



Brigham and Women's Hospital

Founding Member, Mass General Brigham

Mechanical Circulatory Support Devices

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- Jefferson Medical College – Thomas Jefferson University
- Emergency Medicine Residency @Mount Sinai Hospital
- Critical Care Medicine Fellowship @BWH
- Assistant Professor of Emergency Medicine@ HMS
 - Clinical focus: ECMO, Cardiothoracic critical care
 - Research focus: ECMO

DISCLOSURES

- Vsee Health Inc- Stock holder
- UltraSight – Advisory Board



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

- Cardiac disorder that results in both clinical and biochemical evidence of sustained tissue hypoperfusion
- Cardiac disorder that results in a systolic blood pressure <90 mm Hg for ≥ 30 min (or the need for vasopressors, inotropes or mechanical circulatory support to maintain systolic blood pressure ≥ 90 mm Hg) with evidence of hypoperfusion



Table 1. Proposed Definitions of Cardiogenic Shock

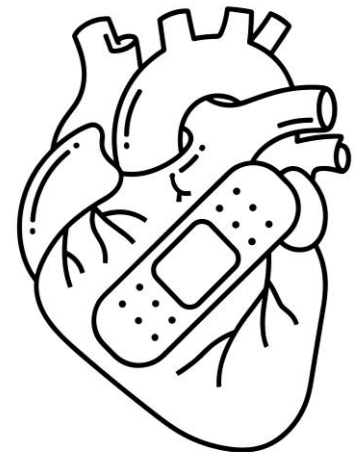
Proposed definition	Cardiac disorder
Definition for clinical practice	Cardiac disorder that results in both clinical and biochemical evidence of sustained tissue hypoperfusion
Definition for clinical trials	Cardiac disorder that results in a systolic blood pressure <90 mm Hg for ≥ 30 min (or the need for vasopressors, inotropes or mechanical circulatory support to maintain systolic blood pressure ≥ 90 mm Hg) with evidence of hypoperfusion
Hemodynamic criteria (optional)	
Cardiac index	≤ 2.2 L/(min·m ²)*
Hypoperfusion criteria (≥ 1)	Elevated arterial lactate (>2 mmol/L)
	Acute kidney injury (creatinine $\geq 2\times$ upper limit of normal) or oliguria (eg, urine output <0.5 mL/(kg·h))
	Acute hepatic injury (eg, ALT $>3\times$ upper limit of normal)
	Cool or mottled extremities
	Altered mental status not explained by an alternative cause
Hemodynamic criteria (optional)	
Cardiac index	≤ 2.2 L/(min·m ²)
Systemic vascular resistance index	>2200 dynes/(cm·sec ⁻⁵)*
Normotensive cardiogenic shock subtype cardiac disorder	Systolic blood pressure ≥ 90 mm Hg without the need for vasopressors, inotropes, or mechanical circulatory support with evidence of hypoperfusion and other potential causes of markers of hypoperfusion have been excluded
Hemodynamic criteria (optional)	
Cardiac index	≤ 2.2 L/(min·m ²)
Systemic vascular resistance index	>2200 dynes/(cm·sec ⁻⁵)*

**TABLE 1****SUSPECT CS: A Mnemonic to Aid in Confirming a Diagnosis of CS**

Symptoms/Signs	Altered mental status, confusion, chest pain or pressure, cold and clammy extremities, rapid pulse, low pulse pressure (<25% of SBP), elevated jugular venous pressure, crackles, rales, orthopnea, paroxysmal nocturnal dyspnea, lower extremity edema
Urine output	Oliguria or anuria, <30 mL/h (<0.5 mL/[kg·h])
Sustained hypotension	SBP <90 mm Hg, MAP <65 mm Hg for >30 min or a >30-mm Hg decrease from baseline, or the need for pharmacological or mechanical support to maintain SBP >90 mm Hg
Perfusion	Evaluate markers of end-organ malperfusion, including lactic acid >2 mmol/L, ALT >200 U/L or >3× upper limit of normal, creatinine ≥2× upper limit of normal, pH <7.2, metabolic acidosis without another known cause
ECG/Echocardiogram	Evaluate acute ischemia, including ECG and sonographic evidence of STEMI (regional wall motion abnormalities); evidence of LV or RV dilation and systolic dysfunction; valvular pathology
Congestion	Presence or absence of congestion based on physical signs and hemodynamics; elucidation of ventricular involvement (LV vs RV vs BiV)
Triage	Appropriate triage/shock team activation or possible transfer to a higher level of care

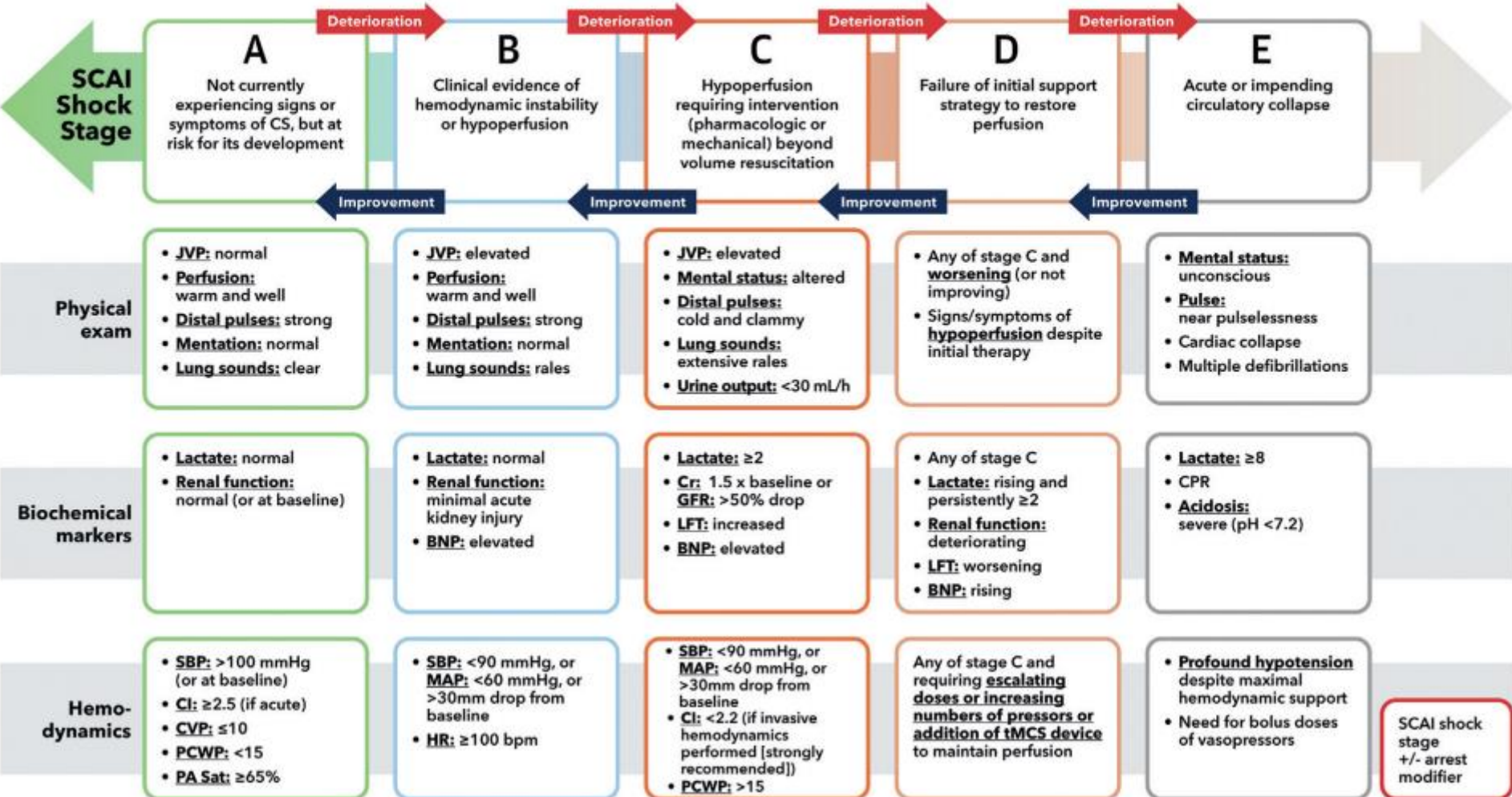
Etiologies

- **Acute myocardial infarction related cardiogenic shock (AMI-CS)**
 - STEMI, NSTEMI
- **Heart failure related cardiogenic shock (HF-CS)**
 - acute myocarditis
 - ischemic cardiomyopathy
 - takotsubo cardiomyopathy
 - peripartum cardiomyopathy
 - alcohol-related cardiomyopathy
 - tachycardia-related cardiomyopathy
 - septic cardiomyopathy
 - cardiac amyloidosis
- **Post-cardiotomy CS**
- **Secondary CS**
 - primary nonmyocardial cardiac causes
 - severe valvular heart disease
 - pericardial disease
 - hemodynamically significant pulmonary embolism



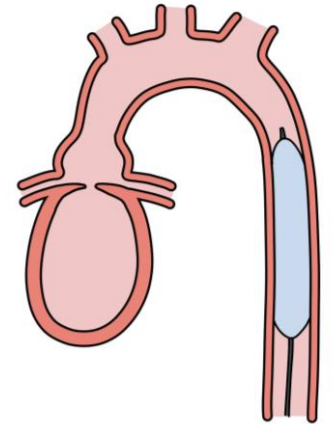
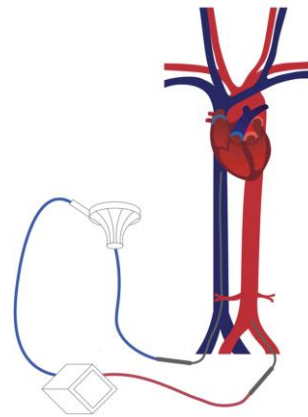
Classification

FIGURE 2 CS Working Group-SCAI Shock Criteria for Classification of CS Severity



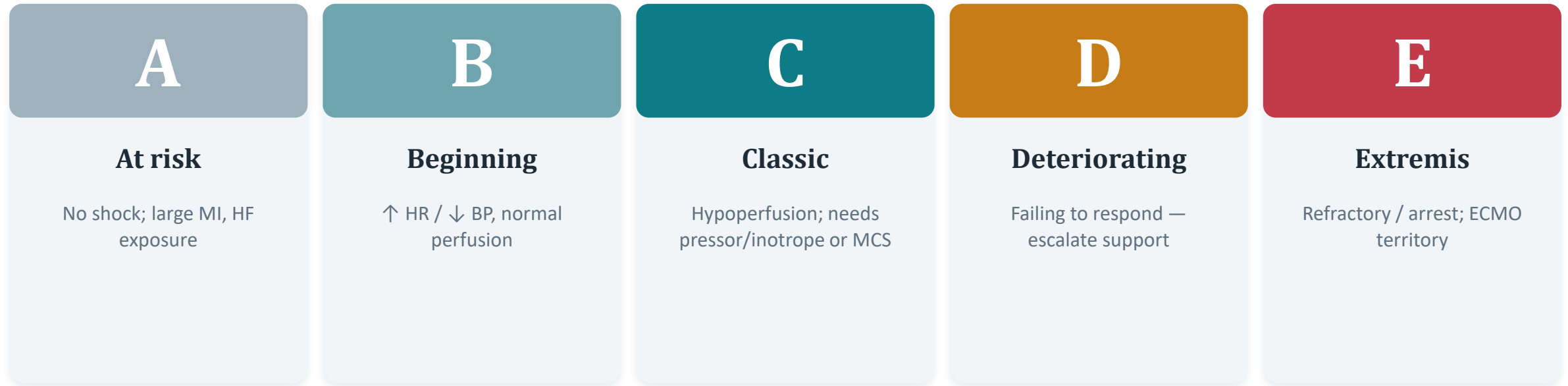
Temporary Mechanical Circulatory Support (MCS)

- Mechanical devices that:
- **Provide short-term hemodynamic support, from hours to weeks**
- **Augment cardiac output**
- **Increase systemic perfusion**
- Can provide ventricular unloading



Where does MCS fit???

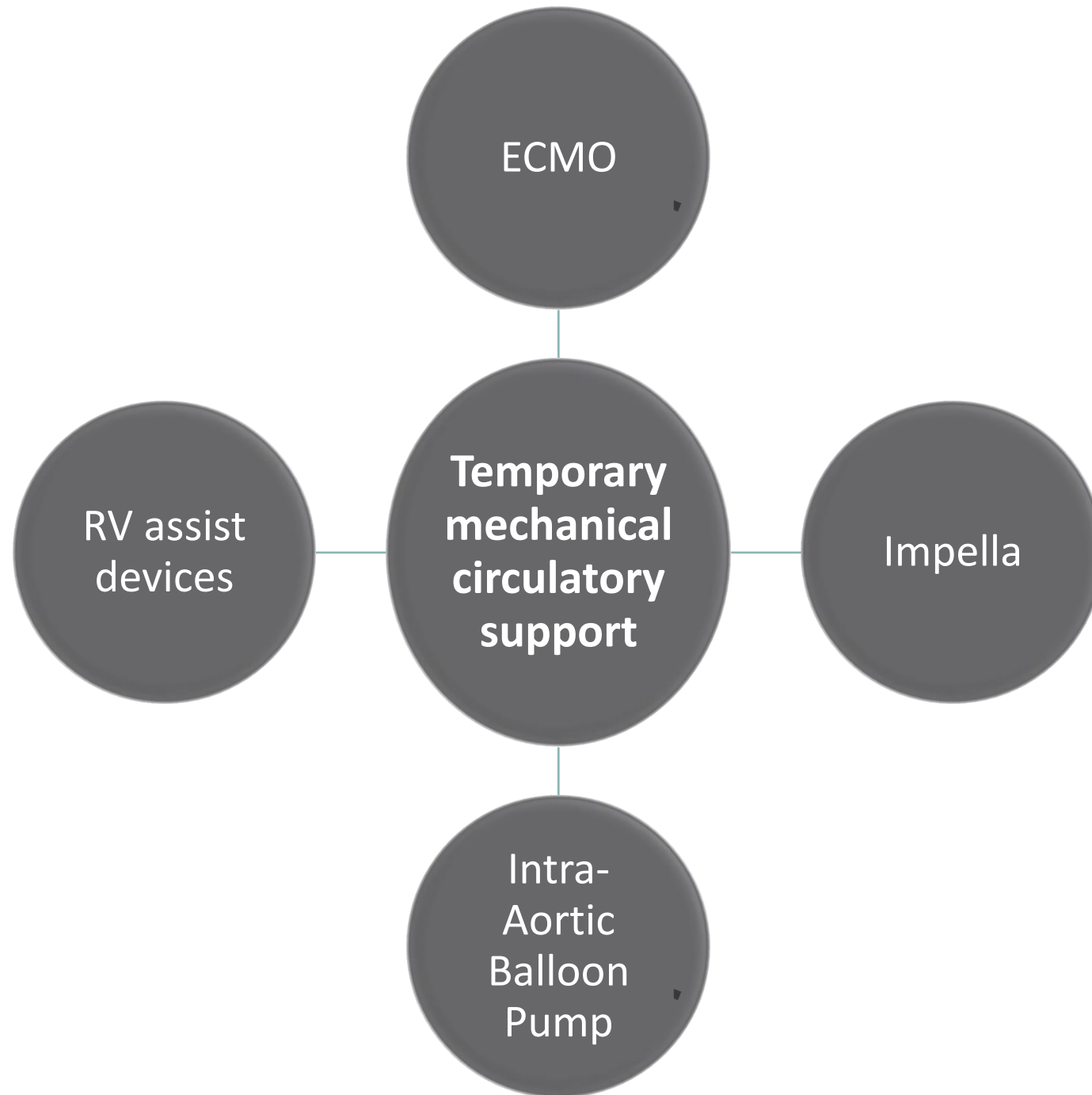
Temporary MCS is an escalation tool. The trigger matters more than the hardware: hypoperfusion despite adequate filling, rising lactate, and failure of pressors are the cues to escalate.



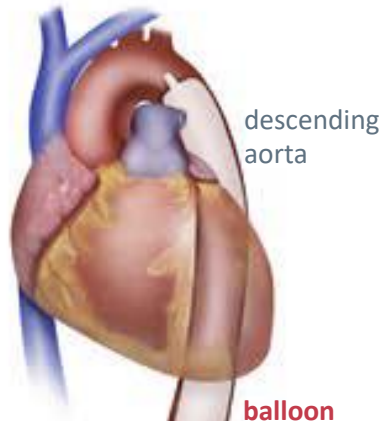
Purpose of temporary MCS

- **Not a cure!!**
- ***Bridge*** patient to reach end destination
 - Recovery
 - Transplant
 - Durable VAD
 - Decision





Intra Aortic Balloon Pump (IABP)



Placed percutaneously via the femoral artery, balloon position in descending aorta just distal to the left subclavian artery, above the renal arteries



INFLATES in diastole

Timed to the diastolic notch. Displaces blood upward → ↑ coronary & cerebral perfusion (diastolic augmentation).



DEFLATES before systole

Creates a vacuum → ↓ afterload, ↓ LV wall stress & myocardial O₂ demand, modest ↑ in cardiac output (increase ~ 0.5 L/min)

Diastolic augmentation & afterload reduction



Contraindications

- Significant aortic regurgitation
- Aortic dissection
- Severe PAD
- Uncontrolled bleeding
- Septic shock

Complications

- Limb ischemia
- Major bleeding
- Other ischemia
 - Spinal cord
 - Renal
 - Mesenteric
 - Stroke



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Intraaortic Balloon Support for Myocardial Infarction
with Cardiogenic Shock

- 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).



2025 ACC/AHA/ACEP/NAEMSP/SCAI Guideline for the Management of Patients With Acute Coronary Syndromes

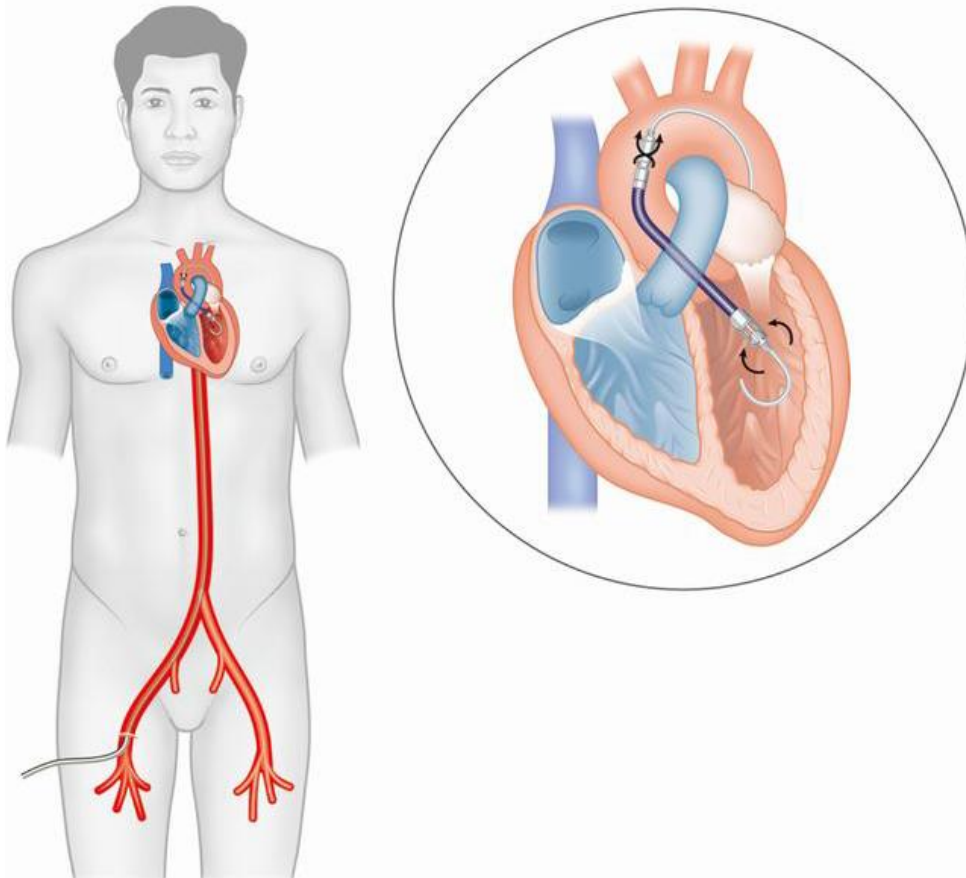
**Recommendations for MCS in Patients With ACS and
Cardiogenic Shock**
Referenced studies that support recommendations are
summarized in the [Evidence Table](#).

COR	LOE	RECOMMENDATIONS
2a	B-R	1. In selected* patients with STEMI and severe or refractory cardiogenic shock, insertion of a microaxial intravascular flow pump is reasonable to reduce death. ¹
2a	B-NR	2. In patients with mechanical complication of ACS, short-term MCS devices are reasonable for hemodynamic stabilization as a bridge to surgery. ²⁻⁴
3: No benefit	B-R	3. In patients with AMI and cardiogenic shock, the routine use of intra-aortic balloon pump (IABP) or venoarterial extracorporeal membrane oxygenation (VA-ECMO) is not recommended due to a lack of survival benefit. ⁵⁻⁹

*See supportive text.



Impella: a micro-axial pump that directly unloads the LV



Placement

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



Directly unloads the LV

Pulls blood from the ventricle and ejects into aorta → ↓ wall stress, ↓ myocardial O₂ demand, ↓ LVEDP



Augments forward flow

Impella CP delivers ~3.5–4 L/min; Impella 5.5 delivers ~5.5 L/min. Improves systemic & coronary perfusion

Contraindications

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

Complications

- **Hemolysis**
- **Bleeding requiring transfusion**
- **Limb ischemia**
- **AKI/renal replacement therapy**
- Arrhythmias
- Tamponade
- Aortic or mitral valve injury
- Stroke
- Device migration
- Device malfunction due to thrombosis



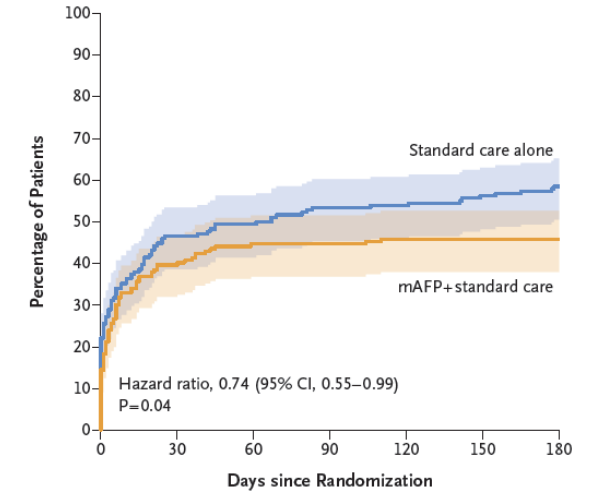
ORIGINAL ARTICLE

Microaxial Flow Pump or Standard Care in Infarct-Related Cardiogenic Shock

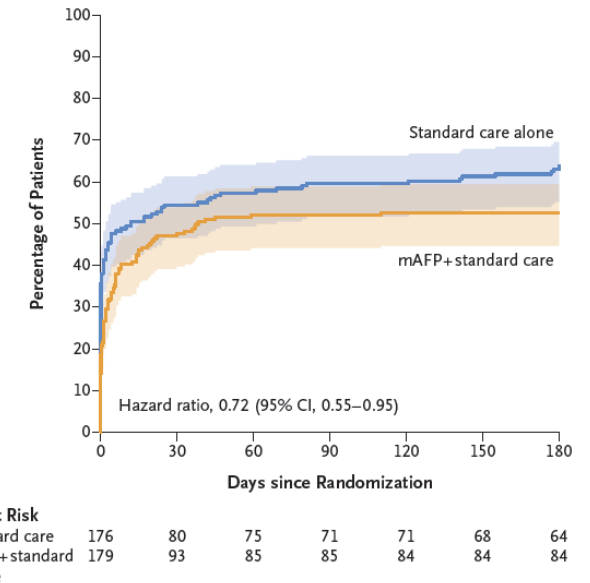
J.E. Møller, T. Engstrøm, L.O. Jensen, H. Eiskjær, N. Mangner, A. Polzin, P.C. Schulze, C. Skurk, P. Nordbeck, P. Clemmensen, V. Panoulas, S. Zimmer, A. Schäfer, N. Werner, M. Frydland, L. Holmvang, J. Kjærgaard, R. Sørensen, J. Lønborg, M.G. Lindholm, N.L.J. Udesen, A. Junker, H. Schmidt, C.J. Terkelsen, S. Christensen, E.H. Christiansen, A. Linke, F.J. Woitek, R. Westenfeld, S. Möbius-Winkler, K. Wachtell, H.B. Ravn, J.F. Lassen, S. Boesgaard, O. Gerke, and C. Hassager, for the DanGer Shock Investigators*

- Who? Cardiogenic shock post STEMI
 - SBP < 100 mm Hg or an ongoing need for vasopressor support
 - Lactate > 2.5 mmol/L
 - LVEF < 45%
- Results:
 - **Mortality was lower** with the use of impella vs. standard care alone
 - **More complications:**
 - A composite safety end-point event (severe bleeding, limb ischemia, hemolysis, device failure, or worsening of aortic regurgitation) occurred more often in impella group than in the standard-care group.
 - Renal-replacement therapy was more with impella vs. standard care.

A Death from Any Cause



B Secondary Composite Cardiac End-Point Event



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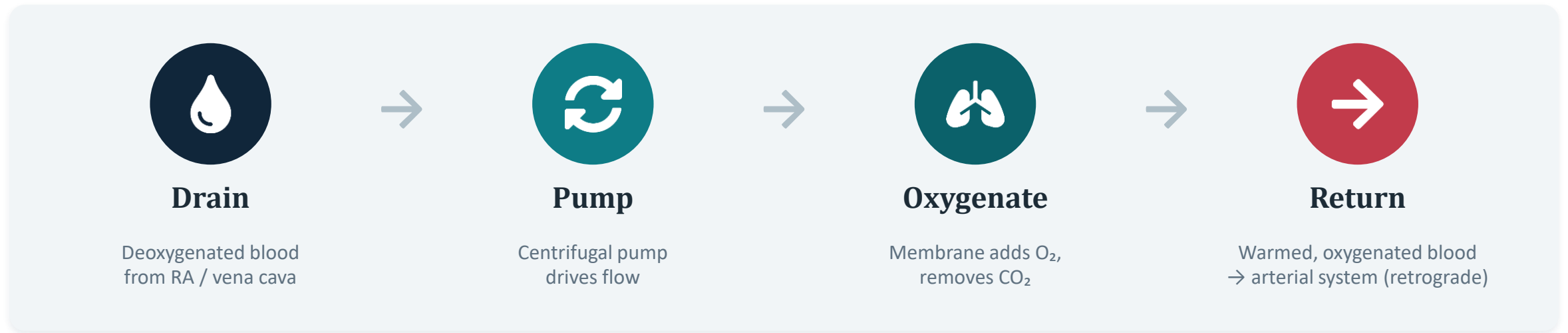
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Peripheral VA-ECMO: heart and lung support



Peripheral VA-ECMO



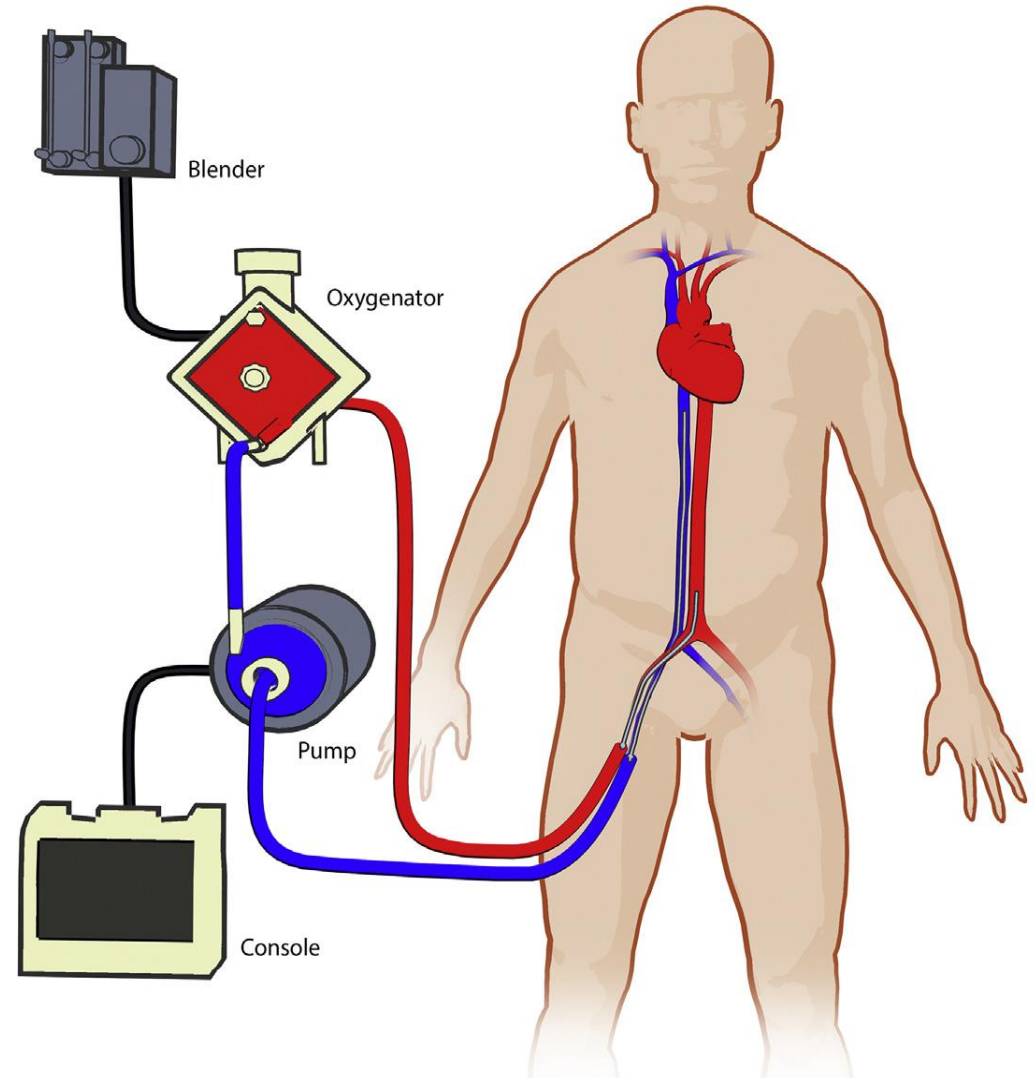
Supports heart AND lungs

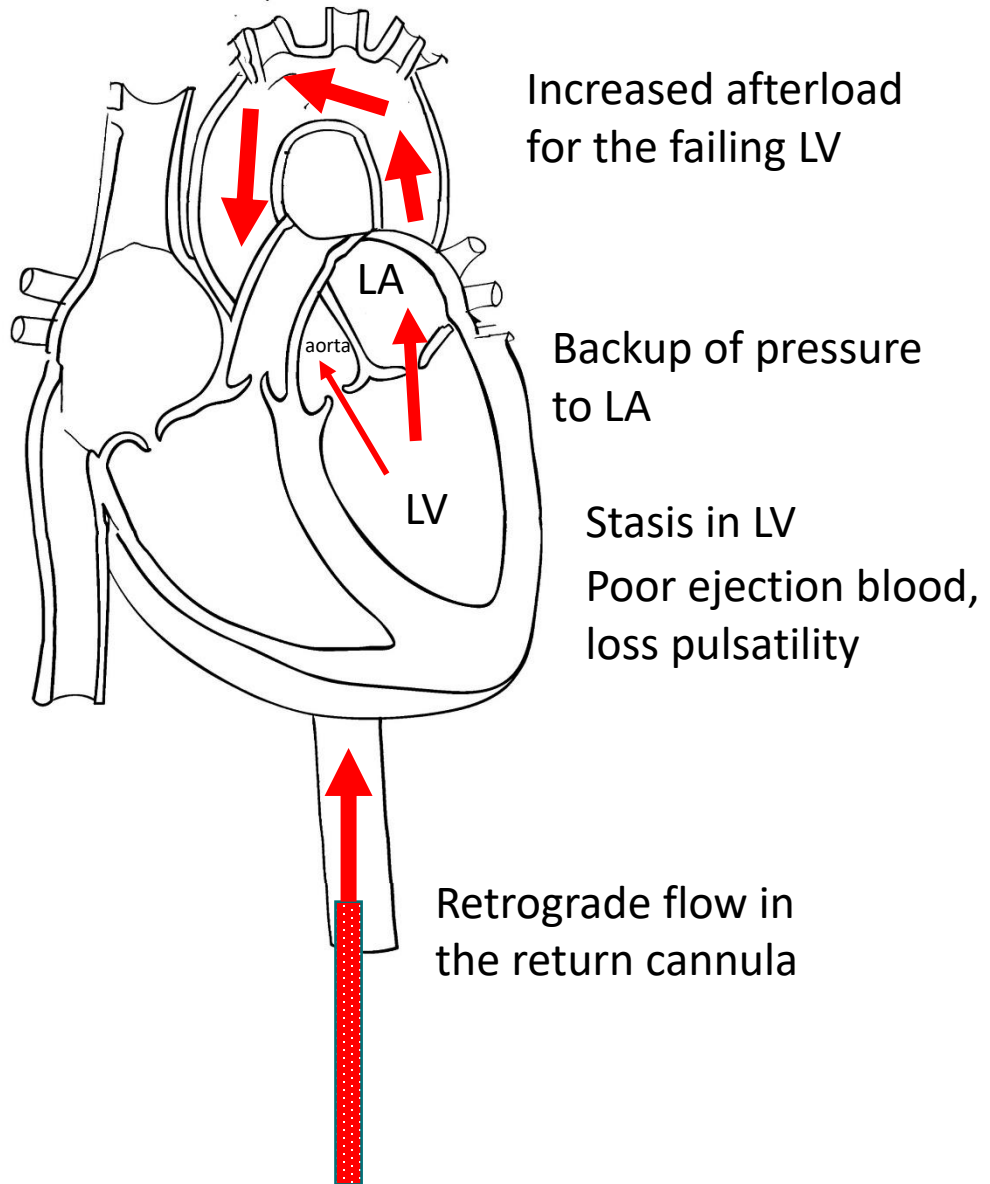
- The only temporary MCS device that oxygenates.
- Can provide full flow/cardiac output (4–7 L/min)
- Unloads RV by draining from IVC/RA



The catch: it raises LV afterload

- Retrograde arterial flow pushes against a failing LV → **LV distension & pulmonary edema.**
- Can prevent left ventricular ejection -> leading to **stasis and thrombosis** within the cardiac chambers





5-MAR-2018 07:23 ADULT:BW 0915

L9E-904

WALLENSTEINKEL

1

0.25mV

NO PAPER

PVC 0

53

ECG
130
25

160

ART 1

74/ 74
RATE 0 74

ART 1
160
50

0

30

PA 2

18/ 18
18

PA 2
350
-99

0

30

CVP 4

17

CVP 4
350
-99

0

45

PRES

-5

PEEP 8
MV 3.6
FIO2 41

14

VNT

VNT ALARM 07:18
VNT ALARM 07:07
VNT ALARM 07:01
ART10 L014 06:47

ALRM

MORE
MENUS

SENSOR

T2 F

TP 1
107.6
86.0
T2

SR 2
SQI 100
EMG SEF 9.0

60

BIS
100
-1

ALARMS:

CD 419T

*DID
COND
ORDER
RELEA
FROM
ACTIV



“ECPELLA”

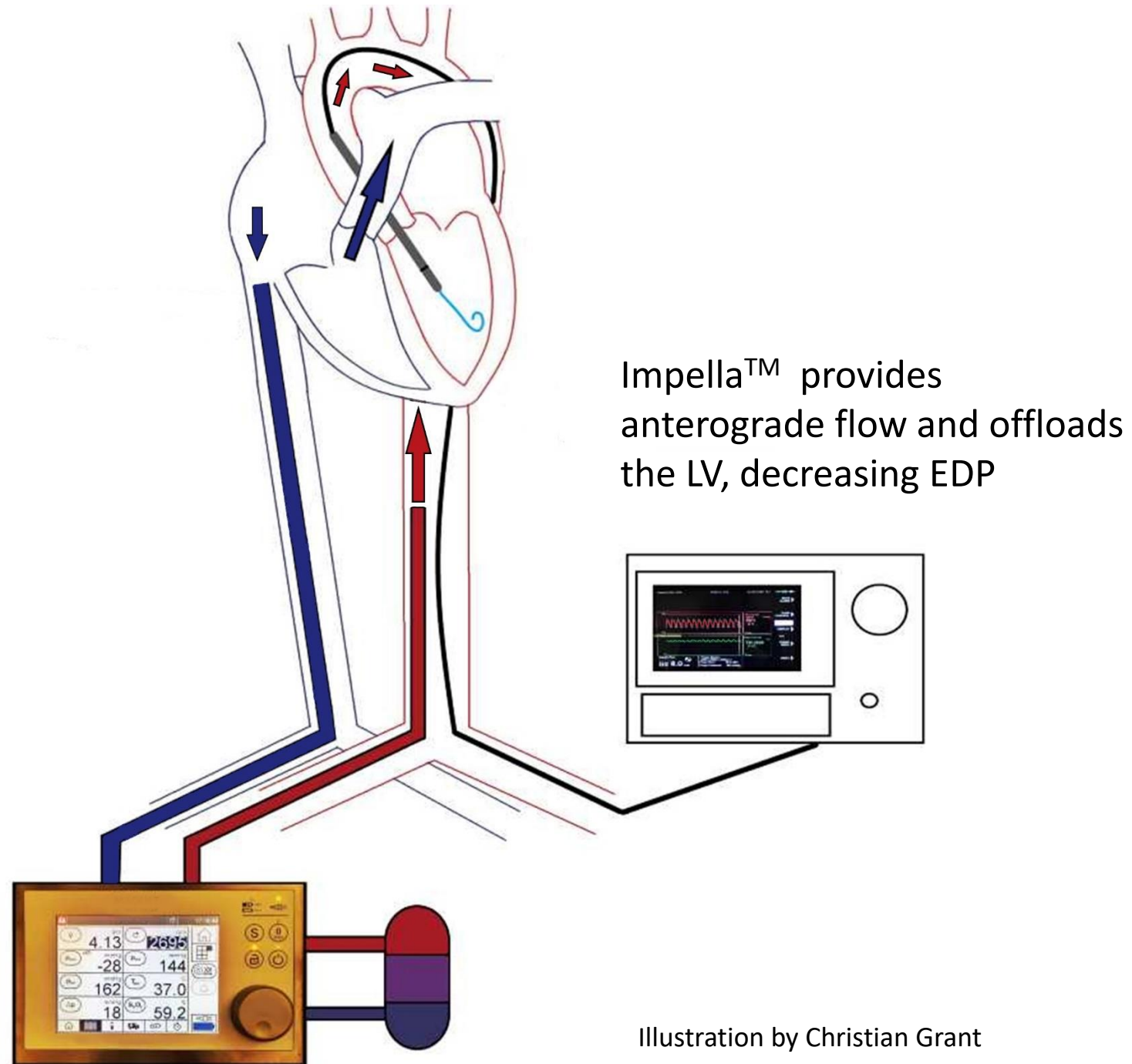


Illustration by Christian Grant



Contraindications

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

Complications

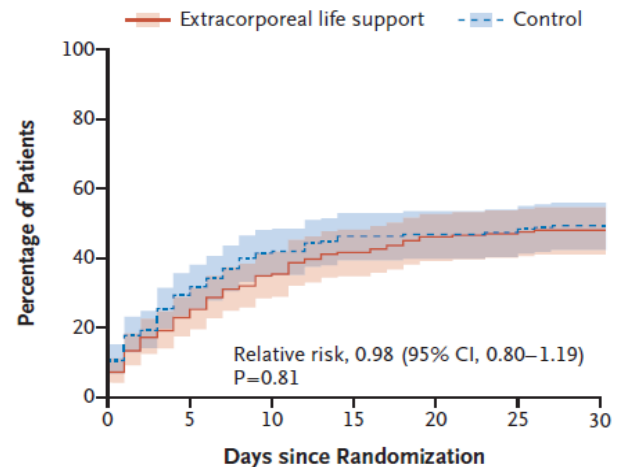
- **Bleeding**
- **Limb ischemia**
- **Hemolysis**
- **AKI/RRT**
- Stroke
- Thrombosis
- Infection
- Tamponade
- Circuit-related complications



ORIGINAL ARTICLE

Extracorporeal Life Support in Infarct-Related Cardiogenic Shock

H. Thiele, U. Zeymer, I. Akin, M. Behnes, T. Rassaf, A.A. Mahabadi, R. Lehmann, I. Eitel, T. Graf, T. Seidler, A. Schuster, C. Skurk, D. Dierschmied, P. Clemmensen, M. Hennersdorf, S. Fichtlscherer, I. Voigt, M. Seyfarth, S. John, S. Ewen, A. Linke, E. Tigges, P. Nordbeck, L. Bruch, C. Jung, J. Franz, P. Lauten, T. Goslar, H.-J. Feistritz, J. Pöss, E. Kirchhof, T. Ouarrak, S. Schneider, S. Desch, and A. Freund, for the ECLS-SHOCK Investigators*



No. at Risk							
Control	208	146	120	109	105	104	100
Extracorporeal life support	209	161	136	119	109	107	105

Figure 1. Death from Any Cause at 30 Days.

Shown are the time-to-event curves for death from any cause at 30 days (the primary outcome) among the patients who received extracorporeal life support plus medical therapy as compared with those who received only medical therapy (control). The shaded areas indicate the 95% confidence intervals.

- Who? AMI associated cardiogenic shock
 - SBP < 90 mm Hg for more than 30 minutes
 - On catecholamines to maintain SBP > 90 mm Hg
 - Lactate > 3 mmol/L
 - Signs of impaired organ perfusion with at least one:
 - altered mental status,
 - cold or clammy skin and limbs
 - urine output of less than 30 ml/hr
- Results:
 - **No difference in 30-day mortality**
 - Complications:
 - **Moderate or severe bleeding and peripheral ischemic vascular complications** warranting surgical or interventional therapy occurred **more often in the ECLS group**.

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*See supportive text.



Right Ventricular Assist Devices



Impella RP / RA-PA pVAD

Isolated RV support:

Blood flow: Right Atrium → Pulmonary Artery

-bypass the failing right ventricle



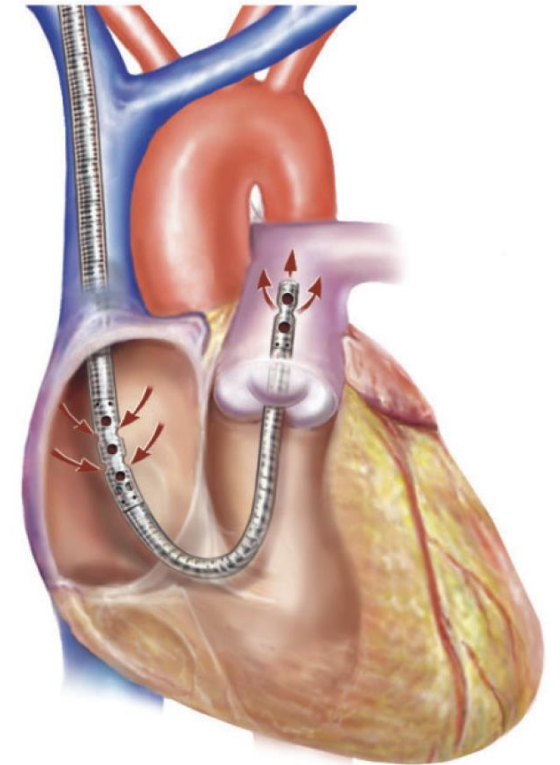
Common use scenarios:

- RV infarct
- post-LVAD implantation RV failure
- RV failure post-cardiotomy
- massive PE post thrombolysis/thrombectomy

Impella RP



RA-PA percutaneous ventricular assist device (e.g. ProtekDuo)



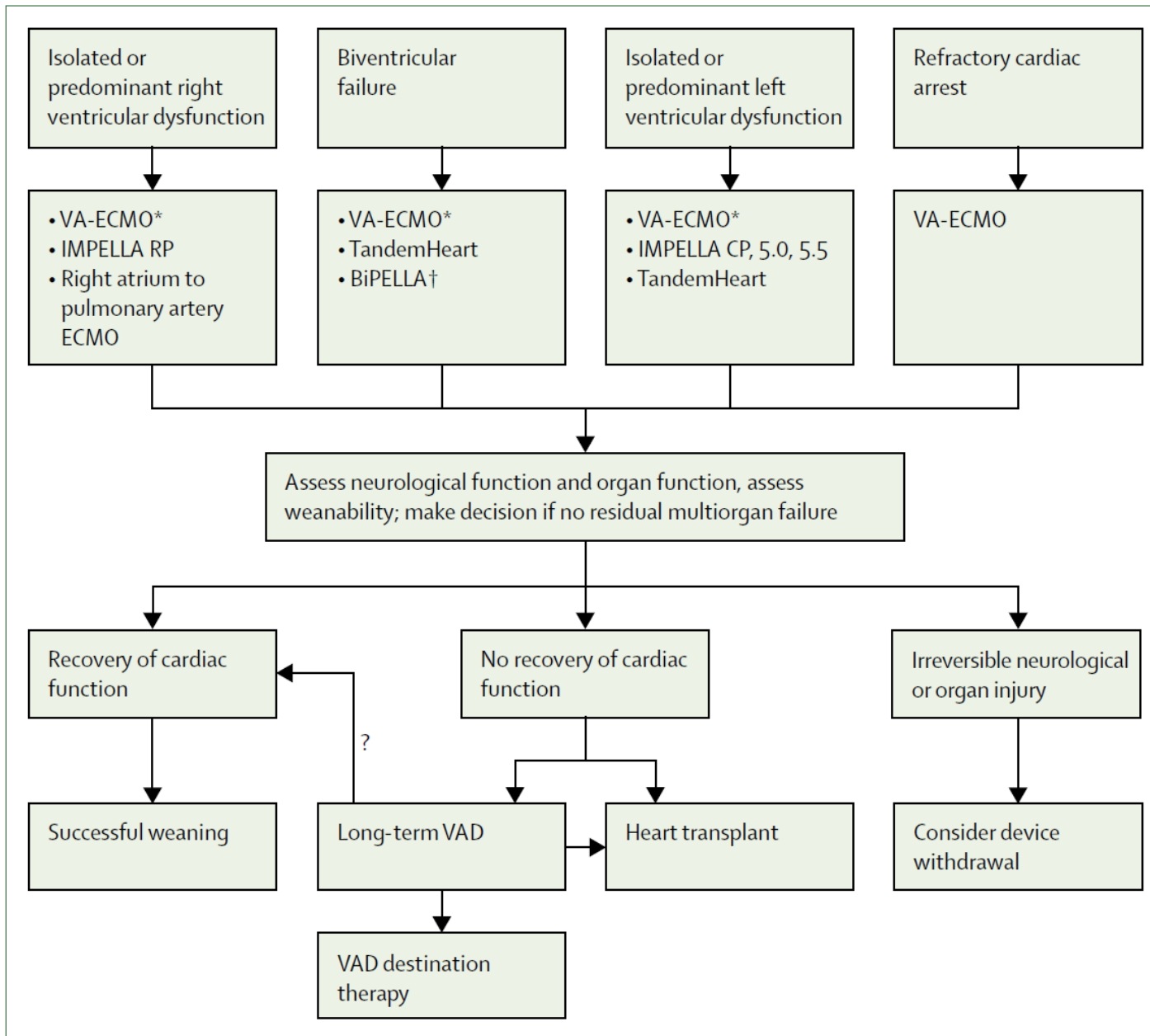
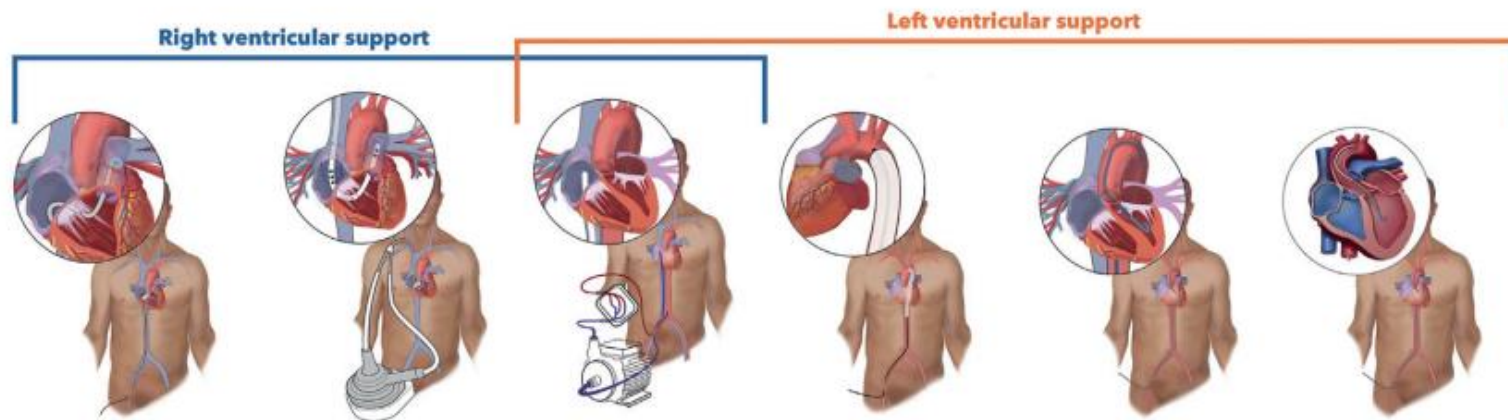


FIGURE 6 Common tMCS Devices Used in CS



	Impella RP Flex	RA-PA pVAD	VA-ECMO	IABP	Impella CP	Impella 5.5
Max flow	3.0 - 4.0 L/min	4.0 - 5.0 L/min	5.0 - 7.0 L/min	0.5 - 1.0 L/min	3.0 - 4.3 L/min	5.0 - 6.0 L/min
Max pump speed	33,000 rpm	7,500 rpm	6,000 rpm	NA	46,000 rpm	33,000 rpm
Mechanism	Axial flow continuous pump (RA-to-PA)	Centrifugal flow continuous pump (RA-to-PA)	Centrifugal flow continuous pump (RA-to-AO)	Balloon inflation-deflation (AO)	Axial flow continuous pump (LV-to-AO)	Axial flow continuous pump (LV-to-AO)
Sheath size	23 F venous peel-away	29 or 31 F venous (inflow)	15-24 F arterial 19-25 F venous	7-8 F arterial	14 F arterial peel-away	23 F arterial peel-away
Typical insertion/ placement	Internal jugular vein	Internal jugular vein	Femoral vein (drain) Femoral artery (return)	Femoral artery or Axillary artery	Femoral artery or Axillary artery	Axillary artery
Direct LV unloading	-	-	-	-	+++	+++
Direct RV unloading	+	+	+	-	-	-
Afterload	-	-	↑↑↑	↓↓	↓	↓
Coronary perfusion	-	-	↑↑	↑↑	↑↑	↑↑

Adapted with permission from Tehrani BN, et al.²¹ AO = aorta; CP = cardiac power; CS = cardiogenic shock; F = French; IABP = intra-aortic balloon pump; LV = left ventricular; NA = not applicable; PA = pulmonary artery; pVAD = percutaneous ventricular assist device; RA = right atrium; RA-PA = right atrium to pulmonary artery; RP = right percutaneous; rpm = revolutions per minute; RV = right ventricular; tMCS = temporary mechanical circulatory support; VA-ECMO = venoarterial extra-corporeal membrane oxygenation.

MOC REFLECTIVE STATEMENT (BRIEF TAKE HOME NOTES FOR REFERENCE)

- **Temporary mechanical circulatory support:**
 - improve hemodynamics
 - augment cardiac output
 - increase systemic perfusion
 - can provide ventricular unloading
 - can support LV only, RV only, or BiV
- **These devices include:**
 - IABP
 - Impella CP/5.5
 - peripheral VA-ECMO
 - Impella RP flex, RA-PA pVAD (ProtekDuo)
- Despite improvement in hemodynamic parameters **large RCT data do not exist** that demonstrate a survival benefit in cardiogenic shock
- **Common complications include:**
 - severe bleeding
 - limb ischemia
 - hemolysis
 - acute kidney injury
 - device specific complications



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3. Combes A, Price S, Slutsky AS, et al. Temporary circulatory support for cardiogenic shock. *Lancet*. 2020 Jul 18;396(10245):199-212
4. Møller JE, Engstrøm T, Jensen LO, Eiskjær H, Mangner N, Polzin A, Schulze PC, Skurk C, Nordbeck P, Clemmensen P, Panoulas V, Zimmer S, Schäfer A, Werner N, Frydland M, Holmvang L, Kjærgaard J, Sørensen R, Lønborg J, Lindholm MG, Udesen NLJ, Junker A, Schmidt H, Terkelsen CJ, Christensen S, Christiansen EH, Linke A, Woitek FJ, Westenfeld R, Möbius-Winkler S, Wachtell K, Ravn HB, Lassen JF, Boesgaard S, Gerke O, Hassager C; DanGer Shock Investigators. Microaxial Flow Pump or Standard Care in Infarct-Related Cardiogenic Shock. *N Engl J Med*. 2024 Apr 18;390(15):1382-1393.
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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 CP
 - C. Impella RP Flex
 - 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 CP and IABP only provide LV support. The Impella RP and Protek-Duo only provide RV support.



Question

- 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.

