Module 1: The Critical Science: Understanding the ABCs of Mechanical Circulatory Support

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Disclosure

All presenters have a speaker agreement with Maquet

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Goals of Mechanical Circulatory Support
A: Myocardial Protection

DEMAND
- Heart Rate
- Contractility
- Afterload

SUPPLY
- Diastolic Pressure (DPTI)
- Microvascular resistance
- Coronary Patency
B: Organ Perfusion

Tissue blood flow

\[ F = \frac{MAP}{VR} \]

Local vascular resistance

Mean aortic pressure

\[ MAP = CO \times TPR \]

\[ CO = HR \times SV \]

Cardiac output

Total peripheral resistance

\[ SV = EDV - ESV \]

Heart rate

Stroke volume

Filling pressure

Cardiac compliance

End-diastolic volume

End-systolic volume

Afterload

Contractility
C: Safety and Ease of Use

- Bleeding
- Vascular Complications
- Cerebrovascular Complications

- Availability
- Rapid Initiation
- Familiarity/Specialist Expertise
Circulatory Support Strategies
1. Inotropic Drugs
# 1. Inotropic Drugs

<table>
<thead>
<tr>
<th>Drug</th>
<th>Action</th>
<th>CO</th>
<th>SVR</th>
<th>MAP</th>
<th>Tissue VR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dobutamine</td>
<td>DA β1 β2 agonism</td>
<td>↑↑</td>
<td>↓</td>
<td>↑↓</td>
<td>↓↑</td>
</tr>
<tr>
<td>Epinephrine</td>
<td>A1 β 1/2 agonism</td>
<td>↑↑</td>
<td>↑↑</td>
<td>↑↑</td>
<td>↑</td>
</tr>
<tr>
<td>Norepinephrine</td>
<td>α1 β1 / 2 agonism</td>
<td>↑↓</td>
<td>↑↑</td>
<td>↑↑</td>
<td>↑↑</td>
</tr>
<tr>
<td>Levosimendan</td>
<td>Ca++ sensitizer</td>
<td>↑↑</td>
<td>↓↓</td>
<td>↑↓</td>
<td>↓</td>
</tr>
<tr>
<td>Milrinone</td>
<td>PDE inhibitor</td>
<td>↑↑</td>
<td>↓↓</td>
<td>↑↓</td>
<td>↓</td>
</tr>
</tbody>
</table>
2. Intra Aortic Balloon Pump

- **Aortic Pressure**
- **Ventricular Pressure**

\[
\frac{\text{DPTI}}{\text{TTI}} = \frac{\text{DIASTOLIC PRESSURE TIME INDEX}}{\text{TIME TENSION INDEX}} = \frac{\text{SUPPLY INDEX}}{\text{DEMAND INDEX}}
\]
2. Intra Aortic Balloon Pump

![Graph showing pressure changes with and without balloon pump assistance.](image-url)
2. Intra Aortic Balloon Pump

Coronary and Microvascular Physiology During Intra-Aortic Balloon Counterpulsation

JACC CV Interv, April 2014

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2. Intra Aortic Balloon Pump

A **Myocardial protection** by improving myocardial perfusion and reducing oxygen demand, especially when **Autoregulation is dysfunctional or exhausted**
- Persistent ischemia (no reflow)
- Sustained hypotension
- **Critical coronary disease** (local maximal microvascular dilation)

B **No direct effect on tissue perfusion** (indirect effect via myocardial protection)

C **Safe and Easy to use**
Intra-aortic Balloon Pump Trials: Questions, Answers and Unresolved Issues

<table>
<thead>
<tr>
<th>Patient Group</th>
<th>Trial</th>
<th>n</th>
<th>Inclusion</th>
<th>Principal End Point</th>
<th>Results (IABP vs Control Group)</th>
<th>Timing of IABP Insertion</th>
<th>Crossover From Control to IABP Group, %</th>
<th>Bleeding Rates</th>
<th>Vascular Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-risk PCI (excluding shock/AMI)</td>
<td>Perera et al</td>
<td>301</td>
<td>LVEF&lt;30% BCIS Jeopardy score ≥8</td>
<td>Composite of death, AMI, CVA or further revascularization at hospital discharge (capped at 28 days)</td>
<td>15.2% vs 16%; OR, 0.94; 95% CI, 0.51–1.76; P=0.85</td>
<td>Pre-PCI</td>
<td>12.0</td>
<td>19.2% vs 11.3%; OR, 1.86; 95% CI, 0.93–3.79; P=0.06 (at hospital discharge, capped at 28 days)</td>
<td></td>
</tr>
<tr>
<td>AMI-without shock</td>
<td>Ohman et al</td>
<td>182</td>
<td>STE-ACS or NSTE-ACS Cardiac catheterization within 24 h of symptoms</td>
<td>Recurrence of infarct-related artery</td>
<td>8% vs 21%; P&lt;0.03</td>
<td>Post-PCI</td>
<td>8.1</td>
<td>2% vs 1%; 5% vs 2%</td>
<td></td>
</tr>
<tr>
<td>Stone et al</td>
<td>437</td>
<td>STE-ACS or NSTE-ACS-urgent catheterization revealing an occluded vessel with regional LV dysfunction</td>
<td>Composite of death, reinfarction, infarct-related artery reocclusion, stroke, new-onset heart failure, or sustained hypertension</td>
<td>28.9% vs 29.2%; P=0.95</td>
<td>Post-PCI</td>
<td>11.5</td>
<td>36% vs 27%; P=0.05 (in-hospital) 0.5% vs 0.4%; P=1.0 (in-hospital; requiring surgical intervention)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>van’t Hof et al</td>
<td>238</td>
<td>STE-ACS Primary PCI</td>
<td>Composite of death, nonfatal reinfarction, stroke or EF&lt;30% at 6 mo</td>
<td>26% vs 26%; P=0.94</td>
<td>Post-PCI</td>
<td>26%</td>
<td>36% vs 32%; P=0.84</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patel et al</td>
<td>337</td>
<td>anterior STE-ACS Primary PCI</td>
<td>Infarct size as a percentage of LV mass</td>
<td>42.1% vs 37.5%; P=0.07</td>
<td>Pre-PCI</td>
<td>30-d mortality</td>
<td>39.7% vs 41.3%; P=0.69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AMI complicated by cardiogenic shock</td>
<td>Thiele et al</td>
<td>600</td>
<td>STE-ACS or NSTE-ACS Early PCI Cardiogenic shock</td>
<td>30-d mortality</td>
<td>39.7% vs 41.3%; P=0.69</td>
<td>Operator discretion (86.6% after PCI)</td>
<td>3.3% vs 4.4%; P=0.51 (severe/life-threatening) 4.3% vs 3.4%; P=0.53 (surgical vascular repair)</td>
<td>3.1% vs 1.7%; P=0.49 (at 30 days) 4.3% vs 1.1%; P=0.09 (at 30 days)</td>
<td></td>
</tr>
</tbody>
</table>
3. Impella Recover

Direct LV Unloading by providing continuous (non-pulsatile)

LV -> aortic flow

2.5 L/min: 13F
3.5 L/min: 14F
5.0 L/min: 22F
3. Impella Recover

3. Impella Recover

**A:** Myocardial protection by decreasing afterload -> reducing oxygen demand (effects on myocardial perfusion??)

**B:** Improves cardiac output without increasing local vascular resistance -> improves tissue perfusion

**C:** (Relatively) Safe and Easy to use but increasing risk of vascular complications, especially with larger bore access

2.5 L/min: 13F
3.5 L/min: 14F
5.0 L/min: 22F
4. Extra-Corporeal Pumps

Tandem Heart
- LA -> Ao continuous flow
- Large bore arterial and venous access
- Trans-septal puncture

VA-ECMO/ECLS
- RA -> Ao continuous flow
- Large bore arterial and venous access
4. Extra-corporeal Pumps

- Improve cardiac output and tissue perfusion
  BUT at the cost of increased afterload -> increased MVO₂
  - (?) Effect on coronary flow
  - Vascular risk ++, Complexity ++
## Circulatory Support Strategies: Summary

<table>
<thead>
<tr>
<th></th>
<th>Myocardial Protection</th>
<th>Tissue Perfusion</th>
<th>Ease of Use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Supply</td>
<td>Demand</td>
<td></td>
</tr>
<tr>
<td>Inotropic drugs</td>
<td>+/-</td>
<td>-</td>
<td>+/-</td>
</tr>
<tr>
<td>IABP</td>
<td>++</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Impella</td>
<td>?</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>VA-ECMO/ECLS</td>
<td>?</td>
<td>-</td>
<td>++ ++ + +</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>+</th>
<th>Desired effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>Undesirable effect</td>
</tr>
<tr>
<td>?</td>
<td>Missing/equivocal data</td>
</tr>
</tbody>
</table>
Selecting the right support strategy

Which device for which patient?

Characterise by Broad Diagnostic Category

OR

Individual Physiology?
BCIS-1: Major Outcomes

Perera et al. JAMA 2010; 364(8):867-874

Primary outcome

Per et al., JAMA 2011;305(12):1329-37

Primary endpoint

Infarct size (% LV), modified ITT all patients with CMR data

<table>
<thead>
<tr>
<th></th>
<th>All (N=337)</th>
<th>IABC (N=161)</th>
<th>SOC (N=176)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>275</td>
<td>133</td>
<td>142</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>39.8</td>
<td>42.1</td>
<td>37.5</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>38.8</td>
<td>42.8</td>
<td>36.2</td>
<td></td>
</tr>
</tbody>
</table>

Infarct size (% LV), modified ITT patients prox. LAD and TIMI flow 0/1

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<thead>
<tr>
<th></th>
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<th>IABC (N=161)</th>
<th>SOC (N=176)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>192</td>
<td>93</td>
<td>99</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>44.4</td>
<td>46.7</td>
<td>42.3</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>42.1</td>
<td>45.1</td>
<td>38.6</td>
<td></td>
</tr>
</tbody>
</table>

Co-primary endpoint: 2-sided p=0.025

PROTECT II Interim Results

Thiele et al. NEJM 2012;367:1267-96
In Summary

- Principles and goals behind mechanical circulatory support
- Different support strategies and how they fit in with the principles
- Tailoring the support strategies for the individual patient