Post-op LVAD Management:
It’s Not About The Pump

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Advanced Heart Failure
DISCLOSURES
Advanced Heart Failure

- 5.7 million adults in US
- >270,000 patients die of heart failure each year
  - Up to 1.5 million are in advanced stages
- February 26th 2019:
  - 3,794 awaiting heart transplant
Is There Another Way?

• Medical therapy
  • Getting better, but not there yet

• Mechanical circulatory support
  • LVAD (Left Ventricular Assist Device)
• Dec. 2, 1982: “Barney Clark Takes One for the Team”

- **1982**: A Seattle dentist named Barney Clark becomes the first human recipient of a permanent artificial heart (Jarvick 7).

- He survives the heart, and the accompanying media circus, for 112 days.
Left ventricular assist device

- Takes blood from LV and delivers it to arterial system
- Unloads failing heart

- Originally introduced as short term bridge to recovery -> bridge to transplantation -> long term “destination therapy” support
Left ventricular assist device

• Components:
  ✓ Inflow cannula implanted in LV
  ✓ Pump
  ✓ Outflow graft to the systemic circulation
  ✓ Surgically tunneled driveline that connects to an external controller
1\textsuperscript{st} Generation LVAD

- HeartMate XVE
  - Pulsatile
2\textsuperscript{nd} Generation LVAD

- HeartMate 2
  - Continuous, axial flow
3rd Generation LVAD

- Centrifugal flow
- Intrapericardial
- Impeller levitation
- Artificial pulsatility
HM3 - Artificial Pulse
HVAD - LAVARE Cycle

High Speed
(+200 RPM or 4000 rpm)

Speed Setpoint
(RPM)

2 sec

Low Speed
(-200 RPM or 1800 rpm)

1 sec

60 sec
ROXY
Post-op Management
WHAT ARE THESE NUMBERS??

- Pump Flow: 4.4 lpm
- Pump Speed: 9790 rpm
- Pulse Index: 3.2
- Pump Power: 6.4 W
- Fixed Mode - Speed Setpoint: 9800 rpm
- Power: 3.8 L/min
- RPM: 3000
- Watts: 4.4
- Flow (L/min): 2
- Time Scale: 20:43:56
- HeartWare
VAD Parameters

• Speed
• Power
• Flow
• Pulsatility
• Only parameter to adjust
• ↑ speed -> impeller spins more rapidly -> greater volume of blood displaced
• Heartmate 2
  • ~ 9,000 – 10,000 rpm
• HVAD
  • ~ 2,400 – 3,200 rpm
• Heartmate 3
  • ~ 5,000 – 6,000 rpm
• The amount of power the device uses to maintain the set speed (watts)

• Higher speed = higher power

• Generally between 2-10 watts
• LVAD’s can provide up to 10 L/min of cardiac output

• The device *estimates* cardiac output based on power consumption and speed

• HVAD and HM3 use hematocrit to estimate serum viscosity to allow for more accurate flow estimation

• ESTIMATE!!
• Heartmate 2/3 -> “Pulsatilly Index” (PI)
• Magnitude of the pulsatility is measured and averaged over 15 second period
• -> Pulsatility Index (Range: 1-10)

• Pulsatility correlates with PI
  ✓ ↑ Pulsatility = ↑ PI
  ✓ ↓ Pulsatility = ↓ PI
HVAD waveforms

- Beginning of diastole
- Beginning of systole
- Time (sec)
* Remember the “2’s”:
  - Pulsatility should be > 2 L/min
  - Trough should be > 2 L/min
Getting into trouble
Preload and Afterload

Preload:
volume entering ventricles

Afterload:
resistance left ventricle must overcome to circulate blood
Preload Problems

• (1) Not enough blood getting to the entire heart
  • Hypovolemia (bleeding, infection, etc)
• (2) Blood not getting from RV -> LV
  • RV failure / pHTN
  • Ventricular arrhythmias
• (3) Too much blood being removed from LV
  • Speed too high -> “Suckdown”
Problems with Preload

- Pump Flow: 2.2 lpm
- Pump Speed: 5600 rpm
- Pulse Index: 1.5
- Pump Power: 5.4
Is the Tank Full??

- Hypovolemia vs. RV Failure
- Look at the CVP
- TTE
Post-VAD Right Heart Failure

• BAD!

• Treatment:
  • Diuresis (get the CVP down!)
  • Inotropes
  • Decrease speed
  • ? Mechanical RV support
Suckdown event

- Septum contacts LVAD cannula
  - Sudden inflow obstruction

- Abrupt drop in flow
- Ectopy
- VT/VF

- Heartmate 2/3 -> drops to “low speed limit” then ramps back to set speed
ARRHYTHMIAS

• Management

✓ Stable
  o YOU HAVE TIME!
  o Correct underlying condition (K+, ▪ speed)
  o Anti-arrhythmics (amio, lidocaine)

✓ Unstable
  o DCCV
Afterload Issues

- Hypertension
- Aortic insufficiency
Hypertension

- Continuous flow VAD is afterload sensitive

- ↑ afterload = pump less effective

- Pump flow and power will go down
- HF symptoms

- Management: BP management and diuresis
Aortic Insufficiency

• De-novo or pre-existing pathology

• Immobility of AV leaflets remodeling from high pressure continuous flow in ascending aorta

• Creates a closed circuit unable to decompress ventricle

• Systolic and diastolic phenomenon

• Symptoms Heart failure
Aortic Insufficiency

• **Treatment**
  • Symptom relief
    • Diuretics
    • Lower LVAD speed
    • Inotropes
    • Afterload reduction
  • Correction
    • Surgical
    • Percutaneous (TAVR)
Pump Related Issues

- Inflow/outflow obstruction
- Pump thrombosis
- Pump not working
  - No battery
  - “Short to shield”
Outflow Obstruction
Pump Thrombosis
Pump Thrombosis

• **Causes:**
  - Pump-related (cannulation site, heat generation)
  - Patient-related (Afib, infection)
  - Management-related (INR, low speed)

• **Symptoms**
  - Heart failure
  - Hemolysis
    - ↑ LDH
    - ↑ plasma free Hgb
Pump Thrombosis

• Management
  • Closed aortic valve
    • Possible surgical emergency
  • Open aortic valve -> treat like CHF
    • Inotropes
    • Diuresis
    • IV Heparin? tPA?
  • Device exchange
Short to shield

• Heartmate 2

• Driveline has 6 wires (3 primary, 3 backup)

• If there is break in insulation -> when electrical system is grounded -> device short-circuits

• Sudden pump stoppage

• Treatment: switch to battery power
THAT'S STRANGE...

I CAN'T FIND A HEARTBEAT!
Physical Examination

Check for a pulse

Listen to the heart
  LVAD hum (all different)
  Listen for aortic closing sounds

Standard HF exam
  Warm/cold
  JVD
  Lung fields
  LE edema
BLOOD PRESSURE MANAGEMENT

• Doppler Blood Pressure
  • (1) Manual BP cuff
  • (2) Use doppler to auscultate brachial/radial artery
    • “Whooshing sounds”
  • (3) Inflate the cuff to occlude the artery
  • (4) Slowly deflate cuff
  • (5) The pressure at which flow returns is Doppler pressure
    • MAP
DRIVELINE IMMOBILIZATION IS PARAMOUNT
Anticoagulation
Figure 3. Thrombotic and hemorrhagic event rates as a function of international normalized ratio (INR) at the time of event per total patient years.

Work that still needs to be done.....

Eliminations of the adverse events:

• Stroke
• Bleeding
• “Cut the Cord” –> complete internalization
  • Battery technology
  • Transcutaneous power
THANK YOU

QUESTIONS?