Treatment of patients after cardiac surgery

Training program Intensive Care
Radboud University Nijmegen Medical Centre
General remarks

- Cardiac surgery reserved for complex cases
  - Sicker patients with multiple comorbidities
  - Older patients who have failed previous procedures

1. Be familiar with pre- and intraoperative history
2. Accurate and repeated hemodynamic monitoring
3. Rapid determination of surgical complications
Important risk factors

- Preoperative EF < 30%
- Left main coronary artery disease
- Diabetes mellitus
- Renal insufficiency (creatinine > 150)
- Symptomatic parenchymal lung disease
- Advanced age
EF in first 24 hours

![Graph showing Ejection fraction (%)]

- Preoperative
- 2 hours
- 24 hours
- 7 days

Ejection fraction (%)
Prolonged EF decrease

- Preoperative EF < 35%
- Duration and severity of hypothermia
- Perioperative ischemia
- Bypass time > 120 minutes
LV compliance in first 24 hours

Pressure

Volume

After surgery

Normal
Mean arterial pressure

- Normal 65 - 85 mm Hg
- Lower MAP (60 - 70 mm Hg) with severe AI and aortic sutures
- Higher MAP (80 - 100) with preexisting hypertension, renal dysfunction or cerebrovascular disease
Postoperative hypertension

- Chronic hypertension
- Anxiety and agitation
- Pain and discomfort
- Perioperative withdrawal of antihypertensive agents
- Vasopressors / volume

- Sedation and pain control
- SNP 0.1 - 8 μg/kg/min
- NTG 50 - 400 μg/kg/min
- Nicardipine 1 - 15 mg/h
- Metoprolol 1 - 10 mg/h
# Postoperative hypotension

<table>
<thead>
<tr>
<th>Aetiology</th>
<th>Myocardial dysfunction</th>
<th>Hypovolemia</th>
<th>Vasodilation</th>
<th>LV Failure</th>
<th>RV Failure</th>
<th>Tamponade</th>
</tr>
</thead>
<tbody>
<tr>
<td>CI</td>
<td>Low (&lt; 2.2 l/min/m²)</td>
<td>Normal/High (&gt; 2.6 l/min/m²)</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>CVP</td>
<td>Low</td>
<td>Low</td>
<td>Variable</td>
<td>High (&gt; 18 mmHg)</td>
<td>High (&gt; 18 mmHg)</td>
<td></td>
</tr>
<tr>
<td>PAOP</td>
<td>Low</td>
<td>Low</td>
<td>High (&gt; 18 mmHg)</td>
<td>Low</td>
<td>Variable</td>
<td></td>
</tr>
<tr>
<td>ECHO</td>
<td>Underfilled LV and RV cavities</td>
<td>Hyperdynamic LV</td>
<td>Poor LV function with adequate filling</td>
<td>Normal LV function with small thick LV</td>
<td>Hypokinetic RV with underfilled LV</td>
<td>Restrictive MV inflow pattern with clot/effusion</td>
</tr>
<tr>
<td>Aetiology</td>
<td>Hypovolemia/bleeding</td>
<td>Prolonged CPB</td>
<td>Prolonged CPB</td>
<td>Pre-op RV dysfunction</td>
<td>Pre-op RV dysfunction</td>
<td>Excessive bleeding with coagulation correction</td>
</tr>
<tr>
<td></td>
<td>Pneumothorax</td>
<td>Vasodilators/ sedatives</td>
<td>Inadequate revascularization</td>
<td>RV ischemia</td>
<td>RV ischemia</td>
<td>Surgical bleeding</td>
</tr>
<tr>
<td></td>
<td>Tamponade</td>
<td>Residual protamine reaction</td>
<td>Stunned myocardium</td>
<td>Severe PHT</td>
<td>Severe PHT</td>
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<tr>
<td></td>
<td>Excessive PEEP</td>
<td>Prolonged CPB</td>
<td>Graft occlusion</td>
<td>Vasospasm</td>
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<tr>
<td></td>
<td>AutoPEEP</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>RV failure / PHT</td>
<td></td>
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</tbody>
</table>
Postoperative management

- Indications pulmonary artery catheter
  - EF < 40%
  - Combined AVR and CABG
  - Mitral or tricuspid valve surgery
  - Jehovah’s Witnesses

Low CVP or PCWP is not an indication for therapy unless MAP or CI are inadequate
# Inotropic agents

<table>
<thead>
<tr>
<th>Low BP</th>
<th>Low Index</th>
<th>High Index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>epinephrine</td>
<td>Norepinephrine Vasopressin</td>
</tr>
<tr>
<td></td>
<td>milrinone/dobutamine</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ norepinephrine</td>
<td></td>
</tr>
<tr>
<td>Low heart rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pace, epinephrine, isoproterenol</td>
<td>No therapy</td>
</tr>
<tr>
<td>High BP</td>
<td>Afterload reduction</td>
<td>Afterload reduction</td>
</tr>
<tr>
<td></td>
<td>epinephrine</td>
<td></td>
</tr>
<tr>
<td></td>
<td>milrinone/dobutamine</td>
<td></td>
</tr>
<tr>
<td>High heart rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ norepinephrine</td>
<td>No therapy or beta blockade</td>
</tr>
</tbody>
</table>

*Milrinone with RV failure / severe PHT*
Tamponade

Often aspecific
Expected physiology

• Chronic pressure-overloaded myocardium
  ▶ Aortic stenosis
  ▶ Hypertension

• Chronic volume-overloaded myocardium
  ▶ Mitral regurgitation
  ▶ Aortic regurgitation
Preload in pressure overloaded myocardium

Higher filling pressures necessary for adequate preload
Preload in pressure overloaded myocardium

AVR with underfilled left ventricle
Systolic anterior movement
Preload assessment after AVR

• After each aliquot of volume resuscitation
  ▶ Cardiac index
  ▶ Blood pressure
  ▶ Ventricular filling pressures
Heart rate in pressure overloaded myocardium

Cardiac output

Heart rate below time needed for maximal EDV

Heart rate above time needed for maximal EDV

90 100

Synchronized A-V contraction extremely important
Preload in volume overloaded myocardium

- After each aliquot of volume resuscitation
  - Cardiac index
  - Blood pressure

Filling pressures insensitive except at the extremes of hypovolemia and hypervolemia
Heart rate in volume overloaded myocardium

- More tolerant of tachycardia and loss of A-V synchrony
- Increase in heart rate decreases EDV but may improve systolic emptying
- Sinus rhythm < 75 usually more deleterious than abnormal rhythm around 90 - 100
Heart rate/rhythm

- Higher heart rate than expected often optimal
- Sinus rhythm most important with pressure overloaded ventricle
- Increased heart rate often very well tolerated
- Atrial fibrillation in 20 - 60% (usually > 48 hours)
Post operative arrhythmias

• Graft dysfunction
• Ischemia
• Hypoxemia
• Electrolyte imbalance
• Acid base disorders
Specific treatment

- Atrial Flutter - atrial pacing (20 mA - 30 to 60 seconds at 110 - 150% of atrial rate)
- Atrial fibrillation - 85% convert to sinus rhythm in the first 24 hours - rate control is a viable alternative
Prevention of AF

![Chart showing prevention of AF with Odds Ratio for various methods: Beta blocker, Sotalol, Amiodarone, Atrial pacing.](Circulation 2002;106:75-80)
Intra-aortic balloon pump

- Helium filled balloon with tip just distal from origin of LSA
- Reduced myocardial oxygen demand, enhanced coronary blood flow and increased cardiac output
- Timing of inflation/deflation by EKG, arterial pressure waveform or physiologic timing algorithm
- Total complication rate 2.6% with major complications < 0.5% (limb, bowel and renal ischemia)
- Attributable mortality < 0.05%

Contraindicated in severe aortic regurgitation and dissection
Indications IABP

• Cardiogenic shock
• VSR and papillary muscle rupture with MI
• Intractable ventricular arrhythmias
• Unstable angina refractory to medical therapy
• High risk PCI / CABG
IABP

Unassisted systole
Unassisted aortic end diastolic pressure
Diastolic augmentation
Balloon inflation
Assisted systole
Assisted aortic end diastolic pressure

Inflation: dicrotic notch - Deflation: arterial pressure rise
Inadequate timing

Early inflation

Increases LV afterload and myocardial oxygen consumption

Late inflation

Minimises diastolic augmentation
Inadequate timing

Early deflation

May promote retrograde blood flow from carotid and coronary arteries

Late deflation

Increases LV afterload and myocardial oxygen consumption
Percutaneous LVAD’s

*Impella 2.5*

- Axial pump placed across the aortic valve via one of femoral arteries
RCT’s with pLVAD’s

<table>
<thead>
<tr>
<th>Study</th>
<th>Patients</th>
<th>Δ Cardiac output, L/min</th>
<th>30-day survival, percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>TandemHeart (pLVAD)</td>
<td></td>
<td>VAD</td>
<td>IABP</td>
</tr>
<tr>
<td>Thiele et al.[52]</td>
<td>41</td>
<td>1.0</td>
<td>0.3</td>
</tr>
<tr>
<td>Burkhoff et al.[53]</td>
<td>42</td>
<td>1.2</td>
<td>0.6</td>
</tr>
<tr>
<td>Impella (pLVAD)</td>
<td></td>
<td>VAD</td>
<td>IABP</td>
</tr>
<tr>
<td>Seyfarth et al.[54]</td>
<td>25</td>
<td>0.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Centrimag (eBiVAD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>John et al.[61]</td>
<td>12</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In studies with TandemHeart more hemorrhagic complications and ischemic limbs

In one with Impella no more complications
## Meta-analysis pLVAD’s

<table>
<thead>
<tr>
<th></th>
<th>Thiele et al.\textsuperscript{16}</th>
<th>Burkhoff et al.\textsuperscript{17}</th>
<th>Seyfarth et al.\textsuperscript{18}</th>
<th>Pooled (random effects model)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LVAD (n = 21)</td>
<td>IABP (n = 20)</td>
<td>LVAD (n = 19)</td>
<td>IABP (n = 14)</td>
</tr>
<tr>
<td>Haemodynamics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CI ± SD (L/min/m\textsuperscript{2})</td>
<td>2.3 ± 0.6</td>
<td>1.8 ± 0.4</td>
<td>2.2 ± 0.6</td>
<td>2.1 ± 0.2</td>
</tr>
<tr>
<td>MAP ± SD (mmHg)</td>
<td>76 ± 10</td>
<td>70 ± 16</td>
<td>91 ± 16</td>
<td>72 ± 12</td>
</tr>
<tr>
<td>PCWP ± SD (mmHg)</td>
<td>16 ± 5</td>
<td>22 ± 7</td>
<td>16 ± 4</td>
<td>25 ± 3</td>
</tr>
<tr>
<td>Clinical outcome</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-day mortality, n (%)</td>
<td>9 (43)</td>
<td>9 (45)</td>
<td>9 (47)</td>
<td>5 (36)</td>
</tr>
<tr>
<td>Reported adverse events</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg ischaemia, n (%)</td>
<td>7 (33)</td>
<td>0 (0)</td>
<td>4 (21)</td>
<td>2 (14)</td>
</tr>
<tr>
<td>Bleeding, n (%)</td>
<td>19 (90)</td>
<td>8 (40)</td>
<td>8 (42)</td>
<td>2 (14)</td>
</tr>
<tr>
<td>Fever of sepsis, n (%)</td>
<td>17 (81)</td>
<td>10 (50)</td>
<td>4 (21)</td>
<td>5 (36)</td>
</tr>
</tbody>
</table>

*Cheng JM. Eur Heart J 2009;30:2102-2108*
Peripheral ECMO

VA-ECMO

- Femoral Artery
- Returning Oxygenated Blood
- De-oxygenated Blood

VV-ECMO

- Internal Jugular Vein
Extracorporeal membrane oxygenation

- Inadequate DO$_2$ despite IABP, MV and inotropic support
- VA ECMO for cardiogenic shock is the fastest growing indication for ECMO worldwide
Advantages of peripheral VA-ECMO

• Easier to place - less invasive
• Percutaneous by intensivists/cardiologists or surgeons
• Lower complication rate with bleeding and infection
Disadvantages

- Increase in left ventricular wall tension which may result in inadequately oxygenated blood to coronary- and cerebral circulation with concomitant respiratory failure

- Echocardiographic monitoring LV dilatation necessary - change in ECMO circuit or percutaneous atrial septostomy
Evidence for ECMO in cardiogenic shock

<table>
<thead>
<tr>
<th>Study</th>
<th>Patients</th>
<th>Survival rate&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Cardiogenic shock etiology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Golding et al. [42] (1992)</td>
<td>91</td>
<td>25.3%</td>
<td>Post-CABG&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Muehrcke et al. [43] (1996)</td>
<td>23</td>
<td>30.4%</td>
<td>Post-CABG&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Magovern et al. [44] (1999)</td>
<td>27</td>
<td>85%</td>
<td>UA or CHF</td>
</tr>
<tr>
<td>Formica et al. [39] (2008)</td>
<td>18</td>
<td>27.8%</td>
<td>AMI/Post-CABG</td>
</tr>
<tr>
<td>Combes et al. [38] (2008)</td>
<td>16</td>
<td>31.3%</td>
<td>AMI</td>
</tr>
<tr>
<td>ELSO [33] (2009)</td>
<td>153&lt;sup&gt;c&lt;/sup&gt;</td>
<td>39%</td>
<td>Not defined</td>
</tr>
</tbody>
</table>

Shock despite MV, IABP and full inotropic support
## ELSO 1985 - 2008

<table>
<thead>
<tr>
<th></th>
<th>Total Patients</th>
<th>Survived ECLS (%)</th>
<th>Survived to Discharge or Transfer (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Neonatal (&lt;1 year)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory</td>
<td>21,916</td>
<td>85</td>
<td>76</td>
</tr>
<tr>
<td>Cardiac</td>
<td>3,266</td>
<td>58</td>
<td>38</td>
</tr>
<tr>
<td>ECPR</td>
<td>354</td>
<td>63</td>
<td>38</td>
</tr>
<tr>
<td><strong>Pediatric (1-16 years)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory</td>
<td>3,693</td>
<td>64</td>
<td>56</td>
</tr>
<tr>
<td>Cardiac</td>
<td>4,036</td>
<td>61</td>
<td>45</td>
</tr>
<tr>
<td>ECPR</td>
<td>691</td>
<td>51</td>
<td>39</td>
</tr>
<tr>
<td><strong>Adult (&gt;16 years)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory</td>
<td>1,416</td>
<td>59</td>
<td>51</td>
</tr>
<tr>
<td>Cardiac</td>
<td>825</td>
<td>46</td>
<td>33</td>
</tr>
<tr>
<td>ECPR</td>
<td>269</td>
<td>36</td>
<td>26</td>
</tr>
</tbody>
</table>
Concluding ECMO remarks

• Early after failure of IABP, MV, inotropic support
• Bridge to decision
• Less costly than VAD’s and can be initiated quickly
• Offers biventricular and respiratory support stabilising patients while suitability for VAD/transplantation is evaluated
Concluding ECMO remarks

• Majority of patients able do be weaned do so within 2 - 5 days (resolution of stunning)

• LV EF < 30% on low circuit flow ECMO (1 - 2 L/min) after 2 days predicts inability to be successfully weaned

• Little point continuing ECMO support for cardiac failure beyond 5 - 7 days