Mechanical Circulatory Support Devices

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  • Research focus: ECMO
Disclosures

• I have no financial disclosures
Objectives

• To provide an overview of the wide array of percutaneous mechanical circulatory support devices available to treat acute cardiogenic shock

• Understand the contraindications and complications of each mechanical circulatory support device
Cardiogenic shock

• End organ dysfunction due to inadequate cardiac output secondary to right, left, or biventricular dysfunction.
Classification

Stage E “Extremis”. A patient with circulatory collapse, frequently (but not always) in refractory cardiac arrest with ongoing cardiopulmonary resuscitation (CPR) or are being supported by multiple simultaneous acute interventions including ECMO-facilitated CPR. These are patients with multiple clinicians at bedside laboring to address multiple simultaneous issues related to the lack of clinical stability of the patient.

Stage D “Deteriorating or Doom”. A patient that is similar to category C but is getting worse. They have failure to respond to initial interventions.

Stage C “Classic” Cardiogenic Shock. A patient that manifests with hypoperfusion that requires intervention (inotrope, pressor or mechanical support, ECMO) beyond volume resuscitation to restore perfusion. These patients typically present with relative hypotension.

Stage B “Beginning” Cardiogenic Shock. A patient who has clinical evidence of relative hypotension or tachycardia without hypoperfusion.

Stage A “At Risk”. A patient who is not currently experiencing signs or symptoms of cardiogenic shock, but is at risk for its development. These patients may include those with acute myocardial infarction, acute and/or acute on chronic heart failure symptoms.
Etiologies

- AMI without mechanical complications complicated by CS
- Acute or acute-on-chronic LV or biventricular failure complicated by CS
- Peripartum cardiomyopathy
- Takotsubo/stress-induced cardiomyopathy
- Cardiac allograft failure/rejection
- Acute myocarditis

- Post-cardiotomy
- Hypertrophic cardiomyopathy with severe outflow tract obstruction
- Acute RV failure complicated by CS
- Post-LVAD implantation
- Post-transplantation
- Pulmonary embolism
- Refractory arrhythmias
- Extracorporeal cardiopulmonary resuscitation (eCPR)
Shock Team

- Multidisciplinary, collaborative team that considers issues specific to cardiogenic shock, including selection, implantation, and management of mechanical circulatory support (MCS) devices.
Temporal trends of MCS use

Contemporary trends in use of mechanical circulatory support in patients with acute MI and cardiogenic shock

Use of MCS in AMICS
What is the evidence?

There is little evidence from RCT’s that support the benefit of MCS in patients with cardiogenic shock.
Purpose of temporary MCS

• To restore systemic perfusion to maintain end-organ function and patient viability

• **Bridge** patient to reach end destination
  • Recovery
  • Transplant
  • Durable VAD
  • Decision
Temporary mechanical circulatory support

- ECMO
- TandemHeart
- RV assist devices
- Intra-Aortic Balloon Pump
- Impella 2.5, CP, 5.0
IABP

• Placed percutaneously via the femoral artery, balloon position in descending aorta.
• It uses counterc pulsation - **inflation of balloon during diastole and active deflation of balloon in systole.**
  • Inflation causes blood to be displaced into the proximal aorta during diastole.
  • Afterload is reduced during systole through rapid balloon deflation (vacuum effect)
• Increases coronary artery blood flow
• Reduces LV afterload
• Decreases myocardial oxygen demand and increases myocardial oxygen supply
• Relatively modest increase in cardiac output
<table>
<thead>
<tr>
<th>Contraindications</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Significant aortic regurgitation</td>
<td>• Limb ischemia</td>
</tr>
<tr>
<td>• Aortic dissection</td>
<td>• Major bleeding</td>
</tr>
<tr>
<td>• Severe PAD</td>
<td>• Other ischemia</td>
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<tr>
<td>• Uncontrolled bleeding</td>
<td>• Spinal cord</td>
</tr>
<tr>
<td>• Septic shock</td>
<td>• Renal</td>
</tr>
<tr>
<td></td>
<td>• Mesenteric</td>
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<tr>
<td></td>
<td>• Stroke</td>
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</tbody>
</table>
• The IABP-SHOCK II

• Primary outcome: 30-day mortality
  • 39.7% in the IABP group vs. 41.3% in the optimal medical therapy group
  • Relative risk [RR], 0.96; 95% CI, 0.79–1.17; \( P=0.69 \)

• No difference in:
  • Time to hemodynamic stabilization
  • ICU LOS
  • Adverse events (eg, bleeding, stroke, peripheral ischemic complications requiring intervention, or infection).
Impella

• Catheter based axial flow pump that is placed percutaneously via femoral artery or surgically via axillary artery.

• Inflow is positioned retrograde across aortic valve in the left ventricle.

• The axial flow pump draws blood from left ventricle and ejects into aorta

• Directly delivers blood to the aorta

• Decreases left ventricular size, pressure, and wall tension

• Decreases oxygen consumption

Contraindications

• LV thrombus
• Mechanical aortic valve
• Severe peripheral arterial disease
• Ventricular septal defect

Complications

• Device migration
• Device malfunction due to thrombosis
• Hemolysis
• Bleeding requiring transfusion
• Arrhythmias
• Limb ischemia
• Tamponade
• Aortic or mitral valve injury
• Stroke
Evidence

• ISAR-SHOCK
  • 25 patients with cardiogenic shock randomly assigned to Impella 2.5 or IABP
  • Increase in cardiac index after 30 min support
  • 30-day mortality similar
  • More hemolysis and transfusion in impella group

• IMPRESS trial
  • 48 patients with severe cardiogenic shock complicating AMI randomly assigned to receive either an Impella CP or an IABP.
  • 30-day mortality and 6-month mortality
  • More bleeding events occurred in the Impella group.
TandemHeart

- Percutaneous device with continuous flow centrifugal.
- Inflow cannula placed into left atrium (LA) via femoral vein and then transseptal puncture.
- Outflow cannula placed in ilio/femoral artery
- Blood is withdrawn from the LA and then returned in a retrograde fashion to the aorta via the femoral artery

Hemodynamics

• Increases cardiac output and mean arterial pressure and
• Decreases cardiac filling pressure by venting the left atrium
• Increases LV afterload from retrograde blood flow up the aorta
Contraindications

- Severe peripheral arterial disease
- Severe bleeding inability to tolerate anticoagulation
- Severe RV failure

Complications

- Device malfunction due to thrombosis
- Hemolysis
- Bleeding requiring transfusion
- Limb ischemia
- Cardiac tamponade
- Stroke
Peripheral VA-ECMO

- Centrifugal pump
- Drainage cannula in IVC via femoral vein
- Return cannula in femoral artery
- Deoxygenated blood is drained from RA/IVC and returned in a retrograde fashion via the femoral artery
- Bypasses heart and lungs to give partial support for both
Hemodynamics

- Unloads RV, by draining blood from systemic venous system
- Provides systemic perfusion with increase in MAP
- Retrograde flow up aorta increases left ventricular afterload
  - Can prevent left ventricular ejection -> leading to stasis and thrombosis within the cardiac chambers
  - Increased left ventricular end-diastolic pressure -> pulmonary edema
Increased afterload for the failing LV

Backup of pressure to LA

Stasis in LV
Poor ejection blood, loss pulsatility

Retrograde flow in the return cannula
Impella™ provides anterograde flow and offloads the LV, decreasing EDP.

Illustration by Christian Grant
Contraindications

• Significant baseline comorbidities (end stage cardiopulmonary disease and not a transplant or VAD candidate, ESRD, ESLD)
• Aortic dissection
• Severe aortic regurgitation
• Unwitnessed or prolonged cardiac arrest
• Severe bleeding inability to tolerate anticoagulation

Complications

• Bleeding
• Thrombosis
• Hemolysis
• Stroke
• AKI
• Infection
• Tamponade
• Circuit-related complications
Extracorporeal life support during cardiac arrest and cardiogenic shock: a systematic review and meta-analysis

Dagmar M. Ouweneel¹, Jasper V. Schotborgh¹, Jacqueline Limpens², Krischan D. Sjauw³, A. E. Engström¹, Wim K. Lagrand⁴, Thomas G.V. Cherpanath⁵, Antoine H. G. Driessen⁶, Bas A. J. M. de Mol⁷ and José P. S. Henriques²

There are no adequately powered RCT’s that support the use of ECMO in patients with cardiogenic shock.
Right Ventricular Assist Devices

Impella RP

Protek-Duo

<table>
<thead>
<tr>
<th>Device</th>
<th>Flow (l/min)</th>
<th>Mechanism</th>
<th>LV support</th>
<th>RV support</th>
<th>Oxygenation</th>
<th>Contraindications</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>IABP</td>
<td>0.5 l/min</td>
<td>Pulsatile flow</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Aortic dissection&lt;br&gt;Aortic regurgitation&lt;br&gt;Severe peripheral vascular disease</td>
<td>Limb ischemia&lt;br&gt;Bleeding</td>
</tr>
<tr>
<td>Impella 2.5</td>
<td>2.5 l/min</td>
<td>Axial Flow</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Severe aortic valve disease&lt;br&gt;Mechanical aortic valve&lt;br&gt;Left ventricular thrombus</td>
<td>Limb ischemia&lt;br&gt;Bleeding</td>
</tr>
<tr>
<td>Impella CP</td>
<td>3.0–3.5 l/min</td>
<td>Axial Flow</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>&lt;br&gt;</td>
<td></td>
</tr>
<tr>
<td>Impella 5.5</td>
<td>6 l/min</td>
<td>Axial Flow</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>&lt;br&gt;</td>
<td></td>
</tr>
<tr>
<td>VA-ECMO</td>
<td>4–7 l/min</td>
<td>Centrifugal flow</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Severe peripheral vascular disease&lt;br&gt;Moderate to severe aortic regurgitation</td>
<td>Limb ischemia&lt;br&gt;Hemolysis&lt;br&gt;Bleeding</td>
</tr>
<tr>
<td>TandemHeart</td>
<td>3.5–4 l/min</td>
<td>Centrifugal flow</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Aortic regurgitation&lt;br&gt;Ventricular septal defect&lt;br&gt;Severe peripheral vascular disease</td>
<td>bleeding&lt;br&gt;Cannula dislodgement&lt;br&gt;Atrial-septal defect&lt;br&gt;Limb ischemia&lt;br&gt;Thromboembolism</td>
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<tr>
<td>Impella RP</td>
<td>2–4 l/min</td>
<td>Axial flow</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Severe tricuspid/pulmonic stenosis&lt;br&gt;Severe tricuspid/pulmonic regurgitation&lt;br&gt;Mechanical tricuspid or pulmonic valve&lt;br&gt;Mural thrombus of right atrium or IVC&lt;br&gt;Vena cava filter</td>
<td>Atrial fibrillation&lt;br&gt;Bleeding&lt;br&gt;Hemolysis&lt;br&gt;Pulmonic valve insufficiency&lt;br&gt;Venous thrombosis</td>
</tr>
<tr>
<td>TandemLife Protek Duo</td>
<td>4–5 l/min</td>
<td>Centrifugal flow</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Severe tricuspid/pulmonic stenosis&lt;br&gt;Mechanical tricuspid/pulmonic valve&lt;br&gt;Mural thrombus of right atrium</td>
<td>Myocardial wall injury/perforation&lt;br&gt;Venous thrombosis&lt;br&gt;Air embolism&lt;br&gt;Arrhythmias&lt;br&gt;Hemolysis</td>
</tr>
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Summary

• Temporary percutaneous mechanical circulatory assist devices improve hemodynamics by supporting the failing LV and or RV.

• Despite improvement in hemodynamic parameters large RCT data do not exist that demonstrate a survival benefit in cardiogenic shock.

• These devices include: IABP, Impella, TandemHeart, peripheral VA-ECMO, Protek-Duo, Impella RP.

• Common complications include severe bleeding, limb ischemia, hemolysis, stroke and device specific complications.
Reference

Question

• A 50 y.o. male was admitted to the ICU with the diagnosis of viral myocarditis. He was treated with inotropes and vasopressors to target a mean arterial pressure of 65 mm Hg. Despite these interventions he had a cardiac index of 1.5 l/min/m² and a lactic acid level of 5.5 mmol/L. His urine output started to trend down to less than 10 cc/hour despite appropriate dose of diuretics. He had an echocardiogram performed that demonstrated severe biventricular dysfunction. The shock team was activated, and decision was made to place the patient on temporary mechanical circulatory support. Which of the following is the most appropriate form of support for this patient?

• A. VA-ECMO
• B. Impella 2.5
• C. Impella RP
• D. Intra-aortic balloon pump
• E. Protek-Duo
Answer Explanation

• Answer A is correct because it is the only form of MCS listed that provides biventricular support.
• Impella 2.5 and IABP only provide LV support. The Impella RP and Protek-Duo only provide RV support.
A 65 y/o M with an anterior STEMI is taken emergently to the cardiac catheterization lab. In the catheterization lab, the patient is successfully revascularized but develops hypotension. A PA catheter is placed, and hemodynamic measurements are consistent with cardiogenic shock. The decision is made to place an intra-aortic balloon pump (IABP). Which following statements regarding IABP is correct?

A. There is strong evidence from randomized control trials that demonstrate IABP use in cardiogenic shock due to acute myocardial infarction leads to decreased mortality.
B. IABP provides up to 5 L/min of cardiac output support.
C. IABP Increases coronary artery blood flow and reduces LV afterload.
D. IABP is safe to use in patients with aortic dissections.
E. IABP mechanism of action is via a centrifugal pump.
Answer Explanation

• Answer C is correct. The IABP inflates during diastole displacing blood into the proximal aorta which increased coronary blood flow and deflates in systole which decreases LV afterload.

• There is no RCT evidence to support the use of IABP in cardiogenic shock secondary to acute MI.

• IABP does not lead to a considerable increase in cardiac output.

• Aortic dissection is a contraindication for IABP use.

• IABP functions via counterpulsation not a centrifugal pump.