Complications of VAD therapy - RV failure

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3/24/18

Goals
- Understand the role of the right ventricle in LVAD function.
- Be able to recognize RV dysfunction in VAD patients.
- Understand the importance of early intervention.
- Anticipating RV dysfunction in the LVAD patient.

- Patients with severe chronic HF have evidence of PH.
- Many patients requiring LVAD have both intrinsic RV dysfunction and an elevated PVR.
- Increased mortality in LVAD patients with severe RV failure.
- Limited options for patients who develop severe RVF.
Anatomy of the right ventricle.

- RV myocardium
  - 2 Layers
    - Superficial fibers ➔ Circumferential
    - Deep fibers ➔ Longitudinal (base to apex)

- LV Myocardium
  - 3 Layers
    - Superficial fibers ➔ Oblique
    - Subendocardium ➔ Longitudinal
    - Between superficial and subendocardium ➔ Circumferential

RV/PVR relationship

- Often overlooked
  - RV afterload is primarily driven by vascular resistance within the pulmonic circulation.
  - PVR >> RV function.

Does the LVAD only affect the LV?

- Expectation: As the LVEDP decreases ➔ PAP should decrease (RV afterload decrease) ➔ increase RV forward flow.

- What about Pulmonary vascular resistance (PVR)?
Understanding pulmonary vascular resistance.

- Definition: The vascular impedance that exists within the pulmonary circulation.

- \( \text{Mean PAP} - \text{Pulm. Wedge Pressure} \) / Cardiac output

The formula does not directly depict the role of vascular resistance in determining PVR.

Changes that occur after LVAD implant

- Reduction in left ventricular end diastolic volume and pressure (preload).

- Changes in the geometry of the ventricular septum.

- Increased preload to the right ventricle.
  (LVAD relies on also receiving preload from the RV).
Mechanisms of RV failure post LVAD implant

- Persistently abnormal RV-PVR relationship
- RV dysfunction + elevated PVR
- Reperfusion injury to RV
- Anesthesia/sedation (sympatholytic and other) related negative inotropic effects on RV
- Excessive leftward shift of the septum from aggressive LV decompression
- Worsening TR in the setting of incompetent valve
- Increased venous return can unmask preexisting RV dysfunction

Right heart failure after LVAD

- INTERMACS definition: signs and findings of persistent RV dysfunction after LVAD implantation.
- Severity of right heart failure was determined by duration of inotrope support or the need for RV mechanical support

Signs and Findings of RV dysfunction

- Documented elevation of right sided filling pressures by clinical exam, echo findings or direct measurements
  - Elevated JVD, Dilated IVC without inspiratory variation or RAP > 16 mmHg
- Other manifestations of elevated central venous pressure:
  - Peripheral edema, worsening hepatic and renal function
Severity of RV dysfunction:

- **Mild RV failure**
  - Meet criteria for elevated right sided pressures with manifestations.
  - Use of post-implant inotropes, inhaled nitric oxide or IV vasodilators for a duration < 7 days.

- **Moderate RV failure**
  - Meet criteria for elevated right sided pressures with manifestations.
  - Use of post-implant inotropes, inhaled nitric oxide or IV vasodilators for a duration > 7 days but < 14 days.

- **Severe RV failure**
  - Meet criteria for elevated right sided pressures with manifestations.
  - Use of post-implant inotropes, inhaled nitric oxide or IV vasodilators for a duration > 14 days.

- **Severe acute RV failure**
  - Meet criteria for elevated right sided pressures with manifestations.
  - Need for RVAD at anytime after LVAD implant or death during index hospitalization with RV failure being primary cause.

Epidemiology

- Incidence of severe RVF requiring mechanical support reportedly 10% to 35%.

- Need for inotrope support with or without mechanical RV support ranges 20-44%

- Increased morbidity and mortality in patients requiring RV support.
Factors contributing to RV failure following LVAD implant

- Female gender
- Requiring circulatory support (vasopressors, IABP or periop cardiac arrest)
- End organ dysfunction (prolonged ventilator support, renal dysfunction, malnutrition, liver dysfunction).
- Pre-op severe RV systolic dysfunction
- Presence of pulmonary vascular disease.

Right ventricular failure in patients with the HeartMate II continuous-flow left ventricular assist device: Incidence, risk factors, and effect on outcomes


for the HeartMate II Clinical Investigators

Objective: The aim of this study was to evaluate the incidence, risk factors, and effect on outcomes of right ventricular failure in a large population of patients implanted with continuous-flow left ventricular assist devices.

Methods: Patients (n = 120) enrolled in the HeartMate II left ventricular assist device (Thoratec, Pleasanton, Calif) bridge-to-transplantation clinical trial were examined for the occurrence of right ventricular failure. Right ventricular failure was defined as requiring a right ventricular assist device, 14 or more days of inotropic support after implantation, and/or inotropic support lasting more than 14 days after implantation. Demographics, along with clinical, laboratory, and hemodynamic data, were compared between patients who and without right ventricular failure, and risk factors were identified.
• Need for pre operative ventilator support
• CVP/PCWP ratio > 0.63
• BUN > 39

Why is it important to recognize RV failure in our LVAD patients?

Early intervention influences patient survival.
Methods: Compared outcomes of 266 patients undergoing LVAD or Bi-VAD at U-Penn from April 1995 to June 2007. Patients were subdivided into planned Bi-VAD placement vs. Delayed Bi-VAD placement based on the timing of RVAD insertion.
Conclusion:
When patients at high risk for failure of isolated left ventricular assist device support are identified, proceeding directly to biventricular assist device implantation is advised because early institution of biventricular support results in dramatic improvement in survival.

Managing RV failure in LVAD patients.
- Pre-operative: Diuresis to decrease CVP.
  - Inhaled nitric oxide or pulmonary vasodilators
  - Inotropes or temporary left sided support
- Intraoperative:
  - Correct moderate or severe tricuspid regurgitation
  - Minimize cardiopulmonary bypass time.
- Post-operative:
  - Do not delay mechanical RV support

Future directions
Predicting right ventricular failure post LVAD
- Risk models
  - Identifying biochemical parameters which can be standardized to predict patients at high risk of RVF post LVAD.
- Echocardiography
  - TAPSE, short/long axis ratio > 0.6, severe tricuspid regurgitation, strain imaging, speckle tracking.
  - Poor reproducibility.
- Hemodynamics
  - Increase CVP/PCWP ratio
Take Home Points

• Unforeseen RV failure remains a significant problem.

• Importance to recognize RV failure post LVAD and also identify at risk patients before implant.

• Early intervention improves survival.

References

