Intra-Aortic Balloon Pump
When and How?

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Background

- First report in humans by Kantowitz et al 1968
- Estimated use in Coronary Artery Bypass in selection of US and Canadian sites in 2000 was 10.3% pre-operative and 3.4% post
  - Increased from 1995 to 2000
- Was Class I AHA/ACC and ECS for AMI with shock but now B in US and C in Europe
3 Major Indications

1. Cardiogenic shock
2. Acute Myocardial Infarction
   – Reduce Infarct Size
     • Increase perfusion
     • Decrease $O_2$ need
3. High Risk PCI
## Comparison: IABP versus control

### Outcome: All-cause 30-day mortality distribution

### Study or subgroup | IABP N | Control N | log [Hazard Ratio] (SE) | Hazard Ratio IV,Random,95% CI | Weight % | Hazard Ratio IV,Random,95% CI
--- | --- | --- | --- | --- | --- | ---
I IABP versus non-IABP
Ohman 2005 | 12 | 10 | -0.28835 (0.63385) | | 3.3 % | 0.75 [0.22, 2.60]
Prondzinsky 2010 | 19 | 21 | 0.43586 (0.60641) | | 3.6 % | 1.55 [0.47, 5.08]
Thiele 2012 | 301 | 299 | -0.0758 (0.12808) | | 80.7 % | 0.93 [0.72, 1.19]
Subtotal (95% CI) | 332 | 330 | | 87.6 % | 0.94 [0.74, 1.20]

Heterogeneity: Tau² = 0.0; Chi² = 0.81, df = 2 (P = 0.67); I² = 0.0%
Test for overall effect: Z = 0.51 (P = 0.61)

2 IABP versus other LVAD
Thiele 2005 | 20 | 21 | 0.08595 (0.47965) | | 5.8 % | 1.09 [0.43, 2.79]
Burkhoff 2006 | 10 | 11 | -0.12869 (0.67585) | | 2.9 % | 0.88 [0.23, 3.31]
Seyfarth 2008 | 13 | 13 | 0.01788 (0.59305) | | 3.8 % | 1.02 [0.32, 3.26]
Subtotal (95% CI) | 43 | 45 | | 12.4 % | 1.02 [0.54, 1.93]

Heterogeneity: Tau² = 0.0; Chi² = 0.07, df = 2 (P = 0.97); I² = 0.0%
Test for overall effect: Z = 0.05 (P = 0.96)

Total (95% CI) | 375 | 375 | | 100.0 % | 0.95 [0.76, 1.19]

Heterogeneity: Tau² = 0.0; Chi² = 0.93, df = 5 (P = 0.97); I² = 0.0%
Test for overall effect: Z = 0.46 (P = 0.64)
Test for subgroup differences: Chi² = 0.05, df = 1 (P = 0.82), I² = 0.0%
Intraaortic Balloon Support for Myocardial Infarction with Cardiogenic Shock

Holger Thiele, M.D., Uwe Zeymer, M.D., Franz-Josef Neumann, M.D., Miroslaw Ferenc, M.D., Hans-Georg Olbrich, M.D., Jörg Hausleiter, M.D., Gert Richardt, M.D., Marcus Hennersdorf, M.D., Klaus Empen, M.D., Georg Fuernau, M.D., Steffen Desch, M.D., Ingo Eitel, M.D., Rainer Hambrecht, M.D., Jörg Fuhrmann, M.D., Michael Böhm, M.D., Henning Ebelt, M.D., Steffen Schneider, Ph.D., Gerhard Schuler, M.D., and Karl Werdan, M.D., for the IABP-SHOCK II Trial Investigators*
30 day mortality

> 90% revascularized with PCI
1 year mortality

p=0.94; log-rank test
Relative risk 1.02, 95% CI 0.88-1.19
<table>
<thead>
<tr>
<th>Baseline Variable</th>
<th>No. of Patients</th>
<th>IABP 30-day mortality (%)</th>
<th>Control 30-day mortality (%)</th>
<th>Relative Risk (95% CI)</th>
<th>P Value for Interaction</th>
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<tbody>
<tr>
<td></td>
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<td>IABP</td>
<td>Control</td>
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<td></td>
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<tr>
<td>Sex</td>
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<td></td>
<td></td>
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<tr>
<td>Female</td>
<td>187</td>
<td>44.4</td>
<td>43.2</td>
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<td>1.03 (0.74–1.43)</td>
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<td>Male</td>
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<td>37.3</td>
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<td>0.92 (0.72–1.18)</td>
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<td>Age</td>
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<tr>
<td>&lt;50 yr</td>
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<td>&gt;75 yr</td>
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<td>53.7</td>
<td>50.0</td>
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<td>1.07 (0.81–1.41)</td>
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<td>Diabetes</td>
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<td>42.9</td>
<td>46.7</td>
<td></td>
<td>0.92 (0.67–1.26)</td>
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<tr>
<td>No</td>
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<td>37.2</td>
<td>38.9</td>
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<td>0.96 (0.74–1.23)</td>
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<td>40.4</td>
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<td>1.06 (0.84–1.34)</td>
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<td>28.9</td>
<td>43.0</td>
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<td>0.67 (0.45–1.01)</td>
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<td>Type of MI</td>
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<td>STEMI/LBBB</td>
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<td>0.96 (0.77–1.21)</td>
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<td>Non-STEMI</td>
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<td>37.5</td>
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<td>STEMI type</td>
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<td>Anterior</td>
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<td>35.4</td>
<td>43.7</td>
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<td>0.81 (0.58–1.13)</td>
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<tr>
<td>Nonanterior</td>
<td>196</td>
<td>48.3</td>
<td>42.2</td>
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<td>1.16 (0.85–1.57)</td>
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<tr>
<td>Previous infarction</td>
<td></td>
<td></td>
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<td>47.9</td>
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<td>1.44 (0.93–2.21)</td>
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<td>No</td>
<td>466</td>
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<td>43.3</td>
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<td>0.86 (0.69–1.07)</td>
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<tr>
<td>Hypothermia</td>
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<tr>
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<td>48.1</td>
<td>44.2</td>
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<td>1.09 (0.82–1.44)</td>
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<tr>
<td>No</td>
<td>372</td>
<td>35.1</td>
<td>39.3</td>
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<td>0.89 (0.68–1.16)</td>
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<tr>
<td>Blood pressure</td>
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<td>&lt;80 mm Hg</td>
<td>161</td>
<td>50.7</td>
<td>46.4</td>
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<td>1.09 (0.79–1.50)</td>
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<tr>
<td>≥80 mm Hg</td>
<td>432</td>
<td>35.9</td>
<td>39.2</td>
<td></td>
<td>0.92 (0.72–1.17)</td>
</tr>
</tbody>
</table>
BUT: Primary end-point: infarct size assessed by MRI

<table>
<thead>
<tr>
<th></th>
<th>IABP</th>
<th>No IABP</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>42.1%</td>
<td>37.5%</td>
<td>0.06</td>
</tr>
</tbody>
</table>

= Bigger infarct!
Mortality by infarct size

Perhaps helped in sicker patients

Crisper sub study Van Nunen EuroIntervention 2015;11:286
Elective Intra-aortic Balloon Counterpulsation During High-Risk Percutaneous Coronary Intervention
A Randomized Controlled Trial

Context
Observational studies have previously reported that elective intra-aortic balloon pump (IABP) insertion may improve outcomes following high-risk percutaneous coronary intervention (PCI). To date, this assertion has not been tested in a randomised controlled trial.

Cumulative Mortality, %

Log-rank $P = .33$

Follow-up, mo
Use in high risk PCI in US
Khera it al Am J Cardiology 2016

• ~ 1,000,000 PCI/year
• 18% considered high risk
  – Mortality risk is 2x higher
  – Previously only IABP but now also other mechanical circulatory support (MCS)

• Used National inpatient sample (NIS) to examine contemporary use of IABP and MCS
IABP and PVAD Use over 8 yr

- Devices per 10,000 PCI
- Years from 2004 to 2012
- Graph showing increasing use of IABP and PVAD over time
Compare IABP with PVAD
How does it work?

- Increase Coronary Blood Flow (CBF)
- Decrease afterload
  - Improve forward flow
  - Decrease myocardial oxygen demand
Approach

1. Theoretical analysis
2. Computer simulation study
3. Systematic review of published hemodynamic changes
4. On-off analysis of acute responses
Theoretical Studies
Blood flow (ml/min/100g)

- Stenosis
  - 50%
  - Reserve
  - "Resting"

Create stenosis

R1
• Normally large reserve in coronaries
• IABP will likely only increase CBF when there is a critical proximal stenosis
• It cannot change flow in an infarcted area (ie after 4-6 hours)
• It cannot overcome the “no-reflow” areas
• It might increase collateral flow
Mod ↑ in SV
Little change in Ppao

Mod ↑ in SV
Large change in Ppao
Modeling Studies
The model – no IABP

- P.A: Pulmonary arterial
- P.V: Pulmonary venous
- L.H: Left heart
- S.A: Systemic arterial
- S.V: Systemic venous
- R.H: Right heart

\[
\frac{dV_{as}(t)}{dt} = \frac{P_{lv}(t) - P_{as}(t)}{R_{as}} \beta_{lv} - \frac{P_{as}(t) - P_{vs}(t)}{R_{cs}} \tag{A1}
\]

\[
P_{as} = \frac{V_{as}}{C_{as}} \tag{A7}
\]

Magder S. et al. (2009), JAP v.106(1)
DURATION OF AUGMENTATION, 1:2 MODE

Arterial systemic, left ventricle and right ventricle pressures with 1:2 IABP

- Arterial pressure
- Left ventricular pressure
- Right ventricular pressure

Pressure (mmHg)

Time (msec) × 10⁴
IABP modeling

Arterial systemic, left ventricle and right ventricle pressures with no IABP

- Arterial pressure
- Left ventricular pressure
- Right ventricular pressure

Arterial systemic, left ventricle and right ventricle pressures with 1:1 IABP

Arterial systemic, left ventricle and right ventricle pressures with 1:2 IABP
Change in contractility (LVes) and balloon timing (1:1 and 1:2)

Message:
Small increase in SV which is larger when LVes is low
  - Less change in SV with 1:2
Change in LVEDP increases with worsening LVes
  - Less effect with 1:2
Systematic review of hemodynamics of IABP

Studied papers that had repeat hemodynamic measurements
**Interpretation:**

- Benefit likely occurs by increasing coronary perfusion when coronaries are stenosed.
- Unlikely to be helpful when coronaries are patent.
Acute Hemodynamic Effects
Hemodynamics with and without IABP

- 27 pt with IABP in place after cardiac surgery
- Average EF 35%
- Baseline Measurement
- Inflation stopped for 2 minutes
- Measurements repeated (no change in therapy)

<table>
<thead>
<tr>
<th>Δ HR</th>
<th>Δ SV</th>
<th>Δ Ppao</th>
<th>Δ Pdiast</th>
</tr>
</thead>
<tbody>
<tr>
<td>NC</td>
<td>-3%</td>
<td>-4%</td>
<td>+6%</td>
</tr>
</tbody>
</table>
Patient on Intra-aortic balloon pump

Which pressure do use to titrate vasopressors?

- Systolic?
- Aug-Diast?
- Mean?

Lower end-diastolic

Lowered by balloon
Patient on Intra-aortic Balloon

1:1

Aug dBP
= 112

1:2

Aug dBP
= 122

“Tangible Benefit”
Number on the monitor is higher and team feels better, but the patient is getting less support for the heart!
Balloon 1:1 (Rupture VSD)
Aug-diast was higher (every 2\textsuperscript{nd}) but ‘v’ wave increased
Summary

• IABP likely is useful when there are tight proximal coronary narrowing
  – It is likely not useful if:
    • there is total occlusion
    • Patency has been restored
    • Past the period of reversibility (<7 hr)

• It likely has little effect of cardiac output
  – Except when CBF is increased

• It likely does not significantly reduce myocardial oxygen need

• It may help reduce LVEDP when it is markedly elevated
  – Eg: use in ruptured VSD or mitral valve with MI
Participating students and residents

- Stephen Yang
- Amjad Al-Rajhi
- Claire-Marine Thirione