Mechanical Circulatory Support in Cardiogenic Shock – What every cardiologist needs to know The Surgeon's view

ACCA Masterclass 2017

R Trimlett (London, UK)
Mechanical Circulatory Support in Cardiogenic Shock – What every cardiologist needs to know The Surgeon's view
## Potential for Cardiac Support

<table>
<thead>
<tr>
<th></th>
<th>TOTAL</th>
<th>DIED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cath Lab</td>
<td>25,011</td>
<td>1,317</td>
</tr>
<tr>
<td>Cardiac Surgery</td>
<td>36,134</td>
<td>990</td>
</tr>
<tr>
<td>Intensive Care</td>
<td>238,248</td>
<td>59,562</td>
</tr>
<tr>
<td>Accident &amp; Emergency</td>
<td>18,142,311</td>
<td>20,358</td>
</tr>
<tr>
<td>Ambulance OOH Arrests</td>
<td>60,000</td>
<td>57,800</td>
</tr>
<tr>
<td>Overall UK Mortality</td>
<td>501,424</td>
<td></td>
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</tbody>
</table>

![Graph showing mortality by location](image-url)
<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>65.1</td>
<td>65.5</td>
<td>65.7</td>
<td>65.7</td>
<td>66.0</td>
<td>66.1</td>
<td>66.2</td>
<td>66.1</td>
<td>66.2</td>
<td>66.0</td>
</tr>
<tr>
<td>Female (%)</td>
<td>19.6</td>
<td>19.8</td>
<td>19.1</td>
<td>19.5</td>
<td>18.8</td>
<td>18.3</td>
<td>18.5</td>
<td>18.9</td>
<td>18.2</td>
<td>17.7</td>
</tr>
<tr>
<td>Emergency or salvage surgery (%)</td>
<td>2.3</td>
<td>2.1</td>
<td>2.2</td>
<td>2.5</td>
<td>1.9</td>
<td>1.8</td>
<td>2.1</td>
<td>2.3</td>
<td>2.2</td>
<td>2.0</td>
</tr>
</tbody>
</table>

![Graphs showing trends in age, female percentage, and emergency or salvage surgery percentage over the years.]
Cardiogenic shock (CS) is the leading cause of death for patients with acute myocardial infarction (MI) who reach the hospital alive. Its incidence has remained constant for 20 years. Rapidly re-establishing infarct-related artery (IRA) blood flow is essential in the management of patients with shock due to right ventricular or left ventricular (LV) failure. A strategy of early revascularization is superior to initial aggressive medical therapy. Despite the advantages of early percutaneous coronary intervention (PCI) or coronary artery bypass graft surgery (CABG), once shock is diagnosed, the mortality rate remains high (~50%) despite intervention, and half of the deaths occur within the first 48 hours.

Cardiogenic Shock Complicating Acute Myocardial Infarction
Expanding the Paradigm
Judith S. Hochman, MD
**Classic Shock Paradigm**

The underlying pathophysiology of CS is profound depression of myocardial contractility, resulting in a vicious spiral of reduced cardiac output (CO), low blood pressure, further coronary insufficiency, and further reduction in contractility and CO. The classic paradigm predicts that compensatory systemic vasoconstriction with high systemic vascular resistance (SVR) should occur in response to the depression of CO (Figure 1).³

Autopsy studies have shown that the pathological basis of CS is extensive MI. Varying pathological stages of infarction confirm the stuttering and progressive nature of the myocardial necrosis as a corollary of the vicious spiral. Combined new and old infarctions consistently involve at least 40% of the LV myocardium in these autopsy specimens.⁴

**Observations That Challenge the Classic Paradigm**

There are several observations derived from the SHOCK (SHould we emergently revascularize Occluded Coronaries in cardiogenic shock?) trial and registry about patients with CS due to LV failure not easily explainable by our traditional concepts. These include the following:

- Average LV ejection fraction (EF) is only moderately severely depressed (30%), with a wide range of EFs and LV sizes noted.
- SVR on vasopressors is not elevated on average, with a very wide range of SVRs measured.
- A clinically evident systemic inflammatory response syndrome is often present in patients with CS.
- Most survivors have class I congestive heart failure (CHF) status.
Clinical research

Predictors of in-hospital mortality in 1333 patients with acute myocardial infarction complicated by cardiogenic shock treated with primary percutaneous coronary intervention (PCI)

Results of the primary PCI registry of the Arbeitsgemeinschaft Leitende Kardiologische Krankenhausärzte (ALKK)\textsuperscript{1}

Uwe Zeymer\textsuperscript{a,}, Albrecht Vogt\textsuperscript{b}, Ralf Zahn\textsuperscript{c}, Michael A. Weber\textsuperscript{c}, Ulrich Tobe\textsuperscript{d}, Martin Gottwik\textsuperscript{e}, Tassilo Bonzel\textsuperscript{f}, Jochen Senges\textsuperscript{f}, Karl-Ludwig Neuhaus\textsuperscript{g}, for the Arbeitsgemeinschaft Leitende Kardiologische Krankenhausärzte (ALKK)

We are the ESC
81 Centres providing at least a working-hours Service.

22 performing less than 400 cases per year.
## Out of Hospital Cardiac Arrest

<table>
<thead>
<tr>
<th></th>
<th>Ventilated before or during</th>
<th>n with data</th>
<th>No Ventilation</th>
<th>n with data</th>
</tr>
</thead>
<tbody>
<tr>
<td>OOHA cases (n)</td>
<td>556</td>
<td></td>
<td>527</td>
<td></td>
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<tr>
<td>Cooling (%)</td>
<td>40.9</td>
<td>479</td>
<td>2.6</td>
<td>421</td>
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<tr>
<td>pH (mean)</td>
<td>7.14</td>
<td>320</td>
<td>7.3</td>
<td>100</td>
</tr>
<tr>
<td>pH (min)</td>
<td>6.0</td>
<td>18.0</td>
<td>7.0</td>
<td></td>
</tr>
<tr>
<td>pH (max)</td>
<td>7.52</td>
<td>9.1</td>
<td>7.6</td>
<td></td>
</tr>
<tr>
<td>Lactate (Mean)</td>
<td>6.7</td>
<td>270</td>
<td>4.1</td>
<td>85</td>
</tr>
<tr>
<td>30 day mortality (%)</td>
<td>47.6</td>
<td>494</td>
<td>6.9</td>
<td>480</td>
</tr>
</tbody>
</table>

= 1,083
Intraaortic Balloon Support for Myocardial Infarction with Cardiogenic Shock

Holger Thiele, M.D., Uwe Zeymer, M.D., Franz-Josef Neumann, M.D., Miroslav Ferenc, M.D., Hans-Georg Dibich, M.D., Jörg Haude, M.D., Gert Richter, M.D., Marcus Hennemund, M.D., Klaus Eppen, M.D., Georg Fuermaier, M.D., Steffen Desch, M.D., Ingo Eitel, M.D., Rainer Hambrecht, M.D., Jörg Fuhrmann, M.D., Michael Blöhm, M.D., Henning Ebelt, M.D., Steffen Schneider, Ph.D., Gerhard Schuler, M.D., and Karl Wendan, M.D., for the IABP-SHOCK II Trial Investigators

RESULTS
A total of 300 patients in the IABP group and 298 in the control group were included in the analysis of the primary end point. At 30 days, 119 patients in the IABP group (39.7%) and 123 patients in the control group (41.3%) had died (relative risk with IABP, 0.96; 95% confidence interval, 0.79 to 1.17; P=0.69). There were no significant differences in secondary end points or in process-of-care measures, including the time to hemodynamic stabilization, the length of stay in the intensive care unit, serum lactate levels, the dose and duration of catecholamine therapy, and renal function. The IABP group and the control group did not differ significantly with respect to the rates of major bleeding (3.3% and 4.4%, respectively; P=0.51), peripheral ischemic complications (4.3% and 3.4%, P=0.53), sepsis (15.7% and 20.5%, P=0.15), and stroke (0.7% and 1.7%, P=0.28).

CONCLUSIONS
The use of intraaortic balloon counterpulsation did not significantly reduce 30-day mortality in patients with cardiogenic shock complicating acute myocardial infarction for whom an early revascularization strategy was planned. (Funded by the German Research Foundation and others; IABP-SHOCK II ClinicalTrials.gov number, NCT00491036.)
Intraaortic Balloon Support for Myocardial Infarction with Cardiogenic Shock

Patients were eligible for the trial if they presented with an acute myocardial infarction (with or without ST-segment elevation) complicated by cardiogenic shock and if early revascularization (by means of PCI or CABG) was planned. A patient was considered to be in cardiogenic shock if he or she had a systolic blood pressure of less than 90 mm Hg for more than 30 minutes or needed infusion of catecholamines to maintain a systolic pressure above 90 mm Hg, had clinical signs of pulmonary congestion, and had impaired end-organ perfusion. The diagnosis of impaired end-organ perfusion required at least one of the following: altered mental status; cold, clammy skin and extremities; oliguria with urine output of less than 30 ml per hour; or serum lactate level higher than 2.0 mmol per liter.

123 patients in the control group (41.3%)
Figure 1. Time-to-Event Curves for the Primary End Point.
Time-to-event curves are shown through 30 days after randomization for the primary end point of all-cause mortality. Event rates represent Kaplan–Meier estimates.
IMPELLA DEVICE

Per-cutaneous / Surgical
2.5L / 5L+
Already anticoagulated.
May cause Haemolysis.
A Randomized Clinical Trial to Evaluate the Safety and Efficacy of a Percutaneous Left Ventricular Assist Device Versus Intra-Aortic Balloon Pumping for Treatment of Cardiogenic Shock Caused by Myocardial Infarction

Melchior Seyfarth, MD,* † Dirk Sibbing, MD,* Iris Bauer, MS,* Georg Fröhlich, MD,† Lorenz Bott-Flügel, MD,† Robert Byrne, MB, MRCPI,* Josef Dirschinger, MD,† Adnan Kastrati, MD,* Albert Schömig, MD †

Munich, Germany
Objectives  The aim of this study was to test whether the left ventricular assist device (LVAD) Impella LP2.5 (Abiomed Europe GmbH, Aachen, Germany) provides superior hemodynamic support compared with the intra-aortic balloon pump (IABP).

Background  Cardiogenic shock caused by left ventricular failure is associated with high mortality in patients with acute myocardial infarction (AMI). An LVAD may help to bridge patients to recovery from left ventricular failure.

Methods  In a prospective, randomized study, 26 patients with cardiogenic shock were studied. The primary end point was the change of the cardiac index (CI) from baseline to 30 min after implantation. Secondary end points included lactic acidosis, hemolysis, and mortality after 30 days.

Results  In 25 patients the allocated device (n = 13 IABP, n = 12 Impella LP2.5) could be safely placed. One patient died before implantation. The CI after 30 min of support was significantly increased in patients with the Impella LP2.5 compared with patients with IABP (Impella: ΔCI = 0.49 ± 0.46 1/min/m²; IABP: ΔCI = 0.11 ± 0.31 1/min/m²; p = 0.02). Overall 30-day mortality was 46% in both groups.

Conclusions  In patients presenting with cardiogenic shock caused by AMI, the use of a percutaneously placed LVAD (Impella LP 2.5) is feasible and safe, and provides superior hemodynamic support compared with standard treatment using an intra-aortic balloon pump. (Efficacy Study of LV Assist Device to Treat Patients With Cardiogenic Shock [ISAR SHOCK]; NCT00417378) (J Am Coll Cardiol 2008;52:1584-8) © 2008 by the American College of Cardiology Foundation
Complex organ dysfunction scores (MODS and SOFA) were used to evaluate overall outcome. Reversal of the hemodynamic derangement resulted in better scores at 30 days in both groups without a significant difference between treatment arms. Explanation for the overall lack of a significant improvement in clinical outcome may be attributable to the protocol used, which left it to the discretion of the physician how long the mechanical device was used, after the primary end point was reached.
Pericutaneous Coronary Intervention for Cardiogenic Shock in the SHOCK Trial

John G. Webb, MD, FACC,* April M. Lowe, MS,† Timothy A. Sanborn, MD, FACC,‡ Harvey D. White, DSc,§ Lynn A. Sleeper, ScD,† Ronald G. Carere, MD, FACC,* Christopher E. Buller, MD, FACC,¶ S. Chiu Wong, MD, FACC,¶ Jean Boland, MD,# Vlad Dzavik, MD,** Mark Porway, MD, FACC,†† Gordon Pate, MB,* Geoffrey Bergman, MD, FACC,¶ Judith S. Hochman, MD, FACC,‡‡ for the SHOCK Investigators

Vancouver and Toronto, Canada; Watertown and Springfield, Massachusetts; Evanston, Illinois; Auckland, New Zealand; New York, New York; and Liege, Belgium
### Table 4. Multivariate Cox Regression Results for One-Year Survival*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter Estimate</th>
<th>Standard Error</th>
<th>Hazard Ratio (95% CI)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>0.077</td>
<td>0.020</td>
<td>2.17 (1.46, 3.22)†</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Systolic blood pressure (mm Hg)‡</td>
<td>−0.025</td>
<td>0.010</td>
<td>0.78 (0.65, 0.94)†</td>
<td>0.009</td>
</tr>
<tr>
<td>Time from randomization to PCI (h)</td>
<td>0.253</td>
<td>0.108</td>
<td>1.29 (1.04, 1.59)</td>
<td>0.019</td>
</tr>
<tr>
<td>Final post-PCI TIMI flow (0/1 vs. 2/3)</td>
<td>2.385</td>
<td>0.614</td>
<td>10.86 (3.26, 36.20)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Multivessel PCI</td>
<td>1.012</td>
<td>0.494</td>
<td>2.75 (1.05, 7.25)</td>
<td>0.040</td>
</tr>
</tbody>
</table>

*Variables with significance p < 0.05 are shown (n = 76). †The hazard ratios and confidence intervals for age and systolic blood pressure are per 10-year or 10 mm Hg increase, respectively. ‡Measured while on support.

CI = confidence interval; PCI = percutaneous coronary intervention; TIMI = Thrombolysis In Myocardial Infarction.
Mitral insufficiency. The SHOCK study excluded enrollment of patients in whom the investigator determined that mitral valve replacement was clinically indicated. Among enrolled patients who had severe mitral regurgitation and underwent PCI alone, the one-year survival rate was a disappointing 33%. Mitral insufficiency is easily missed in shock patients and should be specifically sought with echocardiography or ventriculography before PCI. Although a reduction in mitral insufficiency may occur with PCI, this is unpredictable and infrequent. Severe mitral insufficiency may warrant early surgical correction.
Randomized Ischemic Mitral Evaluation (RIME) Trial

Conclusions

• Compared to CABG alone, addition of MV annuloplasty to CABG in patients with moderate functional ischemic MR improves:
  ▪ Functional capacity and symptoms
  ▪ LV reverse remodelling
  ▪ Mitral regurgitation
  ▪ BNP levels

• The impact of these benefits on longer term clinical outcomes remain to be defined.

• CABG plus MV annuloplasty required longer operation times, increased intubation and hospital stay duration, and blood transfusion.

• Concomitant CABG plus MV annuloplasty should be considered in patients with moderate functional ischemic MR.
Compact CardioHelp VV / VA Portable Device
External Artificial Heart and Lungs

Uses of VA-ECMO

- Cardiogenic shock
- Large myocardial infarction (MI)
- Assistance with CPR using (E-CPR)
- Post-cardiotomy shock

- Bridge to more definitive treatment,
- Bridge to left ventricular assist device (LVAD)
- Bridge to decision

- Cardiomyopathic process
- Fulminant myocarditis
- Sepsis-associated cardiomyopathy

- Pulmonary hypertension
- Pulmonary embolism with right heart failure

- Class IV/stage D heart failure
- Post heart transplantation
CONSIDERATIONS FOR V-A ECMO CANNULATION

- Time / Urgency
- Facilities / Location
- Anatomical Considerations / Physical Size
- Previous or planned Surgery / Vascular Access
CONSIDERATIONS FOR V-A ECMO CANNULATION

ARTERIAL ACCESS

Single Cannula or Multiple Cannulae

Femoral
Subclavian
Aorta
Left Ventricle
Carotid
BODY SURFACE AREA – RULE OF NINES

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PRESSURE OF TIME – TWO QUICKEST STRATEGIES (I)

1. FEMORAL CANNULATION

Ultrasound

Bilateral approach

Percutaneous vs. Open

Sterile Field

Small Cannulae
2. EMERGENCY STERNOTOMY

You will need a saw.

If you have a saw, this is very quick

Bleeding

Sterility

Transport
PRESSURE OF TIME – TWO QUICKEST STRATEGIES (II)

Sternotomy and ‘Clam shell’ incisions both give good emergency access to Heart and Great Vessels.

Clam shell can be done Without a saw.

Need two retractors for Best access.
FEMORAL CANNULATION

X-Ray Guided Approach

0.035” J-wire provided (soft)

Amplatz Super Stiff if prev. femoral op.

Dilate properly and incise skin

Wire can loop down opposite leg

Wire can enter Hepatic or renal veins
FEMORAL VENOUS CANNULATION

CANNULA CHOICE

Size
Multi-stage
Dual Drainage / Ascites
Cannula Positioning
FEMORAL ARTERIAL CANNULATION

CANNULA CHOICE

Size

Distal Perfusion

Side arm vent

Wire re-inforced
ALTERNATIVE FEMORAL ARTERIAL CANNULATION

Division of Inguinal Ligament

10mm Side Graft to External Iliac A.

No Cannula Used

No Distal Perfusion Issues

Simple Decannulation
ALTERNATIVE FEMORAL ARTERIAL CANNULATION

Conventional with Cannulae

Surgical Side Graft
10mm Gelseal
Technique for Cannulation

10mm Graft

3/8” – 3/8” connector

3/8” = 9.56325mm
CONSIDERATIONS FOR V-A ECMO CANNULATION – FACILITIES

Accident and Emergency Resus.

Hybrid Theatre Suite
ALTERNATIVE FEMORAL ARTERIAL CANNULATION
STANDARD CANNULATION SITES IN OPEN CHEST

- Superior vena cava
- Aortic Cannula
- Ascending aorta
- SVC Cannula
- Right coronary artery
- Right atrium
- Right ventricle
- IVC Cannula
- Small cardiac vein
- Inferior vena cava
- Inferior margin
- Arch of aorta
- Pulmonary trunk
- Left auricle
- Anterior interventricular branch of left coronary artery
- Great cardiac vein
- Anterior interventricular groove
- Left ventricle
- Obtuse margin
- Apex
OPEN-CHEST SITUATIONS

In an Emergency pipes can be held in place.

Minimizes retrograde Aortic flow.
OPEN-CHEST SITUATIONS

Often, in complex Aortic cases, the whole Aortic is replaced by a woven Dacron tube.

Haemostasis is a major challenge.

Kinking of grafts is an issue.
Aortic Pulse Amplification

As mean pressure falls along the aorta, the pressure wave is delayed and the pulse amplitude raised.
Aortic Compliance

Figure 6.13. Standard Windkessel model of the aorta and major arteries. Flow enters chamber through one-way valve on the left faster than it can leave through the exit on the right, raising the pressure and distending the elastic wall to position shown by dashed line. When inflow stops, valve closes and fluid leaves the chamber through the narrow resistance (R) on the right.

\[
\frac{1}{RC} = \frac{dP}{PdV} \cdot \frac{dV}{dt}
\]  

(6.18)

Integration of equation 6.18 with respect to time shows that pressure in the chamber declines exponentially from its initial value, \(P_0\), during the period of outflow:

\[
P(t) = P_0 \exp \left[ -t \frac{1}{RC} \right]
\]  

(6.19)
THE IMPORTANCE OF LOW SHEAR STRESSES

Haemolysis

? CVA

Lower Pump RPM

Less ‘Jet Wash’ of Aorta
AVOIDING FLOW-LIMITING CANNULAE WITH GELSEAL GRAFTS

No need to remove when weaning off ECMO

Close with Stapler and leave a small stump.
VA-ECMO IN THE PRESENCE OF AORTIC REGURGITATION

Relative Contraindication

Ignore.

Balloon Pump.

LV Vent.

Change Valve (AVR).

TAVI.

Impella Device.
IMPELLA DEVICE
Rapid Expansion in Cardiac ECMO (UK)
## Overall Outcomes

<table>
<thead>
<tr>
<th></th>
<th>Total Runs</th>
<th>Survived ECLS</th>
<th>Survived to DC or Transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiac</td>
<td>10,982</td>
<td>6,251</td>
<td>56%</td>
</tr>
<tr>
<td>ECPR</td>
<td>3,485</td>
<td>1,382</td>
<td>39%</td>
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<tr>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>4,466</td>
<td>993</td>
<td>40%</td>
</tr>
<tr>
<td></td>
<td>28%</td>
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</table>
A Systematic Research and Meta-analysis

patients with a diagnosis of ACS treated with extracorporeal circulatory support

Results: A total of 913 patients were included in the meta-analysis (mean age 59.1±1.06, 77% male). The event rate of short-term mortality was 62% (95% CI, 60.8-63.4), 6 months mortality was affecting 24% (95% CI, 21.4-26.8%) of patients and 1-year mortality 17% (95% CI, 14.8-19.8%). The event rates of ECS-related complications were: acute renal failure 11%, bleeding 21%, neurologic damage in survivors 20%, sepsis/infections 17% and leg ischemia 10%. Between causes of death, multi-organ failure and brain death affected respectively 14% and 17% of patients. Bridge to ventricular assistance device was offered to 14% of patients treated with ECS and 16% received a transplant.

913 Patients, short term mortality 62%
347 Patients, 6-month mortality 24%
264 Patients, 1-year mortality 17%
219 Patients alive at 1 year = 76% mortality
Percentage Survival to Discharge of Patients placed on VA ECMO patients stratified by Indication.

Acute Cardiac Diagnoses.
Post-cardiotomy.
Acute Decompensation of Chronic Heart Failure.
“Other”
ANNUAL REPORT ON CARDIOTHORACIC TRANSPLANTATION

REPORT FOR 2015/2016
(1 APRIL 2006 – 31 MARCH 2016)

PUBLISHED JULY 2016

PRODUCED IN COLLABORATION WITH NHS ENGLAND
Adult patients on the heart transplant list at 31 March each year for the last 10 years, by year

Number of registrations

72 74 76 103 104 142 165 200 213 188

Active - Non-urgent  Active - Urgent  Suspended

0 50 100 150 200 250

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Post-registration outcome for 147 first non-urgent heart only registrations made in the UK, 1 April 2012 to 31 March 2013