Overview of Mechanical Circulatory Support

OBJECTIVES

• Review the current recommendations for treating advanced heart failure
• Identify the different types of mechanical circulatory support devices currently in use
• Identify the devices primarily used for temporary support during acute cardiogenic shock
• Identify what is extracorporeal membrane oxygenation and its use
• Overview of future devices to treat advanced heart failure
The Clinical Course of HF

Transition to Advanced Heart Failure:
- Treatments - Failing a trial for many major debridings
- Consider MVT
- Transplantation, if eligible
- Consider invasiveness of care and factors to care providers
- Palliative approaches, even if may involve formal hospice

Treatment for Advanced Heart Failure

<table>
<thead>
<tr>
<th>Transplant/VAD evaluation</th>
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<tr>
<td>ARB added to ACEI if hypertensive</td>
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<tr>
<td>Spironolactone if renal function, potassium stable</td>
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<tr>
<td>Iodidine/hydralazine if African American</td>
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<td>Digoxin if symptomatic with spironolactone</td>
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<td>CRT if QRS &gt; 130 msec</td>
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<th>Diuretic therapy</th>
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<tr>
<td>Beta-blockers once circulatory</td>
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<tr>
<td>Defibrillators if life expectancy &gt; 1 year</td>
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| ACEI |
| ARB if ACEI-related cough |

NYHA Class I NYHA Class II NYHA Class III NYHA Class IV

The Clinical Course of HF

Stage D Heart Failure
ShFS or HFSS 50% survival <1 yr. Persistently elevated BNP, Low V02 Max
Establish goals of care, living will, and health care proxy

Transplant Candidate?
(under 70, no end organ damage, no significant co-morbidities)

No
- AICD? Consider changing settings 
  depending on patients wishes
  Assess pain control, screen for depression
  Palliative care consultation
  Consider hospice
  Consider home inotropes
  Consider LVAD destination Rx

Yes
- Refer to transplant center
- Possible LVAD as bridge to transplant
Number of Transplantations over the Years

Types of Left Ventricular Assist Devices

- LVADs can be divided into two main categories
  - Pulsatile LVADs
  - Continuous flow LVADs
- In pulsatile LVADs – a volume of blood varies during the cardiac cycle
- In continuous flow LVAD – smaller, more durable and use either:
  - Axial flow pumps
  - Centrifugal flow pumps

Axial and Centrifugal Flow - Left Ventricular Assist Devices

- Both axial and centrifugal flow pumps have:
  - a central rotor containing permanent magnets and controlled electric currents run through coils contained in the pump housing apply forces to the magnets, which in turn cause the rotors to spin.
  - In the centrifugal pumps, the rotors are shaped to accelerate the blood circumferentially and thereby cause it to move toward the outer rim of the pump
  - In the axial flow pumps the rotors are cylindrical with blades that are helical, causing the blood to be accelerated in the direction of the rotor’s axis
Evolution of the LVAD

The Continuous Flow LVAD

- The CF-LVAD has become a standard of care for the patient with late HF
- Nearly 6,000 CF-LVADs have been placed in the past 6 years
- Represents 95% of the MCS in patients today
- Survival after implantation continues to improve – INTERMACS data:
  - 80% survival at 1 year and 70% survival at 2 years

Improved Survival after LVAD Implantation
The HeartMate II LVAD

- The HMII LVAD
  - Axial flow pump
  - Approved for destination therapy and as a bridge-to-transplantation
  - Long lasting durability
  - Available for wider range of patients and patient sizes
  - Improved survival and quality of life for end-stage heart failure patients

The HeartMate III LVAD

- Continuous flow driven by magnetically suspended axial flow rotor - reduces friction
- Textured blood contacting surface
- Total intra-thoracic placement
- Lower power consumption
- Has artificial pulse technology to help reduce clinical events and blood clotting
- Currently in clinical trials since 2014 - MOMENTUM
The HeartWare HVAD

- The HeartWare HVAD
  - Integrated inflow system
  - Ultra compact design allows use in much smaller patients but powerful enough for larger patients
  - Complete pericardial placement prevents cannula issues that occur with body changes and ventricular changes post-op that become problematic with HMII
  - No pump pocket required
  - No mechanical bearings, impeller is suspended, thus decreasing stress on blood

Social Predictors – Choosing the Patient for LVAD

- Medical compliance
- Drug and alcohol use
- High risk behaviors
- Psychological health
- Ability to understand their disease process
- Ability to be educated
- Social support system
- Reliability of their support system

The Centrimag - Right Ventricular Support

- Approved for use for up to 30 days when needed as a right ventricular assist device (RVAD)
- Capable of delivering high flows up to 9.9 L/min
- Often used as a short term solution for support as longer term solutions are determined
MCS for Cardiogenic Shock

- Indications
  - Post-cardiotomy shock
  - Acute myocardial infarction
  - Cardiac arrest
  - Acute fulminant myocarditis
  - Acute on chronic decompensated heart failure

- Why early use of MCS is appropriate:
  - Protects the lungs and decompress the ventricles
  - Allows to wean from high doses of vasopressors and inotropes
  - Preserve end-organ function
  - Correct metabolic derangements

Management of Cardiogenic Shock

- Intra-aortic balloon pump
- Tandem Heart
- Impella CP, Impella 2.5 and Impella 5.0
- ExtraCoroporeal Membrane Oxygenation (ECMO)

Percutaneous Support in Shock
The Intra-aortic Balloon Pump

- Increases myocardial oxygen perfusion and increases cardiac output
- Deflates in systole and inflates in diastole
- This increases coronary flow in retrograde fashion
- Sits approximately 2 cm from the left subclavian artery

The Tandem Heart

- Can be implanted percutaneously in the catheterization lab
- Only percutaneous system to completely bypass the left ventricle
- Placed via transseptal approach into the left atrium
- Withdraws oxygenated blood and delivers it into the central circulation bypassing the weak LV

The Impella 2.5, 5.0 or CP

- Can be implanted percutaneously in the cath lab (CP or 2.5) or via axillary cutdown or graft (5.0)
- Increases output – max outputs listed
- Independent of rhythm (like IABP) and continuous flow so not time dependent
- Similar issues to IABP such as limb ischemia, infection, hematoma
- More likely to cause hemolysis
Extracorporeal Membrane Oxygenation

Basic concepts of ECMO
- Two types – Veno-arterial (VA) or veno-venous (VV) ECMO
- Two types of cannulation – peripheral or central
- Blood is removed from the venous system either peripherally via cannulation of the femoral vein or centrally via cannulation of the right atrium
  - Oxygenate and extract carbon dioxide

Blood is returned back to the body either peripherally via the femoral artery or centrally via the ascending aorta
- Full cardiopulmonary bypass
- Can allow both heart and lungs to rest
- Provides the body with oxygenated blood and full cardiac output
- Blood is circulated outside of the body by a mechanical pump
- Outside of the body, blood passes through an oxygenator and heat exchanger
Extracorporeal Membrane Oxygenation

Potential Complications with ECMO
- Bleeding
- Hemorrhage into body cavities
- Systemic thromboembolism due to thrombus formation within the ECMO circuit
- Hemolysis
- Cannulation-related issues
- Distal ischemia
- Heparin induced thrombocytopenia
- Renal Injury

Extracorporeal Membrane Oxygenation

Ethical Considerations with ECMO
- The “Bridge to Nowhere” situation – unable to be bridged to device therapy, to recovery or transplantation
- Are we just prolonging their death with ECMO
- Use of intensive resources in the absence of a clear benefit backed by clinical data
- Can someone be DNR on ECMO?

Future of Mechanical Support
- Impella RP
- HeartWare MVAD
- HeartMate X
- HeartMate PHP
- TET technology
The Impella RP – Right Ventricular Support

- Treatment for: RV failure
- Catheter based, Percutaneous VAD
- 22 Fr pump delivered via an 11Fr catheter
- Flow delivery > 4 L/min
- Duration of support: up to 14 days
- Inflow: Inferior vena cava
- Outflow: Pulmonary artery

Heartware MVAD

- MVAD – miniaturized VAD
- First in man implanted July 2015 in Europe
- About the size of a small golf ball, 1/3 the size of the HVAD
- Will allow for less invasive surgery than sternotomy, support for smaller patients and potentially biventricular support

HeartMate X

- Dramatic size reduction
- Will allow for rapid, less invasive implant
- Meet the needs of the RVAD and BIVAD patient populations
- Will have a very high efficiency motor and hydraulics – smaller components and batteries
HeartMate Percutaneous Heart Pump

- A smaller 13 Fr insertion profile
- Expands to a full 24 Fr blood flow pathway allowing for over 4 L/min of mean flow
- Low shear stress to blood
- Reduces end-diastolic pressure, end-diastolic volume and oxygen demand of the myocardium
- Allows quick stabilization of the hemodynamically compromised patient

Transcutaneous Energy Transfer

- Currently all LVADs must be supplied with continuous power, whether from battery pack or external AC power
- Both the Heartmate II, III and the Heartware HVAD device have drivelines allowing for external battery source and power module
- Driveline is a chronic potential source of infection and is cumbersome for the patient
- What is transcutaneous energy transfer (TET)?
- Technology being worked on to allow for energy transfer and battery charge via inductive coupling through the skin

Conclusions

- Mechanical circulatory support comes in two forms
  - Temporary or Durable (Permanent)
- Temporary support in situations of acute hemodynamic instability, shock, as “bridge to decision” (BTD)
  - Impella, IABP, TandemHeart, ECMO, Centrimag RVAD/LVAD
- Durable support for long term management of heart failure patients
  - HeartMate II, III, HeartWare HVAD, and soon HeartWare MVAD
  - Not for everyone
  - Strong social support, compliance
  - Can be destination therapy (DT) or bridge to transplantation (BTT)
Conclusions

- Currently there is only one cure for advanced end-stage heart failure and that is transplantation
  - We are limited by the number of donor hearts and the number of available hearts has not increased over the last several decades
  - The number of heart failure patients continues to increase
  - Our pharmacological therapy can only go so far for the Stage D heart failure patient
- Left ventricular assist devices has given hope to those end-stage patients that otherwise couldn't live long enough to get a transplant
- LVADs improve the quality of life and length of life to those with end stage heart failure who would otherwise die much earlier from their heart failure

Questions about MCS?

I'd like to help, but... You need ECMO. Not Elmo.