Planned, Short-Term RVAD During Durable LVAD Implant: Indications and Management

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Disclosure

- Abbott/St. Jude Med./Thoratec Consultant
Case presentation

- 58 yom with ischemic cardiomyopathy; LVEF 10-15%; s/p multiple PCIs at outside hospital; s/p AICD

- Able to walk ½ block; sleeps on a recliner

- Pre-op RHC: RA 18, PA 72/22/48, PCWP 28, Fick CO 3.73 and Fick CI 1.51; PVR 5.4
  - After npride: PA 60/23/38, PCWP 21, CO 5.6, CI 2.3; PVR 3.03

- To OR for continuous flow LVAD
Pre-operative echo shows severe biventricular dysfunction
What should be done?
Discussion points

• Prediction of RV failure after continuous flow LVAD placement

• Timing of RVAD insertion
  • Simultaneous vs. early post-op vs. delayed post-op

• Device options

• Management considerations
  • Amount of support
  • Duration of support
  • Weaning parameters
  • Other considerations (anticoagulation, ambulation)
RV failure is bad

- Severe right heart failure after LVAD surgery is a serious complication
- Up to 35% of patients receiving a continuous flow LVAD developed post-operative RV failure
- Post-operative RV failure is associated with high rates of mortality (19-43%), and worse survival after cardiac transplant
- Post-LVAD RV failure is also associated with delayed or failed restoration of end-organ function, prolonged ICU course, and prolonged hospital stay
Why does this happen? Complex and dynamic forces at play:

- Mechanical insult from actual surgery
- Cardiopulmonary bypass
- Bleeding; blood and product transfusion
- LVAD placed and turned on

- RV geometry
- RV afterload
- RV size

RV function
Many studies have found a variety of risk factors that increase odds of developing post-operative RV failure…

- Pre-operative temporary mechanical circulatory support as bridge
  - Impella, TandemHeart, VA-ECMO, CentriMag

- High BUN, creatinine, AST, total bilirubin
  - Suggests pre-operative volume overload, inadequate optimization
  - Suggests impaired end-organs caused by end-stage heart failure

- Pre-operative cardiac arrest
  - Particularly AMI in LAD distribution; septal dysfunction

- Pre-operative IV vasopressor medications
  - Suggests vasoplegia
  - Suggests how ill
And there are various formulas and methods to predict RV failure after LVAD

- Right ventricular risk factor score
- EUROMACS-RHF risk score
- Pulmonary artery pulsatility index
- High central venous pressure : pulmonary capillary wedge pressure ratio
- Low right ventricular stroke work index (RVSWI)
- Echocardiographic parameters: severe RV dysfunction
For instance: the Michigan right ventricular failure risk factor score

But this score is limited:

- Based on pre-operative values only
- Does not incorporate intra-operative data for real-time decision-making
What about the EUROMACSES Right-Sided Heart Failure Risk Score?

Only looks at five variables:

- INTERMACS class
- Use of multiple inotropes
- Severe RV dysfunction on echo
- RA/PCWP
- Hemoglobin

But what about patient demographics? And end-organ function?
A final example from Columbia

“Large body size is an important risk factor for mortality on biventricular support and should be incorporated into selection decisions.”

- No other study has duplicated this finding regarding BSA
Do we still lack a perfect predictor?

- Derived from single-center cohorts using variable definitions of RHF
- They have modest predictive value when validated in independent cohorts
- Prediction is difficult because of the complex pathophysiology of RV failure:
  - RV myocardial dysfunction
  - Ventricular interdependence
  - Elevated RV afterload
We are currently unable to accurately predict RV failure

- Even the best meta-analysis identified several predictors but they have low sensitivity (~30%) Diego Bellavia et.al. Eur J Heart Fail 2017
- Variables that stood out on some studies as predictive were meaningless in others
How (and when) to treat RV failure?

Pre-operative optimization:
- Diuresis and volume management
- Pulmonary vasodilators
- Inotropy for adequate systemic BP

Intra-operative options:
- Careful management of blood loss
- Inhaled nitric
- Minimizing transfusions, using coagulation factor replacement

Post-operative management:
- Planned placement of temporary RVAD
We know that unplanned RVAD placement after LVAD leads to poor outcomes

• Only half of patients were able to wean from RVAD support
• Unplanned RVAD resulted in ongoing end-organ dysfunction
• Hospital mortality was significantly higher in unplanned RVAD patients
Placement of prophylactic RVAD in high-risk LVAD patients: the Columbia approach

- Patient who presented with INTERMACS 1 or 2 status
- Severe intra-operative vasoplegia (high-dose pressor requirement, normal estimated cardiac output)
- Renal dysfunction; minimal response to post-CPB diuresis; high CVP
- Severe RV dysfunction on pre-operative or intra-operative echo
- Those that do not tolerate chest closure; allows for chest closure
In equivocal cases, is it better to wait and implant if severe RV failure develops? Unequivocally, do not wait

- Higher risk of post-operative renal failure
- Prolonged mechanical ventilation
- Prolonged ICU course and hospital stay
- Higher mortality - irrecoverable

- Technical complications of RVAD placement
- Another device to monitor

Manageable drawbacks
What are our device options?

- CentriMag
- Protek Duo
- Impella RP
- Second rotary pump
- VA-ECMO
Surgical RVAD versus percutaneous RVAD: our experience

Figure 1. Chest radiographs illustrating placement of A) Impella RP, with femoral cannulation and B) Protek Duo, with internal jugular cannulation

• Percutaneous alternatives to surgical RVAD include the Impella RP and the Protek Duo
• **Impella RP** is a micro-axial intra-corporal device
• **Protek Duo** is a centrifugal flow extra-corporal device
Surgical RVAD versus percutaneous RVAD: our experience

- **Surgical RVAD had significantly higher flows** compared to percutaneous RVAD
  - 5.4 LPM versus 3.8 LPM

- Additionally, **LVAD flows were higher** in the surgical RVAD group versus the percutaneous RVAD group
  - 5.8 LPM versus 5.0 LPM

- Patients with **percutaneous RVAD had shorter device time** than surgical RVAD
  - (11.0 +/- 8.2 versus 21.6 +/- 15.9 days, p = 0.04)

- **pRVAD had lower transfusion requirements** than surgical RVAD
  - 3.1 +/- 3.5 versus 10.7 +/- 9.2 units, p = 0.007)

Surgical RVAD allows higher flows on both RVAD and LVAD than the percutaneous RVAD

However, there was a non-significant trend towards higher mortality with surgical RVAD
Changes in hemodynamic parameters with pRVAD and sRVAD support
Changes in vasopressor and inotrope doses over time with pRVAD (indicated by solid line) and sRVAD (indicated by dotted line)
Surgical RVAD (for example, CentriMag)

- **Versatile inflow site**: internal jugular vein, femoral vein, RA/RV via graft
- **Outflow into the main PA** via 8 mm ringed PTFE graft; 20-22 Fr EOPA cannula into the graft; tunneled through the chest wall
- Allows for RVAD decannulation without opening the chest; can flow higher than percutaneous RVAD
- Able to add in an oxygenator
TandemHeart Protek Duo

- 29 Fr or 31 Fr dual lumen cannula
- Percutaneously introduced via the right IJ and directed through the RVOT and distal to the pulmonary valve
- Drainage holes in the RA; return in the main PA
- Option to add-in oxygenator as needed
- Can be done in the hybrid OR or under TEE guidance
TandemHeart Protek Duo
Other device considerations

• Impella RP:
  • Easy insertion via the femoral vein
  • However, patient cannot ambulate
  • Requires bolus heparin at insertion and subsequent continuous heparin purge, possibly resulting in higher levels of anticoagulation

• VA ECMO:
  • Difficult to differentiate LVAD flow from VA-ECMO flow
  • Competition between VA ECMO and LVAD can result in possible LV thrombus
RVAD Management

• “Flow as much as you can” in the early post-operative period

• Allow for recovery of end-organ function and resolution of post-operative vasoplegia

• Ventricular shape on TTE does not matter: do not consider septal shifting before achieve maximal MCS support

• Do not need pulsatility on a-line or PA line
Adjuncts for RV recovery

• Early institution of CVVH if adequate volume removal cannot be obtained via medication-directed diuresis
• Continuous inhaled nitric oxide and transition to other pulmonary vasodilators
• Maintaining hemoglobin of 8 g/dL or greater
Timing of weaning: **slow is best**

- **When pressors are off or very low**
- **Inotropy is at lower levels**
- **Creatinine and LFTs are normalizing**
- **Use echo to optimize LV on short-axis view**
- **Vasodilatory shock has resolved**
- **Cardiogenic shock is improving**
- **End-organ function has recovered**
- **Need to maintain LV geometry to allow for septal function**

**Patients can be ambulated**

Slowly wean RVAD flows to 2 LPM
RVAD removal: in OR or procedure room

- Bring RVAD flows temporarily to 1 LPM

- Monitor hemodynamics
  - Look at CVP, MAP, PA pressure and pulsatility

- Can check mixed venous and lactic acid

- Echo evaluation
  - But remember: RV contractility is not sole indicator for RVAD removal
RVAD weaning parameters - on echo

- Short axis view is key

- No RV bulging into the LV

- During echo weaning test, evaluate both ventricles
  - Adjust both RVAD and LVAD speeds

- Septum should not be flat: this suggests that patient is volume overloaded or that LVAD speed is not optimized
Other management considerations:

• **Ambulation**: avoid using femoral cannulation such as ProTek Duo and even surgical RVADs which allow for increased mobility. We aim for early mobility

• **Extubation**: Early extubation should always be facilitated

• **Anticoagulation**: We do not provide higher levels of anticoagulation for BiVAD patients
  • Small right-sided embolism undetectable
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Intra-operative course:

- Uneventful placement of HM3 LVAD
- Off bypass with significant pressor requirement; did not improve despite addition of epinephrine
- CVP high (18-20); poor response to diuresis, mixed venous marginal (low 50s)
- RV severely dysfunctional both on inspection and on TEE
- Attempted adjusting LVAD speeds, but no clinical improvement
- Decision made to place TEE-guided ProtekDuo
- New left IJ central line; swan moved to left neck
- Placed 29 Fr ProtekDuo via R IJ, through RVOT and beyond pulmonary valve
- Closed chest after RVAD on and maximum flow; tolerated chest closure well
- To the ICU: HM3 5.3/6000 RPM; RVAD 4.5 LPM; milrinone 0.25; dobutamine 5; pressors low at 4/2; CVP 14; brisk response to diuresis
Post-operative echo after RVAD placement

Echo during RVAD weaning trial
Post-operative course uneventful

- Extubated POD #2
- Pressors off by POD #3, dobutamine weaned off POD #4
  excellent urine output
- RVAD removed POD# 7
- To step-down unit POD #10
- To skilled nursing facility POD #20
Thank You!
3 steps to avoid post ope RV failure

• Patient selection
• Prevention of RV failure
• Treatment of RV failure