Extracorporeal support: Overview of Different Modalities to Support Heart Failure in Children

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Outline

• Overview
• Heart failure in children
• ECLS
  • VA ECMO
  • Ventricular Assist Devices in children
• Future directions
Heart failure in children

- “A person has heart failure when his heart is unable to pump enough blood around to supply the oxygen the body needs”. World Health Organization
- “For a child to grow and develop, the heart needs to maintain normal pump function, to provide optimal blood flow throughout the body”. American Heart Association

- 2 types
  - Over-circulation failure 1% of newborn
  - Pump failure (infection, valve defect, arrhythmias, drugs…)

- Signs and symptoms
  - Non-specific
Nomenclature

• Extracorporeal support (ECLS)
  1. Extracorporeal Membrane Oxygenation (ECMO)
     • Veno-venous VV
     • Veno-arterial VA
  2. Ventricular Assist Devices (VAD)
  3. Cardiopulmonary Bypass (CPB)
Extracorporeal Life Support (ECLS)

- Offered to patients that are likely to die from the primary disease despite optimal conventional therapy
- No specific criteria
- Survival rate of ECMO from ELSO registry (JAN 07)
  - Neonatal respiratory failure 76%
  - Pediatric respiratory failure 56%
  - Adult respiratory failure 51%
  - Neonatal cardiac failure 38%
  - Pediatric cardiac failure 44%
  - Adult cardiac failure 32%
VA ECMO - Indications

- Inability to maintain cardiac output despite maximal inotropic support
- As a bridge to recovery
- As a bridge to cardiac transplantation
- Heart failure from various causes
  - Post-operative complications of a repair of congenital heart defect
    - Unable to wean from Cardiopulmonary Bypass (CPB)
    - Low Cardiac Output Syndrome (LCOS)
  - Cardiomyopathy - Myocarditis - Arrhythmias
- ECPR – Extracorporeal Cardiopulmonary Resuscitation
Contraindications

- End-stage irreversible and inoperable disease
- Significant neurologic impairment
- MultiSystem Organ Failure (MSOF)
- Uncontrolled bleeding
- Limited vascular access

***RELATIVE
It remains a case by case discussion among the ECMO team
VA circuit

VENOARTERIAL ECMO CIRCUIT

- CO₂
- O₂ Blender
- Membrane Oxygenator
- Pre-Membrane Pressure Monitor
- Pump
- Venous Reservoir
- Heat Exchanger
- Post-Membrane Pressure Monitor
- Arterial Cannula
- Fluids
- Heparin
VA ECMO

- Different than CPB
  - Venous drainage is limited to the amount of flow needed
- Circuit blood flow = 30-80% of cardiac output
- Maximize $O_2$ delivery
  - Optimal hematocrit
  - Fully saturated hemoglobin
- Allow for decreased ventilatory support
  - Lung-protective ventilatory strategy
- Allow for weaning of inotropes and vasopressors
- Decompression of left atrium
- Diuresis may be supported by the system
Disadvantages and complications

- Ligation of carotid artery
- Decreased oxygenation to coronaries
- Risks of air or clot embolization
- Risks of bleeding

- Duration of ECMO depends on
  - Recovery
  - Transplantation
  - Related complications
Ventricular Assist Devices (VAD)
## Ventricular Assist Devices (VAD)

- 2 different types

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<th>Non-pulsatile</th>
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<td>Physiological</td>
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<td>Examples in pediatrics</td>
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<td>Berlin heart</td>
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<td>Thoratec</td>
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<td>Jarvik 2000 IVAS</td>
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Ventricular Assist Devices in children

- Berlin heart
  - PULSATILE
  - Pneumatically driven blood pump
  - Univentricular or biventricular
- To maintain the cardiovascular system and improve the pt’s condition
  - Bridge to transplantation
  - Bridge to recovery
The Berlin heart

- **Blood pumps**
  - Membrane separates blood from air
- **4 cannulas (titanium)**
  - Atria
  - Great arteries
- **Valves (unidirectional flow)**
- **Driving unit**
- **Different sizes**
Management of the Berlin heart

- Assessment of cardiac output \( \text{CO} = \text{HR} \times \text{SV} \)
  - Preload (filling of the pumps)
  - Afterload (signs of perfusion)
  - Contractility (external pumps!!!)
  - ECG \( \neq \) pulse
  - Pump rate (and pulse) depends on the machine!
- Anticoagulation
- By the perfusionist!
Risks and complications

- Bleeding
- Infections
- Clots or fibrin deposits in cannulas or pumps
- Insufficient cardiac output - LCOS
- Duration
  - Recovery
  - Transplantation
  - Complications
Limited experience

- Well recognized VAD
  - > 226 children 1990-2006
- Very limited neonatal experience worldwide
  - Guarded prognosis
  - Promising device
- In Canada, still case by case decision
- 3 pediatric cases at the MCH
  - 2002 – youngest in North-America 26 mo
  - 33% survival
  - No neonatal experience
- 4 centres in Canada
Micromed DeBakey

- Axial pump – NON-PULSATILE
- Developed in cooperation with the NASA
- FDA approved in the USA
- Age 5 to 16 yo
- BSA > 0.7m²
Micromed DeBakey

**Advantages**
- Small size and light weight
- Low infection rates
- Easy to implant
- Blood flow probe
- Children device available
- Silent compared to others
- Mobility + QOL

**Disadvantages**
- Pediatric use limited to 5-16 years of age
- Non-pulsatile
- No experience in Canada
Future directions

- Research and development of VAD for infants and neonates
- Promotion of organ donation
- Accessibility of devices in different part of the world
- IABP in children?
- Destination therapy: Mechanical heart?
Intra-aortic balloon pump

- Therapy well used in adult
  - Developed in children 1989
- Principles
  - Balloon placed in descending aorta filled with helium
  - Deflated during systole
    - It creates a vacuum effect and reduces afterload
  - Inflated during diastole
    - It creates better coronary perfusion
  - Challenges to time with cardiac cycle
Advantages and disadvantages

<table>
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<tr>
<th>Advantages</th>
<th>Disadvantages</th>
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<tr>
<td>Easy to install</td>
<td>Timing of inflation and deflation is difficult</td>
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<tr>
<td>Simple to use</td>
<td>New option in pediatric</td>
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<td>Portable equipment</td>
<td>Learning curve</td>
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<td>Less invasive</td>
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Mechanical heart

- Scarce resource: non-availability of organs
- Alternative to heart transplant
- Montreal, Dec 2006
  - 1st HeartMate II mechanical heart
  - Clinical trial by the manufacturer Thoratec
  - Long term device – 10 years
  - 65 year-old man with heart failure
Thank you!