SESSION H8

Surgical Options in Advanced Heart Failure
Jason W. Smith, MD

*Note title changed from Ventricular Assist Devices

Session Description:

This presentation will be an overview of the surgical treatment of advanced heart failure including the definitions of heart failure, options for therapy including transplantation, short-term and long-term mechanical support options and patient selection and referral indications.

Learning Objectives:
Following my presentation, participants will be able to:
1. Recognize the disease burden associated with advanced heart failure in the United States.
2. Know the indications for advanced heart failure therapy.
3. Discuss timing and patient selection for mechanical support device therapy.
Surgical Options in Advanced Heart Failure

37th Annual Advanced Practice in Primary and Acute Care
Seattle, WA
October 9-10, 2014
Jason W. Smith, MD
Assistant Professor of Surgery
Division of Cardiothoracic Surgery
University of Washington

Objectives

- Disease burden of heart failure
- Indications for advanced heart failure therapy
- Surgical options in AHFT
- Timing and patient selection for device therapy

Case 1

- 29 Female developed post-partum cardiomyopathy 6 weeks after a normal delivery.
- Has been followed as an outpatient for 2 years, but has been declining in her physical activity.
- Has been readmitted 2 times in the last 6 months for HF exacerbations.
- Having to decrease BB and diuretics due to low SBP

Case 2

- 76 Female with known CAD treated 10 years ago with stents to the LAD and RCA.
- Presents to the ED with in cardiogenic shock from decompensated heart failure, requiring admission to the ICU for inotropic support and acute dialysis for volume overload.

This is NOT a political speech

- Raised awareness of advanced heart failure therapy
- LVAD Implanted July 2010 then OHT in March 2012

The Scope of the Problem

- How Many Patients are really at risk?
- Will I really have to deal with this patient population?
- Is this a big problem?
- How will I know which patients are candidates?
- What can I do for these patients if I see them?
The Scope of the Problem

- 500,000 new cases/year of heart failure
- 1.1 million hospitalizations/yr for 1st diagnosis of CHF
- 5.1 million patients with CHF costing $29 billion.
- One in nine death certificates related to CHF accounting for 279,000 deaths in 2010
- Driven by aging U.S. population

Heart Failure Statistics

<table>
<thead>
<tr>
<th>Description</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>US Population</td>
<td>304,000,000</td>
</tr>
<tr>
<td>Target Population – 35-74 Age Cohort</td>
<td>139,000,000</td>
</tr>
<tr>
<td>Diagnosed CHF Population – All ages</td>
<td>5,520,000</td>
</tr>
<tr>
<td>NYHA Class III and IV in 35–74 Age Cohort</td>
<td>374,400 (75%)</td>
</tr>
<tr>
<td>Co-morbidities estimated in this Cohort</td>
<td>280,800</td>
</tr>
<tr>
<td>Potential Patients – 35 to 74 years</td>
<td>93,600</td>
</tr>
<tr>
<td>Simple Math: Patients per 100,000 Population</td>
<td>30</td>
</tr>
</tbody>
</table>

Heart Failure Defined

A clinical syndrome characterized by the inability of the heart to generate sufficient cardiac output to meet the metabolic demands of the end organs or to do so only with increased cardiac filling pressures.
Classification of Heart Failure

Functional Capacity

- Class I – No Limitation
- Class II – Slight Limitation
- Class III – Marked Limitation
- Class IV – Symptoms at Rest

Objective Assessment

- A. No CV Disease
- B. Minimal CV Disease
- C. Moderate CV Disease
- D. Severe CV Disease

ACC/AHA Guidelines for the Evaluation and Management of Chronic Heart Failure. 2005

Heart Failure Disease Progression: ACC/AHA Heart Failure Stages

- Refractory End-Stage HF: Marked symptoms at rest despite maximal medical therapy
- Symptomatic HF: Known structural heart disease, shortness of breath and fatigue, reduced exercise tolerance
- Asymptomatic LVD: Previous MI, LV systolic dysfunction, asymptomatic valvular disease
- High Risk: Hypertension, coronary artery disease, diabetes, family history of cardiomyopathy

Stage D Heart Failure

- Truly refractory heart failure despite optimal medical therapy
- 1 year survival < 50% with optimal medical therapy
- ~ 75,000 – 200,000 patients in the U.S

Stage D Heart Failure: Therapeutic Options

- Palliative Care/Hospice
- Inotropic support
- Heart transplant
- Mechanical Circulatory Support
Additive Benefit of HF Therapies

Adapted from Ellenbogen, et al. JACC 2005; 46: 2199 – 203
Palliative Care

- Recommendations
  - Class I
    - On-going family education about HF prognosis at the end of life
    - Education about advanced directives and palliative care and hospice options
    - Discussions regarding inactivation of ICD

Stage D Heart Failure: Therapeutic Options

- Palliative Care/Hospice
- Inotropic support
- Heart transplant
- Mechanical Circulatory Support

Therapeutic Options

- Inotropic support
  - Improves symptoms and end-organ function
  - Ambulatory setting
  - Atrial and ventricular arrhythmias
  - No improvement in survival
  - Poor intermediate term outcomes

Stage D HF: Inotropic Support

REMATCH Medical Therapy
OHSU Outpatient

Stage D Heart Failure: Therapeutic Options

- Palliative Care/Hospice
- Inotropic support
- Heart transplant
- Mechanical Circulatory Support
Therapeutic Options

• Heart transplant
  – Remains the "gold standard"
  – 1 year survival 90% and 10 year survival > 50%
  – Limited number of organs available: ∼2,300 U.S.
  – Many patients with refractory heart failure are not candidates for transplant because of advanced age or comorbidity

Indications for Heart Transplant

• Absolute indications in appropriate patients
  – Hemodynamic compromise due to heart failure
    • Refractory cardiogenic shock
    • IV Inotropic dependence
    • Peak VO2 less than 10 ml/kg/min

Indications for Heart Transplant

• Absolute indications in appropriate patients
  – Severe symptoms of ischemia
    • Limiting activity
    • Not amenable to revascularization
  – Recurrent Symptomatic Ventricular Tachycardia
    • Refractory to all therapeutic modalities

Transplants By Year

J Heart Lung Transplant, vol 33, 2014

Heart Transplants

Kaplan-Meier Survival
(Transplants: January 1982 - June 2010)

ISHLT

Survival is based on adult and pediatric transplant recipients

N = 96,273
N at risk at 25 years = 112

Hunt et al. Circulation 2009;119:e391-e479

Hunt et al. Circulation 2009;119:e391-e479
Indications for Heart Transplant

- Relative indications in appropriate patients
  - Peak VO2 11-14 ml/kg/min (or 55% predicted)
    - Limiting activity
    - Recurrent ischemia
    - Not amenable to revascularization
    - Recurrent instability of fluid balance/renal function

Sources: Hunt et al. Circulation 2009;119:e391-e479

Indications for Heart Transplant

- Insufficient indications
  - Low left ventricular ejection fraction
  - History of class III or IV heart failure
  - Peak VO2 greater than 15 ml/kg/min without other indication

Sources: Hunt et al. Circulation 2009;119:e391-e479

Contraindications

- Other Illness
  - Life threatening likely to limit survival < 5 years
- Vascular disease, severe or symptomatic
  - Carotid or peripheral not amenable to correction
- Severe pulmonary disease
  - Likely to result in ventilator dependence after transplant

Not contraindications to Heart Transplant

- Age 65-70 years
- Renal insufficiency
  - bridge to improvement
  - combined heart-kidney transplant
- Prior malignancy
- Diabetes
- Hepatitis without cirrhosis
- HIV infection
- Sarcoid or amyloid-related cardiomyopathy

Stage D Heart Failure: Therapeutic Options

- Heart transplant
- Inotropic support
- Palliative Care/Hospice
- Mechanical Circulatory Support

“The realities of transplant organ availability, age at the time of transplant evaluation, and comorbidities make heart transplantation an epidemiologically insignificant intervention available to only a few heart failure patients.”

Nearly 100,000 AHFT candidates and only 2500 Transplants
What is MCS?

• Mechanical device which supports ventricular function by removing blood from one cardiac chamber and propelling it forward
• May be used on the right, left or both sides
• May be temporary or “permanent”
• May be used in a variety of situations

Goals of MCS Therapy

• Bridge to Re-evaluation
• Bridge to Recovery
• Bridge to Transplant
• Destination Therapy

Modern MCS Arsenal

Percutaneous VADs

• Temporary devices
  – Support for high risk PCI
  – Rescue of decompensating patient
  – Evaluation of recovery potential
  – Evaluation of patient as potential transplant or long term mechanical support candidate

Durable MCS

• Bridge to Transplant
  – Widely Accepted
  – Increasing use to decrease waitlist mortality
• Bridge to Recovery
  – Very limited
• Destination Therapy
  – Likely the largest application
Durable MCS

HeartMate XVE vs HeartMate II

HeartMate II
- Axial flow pump (non-pulsatile)
- Requires anticoagulation
- Can produce up to 10L/min
- FDA approved

HeartWare HVAD
- Miniature Implantable LVAD
- Intrapericardial
- Magnetic/Hydrodynamic impellar suspension
- 10 liters per minute
- Recently FDA approved
- BTT, DT trial ongoing

Total Artificial Heart
- Same design/principle as 1982 Jarvik 7
- Tilting disc valves
- New outpatient driver
- Bridge to Transplant FDA Approved
- Destination Therapy HDE Approved

HeartMate II Results
- in BTT Therapy

<table>
<thead>
<tr>
<th>Enrollment Period</th>
<th>n</th>
<th>30-Day Operative Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/05-5/06</td>
<td>133</td>
<td>11%</td>
</tr>
<tr>
<td>3/05-3/07</td>
<td>281</td>
<td>8%</td>
</tr>
<tr>
<td>study 4/08-8/08</td>
<td>169</td>
<td>4%</td>
</tr>
</tbody>
</table>

J Am Coll Cardiol 2011;57:1890–8
HeartMate II

- Axial flow pump (non-pulsatile)
- Requires anticoagulation
- Can produce up to 10L/min
- FDA approved

Total Artificial Heart

- Same design/principle as 1982 Jarvik 7
- Tilting disc valves
- New outpatient driver
- Bridge to Transplant FDA Approved
- Destination Therapy HDE Approved

**PMA Results**

**Remember the REMATCH Trial**

- Survival on Intravenous IV Inotropic Support

- 91% INTERMACS 1
- 7.9% CVA
- 68% survival to transplantation

**Neurocognitive Results**

- 93 Patients at 11 centers
- Performance evaluation at 1, 3, 6 months
- Slight improvement
- Most notable for overall stability over 6 months

**Renal and Hepatic Function**

- 309 patients at 18 centers
- Significant improvement in renal function over 6 months
- Significant improvement in liver function over 6 months
- No apparent ill-effects of non-pulsatile flow

**HeartWare ADVANCE**

**Total Artificial Heart**

- 91% INTERMACS 1
- 7.9% CVA
- 68% survival to transplantation

**Renal and Hepatic Function**

- 309 patients at 18 centers
- Significant improvement in renal function over 6 months
- Significant improvement in liver function over 6 months
- No apparent ill-effects of non-pulsatile flow
HeartMate II DT Trial

- 200 patients in 38 centers
- 2:1 randomization between HM2 and HM XVE (134 HM2, 66 XVE)
- NYHA Class IV patients ineligible for transplantation
- Primary end-point was 2 year survival free of disabling CVA or requiring device replacement


Actuarial Survival

Log-rank Test p=0.008

Duration of support (yrs):

<table>
<thead>
<tr>
<th>CF LVAD</th>
<th>1.7</th>
<th>3.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>PF LVAD</td>
<td>0.6</td>
<td>2.1</td>
</tr>
</tbody>
</table>


Actuarial Survival vs. REMATCH

- CF LVAD 68%
- LVAD REMATCH: 25%
- OM REMATCH 8%


Improving Survival in LVAD Trials

Increasing MCS use
Increasing MCS use

HeartMate II Implants

Choosing a Support Device

Device of Choice

Algorithm for MCS

LV failure → Bi-V failure → RV failure → Cardiac-Respiratory Failure

LVAD → RVAD → V-A ECMO

End Organ Failure

Transplant Candidate

Acute Vs Chronic

Surgeon Experience

End Organ Failure

Transplant Candidate

Device of Choice

Algorithm for MCS

Yes

Eligibility for Transplant

No
Cost Effectiveness

**CF LVAD**
- 5 year cost – $360,407
- QALY – 1.87
- Life years – 2.42

$198,184 per quality adjusted life year

**Medical Management**
- 5 year cost – 62,856
- QALY – 0.37
- Life Years – 0.64

$167,208 per life year

Cost of ESRD to Medicare based on Foley RN and Collins AJ. J Am Soc Nephrol. 2007

The Lewin Group estimated gross costs of immunosuppressives following kidney transplant

DT annual costs based on estimates of 1000 DT patients in 2010 costing on average $186,156 per patient

Cost Effectiveness: Incremental Cost to Society

- $20,180
- $196

HeartMate III
- Tinctured inner surface
- No anticoagulation(!)
- Effect on thrombus/CVA?
- Driveline remains
- Clinical Trials late 2013
Fully-Implantable System

- Enhanced Wireless Electricity Transfer (WiTricity)
- 1 hour Internal Battery Life
- Clinical Trials 2014

Future of Total Artificial Heart

- 50cc Device trials beginning (current device 70cc)
- New Inpatient Driver (C2)
- New Outpatient Driver (Freedom-2)

Improved Total Artificial Heart

Miniature VADs

Microaxial Pumps

Ex Vivo Organ Care
Advance Heart Failure Selection Committee Meeting

- Weekly
- Multidisciplinary
- “Robust” conversation
- All points of view represented

Patient Selection

Ideal Candidate?

- Sick but not too sick
- Not too much right heart failure
- Not too much renal dysfunction
- Not malnourished
- Not too septic
- Not supported on mechanical ventilation for too long
- Not too much cerebral underperfusion
- Not too much noncompliance

Patient Age

- Bridge to Transplant:
  Age 14 – 70 years
- Destination Therapy:
  Age 14 – 90 years

CMS Criteria for DT

- NYHA Class IV heart failure
- LVEF < 25%
- VO$_2$ max < 14 ml/kg/min
- Failure of OMM for 45 of last 60 days
- IABP dependent for 7 days
- Inotrope dependent for 14 days

Contraindications to VAD

<table>
<thead>
<tr>
<th>Relative</th>
<th>Absolute</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Active infection</td>
<td>Life expectancy &lt; 3 years due to cause other than HF</td>
</tr>
<tr>
<td>Disabling CVA</td>
<td>Persistent vegetative state</td>
</tr>
<tr>
<td>Severe PVD</td>
<td>Non-cardiac cirrhosis</td>
</tr>
<tr>
<td>COPD</td>
<td></td>
</tr>
<tr>
<td>Restrictive cardiomyopathy</td>
<td></td>
</tr>
<tr>
<td>Active substance/drug abuse with recidivism</td>
<td></td>
</tr>
<tr>
<td>Inadequate social support</td>
<td></td>
</tr>
</tbody>
</table>
Not contraindications to VAD

- Pulmonary HTN
- Renal Insufficiency (Cr > 3.5)
- Recent Substance Use/Abuse
- Low Grade Malignancy (life expectancy > 5 years)
- Obesity (BMI > 40)
- Recent non-hemorrhagic CVA
- Cardiac hepatopathy and ascites

Triggers For Referral

- Two or more HF hospitalizations in the last 6 months
- High diuretic dose: > 150 mg of furosemide daily
- Poor renal function: BUN > 40 mg/dL, creatinine > 1.8 mg/dL
- Systolic BP < 90 mmHg
- Need for inotropic support
- Inability to initiate ACEI or β-blockers
- Need to stop or decrease ACE inhibitors or β-blockers
- Very low LVEF – especially in younger patients
- SHFM Mortality > 15%

Indications for TAH

- Cardiogenic Shock (INTERMACS 1)
  - Viral Myocarditis
  - Decompensated (Chronic) Biventricular CHF
- Ventricular Tachyarrhythmias
- Post Transplant Graft Vasculopathy
- Post-Infarct VSD / Massive MI
- Restrictive/Hypertrophic/Infiltrative Cardiomyopathy
- LVAD Thrombosis
- Congenital Heart Disease (case by case)
- Multiple Mechanical Valves

Survival

Changing Indications?

- Revive – IT
  - NHLBI sponsored
  - Multi-institutional study
  - Class III patients
  - HM2 vs. OMM
  - Now Enrolling

- ROADMAP
  - Thoratec sponsored
  - Multi-institutional study
  - Class IV non-inotrope dependent pts
  - DT pts only
  - HM2 vs. OMM
  - Closed Enrollment
Living with MCS

Outpatient Visits

- Weekly to Every 6 weeks
- Comprehensive Visit
- VAD interrogation
- Accessory Management

Restrictions

Absolute
- Swimming
- Bathing
- Wading

Relative
- Car Driving
- Motorcycle
- Boating

Don’t Ask, Don’t Tell

Complications

- Infection 18%
- GI Bleed/ Epistaxis 18.5%
- CVA / TIA 4-6%
- LVAD Dysfunction 5%
  - Hemolysis
  - Thrombus
  - Pump Stoppage
  - Electrical / Driveline

UWMC Experience

- 217 HeartMate II
- 73 HeartMate IP/VE/XVE
- 35 Thoratec PVAD/IVAD
- 13 Syncardia TAH
- 12 HeartWare HVAD
- 1 Ventracor VentrAssist

3 HM2 Explants – Recovery
20 Device Exchanges – All Cause

* As of December 31, 2013
**UWMC Surgical Devices**

![Graph showing surgical device usage over years]

**6-Month Success**

![Graph showing success rate over years]

**Destination Therapy Survival**

![Graph showing destination therapy survival rates over years]

**Returning Patients to Their Communities**

- Postoperative Length of Stay Less than 21 days
- Q 1-2 week follow up until stable, then monthly
- Follow up can be with local practitioner if desired
  - Anchorage, AK
  - Kalispell, MT
  - Planned: Tacoma, WA, Kirkland, WA

**Case 1**

- 29 Female developed post-partum cardiomyopathy 6 weeks after a normal delivery.
- Has been followed as an outpatient for 2 years, but has been declining in her physical activity.
- Has been readmitted 2 times in the last 6 months for HF exacerbations.
- Having to decrease BB and diuretics due to low SBP

**Case 2**

- 76 Female with known CAD treated 10 years ago with stents to the LAD and RCA.
- Presents to the ED with in cardiogenic shock from decompensated heart failure, requiring admission to the ICU for inotropic support and acute dialysis for volume overload.
Multidisciplinary Team

- Cardiac Surgeons
- Heart Failure Cardiologists
- MCS ARNPs
- Device Coordinators
- Interventional Cardiologists
- CT Anesthesiologists
- Perfusionists
- ICU and Floor Nurses
- Social Workers
- Nutritionists
- Echocardiography Team
- Transplant Coordinators
- EMS services (pre and post hospital care)
- Hospital Administration
- PT/OT/RT

Conclusions

- The heart failure population continues to grow
- Ventricular assist device therapy for end stage heart failure has reached previously unseen levels of safety and efficacy
- New devices have promise of improved surgical outcomes, prolonged durability, and increasing patient and provider acceptance
- Destination Therapy has improved outcomes in patients who are transplant ineligible
- Timing of implantation benefits from early consideration by a multidisciplinary team