ECMO and Percutaneous LVAD in the ICU 2015

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Associate Dean of International Medicine
University of Miami Miller School of Medicine
Potential conflict of Interest

• Support for Educational Conferences
  – Most Cardiovascular Corporations
• Current Sponsored Research Support –
  – Medtronic
    CoreValve Trials, Simplicity trials
• Other Conflicts:
  1. Tendyne Medical Inc.
     • Medical Director and stock holder
  2. Intergene International LLC - Medical Advisory Board
  3. Aegis Medical – Medical Advisory Board
  4. St. George Medical – consultant
Percutaneous assist devices in cardiogenic shock.

A  IABP  

B  Impella  

C  TandemHeart  

D  ECMO  

Werdan K et al. Eur Heart J 2014;35:156-167
# Mechanical circulatory support in cardiogenic shock

## Table 2
Comparison of devices

<table>
<thead>
<tr>
<th></th>
<th>IABP</th>
<th>ECMO</th>
<th>TandemHeart</th>
<th>Impella 2.5</th>
<th>Impella 5.0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pump mechanism</strong></td>
<td>Pneumatic</td>
<td>Centrifugal</td>
<td>Centrifugal</td>
<td>Axial flow</td>
<td>Axial flow</td>
</tr>
<tr>
<td><strong>Cannula size</strong></td>
<td>7.9 Fr</td>
<td>18–21 Fr inflow; 15–22 Fr outflow</td>
<td>21 Fr inflow; 15–17 Fr outflow</td>
<td>13 Fr</td>
<td>22 Fr</td>
</tr>
<tr>
<td><strong>Insertion technique</strong></td>
<td>Descending aorta via the femoral artery</td>
<td>Inflow cannula into the right atrium via the femoral vein, outflow cannula into the descending aorta via the femoral artery</td>
<td>21 Fr inflow cannula into left atrium via femoral vein and transseptal puncture and 15–17 Fr outflow cannula into the femoral artery</td>
<td>12 Fr catheter placed retrogradely across the aortic valve via the femoral artery</td>
<td>21 Fr catheter placed retrogradely across the aortic valve via a surgical cutdown of the femoral artery</td>
</tr>
<tr>
<td><strong>Haemodynamic support</strong></td>
<td>0.5 – 1.0 L min⁻¹</td>
<td>&gt;4.5 L min⁻¹</td>
<td>4 L min⁻¹</td>
<td>2.5 L min⁻¹</td>
<td>5.0 L min⁻¹</td>
</tr>
<tr>
<td><strong>Implantation time</strong></td>
<td>+</td>
<td>++</td>
<td>+++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td><strong>Risk of limb ischaemia</strong></td>
<td>+</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td><strong>Anticoagulation</strong></td>
<td>+</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><strong>Haemolysis</strong></td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td><strong>Post-implantation management complexity</strong></td>
<td>+</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td><strong>Optional active cooling in post-cardiopulmonary resuscitation patients</strong></td>
<td>No</td>
<td>Yes</td>
<td>(Yes)</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

ECMO, extracorporeal membrane oxygenation; IABP, intra-aortic balloon pump; +, ++, ++++, ++++, relative qualitative grading concerning time (‘implantation time’), risk (‘risk of limb ischaemia’), intensity (‘anticoagulation’, ‘post-implantation management complexity’), and severity (‘haemolysis’). Modified from Ouweneel and Henriques.³²
ECMO History

• 1953- First successful CPB procedure by Dr. Gibbon
• 1956- Clowes & Balser developed first membrane oxygenator
• 1972- First successful adult ECMO.
• 1976- First successful neonatal ECMO.
• 1989- Establishment of ELSO organization.
Gibbon heart-lung machine Model II. Reprinted with permission from reference 5.
First Successful ECMO Patient
ECMO Concepts

• Blood is circulated outside the body by a mechanical pump

• Outside the body, the blood passes through an oxygenator and heat exchanger.

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ECMO Components

- ECMO pumps: roller (afterload independent) and centrifugal (fewer gaseous microemboli, preload and afterload dependent.)
- Membrane oxygenators mimic the human lung by interspersing a thin membrane of either microporous polypropylene hollow fibre or non-microporous silicone rubber between the gas and blood
- Heat exchanger to minimize bubble emboli.
- Drainage cannula (21F to 28F) and return cannula (15F to 21F)
- Polyvinyl tubing

ECMO Improvements

- Devices are more durable
- Longer lasting components
- Improved bio-compatibility
- Less hemolysis
- Decreased pressure drop
- Leave blood activation / coagulation cascade intact
- Smaller design
- Less foreign surface area
- Less hemodilution
ECLS Registry Report
January 2014
Figure 3 Femoral Venoarterial ECMO When extracorporeal membrane oxygenation (ECMO) is implemented via femoral venous drainage and femoral arterial return in patients with residual native cardiac function and impaired lung function, reinfused oxygenated bl...

Darryl Abrams, Alain Combes, Daniel Brodie

**Extracorporeal Membrane Oxygenation in Cardiopulmonary Disease in Adults**


http://dx.doi.org/10.1016/j.jacc.2014.03.046
An alternative approach to femoral venoarterial extracorporeal membrane oxygenation (ECMO) is drainage from the internal jugular vein and reinfusion into t...
VA ECMO

- Femoral access is preferred because of ease but with increased risk of ipsilateral ischemia
- Risk of ipsilateral ischemia can be decreased by inserting an additional arterial cannula distal to the femoral artery cannula
- Right common carotid artery or Axillary/Subclavian artery can be used if femoral access is contraindicated (PVD)
- Increased risk of watershed cerebral infarction
- Use of the subclavian artery offers the advantage of allowing patients on ECMO to ambulate

VA ECMO (Respiratory and Hemodynamic)

- **Central:**
  - Drained (venous) – Right Atrium
  - Returned (arterial) – Left Atrium or Proximal Aorta

- **Peripheral:**
  - Drained (venous) - Femoral or Jugular Vein
  - Returned (arterial) – Femoral, Carotid or Axillary, Subclavian

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Figure 2 Single-Site Venovenous Extracorporeal Membrane Oxygenation A dual-lumen cannula in the internal jugular vein permits both venous drainage and reinfusion without the need for femoral cannulation. (Inset) Deoxygenated blood is withdrawn through p...

Darryl Abrams, Alain Combes, Daniel Brodie

**Extracorporeal Membrane Oxygenation in Cardiopulmonary Disease in Adults**


http://dx.doi.org/10.1016/j.jacc.2014.03.046
Figure 1 Two-Site Venovenous Extracorporeal Membrane Oxygenation Venous blood is withdrawn from a central vein, pumped through an oxygenator, and reinfused into a central vein. (Inset) Drainage and reinfusion ports in close proximity may lead to oxygena...

Darryl Abrams, Alain Combes, Daniel Brodie

**Extracorporeal Membrane Oxygenation in Cardiopulmonary Disease in Adults**


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VV ECMO (Respiratory Support)

• Cannulae are usually placed in the right common femoral vein (for drainage) and right internal jugular vein (for infusion).

• Provides respiratory support
### Indications and Highest Level of Evidence for ECMO in Cardiopulmonary Disease

<table>
<thead>
<tr>
<th>Indication</th>
<th>Study Type</th>
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<tr>
<td><strong>Respiratory</strong></td>
<td></td>
</tr>
<tr>
<td>ARDS</td>
<td>Randomized controlled trials</td>
</tr>
<tr>
<td>Hypercapnic respiratory failure</td>
<td>Prospective feasibility studies</td>
</tr>
<tr>
<td>Bridge to lung transplantation</td>
<td>Cohort studies</td>
</tr>
<tr>
<td>Primary graft dysfunction after lung transplantation</td>
<td>Cohort studies</td>
</tr>
<tr>
<td><strong>Cardiac</strong></td>
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<td>Cohort studies</td>
</tr>
<tr>
<td>Fulminant myocarditis</td>
<td>Cohort studies</td>
</tr>
<tr>
<td>Sepsis-associated cardiomyopathy</td>
<td>Case series</td>
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<tr>
<td>Pulmonary hypertension</td>
<td>Case series</td>
</tr>
<tr>
<td>Extracorporeal cardiopulmonary resuscitation</td>
<td>Cohort studies with propensity analyses</td>
</tr>
<tr>
<td>Post-cardiotomy cardiogenic shock</td>
<td>Cohort studies</td>
</tr>
<tr>
<td>Primary graft failure after heart transplantation</td>
<td>Cohort studies</td>
</tr>
<tr>
<td>Bridge to VAD implantation or heart transplantation</td>
<td>Cohort studies</td>
</tr>
<tr>
<td>Prevention of acute right ventricular failure after LVAD implantation</td>
<td>Cohort studies</td>
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ARDS = acute respiratory distress syndrome; ECMO = extracorporeal membrane oxygenation; LVAD = left ventricular assist device; VAD = ventricular assist device.
Potential ECMO Benefits in Cardiogenic Shock & Cardiac Arrest

- Easy to implement
- Fast cannulation / initiation of support
- Can be performed at beside, cath lab or O.R.
  - Biventricular support at high blood flow rates
- Potential to support patients with lung injury as well
- Hemofiltration can be added
- Avoid more expensive implantable device insertions in non-qualified candidates

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# ECMO Cardiac Indications & Outcomes

## Table 1 Indications for ECMO in cardiac failure

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<th>Indication for ECMO</th>
<th>Highest quality studies available</th>
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<td>Sepsis-associated cardiomyopathy</td>
<td>Case series</td>
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<tr>
<td>Decompensated pulmonary hypertension with right ventricular failure</td>
<td>Case series</td>
</tr>
<tr>
<td>Bridge to VAD or heart transplantation</td>
<td>Cohort studies</td>
</tr>
<tr>
<td>Right ventricular support during LVAD implantation in biventricular failure</td>
<td>Cohort studies</td>
</tr>
<tr>
<td>Pulmonary embolism with refractory shock</td>
<td>Case series</td>
</tr>
<tr>
<td>Post-cardiotomy cardiogenic shock</td>
<td>Cohort studies</td>
</tr>
<tr>
<td>Primary graft failure post-heart transplantation</td>
<td>Cohort studies</td>
</tr>
<tr>
<td>Cardiac arrest (ECPR)</td>
<td>Cohort studies with propensity analyses</td>
</tr>
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*VAD* ventricular assist device, *LVAD* left ventricular assist device, *ECPR* extracorporeal cardiopulmonary resuscitation

Fulminant Myocarditis

- 2001 to 2006, 11 pts w/fulminant myocarditis
- 5 BiVAD/6 ECMO
- 21 +/- 5 days on BiVAD vs 13 +/- 4 days in ECMO.
- 1 patient died in each group
- No transplantation
- Quicker recovery of renal and hepatic function on ECMO

Sepsis-associated Cardiomyopathy

- 1/08 – 9/11
- 14 patients, (28-66 yrs)
- No hx of CMP
- ECMO for septic shock refractory to conventional treatment w/severe myocardial dysfunction & multi-organ failure
- LVEF 16% (10% to 30%), CI 1.3 L/min/m (0.7-2.2)
- SVRI was 3162 (2047-7685)
- 10 patients (71%) were discharged to home and alive after 13 months (3-43).
- All 10 survivors w/normal LVEF

Massive Pulmonary Embolism

- 1/92 – 12/05
- 43 patients were referred for ECLS for presumed massive PE
- 7 felt clinically stable and all survived to discharge
- 15 excluded all died: prolonged CPR (5), irreversible injury (4), age > 70 yrs (3), wt > air transportation limit (3) & prolonged intubation (3).
- 21 pts placed on ECLS (2 V-V, 19 V-A), 8 w/cardiac arrest
- 13 of 21 pts (62%) survived and were doing well 1 year from hospital discharge.

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Overall Outcomes

<table>
<thead>
<tr>
<th></th>
<th>Total Patients</th>
<th>Survived ECLS</th>
<th>Survived to DC or Transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Neonatal</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory</td>
<td>27,007</td>
<td>22,782</td>
<td>20,093 74%</td>
</tr>
<tr>
<td>Cardiac</td>
<td>5,425</td>
<td>3,339 62%</td>
<td>2,206 41%</td>
</tr>
<tr>
<td>ECPR</td>
<td>980</td>
<td>626 64%</td>
<td>388 40%</td>
</tr>
<tr>
<td><strong>Pediatric</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory</td>
<td>6,149</td>
<td>4,034 66%</td>
<td>3,496 57%</td>
</tr>
<tr>
<td>Cardiac</td>
<td>6,784</td>
<td>4,443 65%</td>
<td>3,388 50%</td>
</tr>
<tr>
<td>ECPR</td>
<td>2,071</td>
<td>1,123 54%</td>
<td>840 41%</td>
</tr>
<tr>
<td><strong>Adult</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory</td>
<td>5,146</td>
<td>3,317 64%</td>
<td>2,905 56%</td>
</tr>
<tr>
<td>Cardiac</td>
<td>4,042</td>
<td>2,255 56%</td>
<td>1,636 40%</td>
</tr>
<tr>
<td>ECPR</td>
<td>1,238</td>
<td>476 38%</td>
<td>355 29%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>58,842</td>
<td>42,395 72%</td>
<td>35,307 60%</td>
</tr>
</tbody>
</table>

Centers

Centers by Year

![Graph showing the number of centers by year with data from 1990 to 2013. The number of centers increases from 83 in 1990 to 223 in 2013. The graph shows a steady increase in the number of centers over the years.]
ECMO Titration VenoVenous

- Oxygenation is determined by flow rate
- Elimination of CO2 can be controlled by adjusting the rate of countercurrent gas flow through the oxygenator

Respiratory Management

Ventilator settings are reduced during ECMO in order to avoid barotrauma, volutrauma and oxygen toxicity.
Plateau airway pressures should be maintained less than 20 cm H2O and FiO2 less than 0.5.
Reduction of ventilator support is usually accompanied by increased venous return and cardiac output

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Figure 5 ECMO in the Ambulatory Patient Upper-body configurations and compact circuits facilitate mobilization in patients with respiratory failure requiring extracorporeal membrane oxygenation (ECMO).

Darryl Abrams, Alain Combes, Daniel Brodie

**Extracorporeal Membrane Oxygenation in Cardiopulmonary Disease in Adults**

ECMO Titration; VA ECMO

• Arterial oxyhemoglobin saturation of >90 percent for VA ECMO
• Venous oxyhemoglobin saturation of 70 to 80 percent for VA ECMO, measured on the venous line
• Adequate tissue perfusion, as determined by the arterial blood pressure, venous oxygen saturation, and blood lactate level
VA ECMO Hemodynamic Management

• Flow rate must be high enough to provide adequate perfusion pressure and VO2 but low enough to provide sufficient preload to maintain left ventricular output.
• Aggressive diuresis is usually warranted once the patient is stable on ECMO
• Left ventricular output must be monitored by frequent echo and pulsatility
• Minimize inotropes to rest heart
• Low dose inotrope to ensure some contractility and adequate emptying of the left ventricle
VA ECMO Hemodynamic Management

- LV output may worsen in the setting of insufficient unloading of the distended left ventricle
- Can lead to increased cavity pressure, pHTN, pulmonary vascular injury & ARDS
- IABP can be added to central ECMO to increase pulsatility, improve coronary perfusion, and decrease the ventricular afterload. (Doll et al showed higher survival)
- Percutaneous atrial septostomy but does not improve stasis and req repair
- Impella can be used with peripheral ECMO to facilitate LV unloading and prevent stasis


Weaning

• Enhanced aortic pulsatility correlates with improved left ventricular function
• VA ECMO trials are generally short because of the higher risk of thrombus formation.
Weaning

• Increased heparin given potential stasis/thrombosis at low ECMO flows
• Echo to assess cardiac recovery
• Modest inotropic support initiated several hours prior to weaning.
• Flows are slowly reduced to 1–2 L/min with decannulation if stable after 1–2 h

ECMO Complications

• Bleeding
• Hemorrhage into body cavities
• Systemic thromboembolism due to thrombus formation within the ECMO circuit
• Hemolysis
• Cannulation-related issues
• Distal ischemia
• HIT
• Renal Injury
VA ECMO Complications

- Pulmonary hemorrhage
- Cardiac thrombosis

I. retrograde blood flow in the ascending aorta and stasis can occur if LV output is not maintained

- Coronary or cerebral hypoxia –
  I. Blood infused into the femoral artery from the ECMO circuit will preferentially perfuse the lower extremities and the abdominal viscera
  II. Blood from the heart will selectively perfuse the heart, brain, and upper extremities.
  III. The O2 saturation of the blood perfusing the lower extremities and abdominal viscera may be substantially higher than that perfusing the heart, brain, and upper extremities.
  IV. Can be unrecognized unless O2 sat is monitored in upper extremity
Meta-Analyses of ECMO Complications

- 27 studies & 1866 pts
- Studies w/> 10pts and > yr 2000
- Cumulative survival 534/1529 pts
- Significant associated morbidity
- Difficult to separate complications from underlying disease and ECMO (Renal failure)

ELSO Indications

• Acute severe heart or lung failure with high mortality risk despite optimal conventional therapy

• ECLS is considered at 50% mortality risk, ECLS is indicated in most circumstances at 80% mortality risk.
Ethical Considerations

• “Bridge to Nowhere” - Unable to be bridged to recovery, transplant or destination device
• Introducing the “Bridge to Nowhere” upfront
• Is their DNR on ECMO (capping ECMO)
• Prolonging Death with ECPR
• Use of resource intensive technology in the absence of data that establishes a clear benefit

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ELSO Contraindications

• Absolute: Unrecoverable heart and not a candidate for a transplant or VAD

• Relative: Anticoagulation contraindicated, Advanced age, obesity
Conclusion

• ECMO has an evolving role in acute cardiac failure and cardiac arrest with significant life saving potential

• Questions remain about optimal patient populations and clinical scenarios

• Larger randomized controlled trials are needed to best understand the appropriate role of ECMO for its various potential indications
Percutaneous LVAD for High Risk Angioplasty

Why use support?
Historical Perspectives
Percutaneous LV support

ECMO  IABP  CPS  Hemopump  TandemHeart  Impella

70’s  80’s  90’s  00’s
## Comparison of Support Devices

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<tr>
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<tbody>
<tr>
<td>Catheter Size</td>
<td>7.5-9.0</td>
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<td>8.5-10</td>
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<td>12</td>
</tr>
<tr>
<td># Insertion Sites</td>
<td>1</td>
<td>≥2</td>
<td>≥2</td>
<td>1</td>
</tr>
<tr>
<td>Anticoagulation</td>
<td>+</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Transeptal</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Limb ischemia</td>
<td>+</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Priming volume</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Unloads LV</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Requires stable rhythm</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Improves hemodynamics</td>
<td>+</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
</tr>
</tbody>
</table>
IABP Support

PROs:
• Mature technology
• Increases modestly Cardiac Output
• Increases Coronary Perfusion
• Ease of Use
• Low Complication rate?

CONs:
• Does not unload the heart
• Require some cardiac power
• Require a stable rhythm
• No proven benefit on mortality
Unstable angina 6 months after Coronary artery bypass

• 52 Y/O woman, nurse
• Had familial hypercholesterolemia
• Had 2 vessel CABG for LM stenosis
• Admitted with sudden onset of Unstable angina 6 months after surgery
Cardiac Assist TandemHeart

- Access to LA via standard transseptal technique
- Left atrial to Femoral Artery assist at 4-5 l/min
Cardiac Assist TandemHeart

Controller

Pump

Cannula
TandemHeart PTVA® System Arterial Cannula

- Approved indication: Extracorporeal circulatory support for up to 6 hrs.
- Medtronic Bio-Medicus arterial cannula, percutaneous access (15-17F)
- Flow 4-5 l/min
Tandem Heart LVAD Support for Unprotected Complex Left Main Intervention

- 57 year old man with low HDL, hypertension
- Inferior MI 13 years ago; RCA occluded since then
- Abnormal stress test led to cath 3 years ago: 100% RCA, 70% distal LM.
- CABG 3 years ago (LIMA-LAD; veins to RI and CM).
- Now has a strongly positive stress test, global ischemia.
- Cath: Vein grafts occluded. LIMA non-functioning. 100% native RCA; 70-80% distal LM.
- Heavy Ca++

- Left main intervention with percutaneous LVAD support.
TandemHeart RVAD Applications
Patients Requiring Prophylactic Hemodynamic Support During Non-Emergent High Risk PCI on Unprotected LM/Last Patent Conduit and LVEF≤35% OR 3 Vessel Disease and LVEF≤30%

Primary Endpoint = 30-day Composite MAE* rate

Follow-up of the Composite MAE* rate at 90 days

*Major Adverse Events (MAE): Death, Stroke/TIA, MI (>3xULN CK-MB or Troponin), Repeat Revascularization, Cardiac or Vascular Operation of Vasc. Operation for limb ischemia, Acute Renal Dysfunction, Increase in Aortic insufficiency, Severe Hypotension, CPR/VT, Angio Failure
**PROTECT II Study Flow**

**Assessed for Eligibility**
- **N=1082**

**Randomized Intent-to-Treat**
- **N=447**

**Intent-To-Treat (ITT) population**
- **N=447**
  - IABP: **N=223**
    - 90day F/U, N=220
  - IMPELLA: **N=224**
    - 90day F/U, N=222

**Per Protocol (PP) population**
- **N=426**
  - IABP: **30day N=211**
    - 90day F/U, N=210
  - IMPELLA: **30day N=215**
    - 90day F/U, N=213

**Not Eligible:**
- **N=635**
  - 47.8% Met Exclusion criteria
  - 30% Patient refusal, MD decision
  - 13% Unknown
  - 9.2% Referred for CABG

**Per Protocol population**
- Patients that met all inclusion and exclusion criteria.

*Per Protocol population was pre-specified and patients were identified prospectively prior to the statistical analysis.*
PROTECT II MAE Outcome

Intent to Treat (N=447)

Per Protocol (N=426)

MAE = Major Adverse Event Rate

Per Protocol = Patients that met all incl./excl. criteria.
PROTECT II MAE Outcome
Pre-specified High Risk PCI Without Atherectomy Group

Per Protocol (N=374)

30 day MAE

N=191

42.4%

30% MAE

N=183

29.5%

90 day MAE

N=190

51.1%

↓ 30% MAE

N=181

35.9%

Per Protocol= Patients that met all incl./ excl. criteria.

Log rank test, p=0.005

IMPELLA

IABP

Major Adverse Events Rate (%)
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<td>+++</td>
<td>+</td>
</tr>
<tr>
<td><strong>Transeptal</strong></td>
<td>No</td>
<td>No</td>
<td>Yes</td>
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</tr>
<tr>
<td><strong>Limb ischemia</strong></td>
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<tr>
<td><strong>Priming volume</strong></td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td><strong>Unloads LV</strong></td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Requires stable rhythm</strong></td>
<td>Yes</td>
<td>No</td>
<td>No</td>
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<tr>
<td><strong>Improves hemodynamics</strong></td>
<td>+</td>
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Cases Courtesy of Alan Heldman FACC, University of Miami Miller School of Medicine
Thank you