AATS/Cardiothoracic Critical Care Symposium

Balancing Pharmacologic and Mechanical Support

Robert L Kormos MD, FACS, FRCS(C), FAHA
I have no disclosures and will not discuss off label use of drugs or devices
How To Identify Patients for LVAD Therapy

- Refractory heart failure
- Cardiogenic shock

  - Symptoms and clinical exam
  - Invasive hemodynamic criteria
  - Need for inotrope support
Definition of Post-Cardiotomy Failure (Practical Definition)

Cardiac Index < 2.0 L/min/M$^2$
Systolic BP < 90 mm Hg
LVEDP or PCWP > 25
In conjunction with IABP support and max Inotropic support
Increased SVRI
Post-Cardiototomy Failure

- Requiring an IABP: seen in 1 to 10%
  - Survival = 45 to 60%

- Requiring an LVAD: seen in 0.1 to 0.8%
  - Weanability = 40% to 70%
  - Survival = 20% to 50%
Major Causes of Heart Failure Following Cardiac Surgery

- Inadequate myocardial protection
- Incomplete revascularization
- Coronary or LIMA spasm
- Coronary embolism (air or particulate matter)

Translates to ischemia and peri-operative myocardial infarction
Introduction

- Echocardiographic Findings
- Pathophysiology
- Pharmacologic Therapy
  - Diuretics
  - Vasodilators
  - Inotropic agents
- Mechanical Therapy
  - Intra-aortic balloon pump
  - Ventricular assist devices
Echocardiographic Findings

- Dilated ventricle
- Hypokinetic or akinetic segments
- Thrombus
- Mitral regurgitation
Dilated Ventricle
Pathophysiology

- Impaired LVF
- LV dilation and increased Wall stress
- Blood volume Preload
- Na and water retention
- Afterload
- Cardiac Output
- Renal Perfusion
- SVR
- Sympathetic Nervous System
- Renin-Angiotensin-Aldosterone System
- Endothelin
Intra-operative Myocardial Dysfunction

- Ischemic insult of aortic cross-clamp
- Inadequate myocardial protection
- Hypothermia
- Surgical trauma
- Inadequate surgical repair
- Activation of complement cascade
- Reperfusion injury
- Premature or excessive use of inotropes
Goals for Ventricular Support

- Maintain fluid balance
- Decrease LV afterload
- Decrease RV afterload
- Maintain contractility
- Maintain sinus rhythm
Maintaining Preload

- **Risk Factors**
  - Severe RV or LV dysfunction
  - Renal insufficiency
  - Massive transfusion

- **Anesthesia Manipulation**
  - Fluid restriction
  - Furosemide
  - Bumetanide

- **Perfusion Manipulation**
  - Mannitol
  - Hemoconcentration
Nitroglycerin

**Mechanism of Action**
- Mitochondrial aldehyde dehydrogenase $\rightarrow$ NO $\rightarrow$ guanyl cyclase $\rightarrow$ cGMP $\rightarrow$ protein kinases $\rightarrow$ decreased intracellular Ca

**Effects**
- Direct venodilator with variable arterial effects
- Decreases wall tension
- Decreases myocardial work
- Reduces LV filling pressures
- Dilates large coronary arteries
- Tachycardia
Nitroglycerin

• **Advantages**
  - Decreases preload
  - Decreases PVR

• **Disadvantages**
  - Tolerance
  - Methemoglobinemia
  - Hypotension
  - Hypoxemia
  - Platelet inhibition
  - Neurohormonal activation
Nitroglycerin

• Uses
  • Decrease preload
  • Decrease pulmonary artery pressures
  • Treat ischemia
  • Radial artery grafts

• Dose
  • 0.5 ug/kg/min
Predictors for Inotropic Support

- Poor LV or RV function
- Age
- Prolonged cross-clamp or CPB
- High LVEDP
- Post MI
- Urgent surgery
- Re-operation
Ideal Inotropic Agent

• Enhance contractility
  – No increase in preload, afterload, heart rate
• Enhance diastolic function
• Maintain coronary perfusion pressure
• Rapid onset
• Short duration
Intropic Agents

• Catecholamines
  • Dobutamine, Epinephrine

• Phosphodiesterase inhibitors
  • Milrinone

• Calcium Sensitizers
  • Levosimendan
Catecholamines

• Selective
  • dobutamine

• Nonselective
  • Epinephrine, norepinephrine, dopamine

• Increase cAMP formation
  – Systole - protein kinase C increases myocardial Ca
    • Increased chronotropy
    • Increased inotropy
  – Diastole - protein kinase C enhances outward Ca current
    • Increased relaxation
Epinephrine

• Mechanism of action
  • beta1, beta2, alpha1, and alpha2 receptors
  • beta1 at all doses
  • <0.02ug/kg/min beta2
  • Alpha higher doses

• Advantages
  • Stronger inotropic agent
  • Less tachycardia
  • Maintains SVR

• Disadvantages
  – May increase PCWP
  – Increases oxygen demand
  – Arrhythmogenic
  – Produce lactic acidosis
Epinephrine

• Uses
  • Low ejection fractions
  • Low SVR
  • Off pump CABG

• Dosage
  • 0.05 – 0.1 ug/kg/min
Milrinone

• Mechanism of Action
  • PDE-III inhibitor
  • Heart → inotropy
  • Vascular smooth muscle → vasodilation
Milrinone

• Advantages
  • Decrease in PVR and SVR
  • Does not increase oxygen consumption
  • RV inotrope
  • Better diastolic relaxation
  • Less arrhythmogenic
  • Downregulated receptors
  • Beta blockade
  • Combination therapy
Milrinone

• Disadvantages
  • Hypotension requiring vasopressors
  • 2 - 4 hours

• Uses
  • Pulmonary hypertension
  • RV failure
  • Severe LV failure

• Dose
  • 25 – 50 ug/kg
  • 0.25 – 0.75 ug/kg/min
Problem

• Sustained increase in intracellular Ca
  • increase in oxygen demand
  • impair relaxation
  • exacerbate ischemia
• arrhythmias
• myocardial cell death
Mechanical Support

- Partial
  - IABP

- Complete
  - VAD
IABP

- Indications
  - Cardiogenic shock
  - Minimize myocardial infarction
  - Refractory myocardial ischemia
  - Weaning from CPB
IABP

- **Mechanism of Action**
  - Inflates and deflates during diastole
  - Inflated at aortic valve closure
  - Deflated before aortic valve opening

- **Effects**
  - Increased coronary and cerebral blood flow
  - Decreased wall tension and ventricular work
  - Decreased oxygen consumption
  - Low CO
    - Decreased HR, SVR, PCWP
    - Increased CO
IABP

• Complications
  • Limb ischemia
  • Thromboembolic complications
  • Hemolysis and thrombocytopenia
  • Acute aortic dissection
  • Balloon rupture
IABP

• Contraindications
  • Severe aortic insufficiency
  • Aortic pathology
    – Dissecting aortic aneurysm
    – Severe atherosclerotic disease
  • Sepsis
  • Malignant arrhythmias
    – Ventricular fibrillation
Conclusions

• No formula for choosing inotropic agents
• Age, heart rate, ejection fraction, PVR, and SVR
• Mild decreases in EF with bradycardia
  • dobutamine
• Moderate decreases in EF
  • Dobutamine, epinephrine, milrinone
• Severe decreases in EF
  • Combination therapy, IABP
• Elevated SVR or PVR
  • Inodilators, vasodilators
• Renal dysfunction
  • Nesiritide
Therapy for Post-Cardiotomy Failure

• Correct metabolic abnormalities (acid-base, electrolytes)
• Volume loading (reset Starling curve)
• Physiologic pacing (A-V sequential)
• Repair residual anatomical abnormalities (valvular lesions and extra grafts)
• Inotropic support (Milrinone, T₃, Natricore)
• Intra-Aortic balloon pump
Determinants of Myocardial Oxygen Consumption

Left Ventricular Wall Tension

Contractility
Physiologic Principles of an LVAD

A) Decrease LV afterload and LV wall tension
B) Decrease LV preload
   \[ A) + B) = \text{Decreased LV pressure} = \text{Decreased myocardial oxygen consumption} \]
C) Augment myocardial perfusion
D) Maintain physiologically adequate systemic perfusion
Risk Factors to Evaluate Prior to LVAD

- Unsuccessful surgery (unless Trx cand.)
- Preop or intra-op myocardial infarct
- Biventricular failure
- Previous MI or CHF
- Age
- Coagulopathy risk
- Pre-implant multi-organ failure
Things Which Influence Outcome for Post-Cardiotomy Support

- Pre-implant multi-organ failure
- Degree of LV decompression
- Promptness of implant
- Degree of completed myocardial infarction
- Pre-operative LV function
Time-line for Decision Making for Post-Cardiotomy Failure Support

Initial attempt to wean

10-20 min

IABP and/or Inotropic Agents

20 min Failed

Failed

LVAD
Length of Support

• In general RV recovers within 48 hrs to 5 days.
• The LV will usually recover within 5 to 10 days but could take several weeks.
• Given more long-term devices some LV’s may recover after months.
Logistical issues influencing outcome

- The LV is rarely effected in an isolated fashion
- Weaning support before recovery of associated end-organ failure is rarely successful
- Success of weaning will depend upon successful revascularization of viable myocardium
- Isolated RV failure is also rare.
A point about supporting the patient with an RV infarct

• It is dangerous to assume the LV is normal
• Conduction system abnormalities are common
  • Bradycardia can lead to sudden and fatal pulmonary edema
  • Permanent epicardial pacing leads should be placed
• A safer alternative is to use biventricular support
Between January 1995 and December 2004, 5735 VADs were implanted in 601 STS NCD centers. Overall, the percentage of cardiac surgical procedures requiring VAD insertion support was 0.3% of all cardiac operations.

Circulation. 2007;116:606-612.)
### TABLE 6. Detailed Characteristics of VAD Implantation in 2004

<table>
<thead>
<tr>
<th>Implantation Type, %</th>
<th>RVAD (n=32, 27.8%)</th>
<th>LVAD (n=51, 44.4%)</th>
<th>BiVAD (n=32, 27.8%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indication for VAD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bridge to transplant</td>
<td>3.1</td>
<td>25.5</td>
<td>9.4</td>
</tr>
<tr>
<td>Bridge to recovery</td>
<td>40.6</td>
<td>17.7</td>
<td>31.3</td>
</tr>
<tr>
<td>Destination</td>
<td>0</td>
<td>17.7</td>
<td>3.1</td>
</tr>
<tr>
<td>Separation from CPB</td>
<td>56.2</td>
<td>39.2</td>
<td>56.3</td>
</tr>
<tr>
<td>VAD cannulation</td>
<td>50.0 (RA)</td>
<td>37.3 (LA)</td>
<td>87.5 (RA)/59.4 (LA)</td>
</tr>
<tr>
<td></td>
<td>31.3 (RV)</td>
<td>39.2 (LV)</td>
<td>6.3 (RV)/34.4 (LV)</td>
</tr>
<tr>
<td>Explanted</td>
<td>43.3</td>
<td>27.9</td>
<td>41.4</td>
</tr>
<tr>
<td>Discharged from hospital with VAD</td>
<td>28.1</td>
<td>52.9</td>
<td>34.4</td>
</tr>
</tbody>
</table>

RVAD indicates right VAD; LVAD, left VAD; BiVAD, biventricular VAD; CPB, cardiopulmonary bypass; RA, right atrium; RV, right ventricle; LA, left atrium; LV, left ventricle.

### TABLE 4. Predictors of Mortality

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds Ratio</th>
<th>95% Confidence Interval</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salvage procedure</td>
<td>2.65</td>
<td>2.07–3.41</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Reoperation</td>
<td>2.56</td>
<td>2.20–2.97</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Dialysis</td>
<td>2.01</td>
<td>1.35–3.00</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Valve procedure</td>
<td>1.74</td>
<td>1.45–2.10</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Emergent procedure</td>
<td>1.64</td>
<td>1.34–2.02</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Acute MI</td>
<td>1.55</td>
<td>1.20–1.99</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Figure 1. Risk-adjusted operative mortality odds ratios with 95% confidence intervals for nonreference groups (P<0.0001 for trend).

Figure 2. Risk-adjusted operative mortality and morbidity (deep sternal wound infection, permanent stroke, renal failure, prolonged ventilation, or reoperation for any reason) odds ratios with 95% confidence intervals for nonreference groups (P<0.0001 for trend).
Determinants of Outcomes for Postcardiotomy VAD Placement: An 11-Year, Two-Institution Study

Subroto Paul, M.D.,* Marzia Leacche, M.D.,* Daniel Unic, M.D.,* Gregory S. Couper, M.D.,* Thomas E. Macgillivray, M.D.,† Arvind K. Agnihotri, M.D.,† Lawrence H. Cohn, M.D.,* and John G. Byrne, M.D.*

*The Division of Cardiac Surgery, Brigham and Women's Hospital; and †The Cardiac Unit, Massachusetts General Hospital, Boston, Massachusetts

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Preoperative Patient’s Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Survivors (N = 17)</td>
</tr>
<tr>
<td>Male</td>
<td>11 (65%)</td>
</tr>
<tr>
<td>Median Age (years)</td>
<td>45 (13 to 63)</td>
</tr>
<tr>
<td>Median EF (%)</td>
<td>45 (15 to 60)</td>
</tr>
<tr>
<td>Median BSA (m²)</td>
<td>1.9 (1.4 to 2.2)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>5 (29%)</td>
</tr>
<tr>
<td>Pulmonary hypertension</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Hypercholesterolemia</td>
<td>8 (47%)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>2 (12%)</td>
</tr>
<tr>
<td>CVDz</td>
<td>2 (12%)</td>
</tr>
<tr>
<td>COPD</td>
<td>2 (12%)</td>
</tr>
<tr>
<td>Sepsis</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Reoperation</td>
<td>2 (12%)</td>
</tr>
<tr>
<td>CHF</td>
<td>5 (29%)</td>
</tr>
</tbody>
</table>

### Table 3
Preoperative Medications and Labs

<table>
<thead>
<tr>
<th></th>
<th>Survivors (N = 17)</th>
<th>Nonsurvivors (N = 46)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heparin</td>
<td>7 (41%)</td>
<td>14 (30%)</td>
<td>0.304</td>
</tr>
<tr>
<td>Aspirin</td>
<td>7 (41%)</td>
<td>27 (59%)</td>
<td>0.170</td>
</tr>
<tr>
<td>Coumadin</td>
<td>0 (0%)</td>
<td>3 (7%)</td>
<td>0.382</td>
</tr>
<tr>
<td>Pressors</td>
<td>8 (46%)</td>
<td>21 (46%)</td>
<td>0.572</td>
</tr>
<tr>
<td>Milrinone</td>
<td>2 (12%)</td>
<td>6 (13%)</td>
<td>0.631</td>
</tr>
<tr>
<td>Phenytoin</td>
<td>2 (12%)</td>
<td>5 (11%)</td>
<td>0.615</td>
</tr>
<tr>
<td>Norepinephrine</td>
<td>5 (29%)</td>
<td>18 (39%)</td>
<td>0.343</td>
</tr>
<tr>
<td>Dobutamine</td>
<td>1 (6%)</td>
<td>6 (13%)</td>
<td>0.385</td>
</tr>
</tbody>
</table>

### Table 4
Multivariate Predictors of Survival

<table>
<thead>
<tr>
<th></th>
<th>Odds Ratio</th>
<th>Confidence Interval</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median age ≤50 (years) (each additional year)</td>
<td>0.85</td>
<td>0.77 to 0.95</td>
<td>0.004</td>
</tr>
<tr>
<td>Median base deficit ≥0 mEq/L (each additional mEq/L)</td>
<td>0.60</td>
<td>0.48 to 0.91</td>
<td>0.012</td>
</tr>
</tbody>
</table>

C-statistic = 0.86, Hosmer-Lemeshow goodness-of-fit statistic Chi-square_{HL} = 6.3, p = 0.6116.
Mechanical Support for Postcardiotomy Cardiogenic Shock: Has Progress Been Made?

Erik A. Sylvin, M.D., David R. Stern, M.D., and Daniel J. Goldstein, M.D.

Montefiore-Einstein Heart Center, Albert Einstein College of Medicine, Bronx, New York

(J Card Surg 2010;25:442-454)
<table>
<thead>
<tr>
<th>Name of Device</th>
<th>Mechanism of Pump</th>
<th>Location of Pump</th>
<th>Insertion Route</th>
<th>Capable of BIVAD Support</th>
<th>Approved Duration of Support</th>
<th>Max Flows (L/min)</th>
<th>Need for Anticoagulation</th>
<th>Pt May Ambulate</th>
</tr>
</thead>
<tbody>
<tr>
<td>IABP</td>
<td>Pneumatic (pulsatile)</td>
<td>Extracorporeal</td>
<td>Percutaneously, femoral cutdown or transaortic</td>
<td>No</td>
<td>Hours to days</td>
<td>N/A</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Centrifugal</td>
<td>Centrifugal (nonpulsatile)</td>
<td>Extracorporeal</td>
<td>Percutaneously, sternotomy, or femoral cutdown</td>
<td>Yes</td>
<td>Hours to few weeks</td>
<td>≥6</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>ECMO</td>
<td>Centrifugal (nonpulsatile)</td>
<td>Extracorporeal</td>
<td>Percutaneously, sternotomy, Thoracotomy, femoral, or neck cutdown</td>
<td>Yes</td>
<td>Hours to days</td>
<td>6 L</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Abiomed AB 5000</td>
<td>Pneumatic (pulsatile)</td>
<td>Paracorporeal</td>
<td>Sternotomy</td>
<td>Yes</td>
<td>Days to months</td>
<td>6.0</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Abiomed BVS 5000</td>
<td>Pneumatic (pulsatile)</td>
<td>Extracorporeal</td>
<td>Sternotomy</td>
<td>Yes</td>
<td>Hours to days</td>
<td>6.0</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Impella 2.5</td>
<td>Microaxial (nonpulsatile)</td>
<td>Intracorporeal/intravascular</td>
<td>Percutaneously</td>
<td>Yes</td>
<td>Hours to days</td>
<td>2.5</td>
<td>No additional needed</td>
<td>No</td>
</tr>
<tr>
<td>Impella 5.0</td>
<td>Microaxial (nonpulsatile)</td>
<td>Intracorporeal/intravascular</td>
<td>Femoral cutdown</td>
<td>Yes</td>
<td>Hours to days</td>
<td>5.0</td>
<td>No additional needed</td>
<td>No</td>
</tr>
<tr>
<td>Impella LD</td>
<td>Microaxial (nonpulsatile)</td>
<td>Intracorporeal/intravascular</td>
<td>Sternotomy</td>
<td>Yes</td>
<td>Hours to days</td>
<td>6.0</td>
<td>No additional needed</td>
<td>No</td>
</tr>
<tr>
<td>TandemHeart</td>
<td>Centrifugal (nonpulsatile)</td>
<td>Intracorporeal</td>
<td>Sternotomy or percutaneously</td>
<td>Yes</td>
<td>Hours to few weeks</td>
<td>5.0–8.0</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>CentriMag</td>
<td>Centrifugal (nonpulsatile)</td>
<td>Paracorporeal</td>
<td>Sternotomy</td>
<td>Yes</td>
<td>Hours to few weeks</td>
<td>9.9</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Thoratec IVAD</td>
<td>Pneumatic (pulsatile)</td>
<td>Intracorporeal/preperitoneal</td>
<td>Sternotomy</td>
<td>Yes</td>
<td>Months</td>
<td>6.5</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Thoratec PVAD</td>
<td>Pneumatic (pulsatile)</td>
<td>Paracorporeal</td>
<td>Sternotomy</td>
<td>Yes</td>
<td>Weeks to months</td>
<td>6.5</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Bivad = biventricular assist device; N/A = non applicable; Pt = patient.
**TABLE 2**
Recent Published Experience with Extracorporeal Membrane Oxygenation for Postcardiotomy Cardiogenic Shock

<table>
<thead>
<tr>
<th>Study</th>
<th>Number of Patients</th>
<th>Survival to Weaning</th>
<th>Survival to Discharge</th>
<th>Mean Duration of Support</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiser et al., 2001(^65)</td>
<td>51</td>
<td>16 (31%)</td>
<td>8 (16%)</td>
<td>64.7 ± 9.2-85.0 ± 12.5 hours, depending on group</td>
<td>Patients s/p transplant or isolated valve cases more likely to wean</td>
</tr>
<tr>
<td>Smedira and Blackstone 2001(^8)</td>
<td>107</td>
<td>42 (39%)</td>
<td>37 (35%)</td>
<td>Not reported</td>
<td>18 patients bridged to transplant</td>
</tr>
<tr>
<td>Ko et al., 2002(^5)</td>
<td>76</td>
<td>42 (55%)</td>
<td>20 (26%)</td>
<td>99 ± 33 hours in survivors</td>
<td>4 patients BTT or other devices</td>
</tr>
<tr>
<td>Sakamoto et al., 2003(^66)</td>
<td>25</td>
<td>19 (76%)</td>
<td>19 (76%)</td>
<td>82.5 ± 55.4 hours</td>
<td></td>
</tr>
<tr>
<td>D bel et al., 2004(^67)</td>
<td>219</td>
<td>133 (61%)</td>
<td>52 (39%)</td>
<td>2.8 ± 2.2 days</td>
<td>70% of weaned patients also had IABP</td>
</tr>
<tr>
<td>Murashita et al., 2004(^68)</td>
<td>23</td>
<td>16 (70%)</td>
<td>12 (52%)</td>
<td>26.9 ± 18.1 hours in survivors</td>
<td>11 of 12 survivors weaned within 48 hours</td>
</tr>
<tr>
<td>Zhang et al., 2006(^69)</td>
<td>32</td>
<td>14 (44%)</td>
<td>8 (25%)</td>
<td>2.7 ± 1.7 days</td>
<td></td>
</tr>
</tbody>
</table>

BTT = bridge to transplant; IABP = intraaortic balloon pump; s/p = status post.
Weanability = 52%
Survival = 30%
Cannulation for Extracorporeal Support

Exit sites – excise tissue
Attempt to tunnel cannula/tubing
Plan for perm VAD if possible
**TABLE 3**
Clinical Publications Outlining Abiomed BVS 5000 Use for Postcardiotomy Cardiogenic Shock

<table>
<thead>
<tr>
<th>Study</th>
<th>Number of Patients</th>
<th>Survival to Weaning</th>
<th>Survival to Discharge</th>
<th>Mean Duration of Support (Days)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guyton et al., 1993</td>
<td>31</td>
<td>17 (54.8%)</td>
<td>9 (29.0%)</td>
<td>4.7</td>
<td>High incidence of bleeding, respiratory and renal failure</td>
</tr>
<tr>
<td>Minami et al., 1994</td>
<td>26</td>
<td>16 (61.5%)</td>
<td>13 (50%)</td>
<td>Not reported</td>
<td>3 unweanable patients were bridged to transplantation</td>
</tr>
<tr>
<td>Korfer et al., 1999</td>
<td>55</td>
<td>33 (60.0%)</td>
<td>27 (49.1%)</td>
<td>5.7 ± 6.9</td>
<td>5 unweanable patients were bridged to transplantation</td>
</tr>
<tr>
<td>Dekkers et al., 2001</td>
<td>28</td>
<td>17 (61%)</td>
<td>11 (39%)</td>
<td>Not reported</td>
<td>11 BiVAD patients with 73% mortality</td>
</tr>
<tr>
<td>Rodrigus et al., 2002</td>
<td>15</td>
<td>6 (40%)</td>
<td>2 (13%)</td>
<td>5.8 ± 4</td>
<td>All patients received BiVAD support</td>
</tr>
<tr>
<td>Tsai et al., 2002</td>
<td>11</td>
<td>N/A</td>
<td>8 (73%)</td>
<td>5.6</td>
<td>Bridge to transplant</td>
</tr>
</tbody>
</table>

BiVAD = biventricular assist device.
Abiomed AB VAD
Thoratec PVAD Cannulation
Ideal Orientation of Cannulae For Thoratec BiVAD PVAD

- Aortic Outflow Graft
- Pulmonary Artery Outflow Graft
- Right Atrial Inflow Graft
- LV Inflow Graft
Impella 2.5

Impella LD and RD

Left heart support pump

Right heart support pump
### TABLE 4
Experience with the Impella System for Postcardiotomy Cardiogenic Shock

<table>
<thead>
<tr>
<th>Study</th>
<th>Number of Patients</th>
<th>Survival to Weaning</th>
<th>Survival to Discharge</th>
<th>Mean Duration of Support (Hours)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jurmann et al., 2004</td>
<td>6</td>
<td>4 (66.7%)</td>
<td>2 (33.3%)</td>
<td>169 in weaned patients</td>
<td>1 patient with BiVAD for biventricular graft failure</td>
</tr>
<tr>
<td>Siegenthaler et al., 2004</td>
<td>24</td>
<td>16 (66.7%)</td>
<td>11 (45.8%)</td>
<td>61</td>
<td>Strongest predictor of mortality—residual cardiac function at 2, 6, 12 hours postimplant</td>
</tr>
<tr>
<td>Garatti et al., 2006</td>
<td>3</td>
<td>1 (33.3%)</td>
<td>1 (33.3%)</td>
<td>112</td>
<td>Survivor has exited the transplant list</td>
</tr>
</tbody>
</table>

BiVAD = biventricular assist device.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality</td>
<td>61.5</td>
<td>54.2</td>
<td>34.1</td>
<td>40.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mortality/morbidity</td>
<td>77.7</td>
<td>74.3</td>
<td>54.6</td>
<td>62.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Reoperation for bleeding</td>
<td>23.4</td>
<td>23.6</td>
<td>17.5</td>
<td>19.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Stroke</td>
<td>6.6</td>
<td>5.4</td>
<td>4.0</td>
<td>4.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Renal failure</td>
<td>24.9</td>
<td>25.4</td>
<td>18.3</td>
<td>21.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Infection (deep sternum)</td>
<td>1.3</td>
<td>1.4</td>
<td>1.1</td>
<td>1.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Infection (sepsis)</td>
<td>6.2</td>
<td>5.7</td>
<td>5.2</td>
<td>7.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Prolonged ventilation</td>
<td>37.4</td>
<td>40.8</td>
<td>31.2</td>
<td>39.2</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Hernandez et al.\(^{10}\) A decade of short-term outcomes in post cardiac surgery ventricular assist device implantation: Data from the Society of Thoracic Surgeons’ National Cardiac Database. Circulation 2007;116:606-612. (Reprinted with permission.)
Summary

- Post Cardiotomy Failure is not common but is a morbid diagnosis
- Multifaceted approach for treatment is focused upon afterload reduction of the LV and protection of the RV
- Early utilization of Mechanical Circulatory Support is critical for myocardial salvage