OBJECTIVES

- Review the most common LVAD-related complications.

- Discuss the role of imaging in the evaluation of these complications.
OUTLINE

- Continuous Flow LVADs
- Hemostatic Complications
- Infection
- Positioning/Implantation-Related Complications
- Take Home Points
CF-LVADs

- In the US > 2,000 CFLVADs per year

- CF-LVADs
  - HeartMate II (Thoratec, Pleasanton, CA)
  - HeartWare HVAD (HeartWare International, Inc., Framingham, MA)

- >40% of patients on Destination Therapy (DT)

CF-LVADs

- **Survival:**

  ![Graph showing survival rates over months post implant]

  **Continuous Flow LVAD/BiVAD Implants: 2008 – 2013, n = 9372**

  - Months | % Survival |
  - 1      | 95%        |
  - 12     | 80%        |
  - 24     | 69%        |
  - 36     | 59%        |
  - 48     | 47%        |

HEMOSTATIC COMPLICATIONS

- Hemorrhagic:
  - Acquired von Willebrand Syndrome
  - Anticoagulation and antiplatelet therapy

- Thrombotic:
  - Activated coagulation cascade and inflammatory response

GI BLEEDING

- Most common complication

Multifactorial:
- Acquired von Willebrand (loss of high-molecular-weight von Willebrand multimers)
- Anticoagulation
- Impaired platelet aggregation
- Continuous flow physiology promotes angiodysplasia
- Other: erosive gastritis, PUD, etc.
## GI BLEEDING

<table>
<thead>
<tr>
<th></th>
<th>Total Incidence</th>
<th>Gastritis</th>
<th>Gastric Ulcer</th>
<th>AVM</th>
<th>Diverticulitis</th>
<th>Colitis</th>
<th>Colonic Polyp</th>
<th>Colonic Ulcer</th>
<th>Other</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hayes et al.</td>
<td>13.9%</td>
<td>31.3%</td>
<td></td>
<td>60.0%</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Demirozu et al.</td>
<td>19.0%</td>
<td>31.3%</td>
<td></td>
<td>31.3%</td>
<td>18.8%</td>
<td>3.2%</td>
<td>3.2%</td>
<td>20.0%</td>
<td>12.5%</td>
<td></td>
</tr>
<tr>
<td>Aggarwal et al.</td>
<td>22.8%</td>
<td>30.4%</td>
<td>8.7%</td>
<td>21.7%</td>
<td>4.3%</td>
<td>5.1%</td>
<td>13.0%</td>
<td>13.0%</td>
<td>8.7%</td>
<td></td>
</tr>
<tr>
<td>Kushnir et al.</td>
<td>34.8%</td>
<td>28.2%</td>
<td>30.8%</td>
<td></td>
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<td></td>
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<tr>
<td>Wever-Pinzon et al.</td>
<td>17.2%</td>
<td>8.7%</td>
<td></td>
<td>61.0%</td>
<td>8.7%</td>
<td>4.3%</td>
<td>8.7%</td>
<td>8.7%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*AVM = Arteriovenous malformation

## GI BLEEDING

### Factors Predisposing to GI bleeding:

<table>
<thead>
<tr>
<th>Pre-implant variables</th>
<th>Gib (N = 15)</th>
<th>No Gib (N = 49)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age in years, mean (range)</td>
<td>58.33 (33–75)</td>
<td>55.69 (26–75)</td>
<td>0.5</td>
</tr>
<tr>
<td>Gender, F (%)</td>
<td>5 (33.3%)</td>
<td>8 (16.3%)</td>
<td>0.152</td>
</tr>
<tr>
<td>Caucasian race, N (%)</td>
<td>11 (73.3%)</td>
<td>41 (83.7%)</td>
<td>0.369</td>
</tr>
<tr>
<td>Underlying heart disease, ischemic, N (%)</td>
<td>0 (40%)</td>
<td>23 (46.9%)</td>
<td>0.023</td>
</tr>
<tr>
<td>Pump type, N (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HeartMate II (N = 56)</td>
<td>13 (23.2%)</td>
<td>43 (76.6%)</td>
<td>0.91</td>
</tr>
<tr>
<td>HeartWare (N = 8)</td>
<td>2 (25%)</td>
<td>23 (45.9%)</td>
<td>0.91</td>
</tr>
<tr>
<td>BMI, mean (SD)</td>
<td>29.6 (6.6)</td>
<td>28.2 (6.34)</td>
<td>0.49</td>
</tr>
<tr>
<td>BSA, mean (SD)</td>
<td>2.0 (0.21)</td>
<td>2.1 (0.27)</td>
<td>0.35</td>
</tr>
<tr>
<td>Comorbidities, N (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>9 (60%)</td>
<td>24 (49%)</td>
<td>0.455</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>6 (40%)</td>
<td>23 (46.9%)</td>
<td>0.637</td>
</tr>
<tr>
<td>Chronic kidney disease</td>
<td>4 (26.7%)</td>
<td>11 (22.4%)</td>
<td>0.730</td>
</tr>
<tr>
<td>Prior DVT/PE</td>
<td>1 (6.7%)</td>
<td>7 (14.3%)</td>
<td>0.435</td>
</tr>
<tr>
<td>Prior stroke</td>
<td>4 (20%)</td>
<td>10 (20.4%)</td>
<td>0.973</td>
</tr>
<tr>
<td>Prior GI bleed</td>
<td>0</td>
<td>3 (6.1%)</td>
<td>0.326</td>
</tr>
</tbody>
</table>

### Post-implant variables

<table>
<thead>
<tr>
<th>Mean pump speed, RPM (SD)</th>
<th>Gib (N = 15)</th>
<th>No Gib (N = 49)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>HeartMate II (N = 56)</td>
<td>9560 (302)</td>
<td>9490 (405)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>HeartWare (N = 8)</td>
<td>2949 (228)</td>
<td>2710 (169)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Estimated creatinine clearance in mL/min, mean (SD)</th>
<th>Gib (N = 15)</th>
<th>No Gib (N = 49)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>72.4 (46.2)</td>
<td>87.3 (36)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Any infection, N (%)</th>
<th>Gib (N = 15)</th>
<th>No Gib (N = 49)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 (60%)</td>
<td>19 (38.8%)</td>
<td>0.006</td>
<td></td>
</tr>
</tbody>
</table>

*Values included up to time of event for event group.
OTHER HEMORRHAGIC EVENTS

- Hemorrhagic Stroke (2.5%-6%)
- Other Bleeding (2.5%)
  - Retroperitoneal bleeds
  - Pump pocket hematoma
  - Hemopericardium

INTRACRANIAL HEMORRHAGE
HEMOPERICARDIUM
THROMBOTIC AND EMBOLIC COMPLICATIONS

- Flow Induced Device Thrombogenicity
- Hypersensitivity and inflammatory response.

- LVAD thrombosis is a devastating complication
  - Asymptomatic to cardiogenic shock
  - 94% free of pump exchange or death at 6 months
LVAD THROMBOSIS

- New signs and symptoms of HF (CXR useful)
- Change in functional capacity
- Increase in pump power
- Increase in LDH
  - >1100 UI/L 100% sens, 92% spec
- Increase in plasma free hemoglobin
- Increase in BNP
LVAD THROMBOSIS

- “Ramp Study”
  - Repeat tests at different pump speeds (RPM)
  - LVEDD
  - MR
  - AV opening

- Blunted or absent reduction in LVEDD with ↑ RPM → obstruction to flow in device.
LVAD THROMBOSIS
OTHER EMBOLIC/THROMBOTIC EVENTS
CF-LVADs
LVAD-SPECIFIC INFECTIONS

- Definitions:

  - Percutaneous Driveline Infection:
    - Superficial
    - Deep
  - Pocket Infection
  - Pump and/or cannula infection (LVAD endocarditis)
    - Feared complication
    - High mortality
    - Exchange pump

LVAD SPECIFIC INFECTIONS

- Common Complication
  - Driveline Infection: 12-50% of patients
  - Pocket Infection: 0.5% to 7%

- Most common infectious agent:
  - Staphylococcus
    - MRSA
  - Pseudomonas aeruginosa
  - Klebsiella sp.

LVAD SPECIFIC INFECTIONS
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Inflow cannula:
- Perpendicular to septum
- Directed towards mitral valve
- 15-30° from body axis

Pump in sufficiently deep pocket

Outflow cannula
- Too short → compression of RV
- Too long → kinking (flow obstruction)
LVAD MALPOSITION
LVAD MALPOSITION
CANNULA KINKING
TAKE HOME POINTS
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- Girish Shroff, MD
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