Right Ventricular Dysfunction and LVAD Implantation

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Perfect Storm RV Failure

- Increased RV afterload
- Imperfect RV protection
- Unreliable and changing preload
- Unstable vascular tone
- Hypothermia
- Transfusion
- LV filling / balancing septum
RVAD Dilemma

Mechanical support: Assist or nemesis?

Our 6-year experience with ventricular assist devices was reviewed to determine variables associated with improved survival. Forty-three patients (mean age 62 ± 14 years) were supported after balloon pumping and pressure were inadequate. Twenty-eight patients could not be weaned from cardiopulmonary bypass, 12 patients deteriorated in the intensive care unit after cardiac surgery, and three had a bridge to transplantation. Overall, 47% (20/43) of patients could not be weaned from the ventricular assist devices, and 26% (11/43) were weaned but died before discharge, resulting in a hospital mortality rate of 72% (31/43). The remaining 28% (12/43) of patients were discharged and have survived 9 to 62 months. Early institution of ventricular assist devices (p < 0.01), use of biventricular support (p < 0.01), use of ventricular assist devices as a bridge to transplantation (p < 0.05), and increased operator experience (p < 0.05) were associated with improved survival. When patient and disease-related variables were analyzed, only age <60 years (p < 0.01) and unexpectedly preoperative myocardial infarction associated with shock (p < 0.05) were related to improved survival. Death was caused by insufficient ventricular recovery, stroke, multiple organ system failure, sepsis, or a combination of these complications. During long-term follow-up, two patients have died of congestive heart failure, and one is significantly impaired from a stroke. Two other patients are functional class II and seven patients are class I. Although hospital mortality was high (72%), the use of ventricular assist device support resulted in overall “long-term” survival of a significant percentage (38%) of patients. 47% (8/17) in the past 12 months, all of whom would have died without it. Therefore we currently recommend a trial of ventricular assist devices support for most patients who fail to be weaned from cardiopulmonary bypass, deteriorate in the perioperative period, and as a bridge to transplantation. Long-term survival is determined by the complications from ventricular assist devices support and functional status of the remaining myocardium.

Correlates with improved survival

- Early institution
- Biventricular support
- Increased operator experience
- Bridge to transplant
Factors influencing right heart function

- Right Ventricular Function
- Chemical RVAD
- LVAD
- Volume
- Native Heart
Factors influencing LVAD filling

- RV function
  - Intrinsic muscle disease
  - Perfusion (MAP), rhythm
  - Compression
  - TR

- Pulmonary vascular resistance

- Poorly decompressed left ventricle
  - Partial inflow cannula obstruction
  - LV noncompliance
  - Under-driving the LVAD
  - MR, AI

- Volume overload or hypovolemia
Chemical RVAD

LVAD Filling

- Pulmonary Vasodilators
- Inotropes
- Mixed Agents
- Other Factors: Volume, ABG, HR
- Systemic Dilators
- Vasoconstrictors
Chemical RVAD

- Appropriate inotropes
  - Isuprel, Dopamine, Dobutamine, Milrinone, EpiCal

- Maintain MAP
  - flow
  - Vasoconstrictors (Neo, Pit, Levo)
  - IABP

- Pulmonary vasodilators
  - iNO, inhaled Prostacycline, Sildenafil
Don’t confuse correlation with causation

• RV does not fail because of
  • ↑ Creatinine
  • Previous cardiac surgery
  • Low CI
  • ↓ BP
  • ↑ LFT
• RV fails because of
  • Volume overload
  • Transfusion or other conditions → ↑ PVR
  • Poor LVAD filling
  • Poor RV perfusion
  • Inability to lower CVP or intrinsic hepatic disease
High Risk Patients for RV failure

- Pre-op RV > LV failure
  - Low PA pressures with small pulse pressure
  - Atrial septum bowing leftward
  - Normal PCWP
- Intrinsic RV muscle disease
  - Amyloidosis, HOCM, MI
  - Post-transplant constrictive restrictive disease
- Less responsive pulmonary vascular resistance
  - Recent pulmonary embolism
  - Pneumonia
- Small, noncompliant LV cavity
Right Heart Failures

- **HeartMate I** (92 implants, 1991–2008)
  - 24% Transitional RVAD (22 patients, mean 45.5 mins.)
  - 12% Longer-term RVAD (11 patients, mean 5 days)
  - 18% Open Chest (17 patients, mean 5.8 days)

- **HeartMate II** (116 implants, 2005–2011)
  - 1% Transitional RVAD (1 patient, 120 mins.)
  - 1% Longer-term RVAD (1 patient, 2 days)
  - 2% Open Chest (2 patients, mean 3 days)
Right Heart Failures

- Transitional RVAD
- Open Chest
- RVAD
- Overall

HM I vs HM II
Early versus late HeartMate implants

<table>
<thead>
<tr>
<th></th>
<th>Early (1991-2007)</th>
<th>Late (last 100 LVADs)</th>
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<tbody>
<tr>
<td>Transitional RVAD</td>
<td>23/144</td>
<td>0/100</td>
</tr>
<tr>
<td>Open Chest</td>
<td>18/144</td>
<td>1/100</td>
</tr>
<tr>
<td>RVAD</td>
<td>13/144</td>
<td>0/100</td>
</tr>
<tr>
<td>Overall</td>
<td>38/144</td>
<td>1/100</td>
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</tbody>
</table>
Survival Comparison

HeartMate I vs. HeartMate II

HM I; N = 81  HM II; N = 53

P = 0.024
Why the current success

- Better pre-operative resuscitation
  - Inotropic support ($\beta$ agonists > $\alpha$ agonists)
  - Volume management
  - Optimizing pacer settings
- Earlier intraoperative institution of inotropic support
  - Isuprel 0.2-.4 µ/min
  - Dopamine 2-4 µ/kg/min
  - Pitressin to maintain MAP > 75
- Routine, prophylactic iNO with uninterrupted ventilation transitioning to Sildenafil in all patients
- Volume control
  - Hemoconcentration during CPB
  - Aggressive diuresis
Why ..... 

- **Standardized operative technique**
  - Assurance of inflow cannula position and drainage
  - No compression of right ventricle
  - Smooth blood flow pathway
  - Treat mediastinal blood even if no clear tamponade

- **Right heart friendly insertion technique**
  - Unclamped, beating heart
  - Decompressed LV and RV
  - Normothermia

- **Repair of native cardiac defects**
  - Mitral valve ring 50%
  - Tricuspid valve repair of replacement 25%
  - Aortic valve closure 25%
  - Closure of PFO 20%

- **Standardized post-operative management**
  - Maintain arterial pulsatility
Conclusion

- Right heart dysfunction universal
- Right heart failure avoidable
- Don’t leave OR with inadequate hemodynamics, leave the chest open or place RVAD if necessary
Management of the Right Heart

• Maintain arterial pulsatility
  – MAP of 90 early if RV function in question

• Balance the intra-atrial septum
  – Maximize HMII rpm without a shift
  – Volume control with diuretics and/or ultrafiltration

• Minimize RV afterload
  – Routine, prophylactic inhaled Nitric Oxide and Sildenafil

• Inotropes until RV resuscitated (3-5 days)

• Be prepared for complications
  – Pneumonia
iNO after LVAD implantation: A prospective, randomized, double blind, multicenter, placebo-controlled trial

- 150 patients (PVR >200) randomized to +/- iNO
- Intention to treat analysis
- Purpose - efficacy and safety
- Results  iNO vs. no iNO
  - RVD 9.6% vs. 15.6%
  - Mechanical ventilation 2 days vs. 3 days
  - RVAD 5.6% vs. 10%
  - 20% (15/73) open label vs. 26% (20/77) crossover

Potapov et al 2011 30(8) 870-8
iNO after LVAD implantation: A prospective, randomized, double blind, multicenter, placebo-controlled trial

CONCLUSIONS:

“iNO at 40 ppm in the perioperative phase of LVAD implantation did not achieve significance for the primary end point of reduction in RVD. Similarly, secondary end points of time on mechanical ventilation, hospital or ICU stay, and the need for RVAD support after LVAD placement were not significantly improved.”

Potapov et al JHLT 2011 30(8) 870-8
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• Inadequate primary and secondary end points
• Poor selection of high risk patients
iNO after LVAD implantation

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• Poor characterization of RVD
• High crossover rates with intention to treat analysis
• Inadequate primary and secondary end points
• Poor selection of high risk patients
• Multifactorial etiology of RVD ignored
iNO safe and effective in prophylaxis and rescue after LVAD implantation: A prospective, randomized, double blind, multicenter, placebo-controlled, crossover trial

Results

- 38% reduction in RVD
- 50% fewer days ventilated
- 26% of no iNO required rescue
- 44% fewer RVADs required
- Overall predicted RVD of 50% reduced to 15% with selected iNO usage

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Examples

- In the Operating room
- Upon arrival in the ICU
- 8 hours post op
Questions