New Patient Referral:

Contact any of the following:
- Cardiothoracic Surgery Mechanical Circulatory Support / VAD-Heart Transplant Office: 614-293-3787 or 800-538-1886
- Heart Failure Cardiology: 614-293-9480

Patient Selection

VAD Candidacy
- Decision involves multidisciplinary team evaluation and presentation to patient selection committee which occurs weekly

Indications for Long-term Support with VAD
- Class IV, ACC/AHA Stage D heart failure symptoms, EF < 25%
- Refractory cardiogenic shock (INTERMACS category 1)
- Dependent on IABP or other form of temporary mechanical circulatory support (MCS) such as Impella® or ECMO for ≥7 days
- Intermittent/continuous inotrope therapy (INTERMACS category 2-3) for ≥14 days
- Evidence of poor cardiac output with low cardiac index (< 2.3 L/min), elevated filling pressures (PCWP > 20 mmHg) and hypotension with SBP < 90 mmHg
- Cardiopulmonary exercise testing with peak VO₂ < 14 ml/kg/min with cardiac limitation and/or poor prognostic indicators with other parameters e.g. < 50% predicted peak VO₂, poor ventilatory response VE/VCO₂ > 35
- Refer to Centers for Medicare & Medicaid Services (CMS) guidelines for Ventricular Assist Device (VAD) therapy for more information

Intent of VAD Placement

Bridge-to-Transplant
- For patients eligible to be listed as candidates for heart transplantation, refer to OSUWMC Heart Transplant Manual

Destination Therapy
- Currently not a transplant candidate as agreed upon by the Transplant Patient Selection Committee, including relative contraindication to transplant
- Relative contraindication or issue that prevents candidacy currently, but patient is a potential candidate with resolution of contraindication/issue
- Meets above criteria for mechanical support or dependent on long-term administration of inotrope to maintain a stable state
- Failure to respond to optimal medical management.
- Life expectancy >2 years when considering malignancy and comorbidities

Postcardiotomy
- Used as temporary means of circulatory support after open-heart surgery until determination is made for prognosis and long-term management needs

Contraindications

Absolute
- Potentially reversible cause of heart failure
- End organ or multi-system organ failure including impending renal or hepatic failure unless a multi-organ transplant candidate
- Active systemic infection with the exception of driveline infection
- Active evolving CVA or neurologic deficits impairing ability to manage device e.g.:
  - Daily activities
  - Rehab potential
  - Cognitive function per neurocognitive evaluation
- Severe pulmonary disease with FEV₁ < 30% predicted
- Coexisting terminal condition such as metastatic disease or cirrhosis
- Refractory/recurrent ventricular tachycardia
  - Consider short-term/intermediate-term MCS to assess resolution prior to implantation of a long-term VAD

Relative
- Age >75 years, unless minimal other clinical risk factors such as:
  - High-risk with biventricular failure
  - Other concerning comorbidities
- CKD Stage IV with serum creatinine >3.0 mg/dL
- Severe chronic malnutrition e.g. BMI < 21 kg/m² in males and < 19 kg/m² in females, prealbumin < 15 ml/dL for either gender
- Inability to tolerate or contraindication to anticoagulation
- High bleed risk
- Morbid obesity (BMI > 40 kg/m²)
- Poor rehabilitation potential due to:
  - Related to comorbidities
  - Neurologic issues
- History of:
  - Unstable psychiatric illness
  - Poor social support
  - Noncompliance that could impair ability to maintain or operate VAD

Risks of VAD Implant Surgery

- VAD implant surgery carries risks of severe complications including arrhythmia, bleeding, device failure, infection, kidney failure, respiratory failure, stroke, and thrombosis.
Pre-VAD Testing and Consults

- In urgent cases, more abbreviated testing may be completed.
- Cardiac studies and multidisciplinary consultations should be performed at OSUWMC.

Laboratory Testing

- Chemistries:
  - Sodium, potassium, chloride, bicarbonate, BUN, creatinine, calcium, phosphorous, and magnesium
  - Arterial blood gas on room air
- Nutrition assessment:
  - Total protein, albumin, prealbumin
- Hepatic chemistries:
  - ALT, AST, alkaline phosphatase, total and direct bilirubin
- Endocrine:
  - Thyroid function panel, Hemoglobin A1C
- Hematology:
  - CBC with platelets and differential, Iron studies
  - Coagulation studies:
    - PT/INR, PTT
    - Protein C, Protein S, Lupus Anticoagulant, Factor V Leiden w/ Prothrombin Mutation, Anticardiolipin antibodies, Von Willebrand Multimeric study
- Infectious screening (results are not a contraindication to candidacy, but could affect patient management):
  - High-risk MRSA/MSSA screening (nares only)
  - HIV and hepatitis C screening
  - U/A total with reflex to culture
- If indicated based upon patient history and/or comorbidities
  - 24-hour urine collection for creatinine clearance and proteinuria in renal dysfunction concerning for candidacy
  - Toxicology screening

Imaging

- Echocardiogram
- Obtain Head CT for all patients with history of CVA
- Obtain Carotid Duplex on patients > 65 years of age or ischemic disease
- Chest radiograph
  - CT scan if needed to assess clinical or laboratory findings
- Panorex dental imaging (dental consult if abnormal)
- If cirrhosis is a concern based on history, exam, laboratory findings, consider hepatic system imaging (ultrasound, CT, or MRI) and Hepatology consultation.

Procedures

- 12-lead ECG
- Peak VO₂ (if patient capable) with VE/VCO₂ ratio, % predicted peak VO₂ achieved, RER
- Left heart catheterization, if not recently completed
- Right heart catheterization and potential vasodilator study
  - A vasodilator study should be performed when PVR > 3 Woods units, TPG > 12 mmHg, or PA systolic ≥ 55 mmHg, while maintaining systemic systolic arterial pressure > 85 mmHg
  - PVR > 8 Woods units undesirable for LVAD placement
- Pulmonary function tests (if patient capable of performing), including:
  - Spirometry
  - Lung volumes
  - DLCO

Clinical Assessment

- Preoperative Risk Stratification scoring should be performed on each patient using the following scores:
  - Intermacs Score
  - Heart Mate II Risk Score
  - Right Heart Failure Risk Score
  - Stanford Integrated Psychosocial Assessment for Transplantation (SIPAT)
- Consultant Evaluation
  - Cardiothoracic surgery evaluation
  - Social work evaluation (assessment of patient and family support)
  - Transplant infectious diseases consult
  - Transplant psychology/psychiatry consult required with SIPAT scoring
  - Formal neurocognitive testing, if indicated and feasible, based on clinical urgency of evaluation
  - Palliative care consult
  - Nutrition consult, if indicated
  - Other specialized studies may be requested when indicated for patient-specific clinical conditions

Management Immediately after VAD Placement

- See Appendix A for Initial Post-Insertion Antithrombotic Management.
- See Appendix C for a comparison of Mechanical Circulatory Assist Devices.

Discharge Planning and Education

Anticoagulation Plan

- See Appendices A and B for anticoagulation plan at discharge and ambulatory anticoagulation management.

Patient/Family Education

Assure awareness and understanding of:
- VAD equipment and recognizing emergencies
- VAD precautions and dressing changes
- Anticoagulation plan
- Discharge medications
- Follow-up appointments
Community Education
- Provide a comprehensive packet of information pertaining to the patient’s VAD to local health care providers:
  - Primary care physician and local cardiologist
  - EMS services
  - Local emergency room
  - Home health services (if applicable).
- Contact VAD Coordinator (614-293-3787 or 800-538-1886) to offer and provide on-site community education.

Management Considerations for Complications Unique to VADs

Inpatient Acute Workup and Management of Bleeding or Anemia
- Common sources:
  - Nasal/upper airway
  - Gastrointestinal
  - Arteriovenous malformations (AVMs) in one of the above locations
  - Hemolysis
- Step wise workup and/or acute treatment options:
  - Laboratory testing:
    - PT/INR/PTT
    - Increase frequency of hemoglobin/hematocrit evaluation
    - Multimeric von Willebrand testing for acquired WVF deficiency (if not already tested post-LVAD placement)
    - Consider hemolysis work-up if no overt sign of bleeding
  - Hold therapy and consider reversal:
    - Consider any history of bleeding/clotting related problems and indications for antithrombotic therapy aside from mechanical circulatory support
    - Notify attending surgeon if factor products are being considered for reversal
  - Obtain appropriate consults and consider common interventions
    - ENT
      - Evaluate for source control and/or cauterization
      - Mupirocin 2% (Bactroban®) every 12 hours to each nostril to maintain moist nasal passages
      - Oxymetazoline 0.05% (Afrin®) to each nostril every 12 hours as needed for epistaxis
    - Gastroenterology:
      - Pantoprazole (Protonix®) 80 mg IV bolus followed by continuous infusion at 8 mg/hr x 48-72hr
      - GI evaluation:
        - Enteroscopy and/or colonoscopy
        - May also consider angiography and cautery, balloon-assisted enteroscopy, video-capsule enteroscopy, surgery

- Long-term management:
  - Consider decreasing anticoagulation / antiplatelet therapy intensity
  - If evidence of a WVF deficiency:
    - Ischemic cardiomyopathy: consider decreasing INR goal
    - Non-ischemic cardiomyopathy: if no history of hemolysis or thrombosis, consider decreasing/discontinuing antiplatelet therapy
  - Refractory bleeding despite interventions above (therapies below likely require insurance approval):
    - Obtain hematology consult and consider role of oral antifibrinolytics (i.e. aminocaproic acid) or Humate P.
    - If gastrointestinal AVMs present that are not amenable to intervention, consider octreotide 50 mcg subcutaneous every 8 hours

Inpatient Acute Workup and Management of Hemolysis
- Hemolysis may be the presenting symptom of an underlying process including thrombosis, infection, or other mechanical or physiologic dysfunction
- Common presentation includes:
  - Non-hemorrhagic anemia
  - Urine color changes
  - Appearance of hematuria (can be brown or black in severe cases)
  - Hyperkalemia
  - Hemolyzed labs
    - Grossly hemolyzed labs require a physician phone call to the lab to be released
  - VAD pump alarms
- Step-wise workup for contributing factors:
  - Evaluate MCS function for contributing factors
    - Investigate documentation and alarm history for suction events, power spikes, speed changes, volume status, RV function, arrhythmias
  - Evaluate cannula(e) position for obstruction/thrombus
    - Echocardiography- consider Echocardiographic RAMP study
  - CT with or without contrast-consider risks of IV contrast in context of any current evidence of renal injury
  - Ensure optimal anticoagulation per previously established goals
  - Send labs to establish presence and degree of hemolysis and potential contributors
    - LDH (commonly 300-500 units/L for most forms of mechanical circulatory support)
• Levels > 1000 units/L or increases by 300 units/L suggestive of worsening hemolysis
• Liver failure may affect lab specificity
  ▪ Haptoglobin
    • < 6 mg/dL indicates probable hemolysis (does NOT quantify it)
  ▪ Plasma Free Hemoglobin (normal 0-5 mg/dL)
    • Levels > 40 mg/dL or rapid changes represent new and/or significant hemolysis
    • Longer turn-around time - if no result within 24hr, likely result is normal
  o Blood cultures
    ▪ An association has been identified with bacteremia and hemolysis in LVAD patients - in some cases presenting as thrombosis
  o Urine assessment – send baseline urinalysis, urine culture and document overall appearance and changes daily
    ▪ Likely hemolysis evidenced by presence of casts and color changes (darkened tea-color, red, or black are highly suggestive of hemolysis)
  o Other labs/considerations:
    ▪ Hypercoagulable states (i.e. HIT)
    ▪ CBC with differential
    ▪ Reticulocyte count

• Treatment
  o Mechanical dysfunction
    ▪ Decrease speed/flow rates if possible
    ▪ If hypovolemic, give volume challenge
    ▪ Assess RV function
      ▪ Medical optimization
    ▪ Alkalize urine and optimize fluid status (Sodium Bicarbonate 150 mEq/1000 ml Sterile Water) at 1 ml/kg/hr and treat to a goal urine pH of > 7.5
  o Optimize anticoagulation
    ▪ Ensure therapeutic anticoagulation via heparin or warfarin
    ▪ More aggressive antithrombotic therapy may be appropriate (contact OHS Pharmacy Specialist)
    ▪ Severe hemolysis increases platelet activation – consider adding abciximab or epifibatide depending on renal function and potential surgical plan
      ▪ Consider switching heparin or warfarin to bivalirudin and reassess long-term antithrombotic strategy
    ▪ Augment antiplatelet therapy by one or more of the following strategies
      o Increase aspirin dose
      o Add clopidogrel
      o Add dipyridamole
    ▪ Increase INR goal
    ▪ If infection – consult Transplant/VAD Infectious Diseases for assessment and/or treatment
      o Consider acutely increasing anticoagulation goals until infection control is gained

### Perioprocudural Planning and Considerations in Patients with VADs

• Anticoagulation planning:
  o Evaluate current antithrombotic regimen (e.g. warfarin, aspirin, clopidogrel)
    ▪ OSUWMC Management of Antiplatelet Therapy in Patients with Arterial Stents Around the Time of Surgeries and Procedures guideline
      o Determine INR threshold required to enable procedure
      o Determine anticoagulation bridging plan
  
• Depending on procedure, strongly prefer admission to OHS service for transition to unfractionated heparin infusion
• Bridging with alternative anticoagulation (i.e. enoxaparin, dalteparin) should only be done under the discretion of the attending cardiac surgeon
• Perioperative antibiotics
  o Prophylactic antibiotic coverage should account for site of procedure, previous infections, proximity to driveline site or VAD pocket, and any other potential exposure or bacteremia secondary to the procedure. In some circumstances this requires broader prophylactic antibiotic coverage.
  o Visit Preoperative Antibiotic Order Grid for guidance and/or contact pharmacy
References


Order sets and Tools

- OSU IP OHS: Pre-Operative Heart Surgery
- OSU IP OHS: Post Phase I Heart Surgery
- OSU IP OHS: OHS Frequent Orders
- OSU IP OHS: Admission OHS/PVS Readmission
- OSUWMC Patient Care Standards Of Practice:VAD Policy

Quality Measures

- One-year survival
- Blood utilization in readmissions
- Postoperative LOS
- Functional status
- Incidence / prevalence rate of infection

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Guideline Approved


Disclaimer: Clinical practice guidelines and algorithms at The Ohio State University Wexner Medical Center (OSUWMC) are standards that are intended to provide general guidance to clinicians. Patient choice and clinician judgment must remain central to the selection of diagnostic tests and therapy. OSUWMC’s guidelines and algorithms are reviewed periodically for consistency with new evidence; however, new developments may not be represented.

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## Appendix A

### Initial Post-Insertion Antithrombotic Regimen for Inpatients

<table>
<thead>
<tr>
<th>Device</th>
<th>Aspirin</th>
<th>Heparin infusion (once hemostasis achieved)</th>
<th>Initial Warfarin INR Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Long-term Devices</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heartmate II and Heartmate III</td>
<td>POD 0: 325 mg x1</td>
<td>• 24 hours Postop: o Initiate &quot;Heparin – no dose escalation at 5 units/kg/hr&quot;</td>
<td>2-3</td>
</tr>
<tr>
<td></td>
<td>Ongoing: 81mg daily</td>
<td>• 48 hours Postop: o Re-Check aPTT then increase rate to 8 units/kg/hr and titrate to institutional PTT goal using &quot;Heparin Cardiac Sliding Scale&quot;</td>
<td></td>
</tr>
<tr>
<td>Heartware</td>
<td>POD 0: 325 mg x1</td>
<td>• 24 hours Postop: o Initiate &quot;Heparin – no dose escalation at 5 units/kg/hr&quot;</td>
<td>2-3</td>
</tr>
<tr>
<td></td>
<td>Ongoing: 325 mg daily</td>
<td>• 48 hours Postop: o Re-Check aPTT then increase rate to 8 units/kg/hr and titrate to institutional PTT goal using &quot;Heparin Cardiac Sliding Scale&quot;</td>
<td></td>
</tr>
<tr>
<td>Centrimag</td>
<td>POD 0: 325 mg x1</td>
<td>• Within 12 hr Postop: o Initiate &quot;Heparin – no dose escalation at 5 units/kg/hr&quot;</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Ongoing: 81mg daily</td>
<td>• By POD1: o Increase to &quot;Heparin Cardiac Sliding Scale&quot; titrating to institutional PTT goal</td>
<td></td>
</tr>
<tr>
<td>Abiomed Ventricle</td>
<td>POD 0: 325 mg x1</td>
<td>• Within 12 hr Postop: o Initiate &quot;Heparin – no dose escalation at 5 units/kg/hr&quot;</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Ongoing: 81mg daily</td>
<td>• By POD1: o Increase to &quot;Heparin Cardiac Sliding Scale&quot; titrating to institutional PTT goal</td>
<td></td>
</tr>
<tr>
<td>Abiomed BVS 5000</td>
<td>POD 0: 325 mg x1</td>
<td>• Within 12 hr Postop: o Initiate &quot;Heparin – no dose escalation at 5 units/kg/hr&quot;</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Ongoing: 81mg daily</td>
<td>• By POD1: o Increase to &quot;Heparin Cardiac Sliding Scale&quot; titrating to institutional PTT goal</td>
<td></td>
</tr>
<tr>
<td>Impella</td>
<td>POD 0 and Ongoing: 81mg daily</td>
<td>• See Impella Order Set</td>
<td>N/A</td>
</tr>
</tbody>
</table>

### Anticoagulation Plan for Discharge

<table>
<thead>
<tr>
<th>Device</th>
<th>Aspirin</th>
<th>Initial Warfarin INR Goal</th>
<th>Follow-up Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Long-term Devices</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heartmate II</td>
<td>81mg daily</td>
<td>2-3 (standard)</td>
<td>• INR follow-up within 2-3 days of discharge and then twice weekly until stable&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Heartware</td>
<td>325 mg daily</td>
<td>2-3 (standard)</td>
<td>• All patients should be discharged on a proton pump inhibitor unless a contraindication exists</td>
</tr>
</tbody>
</table>

---

**Disclaimer:** These are initial recommendations for antiplatelet/anticoagulation based on the type of ventricular assist device. These may need to be individualized based on the hypercoagulable state(s) or history of bleeding of the patient.

---

<sup>a</sup> Safety and efficacy of apixaban, dabigatran, rivaroxaban, enoxaparin, or other anticoagulants in patients with ventricular assist devices has not been established and therefore use should be reserved only for special circumstances after consultation with the OHS specialty pharmacist and approval of the attending cardiac surgeon.

<sup>b</sup> Coagulation regimen should be tailored in the context of preoperative coagulation abnormality workup results, additional thrombotic risk factors and perioperative thrombosis/hemostasis course

<sup>c</sup> Stable is defined as two therapeutic INRs on the same total weekly dose
Appendix B

## Ambulatory Anticoagulation Management

<table>
<thead>
<tr>
<th>Timeframe Since LVAD Implantation</th>
<th>Anticoagulation Monitoring Frequency(^\text{A})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implantation to ≤ 3 months</td>
<td>• Monitor INR twice weekly until stable(^\text{B}) then once weekly</td>
</tr>
<tr>
<td></td>
<td>• LDH monthly</td>
</tr>
<tr>
<td>&gt; 3 to 6 months from most recent implantation</td>
<td>• Can decrease monitoring to every two weeks if stable(^\text{B})</td>
</tr>
<tr>
<td></td>
<td>• Von Willebrand Multimeric study once between 3 and 6 months postoperatively</td>
</tr>
<tr>
<td>&gt; 6 months from most recent implantation</td>
<td>• Consider decreased frequency of monitoring if patient remains on stable(^\text{B}) regimen without bleeding, hemolysis or thrombosis (minimum of INR checks every 4 weeks)</td>
</tr>
</tbody>
</table>

\(^\text{A}\) Increased frequency of monitoring should be considered particularly if a) new bleeding or thrombosis events have occurred, b) presence of new infection, or c) changes in interacting medications have been added/discontinued in the patient’s regimen

\(^\text{B}\) Stable is defined as two therapeutic INRs on the same total weekly dose

### Routine Outpatient Assessment for Indicators of Bleeding, Hemolysis or Thrombosis

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
<th>Other Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verify INR Goal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verify patient dose, tablet strength</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missed doses</td>
<td>Y/N</td>
<td>Number of missed doses and when</td>
</tr>
<tr>
<td>Extra doses</td>
<td>Y/N</td>
<td>Number of extra doses and when</td>
</tr>
<tr>
<td>Medication changes: initiation, discontinuation, and/or dose adjustment</td>
<td>Y/N</td>
<td>Medication name, strength, duration of therapy, and degree of interaction with warfarin</td>
</tr>
<tr>
<td>Examples: antibiotics, amiodarone, OTC/herbal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diet changes (vitamin K)</td>
<td>Y/N</td>
<td>Number and type of servings, nutritional supplements</td>
</tr>
<tr>
<td>Alcohol intake</td>
<td>Y/N</td>
<td>Number and type of drinks (compare to baseline)</td>
</tr>
<tr>
<td>Tobacco use</td>
<td>Y/N</td>
<td>If “yes” - Increased/decreased?</td>
</tr>
<tr>
<td>Recent illness:</td>
<td>Y/N</td>
<td>Identify symptoms</td>
</tr>
<tr>
<td>• N/V/D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• ED/Hospitalization</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bleeding/bruising:</td>
<td>Y/N</td>
<td>Identify site, amount, frequency, duration</td>
</tr>
<tr>
<td>• Epistaxis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Hematuria</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• BRBPR, blood in stool</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Bruises</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Other (e.g., from driveline exit sites)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Falls/injuries</td>
<td>Y/N</td>
<td></td>
</tr>
<tr>
<td>Stroke/TIA symptoms</td>
<td>Y/N</td>
<td></td>
</tr>
<tr>
<td>Upcoming surgery or procedures</td>
<td>Y/N</td>
<td></td>
</tr>
<tr>
<td>LVAD alarms</td>
<td>Y/N</td>
<td></td>
</tr>
</tbody>
</table>

- Evaluate and consider inpatient admission if one or more of the following criteria are met (see Section V for specifics on workup considerations if admitted):
  - INR > 5.0 with evidence of complication
    - If point of care test used, then confirm with venipuncture
  - INR 0.2 – 0.5 below goal
    - If point of care test used, then confirm with venipuncture
  - LVAD alarms
  - Evidence of hematuria/hemolysis
  - Any INR value with new evidence of:
    - Infection
    - Bleeding
    - Hemolysis
    - Thrombosis
# Appendix C

## Long-term Circulatory Support Devices

<table>
<thead>
<tr>
<th>Flow Type</th>
<th>Syncardia Total Artificial Heart (TAH)</th>
<th>HeartMate II</th>
<th>HeartWare (HVAD)</th>
<th>HeartMate III (investigational use)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pulsatile</td>
<td>Nonpulsatile axial flow</td>
<td>Nonpulsatile centrifugal flow</td>
<td>Nonpulsatile centrifugal flow</td>
</tr>
<tr>
<td><strong>Support Duration</strong></td>
<td>Long-term</td>
<td>Long-term</td>
<td>Long-term</td>
<td>Long-term</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>Implanted- replaces heart</td>
<td>Implanted</td>
<td>Implanted</td>
<td>Implanted</td>
</tr>
<tr>
<td><strong>Image</strong></td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Mechanics</strong></td>
<td>2 ventricles; Pneumatic drive</td>
<td>Axial rotor spins 6,000 – 13,000 RPMs 8,000-10,000 typical</td>
<td>Magnetically-levitated impeller spins 2000-3000 RPMs</td>
<td>Magnetically-levitated impeller spins 3,000-9,000 RPMs 4,000-6,000 typical</td>
</tr>
<tr>
<td><strong>Device with external components</strong></td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
<td><img src="image7.png" alt="Image" /></td>
<td><img src="image8.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Volume</strong></td>
<td>70 ml max</td>
<td>125 ml total</td>
<td>45 ml</td>
<td>80ml total</td>
</tr>
<tr>
<td><strong>Support range</strong></td>
<td>Up to 9 L/min</td>
<td>Flow estimated up to 10 L/min</td>
<td>Flow estimated up to 10 L/min</td>
<td>Flow estimated up to 10 L/min</td>
</tr>
<tr>
<td><strong>Back-up Method</strong></td>
<td>Second console built in</td>
<td>Back-up Controller</td>
<td>Back-up Controller</td>
<td>Back-up Controller</td>
</tr>
<tr>
<td><strong>Defib/ Cardiovert</strong></td>
<td>No native ventricles! No need for defib</td>
<td>Must put to battery, then defib/cardiovert</td>
<td>Must put to battery, then defib/cardiovert</td>
<td>Must put to battery, then defib/cardiovert</td>
</tr>
<tr>
<td><strong>Chest Compressions?</strong></td>
<td>No native ventricles! No need for CPR</td>
<td>Refer to Referenced Article Below**</td>
<td>Refer to Referenced Article Below**</td>
<td>Refer to Referenced Article Below**</td>
</tr>
<tr>
<td><strong>Transport</strong></td>
<td>Pair of batteries about 12 hours</td>
<td>Batteries about 4 hours</td>
<td>Pair of batteries about 12 hours</td>
<td></td>
</tr>
<tr>
<td><strong>Special Notes</strong></td>
<td>Refer to anticoagulation/ antiplatelet protocol</td>
<td>Daily self-test</td>
<td>Daily self-test</td>
<td></td>
</tr>
</tbody>
</table>

### Appendix C Continued

#### Short-term to Intermediate-term Circulatory Support Devices

<table>
<thead>
<tr>
<th></th>
<th>Impella 2.5, 3.5, 5.0</th>
<th>Abiomed BVS 5000</th>
<th>Centrimag</th>
<th>Tandem Heart</th>
<th>Abiomed Ventricle</th>
<th>Extra Corporeal Membrane Oxygenation (ECMO)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flow Type</strong></td>
<td>Non-pulsatile axial flow</td>
<td>Pulsatile</td>
<td>Nonpulsatile, centrifugal flow</td>
<td>Centrifugal</td>
<td>Pulsatile</td>
<td>Centrifugal</td>
</tr>
<tr>
<td><strong>Support Duration</strong></td>
<td>Short term</td>
<td>Short term</td>
<td>Short Term</td>
<td>Short term</td>
<td>Intermediate term</td>
<td>Short term</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>Percutaneous</td>
<td>Extracorporeal</td>
<td>Extracorporeal</td>
<td>Extracorporeal</td>
<td>Paracorporeal</td>
<td>Extracorporeal</td>
</tr>
<tr>
<td><strong>Image</strong></td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Mechanics</strong></td>
<td>Axial rotor spins</td>
<td>2 blood sacs; mimics native heart</td>
<td>Impellar spins</td>
<td>3 rotating cones</td>
<td>Blood sac Pneumatic drive</td>
<td>Membrane oxygenator</td>
</tr>
<tr>
<td><strong>Volume</strong></td>
<td>N/A</td>
<td>100 ml</td>
<td>N/A</td>
<td>10 ml</td>
<td>100 ml</td>
<td>1 L</td>
</tr>
<tr>
<td><strong>Support Range</strong></td>
<td>Up to 2.5, 3.5, and 5.0 L/min respectively</td>
<td>Up to 6 L/min</td>
<td>Up to 9.9 L/min</td>
<td>Up to 4 L/min; depends on catheter size.</td>
<td>Up to 6 L/min</td>
<td>2 – 6 L/min Do not run at &lt; 500 ml/min</td>
</tr>
<tr>
<td><strong>Defib/Cardiovert</strong></td>
<td>May defib/cardiovert No special precautions</td>
<td>May defib/cardiovert No special precautions</td>
<td>May defib/cardiovert No special precautions</td>
<td>May defib/cardiovert No special precautions</td>
<td>May defib/cardiovert No special precautions</td>
<td>May defib/cardiovert No special precautions</td>
</tr>
<tr>
<td><strong>Chest Compressions?</strong></td>
<td>Drop flow to 1 L/min during CPR</td>
<td>No chest compressions</td>
<td>Last Resort</td>
<td>No chest compressions</td>
<td>No chest compressions</td>
<td>No chest compressions</td>
</tr>
<tr>
<td><strong>Transport</strong></td>
<td>Battery 60 min</td>
<td>Battery 60 min</td>
<td>Battery 60 min</td>
<td>Battery 60 min</td>
<td>Battery 60 min</td>
<td>Battery 60 min</td>
</tr>
<tr>
<td><strong>Special Notes</strong></td>
<td>• Purge fluid to Impella: Heparin 25,000 units/ Dextrose 10% 1000mL (25 units/mL)</td>
<td>• Allow 2 minutes between each change in blood pump position to assess effect.</td>
<td>• If on BiVAD support, pumps do not have to be at the same height.</td>
<td>• High-thrombogenic risk, evaluate for pump thrombus routinely</td>
<td>• Placed in cardiac cath lab with back up from cardiac surgeon</td>
<td>• Allow 2 minutes between each change in pump settings to assess effect.</td>
</tr>
</tbody>
</table>