% CI, 1.8–2.8), UNOS list Status 1B (OR, 1.9; 95% CI, 1.2–3.0), listed in Era 2 (OR 1.8; 95% CI, 1.4–2.2), and white race (OR 1.3; 95% CI, 1.1–1.6).

CONCLUSIONS: Despite an increase in the number of children listed as Status 1A, there was more than a 50% reduction in waitlist mortality in the new era. Irrespective of other factors, patients supported with a VAD were 4 times more likely to survive to transplant.

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• Era 1 1999-2004
• Era 2 2005-2012
• 50% reduction in waitlist mortality
Devices/Options

• ECMO
  – Any age/size, any anatomy/CHD
• Centrimag/Pedimag
  – Any age/size
• Berlin Excor
  – Babies/kids (too small for a Heartware)
• Heartware or Heartmate II
  – School-age +
• Total artificial heart (TAH)
  – Teenagers/adult size even if abnormal anatomy
Management issues

- Bleeding/thrombosis/stroke
- Congenital heart disease/anatomic issues/size
- Infection risk
- End organ dysfunction
- Quality of life
- Training for staff and for the family
- Sensitization
- Transplant candidacy
Devices/Options for the Smallest Patients

- ECMO
  - Any age/size, any anatomy
- Centrimag/Pedimag
  - Any age/size
- Berlin Excor
  - Babies/kids (too small for a Heartware)
ECMO Indications

- Acute cardiopulmonary arrest (ECPR)
- For acute cardiopulmonary failure when patients are too unstable to go to the OR for another device
- To stabilize a patient for transfer
- Acute fulminant myocarditis
- Primary graft dysfunction (post-transplant)
- Acute hemodynamically significant rejection (post-transplant)
Advantages of ECMO

• Can be rapidly initiated
• Able to support 1 or 2 ventricles, can be used in complex anatomy and can provide gas exchange
• Can be rapidly & easily discontinued
• Widely available
• Compatible with intra- and inter- hospital transport
• Easy “renal replacement” therapy
ECMO
Disadvantages of ECMO

• It provides only temporary support requiring significant sedation with significant risk of bleeding and infection
• Benefit/harm curves cross at around 7-10 days
• Device complexity – ICU only
• Non-pulsatile?
• Allo-sensitization/immunosuppressive?
• *Ideally would like to avoid ECMO in pediatric heart failure patients as a bridge to transplant*
Pediatric Heart Transplants
Kaplan-Meier Survival by Mechanical Circulatory Support Usage*
(Transplants: January 2005 – June 2012)

All pair-wise comparisons were significant at $p < 0.0001$ except No ECMO/VAD/TAH vs. VAD or TAH, no ECMO.

- ECMO, no VAD or TAH (N=190)
- VAD or TAH, no ECMO (N=566)
- No ECMO/VAD/TAH (N=2,311)

* LVAD, RVAD, TAH, ECMO
Pedimag/Centrimag (Thoratec)

- Magnetically levitated centrifugal pumps
- Pedimag <10kg (flow up to 1.5L/min, 14ml prime, ¼ inch tubing)
- Centrimag >10kg (up to 10L/min, 31 mL prime, 3/8 in tubing)
- Both are FDA cleared for 6 hours use for extra-corporeal circulatory support.
- CentriMag is FDA cleared for 30 day use as an RVAD
Pedimag/Centrimag (Thoratec)
Use of Pedimag/Centrimag at Duke

- Temporary right heart support after LVAD
- Temporary right heart support after transplant (adults)
- Bridge to transplant (LVAD, BiVAD)
- Temporary bridge to Berlin Excor (LVAD or BiVAD)
Berlin Heart

• Only dedicated pediatric device that is FDA approved for long term support as a bridge to transplant
• Pulsatile device with valves
• Significant risk for stroke (30%), bleeding (40-50%) and infection (50%)
Transplants and Berlin Implants - US

- BH Implants
- Transplants

Year: 2000 to 2011
Berlin Excor Pediatric
Bleeding/thrombosis/stroke

- Anticoagulation can be the most difficult to manage in the periop period (bleeding, inflammation, NPO)
- Start with Pedi/Centrimag then transition to Excor via bedside pump change
- It is advised to make friends with a hematologist
- Monitor inflammatory markers closely and consider steroids if markers are rising (if no infection)
- Omega 3/fish oil, Vitamin C/E when taking po
- Aspirin and dipyridamole with tolerating feeds
Pt scenario #1

• 7 day old presented with cardiogenic shock due to DCM and was placed on VA ECMO at referring facility
• Transported to Duke on ECMO
• Transitioned to 10cc Berlin 1 week later
• Supported for 6 weeks until donor heart became available
• Doing well 1 year post-transplant
Pt scenario #2

• 2 month old with progressive congestive heart failure due to DCM transferred from referring facility
• Cannulated for VA ECMO on day of arrival due to cardiogenic shock
• Pedimag LVAD placed 12 days later
• Supported for 3 months until transplant (2 circuit changes) and is now doing well
Pt scenario #3

• 9 month old with cardiogenic shock s/p 2 episodes of bradycardic arrest arrived from outside hospital and placed emergently on VA ECMO

• 2 weeks later Pedimag LVAD placed

• 2 weeks later transitioned to Berlin Excor at bedside

• 2 months later transplanted and doing well with mild developmental delay from hypoxic brain injury
Pt Scenario #4

- 4 month old presented with respiratory distress and treated for sepsis, progressed to respiratory failure, subsequently diagnosed with DCM (severely dilated LV with severely decreased function)
- Transferred to Duke, acidotic on arrival
- Urgent implant of Pedimag (avoid Ecmo!)
- LV apex pathology consistent with myocarditis, treated with steroids and IVIG
- Subdural bleed, anticoagulation held x 2 days without complication
- Recovery of function at one week
- Pedimag explanted 8 days after implant
- Doing well currently with normal ventricular function
Devices/Options for Bigger Kids

• Heartware or Heartmate II
  – School-age +

• Total artificial heart (TAH)
  – Teenagers/adult size even if abnormal anatomy
Heartware HVAD

- Increasing use in children for left ventricular failure
- FDA approved as a bridge to transplant (not based on adult/peds)
- Being used in increasingly smaller children
- First choice for kids of any age if they are big enough for the device to fit, our smallest being 27kg

From the Heartware Instructions for Use:
**CAUTION:** Safety and effectiveness in persons less than 18 years of age and in persons with a BSA of less than 1.5 m² have not been established.
Heartware HVAD

- Ideal for children with anticipated prolonged waiting time to allow for better rehab and for discharge home until ideal heart becomes available
- “Bridge to decision or candidacy” (i.e. chemotherapy induced cardiomyopathy)
- “Destination therapy” (i.e. Muscular dystrophy)
Heartware MVAD

Clinical Trials

MVAD Advantage™ CE Trial

A multi-center, prospective, non-randomized, single-arm trial evaluating the clinical safety and performance of the MVAD® System for the treatment of advanced heart failure. The trial will enroll 70 patients at 11 sites in the United Kingdom, Austria, Australia, France and Germany. In the trial, patients will be implanted with the MVAD® Pump via sternotomy or thoracotomy, and the device will be evaluated for short- and long-term use.
Pt scenario #5

• 9 year old with a history of metastatic osteosarcoma and chemotherapy induced cardiomyopathy
• Presented with acute decompensated congestive heart failure
• Supported with a Heartware HVAD left ventricular assist device since January
• Lives at home, attends school 3 ½ days per week, no device complications
Syncardia Total Artificial Heart (TAH)
SynCardia 70cc Total Artificial Heart

Indicated for use as a bridge to transplantation in cardiac transplant-eligible candidates at risk of imminent death from biventricular failure (>1.7m² or adequate fit on T10)

70cc DT study approval 12/2014.
HUD designation for DT received 2012.

- The SynCardia 70cc TAH-t has the CE mark for use as a bridge to transplant.
- In the United States, the SynCardia 70cc TAH-t is approved for use as a bridge to transplant.
- **CAUTION:** When used for destination therapy, the SynCardia 70cc TAH-t is an Investigational Device - Limited by United States Law to Investigational Use.
INTERMACS: Competing Outcomes
for the TAH, BiVADs and LVADs

SynCardia Total Artificial Heart*
ALL (BTT Listed and Likely to be Listed)

Number of Patients at Risk

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<th>24</th>
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Biventricular Assist Devices (BiVADs)*

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Left Ventricular Assist Devices (LVADs)*

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<th>3% Explanted</th>
<th>18% Death</th>
<th>1% Explanted</th>
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*Primary Prospective Implants: June 23, 2006 - September 30, 2012
Pt scenario #6

• 18 yr old history of HLHS s/p Fontan with failing Fontan physiology and worsening PLE for several years (54kg)

• Listed for heart transplant for >1 year with worsened status and PLE symptoms (poor tx candidate) so the TAH was offered

• Chest-CT fit test….70cc TAH likely too big

• Underwent placement of 50cc TAH under compassionate use at BTT
Syncardia Pearls

• No electrical activity, no EKG
• Lines are tricky (nothing can enter the “heart”)
• No catheterizations to check hemodynamics or vessel patency
• Echo imaging really only helpful to look for effusions
Decreased right sided output

- No pleural or pericardial effusion
- Things were getting worse.....so back to the OR
Syncardia TAH

- Supported for 4 months with “stable hemodynamics”
- No improvement in PLE symptoms
- Poor nutrition, poor wound healing, debility
- Progressive weakness, respiratory failure and hypotension with increased vasopressor support
- Died September 6th (withdrawal at request of the patient/family)
Syncardia TAH

- Over 1400 implants worldwide with 79% bridge to transplant rate
- Ideal choice after irreversible graft dysfunction while waiting on re-transplant (no immunosuppression needed)
- Older/bigger patients with complex anatomy or severe biventricular failure
- Plans for a 50cc device trial
In summary

• There are *slowly* increasing numbers of device options for mechanical support in children, although much less than in the adult world

• ECMO is good when you need it, but should be avoided as a bridge to transplant when possible

• Pedimag/Centrimag is a good option for temporary or long-term ventricular support as a bridge to transplant
In summary

• Heartware HVAD is an ideal choice for long-term support in larger children

• Syncardia TAH is an option for bridge to transplant in bigger teenagers with complex anatomy, biventricular failure, or after graft failure while awaiting re-transplant

• This is a complicated business and it takes a dedicated well-trained multidisciplinary team to make it successful
Thank you!
Mechanical Circulatory Support Strategies in Children

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Duke University
Extra slides.....
Interhospital Transport of Children Requiring Extracorporeal Membrane Oxygenation Support for Cardiac Dysfunction

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1Department of Pediatrics, The Little Frank Abercrombie Section of Pediatric Cardiology, Texas Children’s Hospital, Baylor College of Medicine, Houston, Tex, USA; 2Department of Pediatrics, Section of Cardiology, Pediatric Critical Care Medicine, Congenital Cardiac Anesthesiology and Pediatric Cardiothoracic Surgery, College of Medicine—University of Arkansas Medical Sciences, Arkansas Children’s Hospital, Little Rock, Ark, USA

ABSTRACT

Objective. Many centers are able to emergently deploy extracorporeal membrane oxygenation (ECMO) as support in children with refractory hemodynamic instability, but may be limited in their ability to provide prolonged circulatory support or cardiac transplantation. Such patients may require interhospital transport while on ECMO (cardiac mobile [CM]-ECMO) for additional hemodynamic support or therapy. There are only three centers in the United States that routinely perform CM-ECMO. Our center has a 20-year experience in carrying out such transports. The purpose of this study was twofold: (1) to review our experience with pediatric cardiac patients undergoing CM-ECMO and (2) identify risk factors for a composite outcome (defined as either cardiac transplantation or death) among children undergoing CM-ECMO.

Design. Retrospective case series.

Setting. Cardiovascular intensive care and pediatric transport system.

Patients. Children (n = 37) from 0–18 years undergoing CM-ECMO transports (n = 38) between January 1990 and September 2005.

Interventions. None.

Measurements and Main Results. A total of 38 CM-ECMO transports were performed for congenital heart disease (n = 22), cardiomyopathy (n = 11), and sepsis with myocardial dysfunction (n = 4). There were 18 survivors to hospital discharge. Twenty-two patients were transported a distance of more than 300 miles from our institution. Ten patients were previously cannulated and on ECMO prior to transport. Thirty-five patients were transported by air and two by ground. Six patients underwent cardiac transplantation, all of whom survived to discharge. After adjusting for other covariates post-CM-ECMO renal support was the only variable associated with the composite outcome of death/need for cardiac transplant (odds ratio = 13.2, 95% confidence interval, 1.60–108.93; P = 0.003). There were two minor complications (equipment failure/dysfunction) and no major complications or deaths during transport.

Conclusions. Air and ground CM-ECMO transport of pediatric patients with refractory myocardial dysfunction is safe and effective. In our study cohort, the need for post-CM-ECMO renal support was associated with the composite outcome of death/need for cardiac transplant.

Key Words. ECMO; Mobile; Cardiac; Children; Transplant

- 38 mobile ECMO transports
- 47% survived to discharge
- 6 patients transplanted
- All survived
Management and Outcomes in Pediatric Patients Presenting with Acute Fulminant Myocarditis

Sarah A. Teele, MD, Catherine K. Allan, MD, Peter C. Loussen, MBBS, Jane W. Newburger, MD, MPH,
Kimberlee Gervreau, ScD, and Ravi R. Thiagarajan, MBBS, MPH

Objective To investigate factors associated with mechanical circulatory support and survival in patients with acute fulminant myocarditis (AFM).

Study design Retrospective cohort of AFM patients admitted to the cardiac intensive care unit during 1996-2008. AFM was defined as distinct onset of symptoms <14 days before admission, rapid-onset cardiogenic shock, and normal left ventricular size. Demographic and physiological variables were compared between patients treated with extracorporeal membrane oxygenation (ECMO) and those who were not and between survivors and nonsurvivors.

Results Twenty patients (median age 12.7 years) met inclusion criteria. Seventeen patients (85%) survived to hospital discharge. One underwent heart transplantation. Ten (50%) patients required ECMO, and 7 (70%) of these survived. On admission, patients requiring ECMO had elevated lactate (9 vs 1 mmol/L), creatinine (0.8 vs 0.6 mg/dL), and aspartate aminotransferase (295 vs 35 IU/L) (all P < .05) and a trend towards increased incidence of dysrhythmias (80% vs 30%, P = .07). During hospitalization, non-survivors had higher peak lactate (10 vs 3 mmol/L), creatinine (1.5 vs 0.8 mg/dL), and aspartate aminotransferase (3007 vs 156 IU/L) (all P < .05) compared with survivors.

Conclusions Patients with AFM with end organ dysfunction or arrhythmias on admission may require mechanical circulatory support. The transplant-free survival rate in this critically ill cohort was excellent (80%). (J Pediatr 2011;158:638-43).

- 85% overall survival
- 50% required ECMO
  - 70% survival in ECMO (6.3 days median support)
- 30% converted to VAD (1 OHT, 2 deaths)
Extracorporeal membrane oxygenation for the support of infants, children, and young adults with acute myocarditis: A review of the Extracorporeal Life Support Organization registry

Satish K. Rajagopal, MD; Christopher S. Almond, MD, MPH; Peter C. Laussen, MBBS; Peter T. Rycus, MPH; David Wypij, PhD; Ravi R. Thiagarajan, MBBS, MPH

Objective: To describe survival outcomes for pediatric patients supported with extracorporeal membrane oxygenation for severe myocarditis and identify risk factors for in-hospital mortality.


Setting: Data reported to Extracorporeal Life Support Organization from 116 extracorporeal membrane oxygenation centers.

Patients: Patients <18 yrs of age supported with extracorporeal membrane oxygenation for myocarditis during 1995 to 2006.

Interventions: None.

Measurements and Main Results: Of 19,348 reported pediatric patients supported with extracorporeal membrane oxygenation uses from 1995 to 2006, 260 runs were for 255 patients with a diagnosis of myocarditis (1.3%). Survival to hospital discharge was 61%. Seven patients (3%) underwent heart transplantation and six patients survived to discharge. Of 100 patients not surviving to hospital discharge, extracorporeal membrane oxygenation support was withdrawn in 70 (70%) with multiple organ failure as the indication in 58 (83%) patients. In a multivariable model, female gender (adjusted odds ratio, 2.3, 95% confidence interval, 1.3–4.2), arrhythmia on extracorporeal membrane oxygenation (adjusted odds ratio, 2.7, 95% confidence interval, 1.5–5.1), and renal failure requiring dialysis (adjusted odds ratio, 5.1, 95% confidence interval, 2.3–11.4) were associated with increased odds of in-hospital mortality.

Conclusion: Extracorporeal membrane oxygenation is a valuable tool to rescue children with severe cardiorespiratory compromise related to myocarditis. Female gender, arrhythmia on extracorporeal membrane oxygenation, and need for dialysis during extracorporeal membrane oxygenation were associated with increased mortality. (Crit Care Med 2010; 38:382–387)

Key Words: myocarditis; pediatrics; extracorporeal membrane oxygenation

- Survival to hospital discharge 61%
- Duration of ECMO
  - Survivors 168 hrs (145-226)
  - Non-survivors 245 hrs (145-347)
- Risk factors for death – female gender, arrhythmia on ECMO, and need for dialysis
Extracorporeal Membrane Oxygenation for Bridge to Heart Transplantation Among Children in the United States

Analysis of Data From the Organ Procurement and Transplant Network and Extracorporeal Life Support Organization Registry

Christopher S. Armond, MD, MPH; Tajinder P. Singh, MD, MSc; Kimberlee Gauvreau, ScD; Gary E. Piercey, BS; Francis Fynn-Thompson, MD; Peter T. Kycus, MPH; Robert H. Bartlett, MD; Ravi R. Thiagarajan, MBBS, MPH

Background—Extracorporeal membrane oxygenation (ECMO) has served for >2 decades as the standard of care for US children requiring mechanical support as a bridge to heart transplantation. Objective data on the safety and efficacy of ECMO for this indication are limited. We describe the outcomes of ECMO as a bridge to heart transplantation to serve as performance benchmarks for emerging miniaturized assist devices intended to replace ECMO.

Methods and Results—Data from the Extracorporeal Life Support Organization Registry and the Organ Procurement Transplant Network database were merged to identify children supported with ECMO and listed for heart transplantation from 1994 to 2009. Independent predictors of wait-list and posttransplantation in-hospital mortality were identified. Objective performance goals for ECMO were developed. Of 773 children, the median age was 6 months (interquartile range, 1 to 44 months); 28% had cardiomyopathy; and in 38%, a bridge to transplantation was initiated at ECMO initiation. Overall, 45% of subjects reached transplantation, although one third of those transplanted died before discharge; overall survival to hospital discharge was 47%. Wait-list mortality was independently associated with congenital heart disease, cardiopulmonary resuscitation before ECMO, and renal dysfunction. Posttransplantation mortality was associated with congenital heart disease, renal dysfunction, ECMO duration of >14 days, and initial ECMO indication as a bridge to recovery. In the objective performance goal cohort (n=485), patients with cardiomyopathy had the highest survival to hospital discharge (63%), followed by patients with myocarditis (59%), 2-ventricle congenital heart disease (45%) and 1-ventricle congenital heart disease (33%).

Conclusion—Although ECMO is effective for short-term circulatory support, it is not reliable for the long-term circulatory support necessary for children awaiting heart transplantation. Fewer than half of patients bridged with ECMO survive to hospital discharge. More effective modalities for chronic circulatory support in children are urgently needed. (Circulation. 2011;123:2975-2984.)

Key Words: heart defects, congenital | extracorporeal membrane oxygenation | outcome assessment | pediatrics | transplantation | heart failure | heart-assist device

- 10% of pediatrics patients listed for OHT are bridged with ECMO
- 45% survived to transplant
  - 80% of OHT survived to discharge
- 10% recovered
- 40% died or were de-listed for deterioration
- Median Support time for non-survivors
  - 10.3 days

Risk Factors for Death
- Structural heart disease
- Support > 14 days
- Renal dysfunction
- Initial support for Bridge to Recovery
When to Switch from ECMO to VAD?

- Successful weaning unlikely after 7 days
- Successful weaning very unlikely after 10 days
- Planning for conversion to VAD must begin early in ECMO course
Outcome of Extracorporeal Membrane Oxygenation for Early Primary Graft Failure After Pediatric Heart Transplantation

Cecile Tissot, MD, Shannon Buckvold, MD, Christina M. Phelps, MD, D. Dunbar Ivy, MD, David N. Campbell, MD, Max B. Mitchell, MD, Suzanne Osorio da Cruz, DVM, Bill A. Pietra, MD, Shelley D. Miyamoto, MD

Aurora, Colorado

Objectives
We sought to analyze the indications and outcome of extracorporeal membrane oxygenation (ECMO) for early primary graft failure and determine its impact on long-term graft function and rejection risk.

Background
Early post-operative graft failure requiring ECMO can complicate heart transplantation.

Methods
A retrospective review of all children requiring ECMO in the early period after transplantation from 1990 to 2007 was undertaken.

Results
Twenty-eight (9%) of 310 children who underwent transplantation for cardiomyopathy (n = 110) or congenital heart disease (n = 23) required ECMO support. The total ischemic time was significantly longer for ECMO-rescued recipients compared with our overall transplantation population (276 ± 86 min vs. 242 ± 70 min, p < 0.01). The indication for transplantation, for ECMO support, and the timing of cannulation had no impact on survival. Hyperacute rejection was uncommon. Fifteen children were successfully weaned off ECMO and discharged alive (54%). Mean duration of ECMO was 2.8 days for survivors (median 3 days) compared with 4.8 days for non-survivors (median 5 days). There was 100% 3-year survival in the ECMO survivor group, with 13 patients (46%) currently alive at a mean follow-up of 8.1 ± 3.8 years. The graft function was preserved (shortening fraction 36 ± 7%), despite an increased number of early rejection episodes (1.7 ± 1.6 vs. 0.7 ± 1.3, overall transplant population, p < 0.05) and hemodynamically compromising rejection episodes (1.3 ± 1.9 vs. 0.7 ± 1.3, overall transplant population, p < 0.05).

Conclusions
Overall survival was 54%, with all patients surviving to at least 3 years after undergoing transplantation. None of the children requiring >4 days of ECMO support survived. Despite an increased number of early and hemodynamically compromising rejections, the long-term graft function is similar to our overall transplantation population. (J Am Coll Cardiol 2009;54:730–7) © 2009 by the American College of Cardiology Foundation

• 9% of OHT patients required post-tx ECMO
• 53% of these survive to discharge
• Long term survival equivalent to non-ECMO Tx patients
Mechanical circulatory support after paediatric heart transplantation

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David Crossland and Massimo Griselli

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Received 16 July 2011; received in revised form 17 January 2012; accepted 24 January 2012

Abstract

OBJECTIVES: Mechanical circulatory support (MCS) may be required after orthotopic heart transplantation (OHTx) in children for the treatment of failure or rejection. We review the incidence and outcomes of post-transplant MCS in our institution.

METHODS: MCS was classified as early (<1 month since transplant) or late (>1 month since transplant) and the support offered was either veno-arterial extracorporeal membrane oxygenation (VA-ECMO) or a ventricular assist device (VAD). From 2003 to the present, 100 children (<16 years) underwent OHTx. Fifteen (15%) had 17 episodes of MCS. MCS was instituted early in 10 and late in seven episodes. Two children required two episodes of support. VA-ECMO was used in 12 episodes (71%). Two children required VAD support alone (12%). In three (17%) episodes ECMO was subsequently converted to VAD.

RESULTS: Among 10 children with early failure, eight were successfully weaned from support with recovery of graft function. In the late failure group, three of six patients died. All but four patients underwent re-transplantation with no perioperative deaths. Overall survival to discharge was 66%. The early failure group shows a better survival rate to hospital discharge compared with the late failure group (78 vs. 50%, P < 0.0001).

CONCLUSIONS: The incidence of post-transplant MCS for graft failure in our patients was 15%. Early graft failure has a better outcome than late failure. Re-transplantation has good mid-term outcomes in children. A stepwise approach with a multimodality MCS strategy improves survival in this group of patients.

Keywords: Mechanical circulatory support • Paediatric heart transplantation • Extracorporeal membrane oxygenation • Ventricular assist device

- 10% incidence of PGF/early AR requiring ECMO
- 80% recover function and recover
- 6% incidence of late rejection requiring MCS
- 50% died