Pearls and Wisdom in the Management of Cardiogenic Shock and Heart Failure

Moderator & Additional Panelist:

David Zhang, MD
Eugene Lian, MD

Virginia Mason Franciscan Health
Center for Cardiovascular Health

Acute Myocardial Infarction and Cardiogenic Shock

Wayne S. Hwang, MD FACC
Virginia Mason Medical Center
Director, Cardiac Catheterization Laboratory

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Disclosures

- NO RELEVANT DISCLOSURES

Case

- 60 y/o M
- STEMI anterolateral
- Ongoing chest pain onset 1 hr ago
- BP 90/45 on low dose levophed HR 105
- Pulmonary edema on cxr, crackles on exam
- Lactate 4
- Neurologically intact

Would anyone NOT take this patient to the Cath Lab?

- Proximal LAD 100% timi 0
- Remaining coronaries 30-70% timi 3
- LVEDP 35mmhg
- 2plus femoral pulses, no known PAD

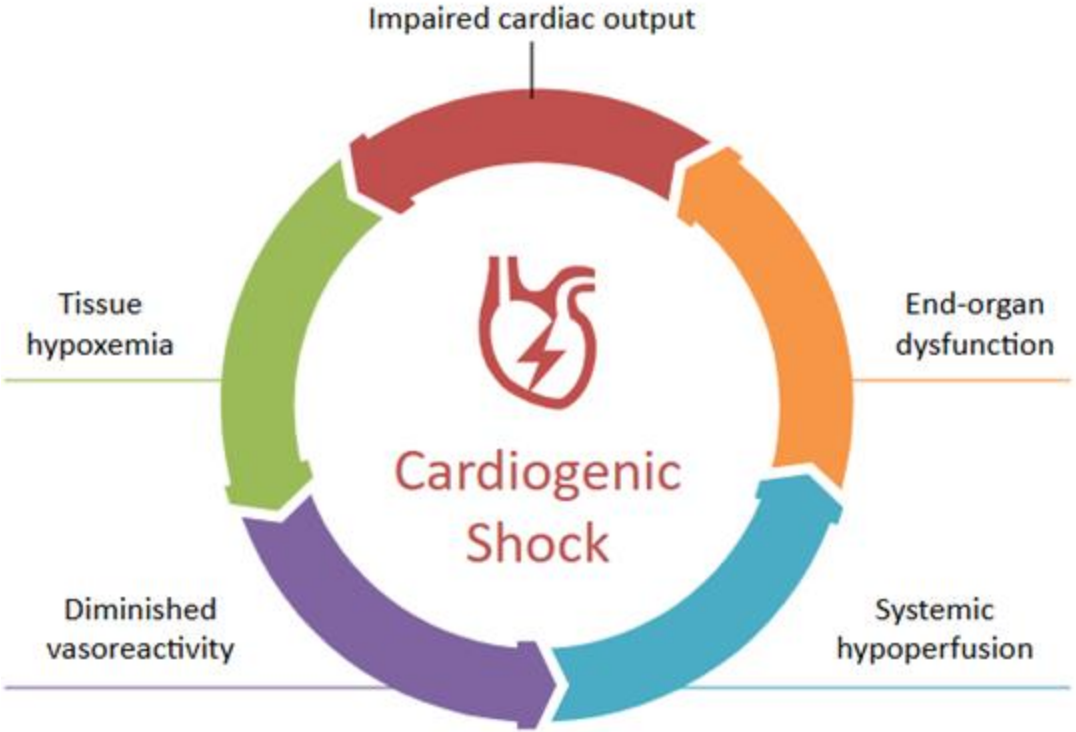
Who would use Mechanical Circulatory Support (MCS)?

- Why?
- Why not?
- If Yes, which MCS?
  - IABP
  - Micro-Axillary pump (Impella)
  - VA-ECMO
- And, when? Before, during or after PCI?

Background

- STEMI presentations
- 1 in 10 will develop CS
- 1/2 will survive

What is Cardiogenic Shock?



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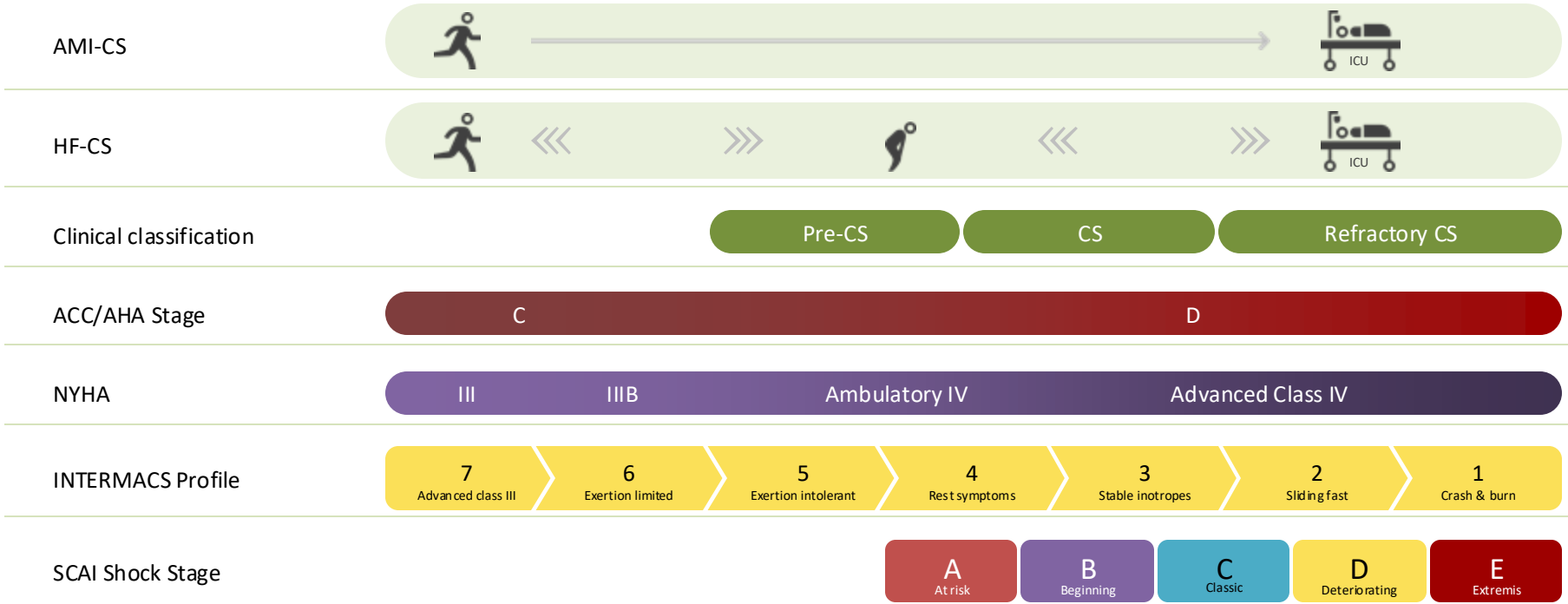
Phenotyping: AMI vs ADHF Cardiogenic Shock



Heart Failure-Related Cardiogenic Shock: Pathophysiology, Evaluation and Management Considerations. Abraham, JACOB et al. Journal of Cardiac Failure, Volume 27, Issue 10, 1126- 1140

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Medical Therapy? Doesn't Help

Vasopressor Use in Cardiogenic Shock – Evidence Summary

- **Key RCTs & Meta-analyses**
- **SOAP II (NE vs Dopamine, 2010, NEJM)**
  - Subgroup: Cardiogenic shock
  - **Norepinephrine ↓ mortality, ↓ arrhythmias** vs dopamine
- **OPTIMA-CC (Epi vs NE, 2018, JACC)**
  - AMI-related CS, RCT (n=57)
  - Epinephrine → more refractory shock, acidosis, lactate rise
  - Trial stopped early (safety concerns)
- **Meta-analysis: Epinephrine in CS (2018, n=2,583, Crit Care Med)**
  - Epinephrine strongly associated with ↑ short-term mortality (OR ~4)
- **Recent Cohorts (2010–2022)**
  - NE associated with fewer arrhythmias than dopamine
  - Observational data: NE often used in sicker patients → mixed signals on mortality

Consensus Takeaway

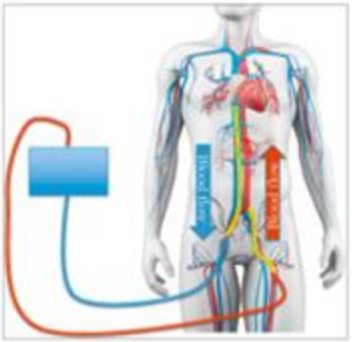
- **Norepinephrine = preferred first-line vasopressor** (better safety, fewer arrhythmias)
- **Dopamine = avoid** (↑ arrhythmias, worse outcomes in CS)
- **Epinephrine = last resort** (metabolic complications, possible ↑ mortality)
- Evidence base still limited → more RCTs needed

Mechanical Circulatory Support

IABP

Micro-axillary flow pump (Impella)

Extracorporeal membrane oxygenation (VA – ECMO)



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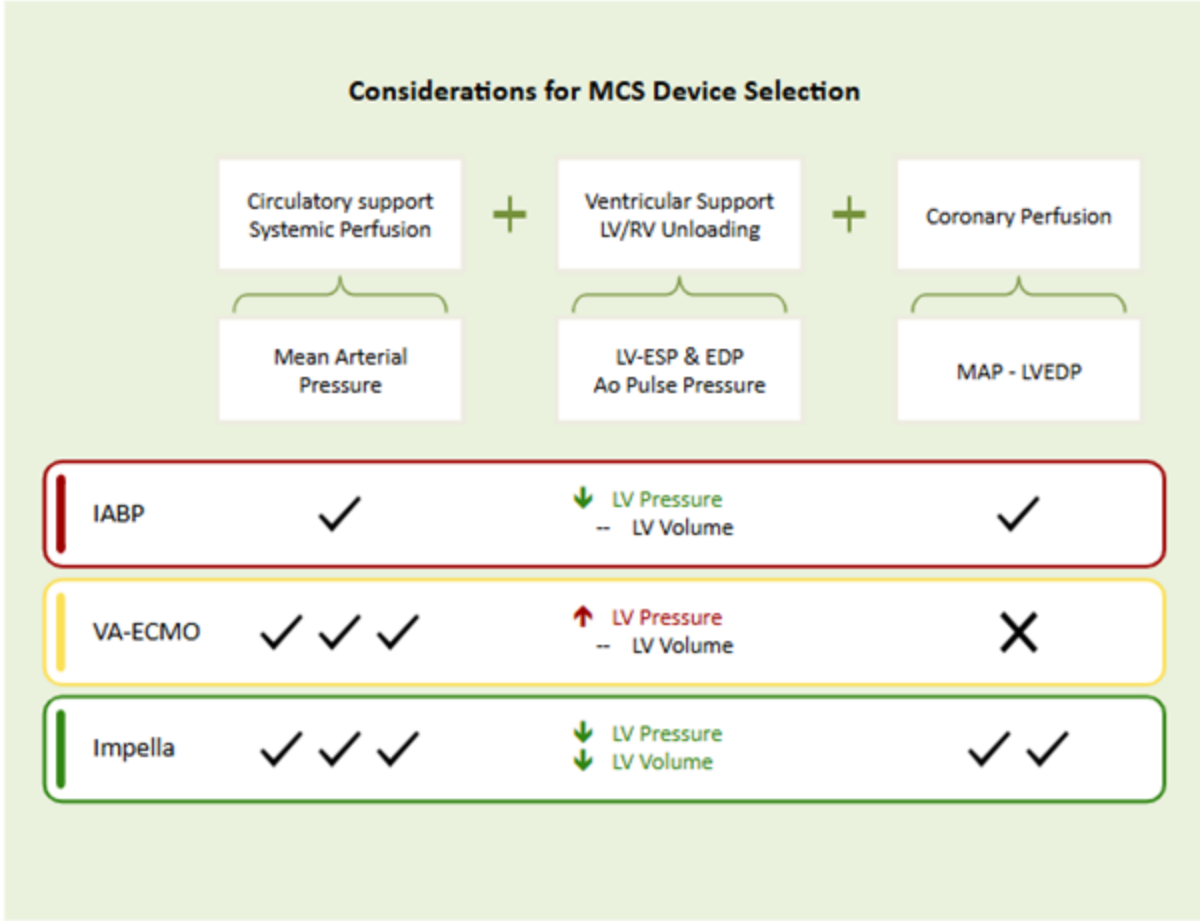
Impella provides circulatory support, ventricular unloading & coronary perfusion



Adapted from Esposito, M. L., & Kapur, N. K. (2017). Acute mechanical circulatory support for cardiogenic shock: the "door to support" time. *F1000Research*, 6, 737. https://doi.org/10.12688/f1000research.11150.1

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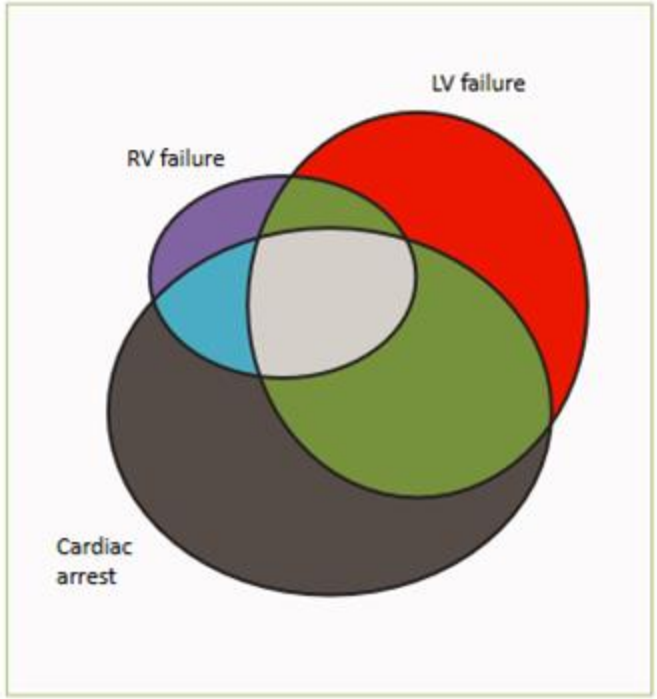
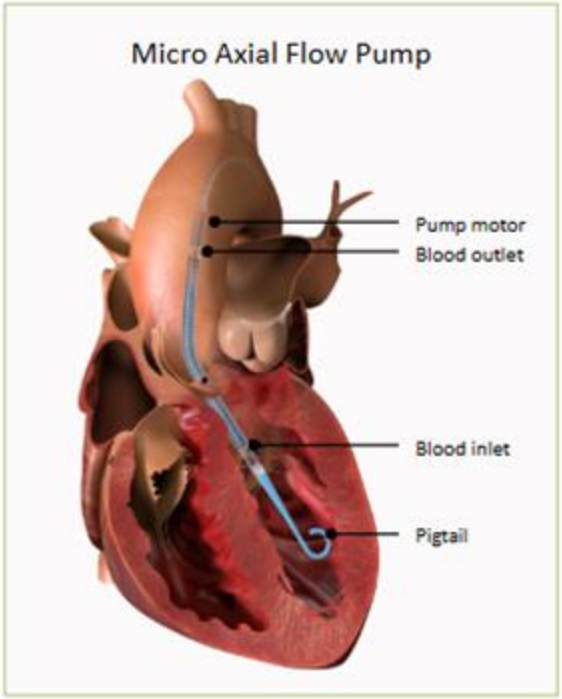
AMI - Cardiogenic Shock



MCS device trial hypothesis

Routine Impella CP use reduces mortality in AMICS due to STEMI



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DanGer Shock RCT

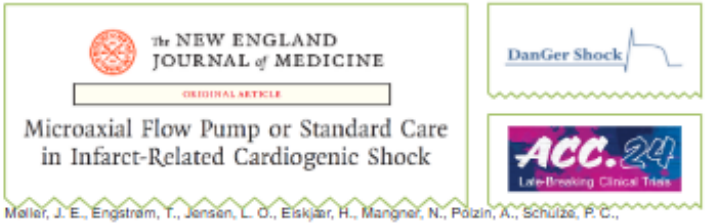
Independent investigator-initiated study

First completed Impella RCT in AMICS

- 360 patients randomized from 2013 to 2023
- 14 centers across Denmark, Germany and UK

MCS device trial hypothesis

- Routine Impella CP use reduces mortality in AMICS due to STEMI



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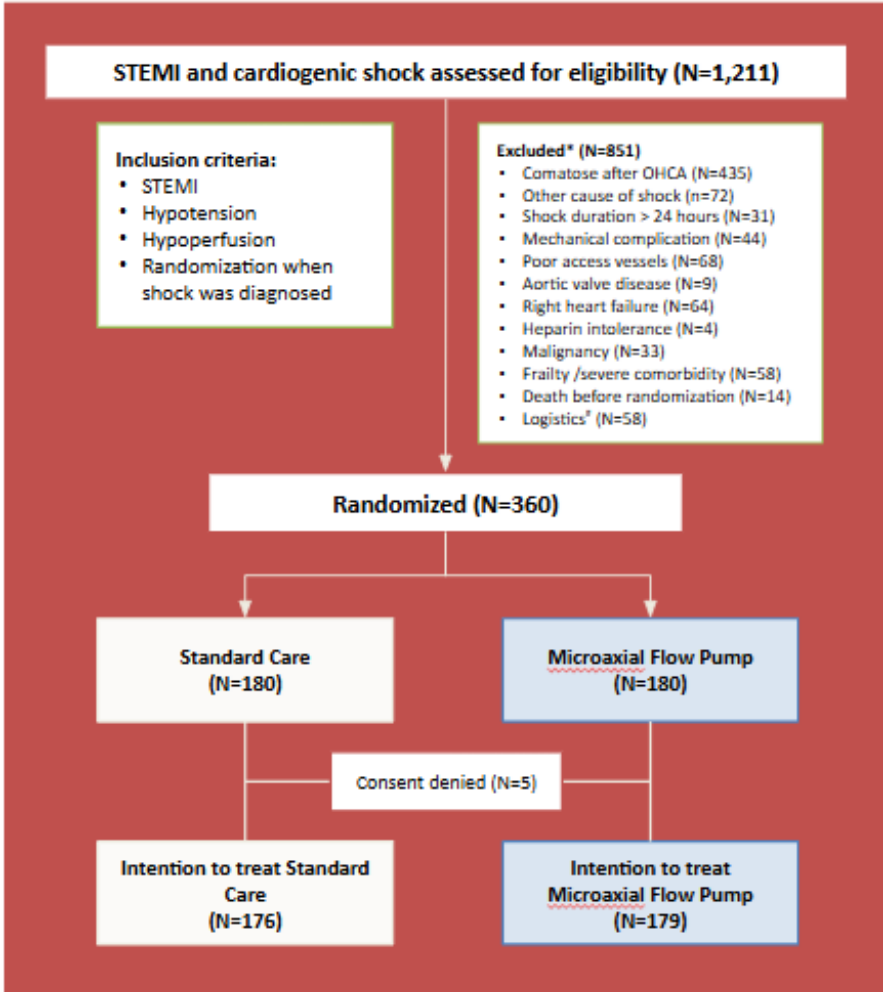
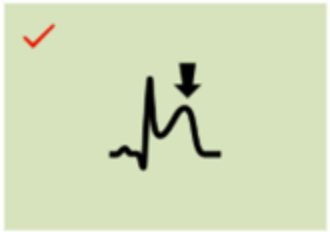


The Key: Patient Selection

Inclusion criteria



STEMI

Hypotension and hypoperfusion
(SBP<100 mmHg, Lactate > 2.5)

LVEF < 45%

Randomization when shock was diagnosed

Key exclusion criteria

Comatose OHCA

RV failure

Mechanical complications

Møller, J. E., Engstrøm, T., Jensen, L. O., Eiskjær, H., Mangner, N., Polzin, A., Schulze, P. C., Skurk, C., Nordbeck, P., Clemmensen, P., Panoulas, V., Zimmer, S., Schäfer, A., Werner, N., Frydland, M., Holmvang, L., Kjaergaard, J., Sørensen, R., Lønborg, J., Lindholm, M. G., ... DanGer Shock Investigators (2024). Microaxial Flow Pump or Standard Care in Infarct-Related Cardiogenic Shock. *The New England journal of medicine*, *390*(15), 1382–1393. https://doi.org/10.1056/NEJMoa2312572

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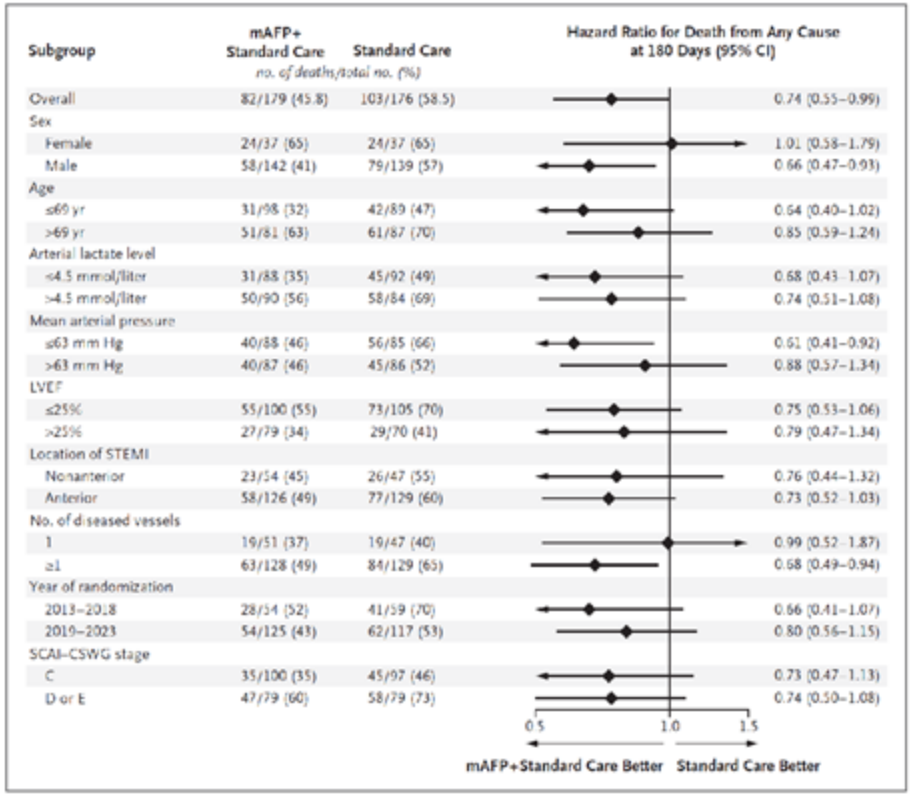
Prespecified Subgroups



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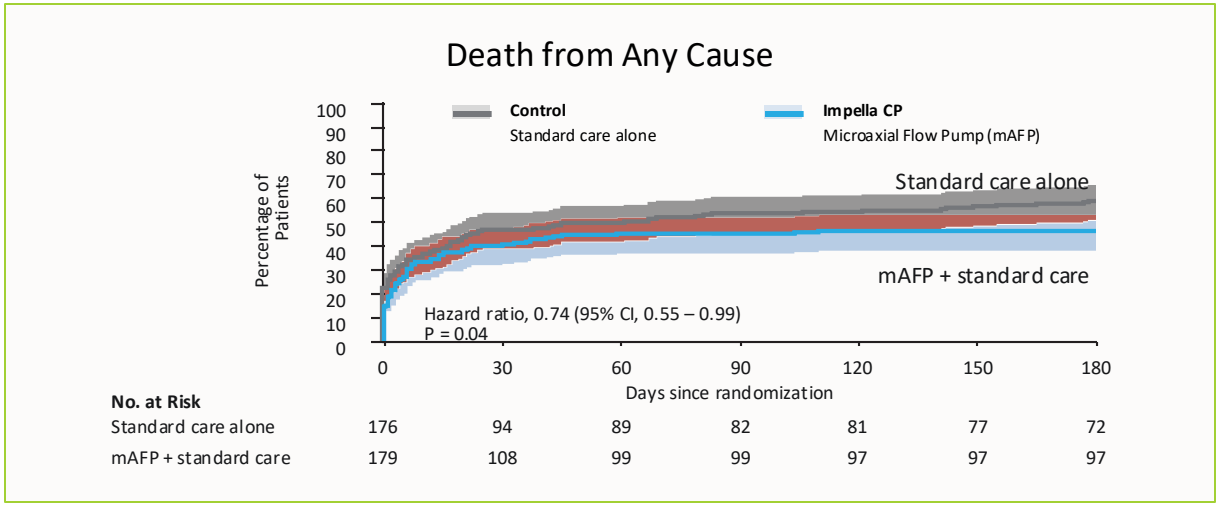
Routine use of ımpella CP produced a 26% relative reduction in mortality at 6 months

in AMICS due to STEMI compared to standard care alone

The NEW ENGLAND JOURNAL of MEDICINE
Microaxial Flow Pump or Standard Care in Infarct-Related Cardiogenic Shock



26%	8	12.7%
Relative mortality reduction	NNT	Absolute mortality reduction

Inclusion Criteria

- Cardiogenic Shock due to STEMI
- STEMI <36 hours
- Lactate >2.5 mmol/L or SvO_2 <55%
- LVEF <45%

Key Exclusion Criteria

- Shock >24 hours
- Comatose after OHCA (In-ambulance/ in-hospital CA not excluded)
- Severe RV failure

Møller, J. E., Engstrøm, T., Jensen, L. O., Eiskjær, H., Mangner, N., Polzin, A., Schulze, P. C., 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, M. G., … DanGer Shock Investigators (2024). Microaxial Flow Pump or Standard Care in Infarct-Related Cardiogenic Shock. *The New England journal of medicine*, *390*(15), 1382–1393. https://doi.org/10.1056/NEJMoa2312572

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Impella CP further reduces mortality in patients younger than 77

- in AMICS due to STEMI compared to standard care alone

1. Møller, J. E., Engstrøm, T., Jensen, L. O., Eiskjær, H., Mangner, N., Polzin, A., Schulze, P. C., 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, M. G., … DanGer Shock Investigators (2024). Microaxial Flow Pump or Standard Care in Infarct-Related Cardiogenic Shock. *The New England journal of medicine*, *390*(15), 1382–1393. https://doi.org/10.1056/NEJMoa2312572
2. Klein, A., et al. DanGer Shock Investigators (2024). Treating Older Patients in Cardiogenic Shock with a Microaxial Flow Pump: Is it DANGERous?. Journal of the American College of Cardiology, S0735-1097(24)10416-0. Advance online publication. https://doi.org/10.1016/j.jacc.2024.11.003
3. Klein, A., et al. DanGer Shock Investigators (2024). Treating Older Patients in Cardiogenic Shock with a Microaxial Flow Pump: Is it DANGERous? SUPPLEMENTAL APPENDIX. Journal of the American College of Cardiology, S0735-1097(24)10416-0. Advance online publication. https://doi.org/10.1016/j.jacc.2024.11.003

Klein 2024

Overall[1]	Patients < 77 y.o.[2]
P=0.04 / N= 355	P=0.001 / N=274
26% Relative mortality reduction	35.7% Relative mortality reduction[3]
8 NNT	5 NNT
12.7% Absolute mortality reduction	20% Absolute mortality reduction

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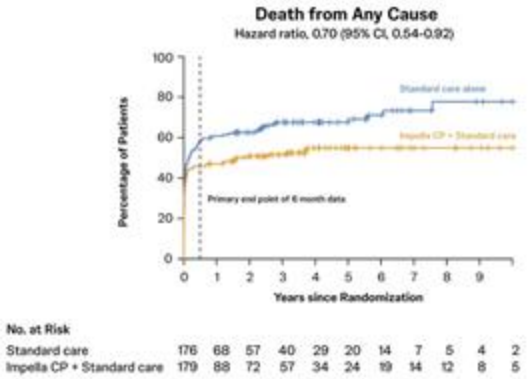
New long-term data from the DanGer Shock RCT validates original findings and confirms the survival benefit of Impella CP increases year over year*

The NEW ENGLAND JOURNAL of MEDICINE



10	16.3%	600
years	absolute mortality Reduction[1]*	Average days alive gained by Impella CP[1]*

Death from any cause occurred in

- **94 of 179 patients (52.5%)** in the Impella CP group and
- **121 of 176 patients (68.8%) in the standard-care group** (hazard ratio: 0.70; 95% CI: 0.54 to 0.92)[1]

Median time to death was

- **577 days** for patients in the Impella CP group
- **61 days** for patients in the standard-care group

Mean difference in days alive at 10 years was 600 days (95% CI 235 – 966 days)[1]

*Compared to standard care in STEMI with cardiogenic shock

1. Møller J, et al. Long-Term Outcomes of the DanGer Shock Trial N Engl J Med 2025.

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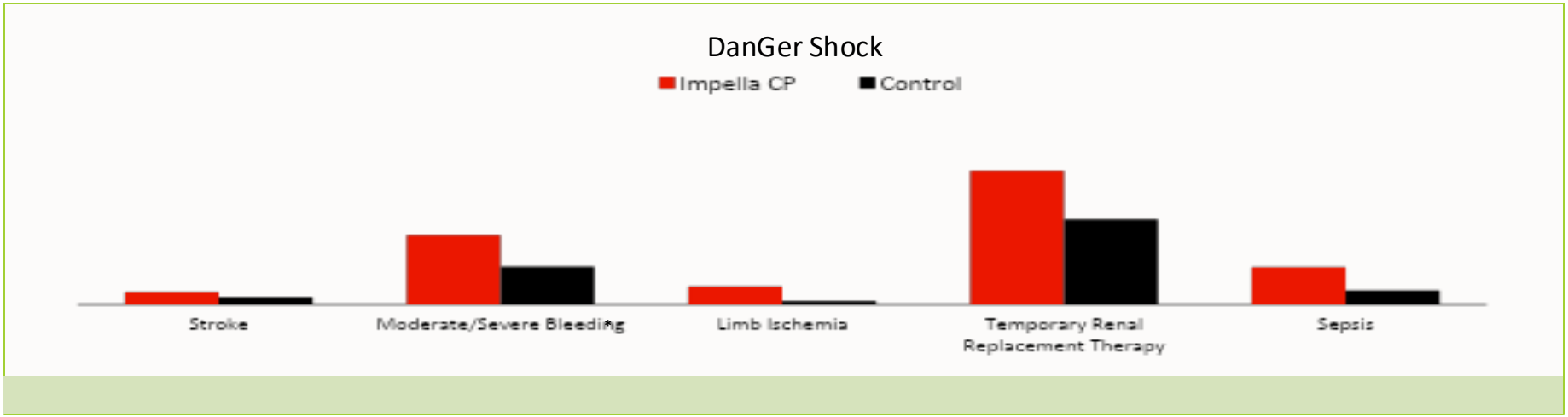
Increased survival with Impella CP is associated with more adverse events

Adverse events do not overshadow the significantly reduced mortality benefit with Impella CP



* Bleeding Rates: Control NO ECMO (3.5%), Control WITH ECMO (48.5%), Impella NO ECMO (15.8%), Impella WITH ECMO (67%).

Møller, J. E., Engstrøm, T., Jensen, L. O., Eiskjær, H., Mangner, N., Polzin, A., Schulze, P. C., 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, M. G., ... DanGer Shock Investigators (2024). Microaxial Flow Pump or Standard Care in Infarct-Related Cardiogenic Shock. *The New England journal of medicine*, *390*(15), 1382–1393. https://doi.org/10.1056/NEJMoa2312572

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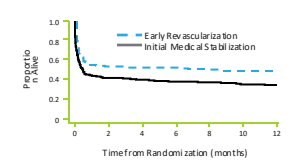
DanGer Shock is a guideline changing trial

Revascularization Strategy Trials

SHOCK: Early Revasc[1]



PRIMARY END-POINT

9.3% Absolute Reduction

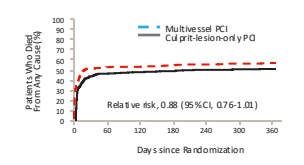
SECONDARY END-POINT

in 18 [illegible] 0.03)

ESC I-B

NNT 8 to save one additional life

Culprit Shock[2]



PRIMARY END-POINT

9.5% Absolute Reduction in 30-Day Mortality & RRT (p=0.01)

INDIVIDUAL END-POINT

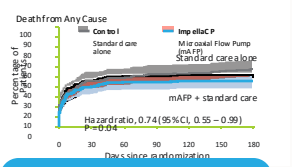
8.3% Absolute Reduction

ESC I-B

NNT 12 to save one additional life

MCS Device Trials

DanGer (Impella)[3]



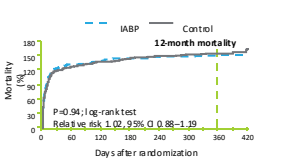
PRIMARY END-POINT

12.7% Absolute Reduction

American Heart Association / ESC 2a

NNT 8 to save one additional life

IABP Shock II[4]



PRIMARY END-POINT

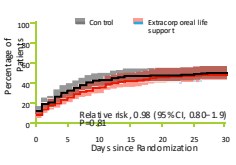
No Difference in 30-Day Mortality (p=0.69)

EXTENDED END-POINT

No Difference in 1-Year Mortality

American Heart Association 3 / ESC III-B

ECLS Shock[5]



PRIMARY END-POINT

No Difference in 30-Day Mortality (p=0.81)

EXTENDED END-POINT

No Difference in 180-Day Mortality

American Heart Association 3 / ESC IIa

Data presented on this slide to put results from various MSC studies into perspective, and are not intended to imply a direct comparison among the studies.

1. Hochman J, et al. Early revasc in AMI-CS. N Engl J Med 1999. DOI: 10.1056/nejm199908263410901
   Hochman J, et al. One-Year Survival. JAMA, January 10, 2001—Vol 285
2. Thiele H, et al. PCI strategies in patients with AMI-CS. N Engl J Med 2017. DOI: 10.1056/NEJMoa1710261
   Thiele H, et al. One-Year Outcomes. N Engl J Med 2018. DOI: 10.1056/NEJMoa1808788
3. Møller J, et al. DanGer PLACEHOLDER. N Engl J Med 2024. DOI: 10.1056/NEJMoa2312572
4. Thiele H, et al. Intraaortic Balloon Support for MI-CS. N Engl J Med 2023. DOI: 10.1056/NEJMoa2307227
   Thiele H, et al. IABP-SHOCK II final 12 month results. Lancet 2013. DOI: 10.1016/S0140-6736(13)61783-3
5. Thiele H, et al. ECLS in infarct-related CS. N Engl J Med 2012. DOI: 10.1056/NEJMoa1208410
6. Byrne R, et al. 2023 ESC Guidelines for the management of ACS. Eur Heart J 2023; 44:3720-3826
7. O'Gara PT, et al. 2013 ACCF/AHA guideline for the management of STEMI. J Am Coll Cardiol. 2013;61:e78-140

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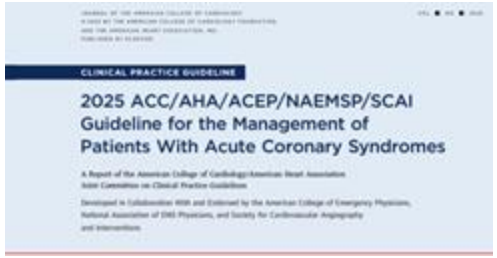
2025 ACC/AHA Guideline for Management of ACS



- Impella is Class 2a for selected STEMI patients with severe or refractory cardiogenic shock.
- IABP and VA-ECMO are downgraded to Class 3: No Benefit for routine use in AMI Cardiogenic Shock due to their lack of survival benefit.

This is the first update to the ACC/AHA guidelines in more than 12 years for patients with Acute Coronary Syndrome and Cardiogenic Shock

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]

Rao SV, et al. 2025 ACC/AHA/ACEP/NAEMSP/SCAI Guideline for the Management of Patients with Acute Coronary Syndromes. J Am Coll Cardiol. 2025

CS is Extremely Complicated

- Cannot be managed by 1 person/service alone
- Need a comprehensive shock team approach

- ICU with CS expertise
    - RN's with CS / advanced MCS experience
    - Cardiac anesthesiologist team
    - CHF dedicated in house team
    - General cardiology advanced imaging team
    - CTS
    - IC / Structural

Standardized protocols
    - periprocedural planning
    - execution
    - drug administration
    - weaning strategies
    - discharge planning/outpatient transition and GDMT, device considerations

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Conclusions

AMI, by definition, leads to a decrease in cardiac output and subsequent triggering of compensatory mechanisms

- Transient shock
- Sustained shock HIGH MORTALITY

Pressor therapy escalation often needed, but does not help underlying problem

Primary PCI, early revascularization (of culprit lesion) is clearly the goal.

Using MCS (Mechanical circulatory support) is an important tool and proven to be beneficial, on the whole, in patients with sustained cardiogenic shock.

Using MCS has potential serious complications, however, so the risk/benefit must be weighed carefully.

One size does not fit all!! A cardiogenic shock multidisciplinary team is required to individualize care for best possible outcomes.

Divider Slide Keep/edit as appropriate

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Thank You

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Complexities in Managing Right Heart Failure and Pulmonary Hypertension

Marina Jansen, MD

Virginia Mason Franciscan Health
Center for Cardiovascular Health

Disclosures

- NO RELEVANT DISCLOSURES

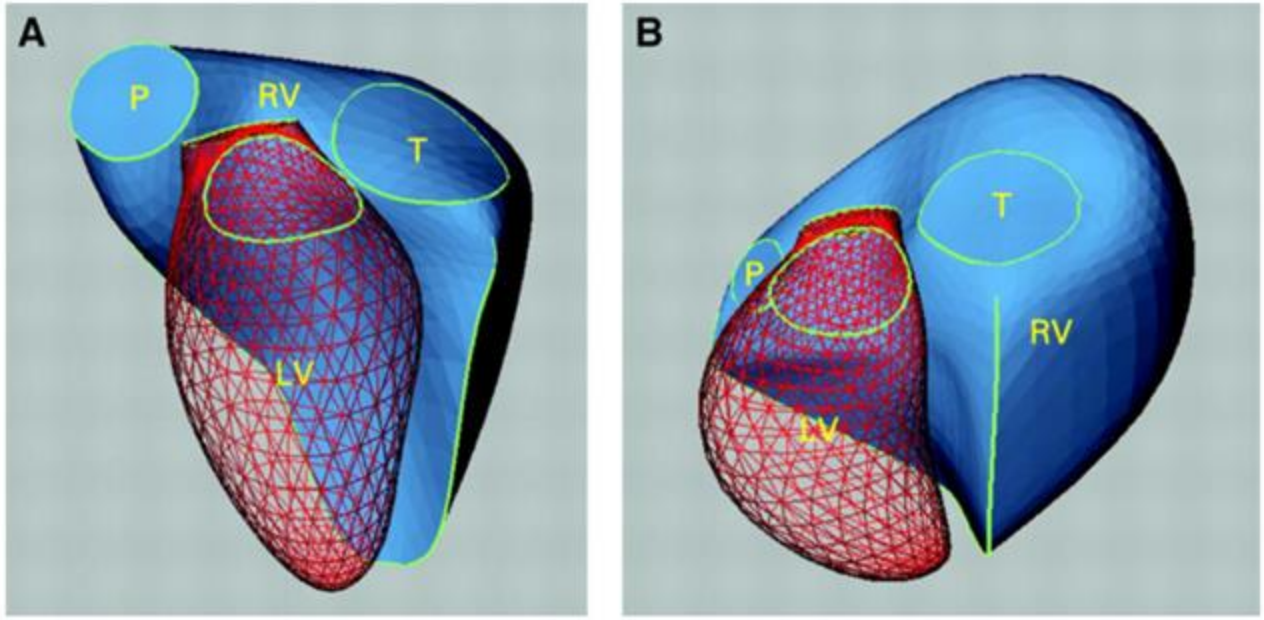


Figure 2. Right ventricular (RV) geometry in health and disease. Three-dimensional reconstructions of the RV illustrating its complex shape in a normal subject (**A**). RV remodeling in diseased hearts can result in profound shape change with RV dilation caused by chronic volume or pressure overload (**B**). The red mesh surface is the left ventricle (LV), and the solid blue surface is the RV. P indicates pulmonary valve; and T, tricuspid valve. Reprinted from Sheehan and Redington[3] with permission from BMJ Publishing Group, Ltd. Copyright © 2008, BMJ Publishing Group, Ltd.

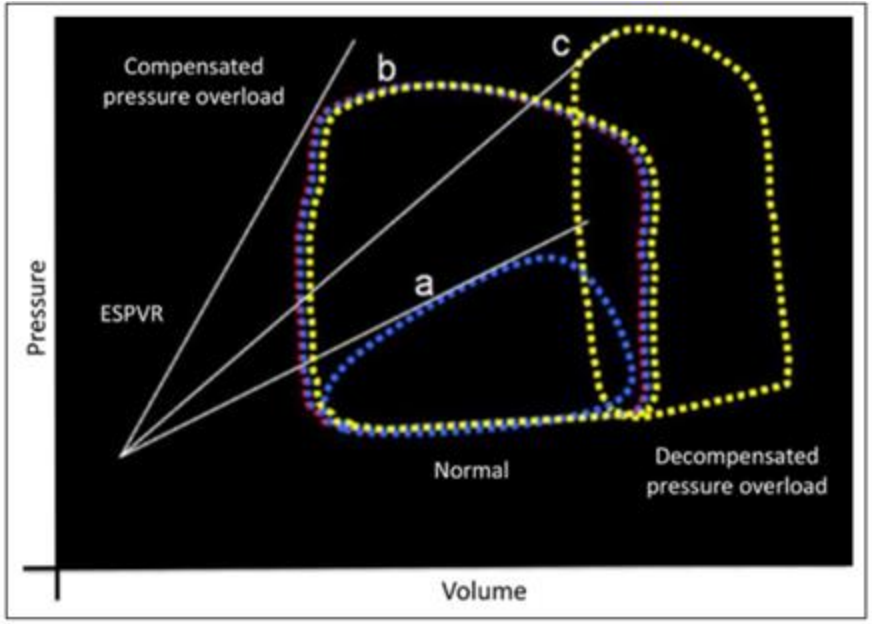
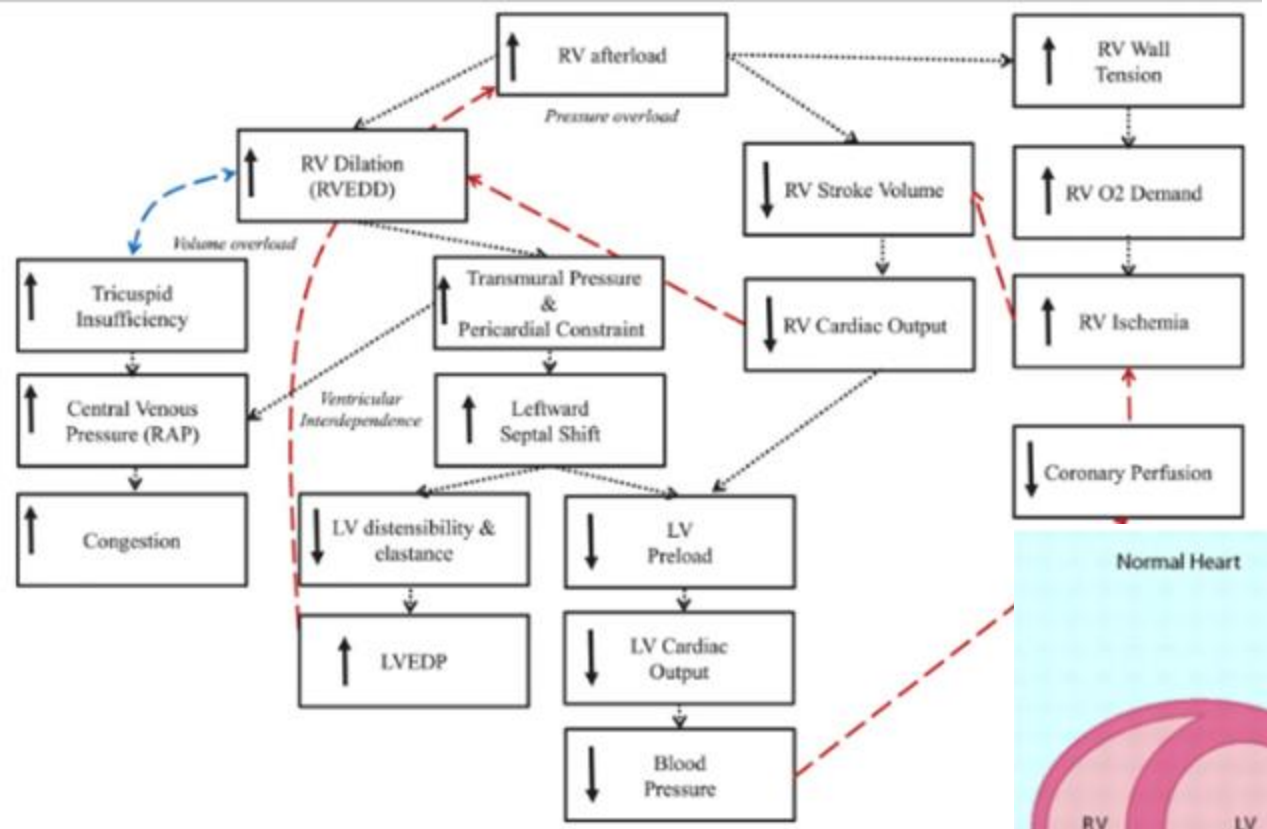
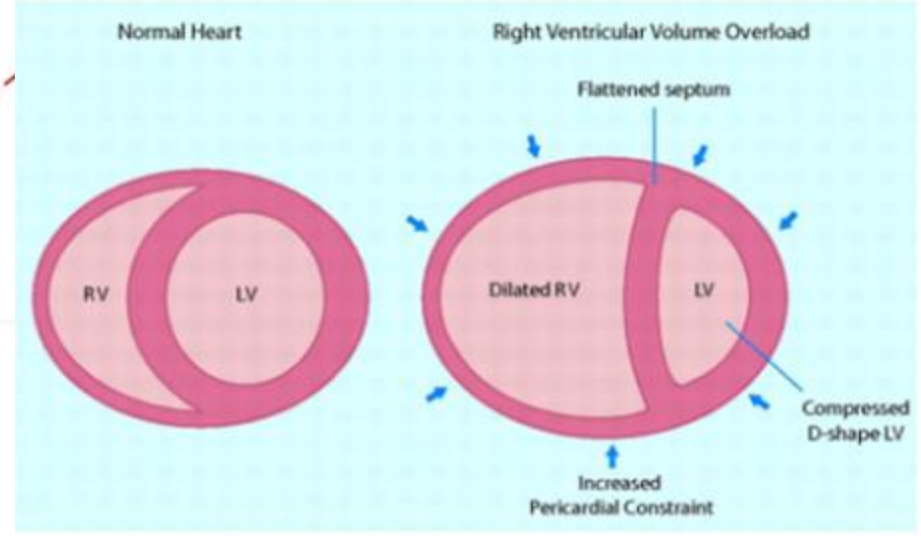


Figure 3. Right ventricular (RV) pressure-volume (PV) loops. RV PV loops obtained by a conductance catheter. White solid lines reflect the end-systolic PV relationships (ESPVR) of a series of loops generated by varying the loading conditions. The slope of ESPVR line reflects the RV end-systolic elastance (Ees). A steeper slope represents higher Ees. Loop a depicts a normal RV PV loop. A lower proportion of RV stroke work goes to pressure generation, with a higher proportion going to blood momentum. In the normal state, in contrast to the left ventricle (LV), there is a relative absence of RV isovolemic periods. The high momentum of blood ejecting from the RV into the low-pressure pulmonary circulation results in continued RV ejection after LV systolic ejection has ended into RV relaxation. Loop b represents a compensated, chronically hypertensive RV. Loop c is obtained from a decompensated hypertensive RV. Note the decrease in RV Ees from the compensated RV depicted in loop b to the decompensated RV depicted by loop c. Reproduced from Friedberg and Redington[13] with permission.





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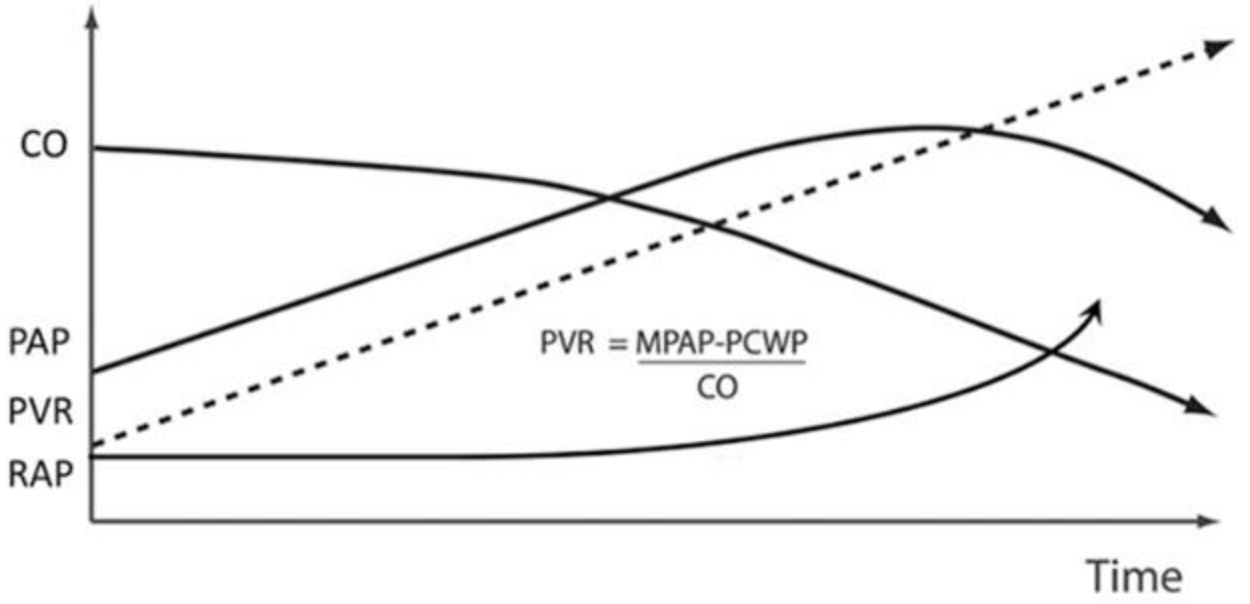


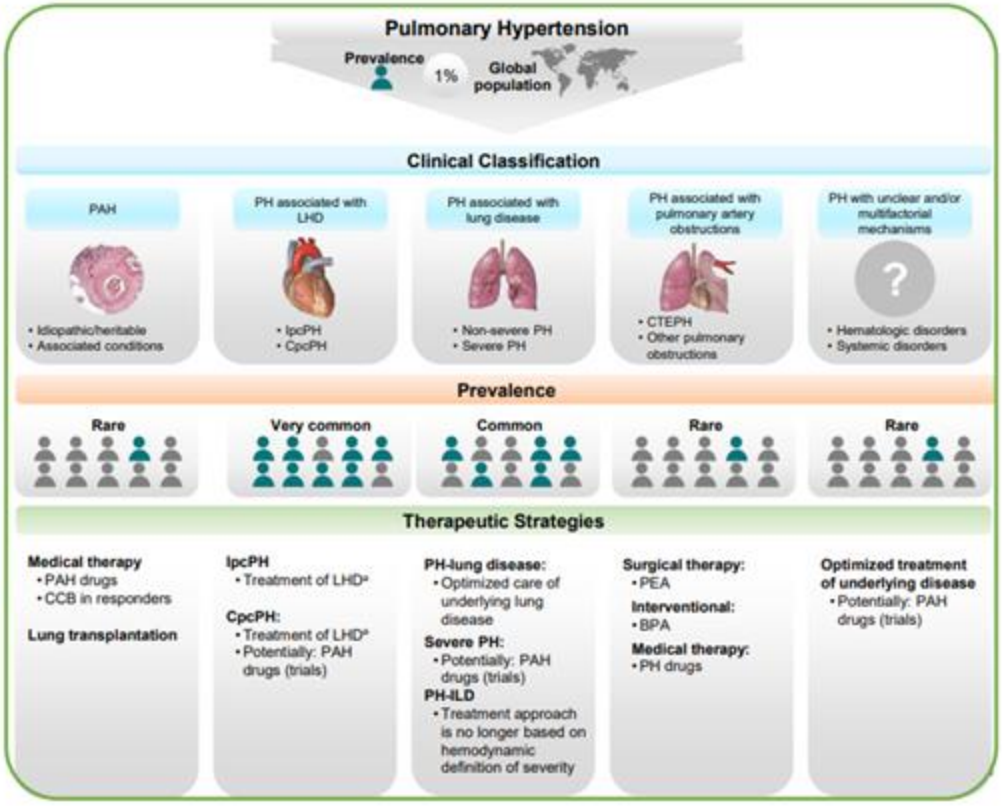
Figure 8. Hemodynamics in progressive pulmonary vascular disease. A decrease in pulmonary arterial pressure (PAP) in patients with pulmonary hypertension may be a sign of low cardiac output (CO) and severe right ventricular dysfunction. MPAP indicates mean PAP; PCWP, pulmonary artery capillary wedge pressure; PVR, pulmonary vascular resistance; and RAP, right atrial pressure. Adapted from Haddad et al[18] with permission. Copyright © 2008, American Heart Association.

What is the most common cause of right ventricular heart failure?

… pulmonary hypertension

Classification, Prevalence, and Treatment of PH[1,2]

Definition	Hemodynamic characteristics
PH	mPAP >20 mmHg
Pre-capillary PH	mPAP >20 mmHg PAWP ≤15 mmHg **PVR >2 WU**
IpcPH	mPAP >20 mmHg PAWP >15 mmHg **PVR ≤2 WU**
CpcPH	mPAP >20 mmHg PAWP >15 mmHg **PVR >2 WU**
Exercise PH	**mPAP/CO slope between rest and exercise >3 mmHg/L/min**

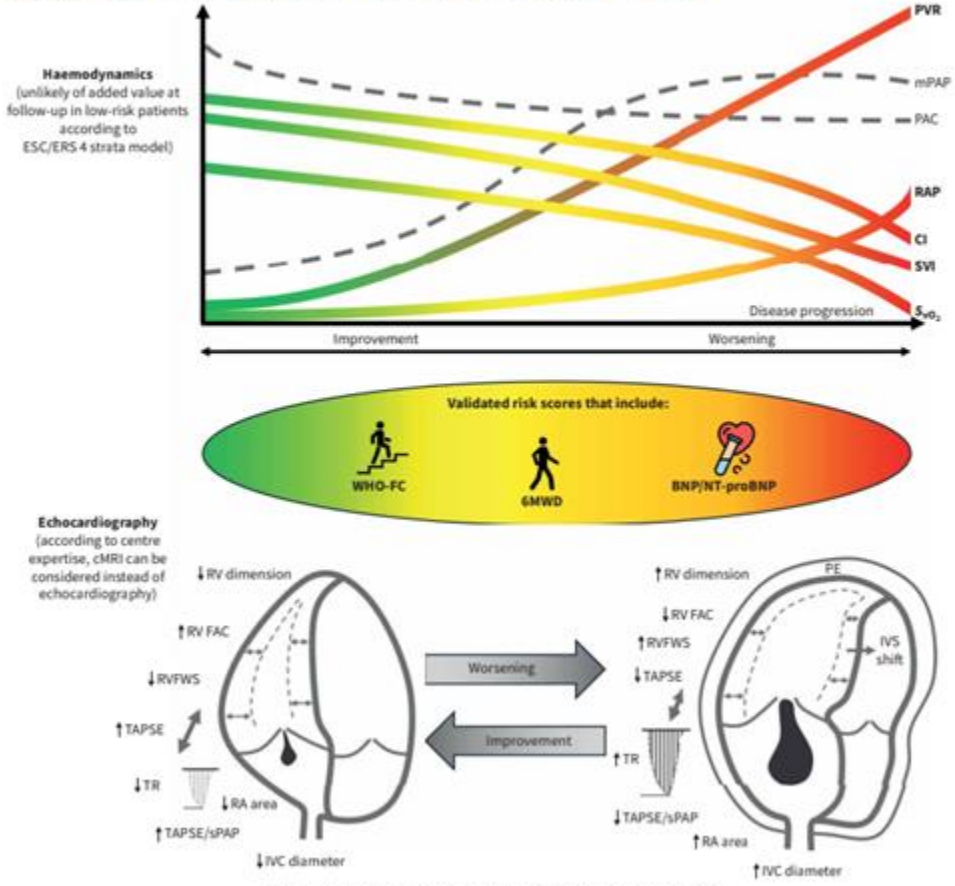


Footnotes captured in speaker notes.

1. Humbert M, et al. *Eur Respir J.* 2022 Aug 30:2200879.
2. Humbert M, et al. *Eur Heart J.* 2022;43(38):3618-3731.
3. McDonagh TA, et al. *Eur Heart J.* 2021; 42: 3599-3726.
4. Vahanian A, et al. *Eur Heart J.* 2022;43:561-632.

Risk stratification and treatment goals in pulmonary arterial hypertension

Fabio Dardi, Athénaïs Boucly, Raymond Benza, Robert Frantz, Valentina Mercurio, Horst Olschewski, Göran Rådegran, Lewis J. Rubin and Marius M. Hoeper

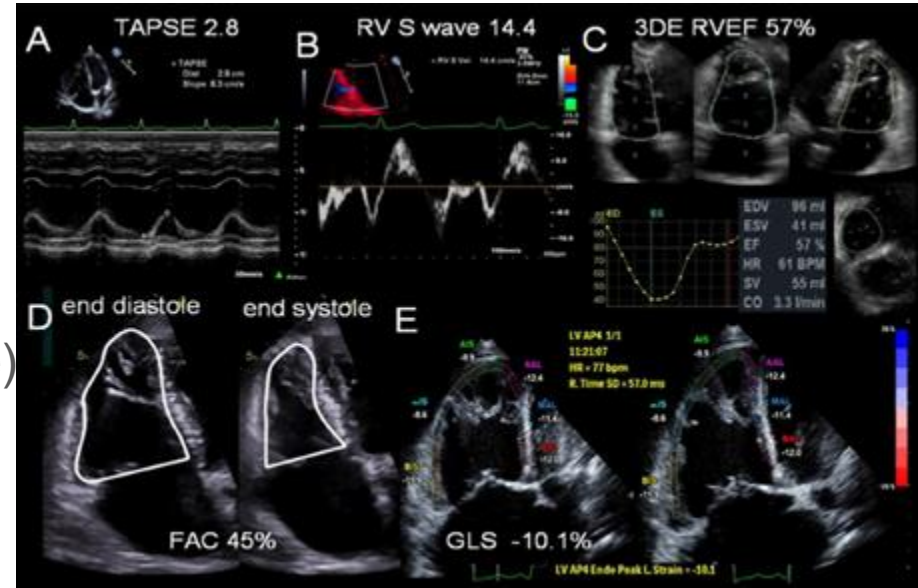


Right ventricular echocardiography guidelines.

Key Right Heart Parameters:

1. PA diameter (normal <25 mm)
2. RA area (normal <18 cm2)
3. RV/LV dimension (less than 1)
4. LAVI (less than 34 ml/m2)
5. IVC diameter (<21 mm, >50% respiratory variation)
6. E/e (<14, use lateral wall if there is septal flattening)

1. RV FAC (normal 35% and above)
2. Septal flattening
3. TAPSE (normal 1.7 cm or more)
4. TRV (normal <2.8 m/sec)
5. TAPSE/sPAP ratio (normal 0.5 or more)



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GOALS:

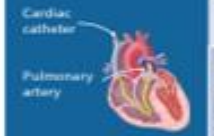
Domain	Treatment goals	Comments	Limitations
Exercise tolerance 	**6MWD >440 m** **WHO-FC I or II**	Not disease-specific, potentially affected by conditions other than PAH	Goals may not be achievable in patients with other conditions limiting exercise capacity
RV function and strain 	**BNP <50 ng·L^{-1}** **NT-proBNP <300 ng·L^{-1}**	Not disease-specific, potentially affected by conditions other than PAH	Goals may not be achievable in patients with interfering conditions
	Need for research prioritisation: RA area <18 cm^2 TR, none or trace TAPSE/sPAP >0.32 mm·mmHg^{-1}	Other imaging parameters from echocardiography and MRI are emerging	TAPSE/sPAP threshold requires further validation
Haemodynamics 	**RAP <8 mmHg** **CI ≥2.5 L·min^{-1}·m^{-2}** **SVI >37 mL·m^{-2}** **S_{vO_2} >65%** **PVR <5 WU**	Uncertain added value in low-risk patients according to ESC/ERS 4 strata model PVR <5 WU treatment goal may not apply to patients with congenital heart disease	Established prognostic value; however, not necessarily independent of noninvasive parameters
	Need for research prioritisation: mPAP <30–35 mmHg PAC ≥2.5 mL·mmHg^{-1}	With emerging therapies and effective combination treatment strategies, comprehensive haemodynamic assessment of treatment response is expected to play a prominent role in the management of patients with PAH	The proposed thresholds may be associated with long-term survival; however, this is not evidence-based and requires further validation

FIGURE 3 Comprehensive treatment goals in pulmonary arterial hypertension (PAH). RV: right ventricle; 6MWD: 6-min walk distance; WHO-FC: World Health Organization functional class; BNP: brain natriuretic peptide; NT-proBNP: N-terminal pro-BNP; RA: right atrium; TR: tricuspid regurgitation; TAPSE/sPAP: tricuspid annular plane systolic excursion/systolic pulmonary artery pressure ratio (estimated by echocardiography); RAP: right atrial pressure; CI: cardiac index; SVI: stroke volume index; S_{vO_2}: mixed venous oxygen saturation; PVR: pulmonary vascular resistance; WU: Wood Units; mPAP: mean pulmonary artery pressure; PAC: pulmonary arterial compliance; ESC: European Society of Cardiology; ERS: European Respiratory Society.

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TABLE 1 Main triggering and/or worsening factors in acute right heart failure (RHF)

	Mechanisms	Management
Supraventricular arrhythmia	Due to atrial remodelling and dilation Loss of atrial function contributes to impaired RV function	Avoid β-blockers and calcium channel blockers Consider digoxin to reduce heart rate Consider amiodarone for medical cardioversion Electric cardioversion/radiofrequency ablation according to the type of arrhythmia and tolerability
Infection	Translocation from the bowel Bacteraemia due to central-line infection (*i.v.* epoprostenol) Intercurrent infection	Consider rapid empirical treatment after bacteriological analysis Central line removal in in case of catheter infection
Hypoxaemia	PFO opening caused by right-atrial overload Severe V'/Q' mismatch (*e.g.* CTEPH) Severe lung diffusion impairment (*e.g.* PVOD, group 3 PH) Eisenmenger syndrome (right-to-left shunt) Intercurrent disease (*e.g.* pneumonia, atelectasis)	Noninvasive oxygen therapy to maintain S_{aO_2} >90% (high-flow oxygen therapy) Avoid mechanical ventilation/hypercapnia and hyperinflation
Surgery and anaesthesia	Rapid changes in ventricular preload, afterload and contractility due to volume shifts, anaesthetic agents, mechanical ventilation	Adopting a multidisciplinary approach in an expert centre with a systematic pre-operative risk assessment and optimisation Consider a carefully planned nonemergency surgery and close perioperative monitoring Post-operative management in ICU to detect early acute decompensated RHF
Others	Pulmonary embolism Anaemia Noncompliance	Curative anticoagulation Blood transfusion Educational programme

RV: right ventricle; *i.v.*: intravenous; PFO: patent foramen ovale; V'/Q': ventilation/perfusion ratio; CTEPH: chronic thromboembolic pulmonary hypertension; PVOD: pulmonary veno-occlusive disease; PH: pulmonary hypertension; S_{aO_2}: arterial oxygen saturation; ICU: intensive care unit.

TABLE 2 Monitoring of acute right heart failure (RHF) in pulmonary hypertension and warning parameters suggesting evolution toward refractory right ventricular (RV) failure

	Parameters	Indications	Indicators of progression toward refractory RHF
Clinical signs	General symptoms Clinical signs of poor peripheral perfusion Neurological disorders Urinary output	Should be monitored in all patients	Recurrent syncope on medical treatment Agitation, confusion Poor diuresis or anuria Persistent congestive symptoms (without weight loss) despite optimal treatment
Vital signs	Systemic blood pressure/pulse pressure Heart rate Respiratory rate/oxygen saturation Temperature	Should be monitored in all patients	Systemic hypotension needing increased dose of vasopressors Low systemic pulse pressure Tachycardia
Biological parameters	BNP or NT-proBNP Troponin BUN-creatinine/eGFR Lactates Liver enzymes	Should be monitored in all patients	Persistent high levels of BNP or NT-proBNP Increased troponin (RV ischaemia) High level of lactate Persistent severe cardiorenal syndrome on medical treatment High levels of transaminases and bilirubin due to congestive and/or shock liver
Venous central line	Central venous pressure S_{vO_2}	For inotrope or vasopressor support	Increasing or persistent high central venous pressure despite optimal medical treatment Decreasing or persistent low S_{vO_2} despite optimal medical treatment
Echocardiography parameters	RV function (TAPSE, S wave, RV strain) Ventriculo-arterial coupling (TAPSE/sPAP) Tricuspid insufficiency severity RA size, RA strain RV/LV interdependence Cardiac output Pericardial effusion Inferior vena cava diameter	Should be monitored in all patients	No improvement in RV function parameters under optimal medical treatment Compression of left-sided heart chambers Abundant pericardial effusion Severe tricuspid insufficiency
Right heart catheterisation	Right atrial pressure Cardiac output S_{cvO_2} Stroke volume index	Prefer punctual haemodynamic assessment Consider continuous invasive haemodynamic monitoring only in selected complex cases	No improvement in cardiac output or stroke volume index on optimal medical management No improvement in RAP on optimal medical management No improvement in S_{cvO_2} on optimal medical management

BNP: brain natriuretic peptide; NT-proBNP: N-terminal pro-BNP; BUN: blood urea nitrogen; eGFR: estimated glomerular filtration rate; S_{vO_2}: mixed venous oxygen saturation; TAPSE: tricuspid annular plane systolic excursion; sPAP: systolic pulmonary arterial pressure; RA: right atrium; LV: left ventricle; S_{cvO_2}: central venous oxygen saturation; RAP: right atrial pressure.

Transplantation, bridging, and support technologies in pulmonary hypertension

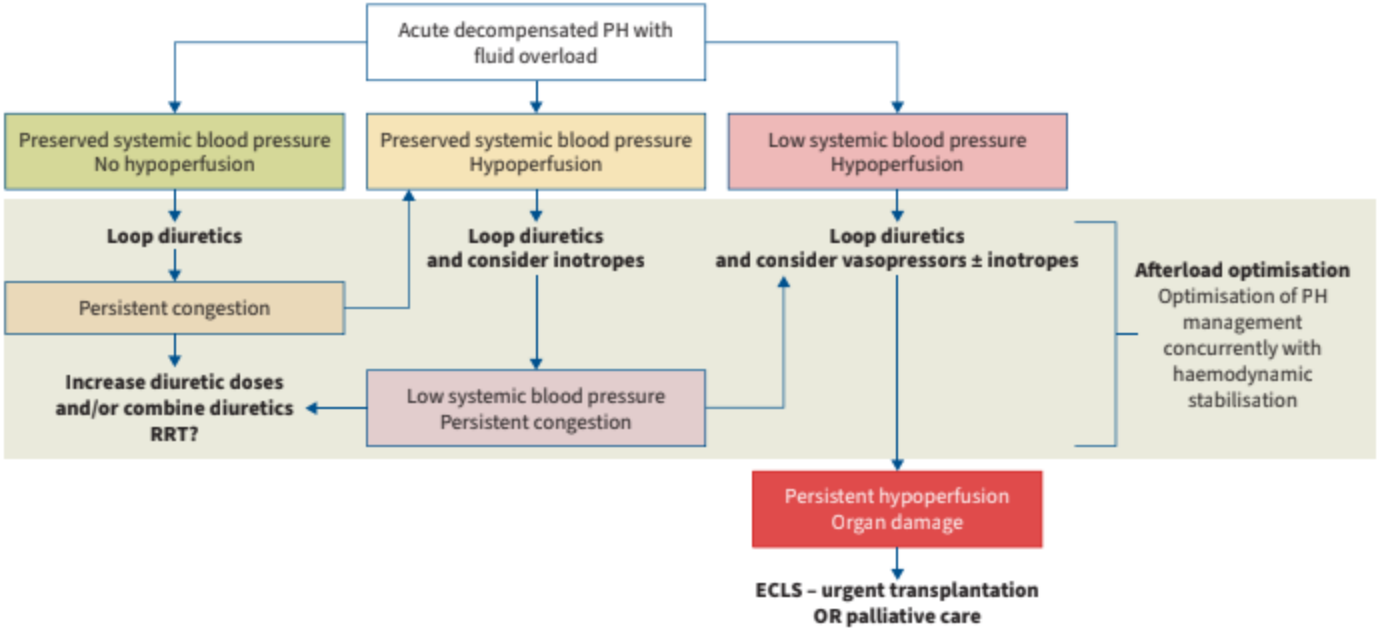

FIGURE 1 Management of acute decompensated pulmonary hypertension (PH) in the intensive care unit. RRT: renal replacement therapy; ECLS: extracorporeal life support.

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ECLS and lung transplant

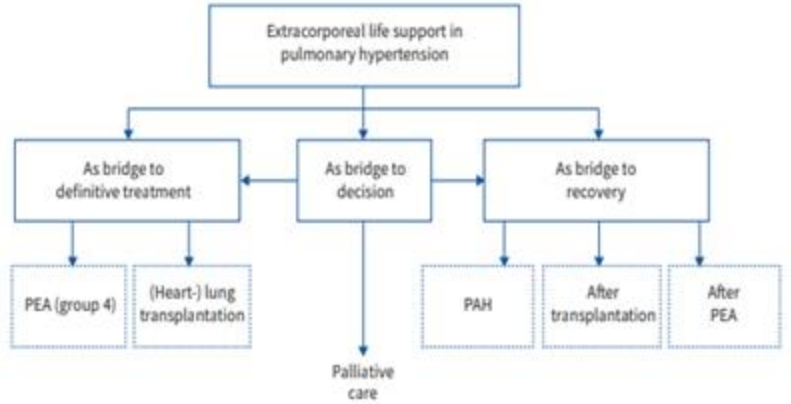

FIGURE 2 Indications for extracorporeal life support in pulmonary hypertension. PEA: pulmonary endarterectomy; PAH: pulmonary arterial hypertension.

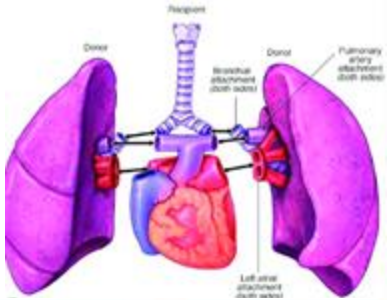

TABLE 3 General recommendations for transplant in pulmonary hypertension

General recommendations for transplant
Lung transplant as a treatment option to be formalised into curricula for residents and fellows training in pulmonary medicine, cardiology and cardiac and thoracic surgery
Patients to be engaged in discussions about transplantation as a treatment option early in their treatment course
PH programmes to develop formal referral mechanisms and integration with transplant centres to facilitate communication and timely referral
Patients with high-risk features at the time of diagnosis to be referred early for transplant assessment
Decisions to list patients should be comprehensive and include risk assessment, severity of right heart failure, comorbidities (in particular, modifiable comorbid conditions), anticipated waitlist times (blood type, sensitisation, size, graft allocation rules) and donor pool, and incorporate patient preferences and bridging options discussed and planned for
Bilateral lung transplant is the preferred option for the majority of patients
Bridging using extracorporeal support to be considered for suitable candidates. Both bridging to decision as well as transplant should be considered
The ECMO configuration should be tailored to the unique physiological circumstances, as well as centre expertise[#]
Post-operative VA-ECMO may be used as needed in select patients following transplantation

ECMO: extracorporeal membrane oxygenation; VA: veno-arterial. [#]: we want to advise programmes to do the right thing for a patient, not just what they "know how to do"; send to a specialised centre if needed.

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Thank You

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Successful Anesthesia for a Cardiac Patient

Ricky S. Harika, MD
Section Head, Cardiothoracic Anesthesiology
Department of Anesthesiology
Virginia Mason Medical Center
October 4, 2025

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I have no relevant disclosures.

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Preoperative Considerations

1) Preoperative evaluation by Anesthesiology team
    a) Pre-anesthesia assessment clinic at Virginia Mason Medical Center
        i) 206-625-7271
        ii) dt.paac@commonspirit.org
        iii) Cerner message: DT PAAC
    b) Virtual or In-person
    c) Gather data (including OSH records) and organize into a note
    d) Cardiothoracic Anesthesiology review

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What Really Matters?

1) Pulmonary
    a) URI within past 4 weeks
    b) Acute change or worsening chronic lung disease
        i) PFTs? Pulmonology?
    c) Smoking cessation
2) Endocrine
    a) Uncontrolled diabetes
        i) Ketoacidosis, autonomic dysfunction and hemodynamic compromise, renal dysfunction, infection
3) Acute/Chronic Pain and Anxiety
    a) Tachycardia, hypertension, hyperventilation and atelectasis (hypoxia/hypercapnia)

Medications

1) **SGLT2** -glifozin (Ex: Empagliflozin/Jardiance)
    a) Euglycemic ketoacidosis
    b) > 72 hours
2) **GLP-1** (Ex: Semaglutide/Ozempic)
    a) Delayed gastric emptying → increased aspiration risk
    b) Hold daily dose or weekly dose

CommonSpirit Recommendations (Nov, 2024)

Recommendations:[2,3]

Generic Name	Brand Name	Hold Before Surgery
Canagliflozin	Invokana	Stop 3 days
Canagliflozin + Metformin	Vokanamet	Stop 3 days
Dapagliflozin	Forxiga, Edistride	Stop 3 days
Dapagliflozin + Metformin	Ebymect / Xigduo	Stop 3 days
Dapagliflozin + Saxagliptin	Qtern	Stop 3 days
Empagliflozin	Jardiance	Stop 3 days
Empagliflozin + Metformin	Synjardy	Stop 3 days
Empagliflozin + Linagliptin	Glyxambi	Stop 3 days
Ertugliflozin	Steglatro	Stop **4** days
Ertugliflozin + Metformin	Segluromet	Stop **4** days
Ertugliflozin + Sitagliptin	Steglujan	Stop **4** days

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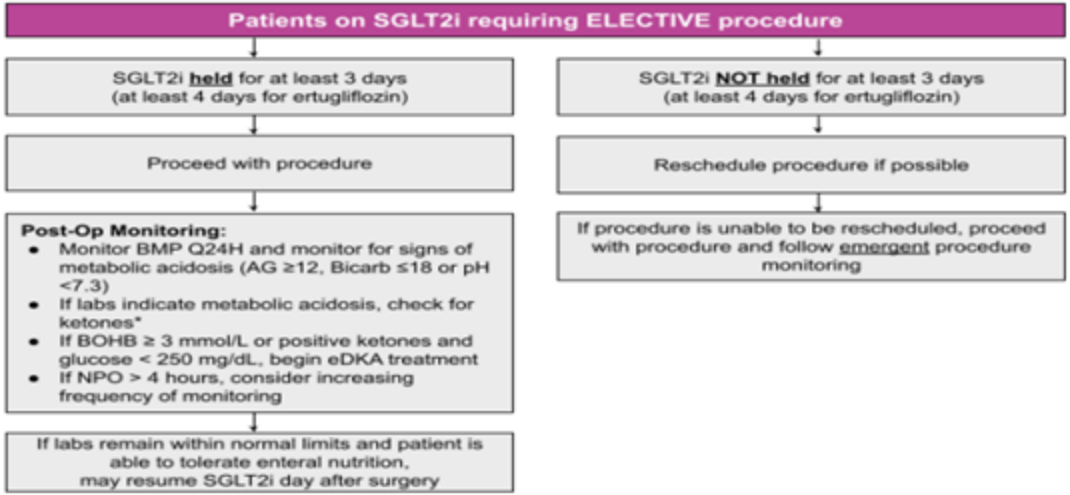
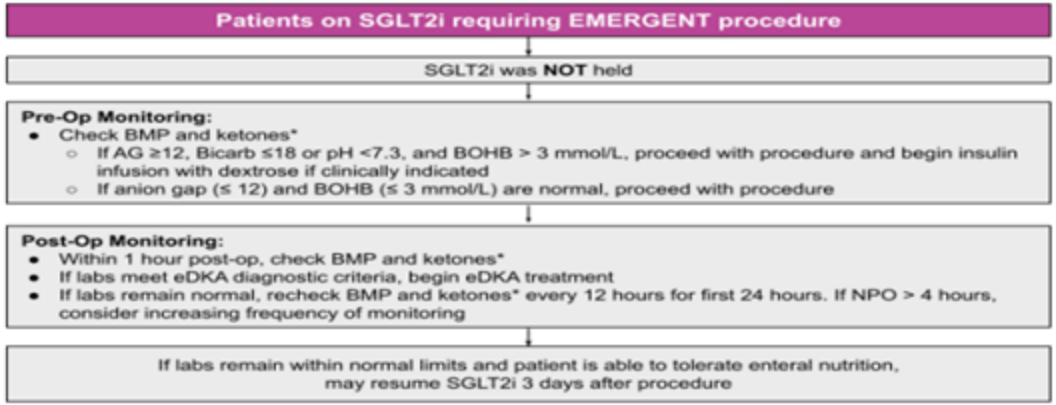
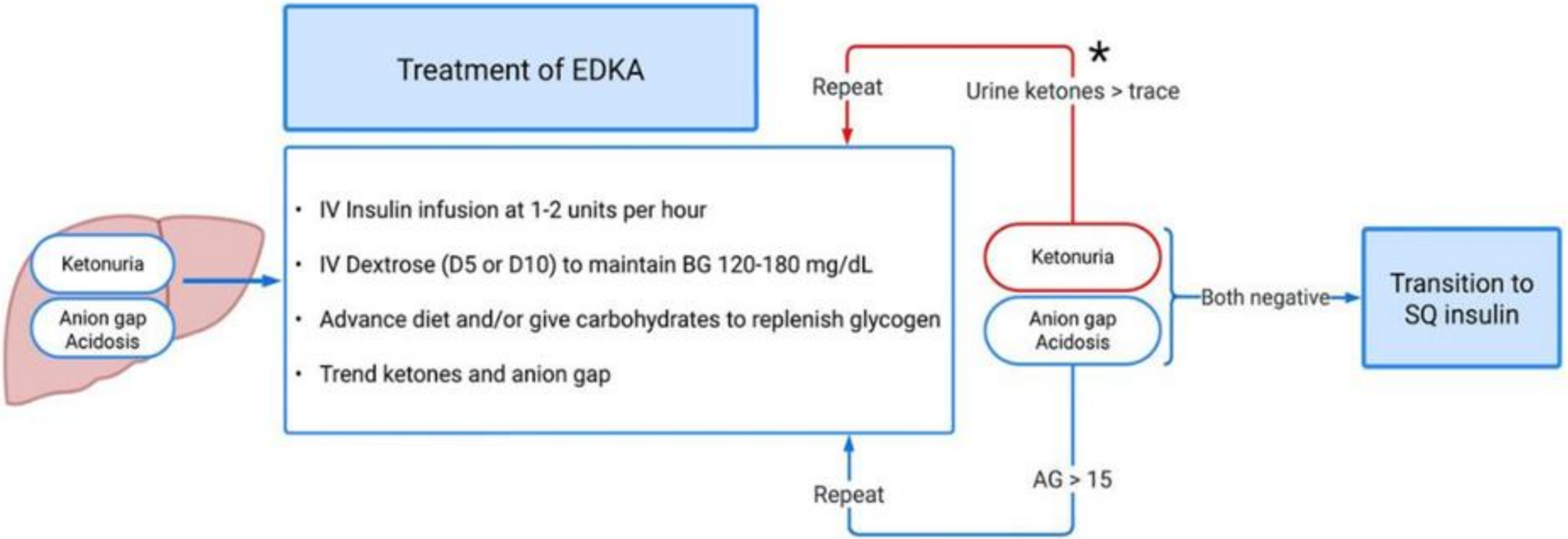

Patients on SGLT2i requiring ELECTIVE procedure
SGLT2i held for at least 3 days (at least 4 days for ertugliflozin)
Proceed with procedure
Post-Op Monitoring:
Monitor BMP Q24H and monitor for signs of metabolic acidosis (AG ≥12, Bicarb ≤18 or pH <7.3)
If labs indicate metabolic acidosis, check for ketones*
If BOHB ≥ 3 mmol/L or positive ketones and glucose < 250 mg/dL, begin eDKA treatment
If NPO > 4 hours, consider increasing frequency of monitoring
If labs remain within normal limits and patient is able to tolerate enteral nutrition, may resume SGLT2i day after surgery
SGLT2i NOT held for at least 3 days (at least 4 days for ertugliflozin)
Reschedule procedure if possible
If procedure is unable to be rescheduled, proceed with procedure and follow emergent procedure monitoring


Patients on SGLT2i requiring EMERGENT procedure
SGLT2i was NOT held
Pre-Op Monitoring:
Check BMP and ketones*
If AG ≥12, Bicarb ≤18 or pH <7.3, and BOHB > 3 mmol/L, proceed with procedure and begin insulin infusion with dextrose if clinically indicated
If anion gap (≤ 12) and BOHB (≤ 3 mmol/L) are normal, proceed with procedure
Post-Op Monitoring:
Within 1 hour post-op, check BMP and ketones*
If labs meet eDKA diagnostic criteria, begin eDKA treatment
If labs remain normal, recheck BMP and ketones* every 12 hours for first 24 hours. If NPO > 4 hours, consider increasing frequency of monitoring
If labs remain within normal limits and patient is able to tolerate enteral nutrition, may resume SGLT2i 3 days after procedure

Treatment of eDKA



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Chow, et al., 2023

GLP-1: American Society of Anesthesiologists (ASA) Recommendations

Day of the Procedure:

- If gastrointestinal (GI) symptoms such as severe nausea/vomiting/retching, abdominal bloating, or abdominal pain are present, consider delaying elective procedure, and discuss the concerns of potential risk of regurgitation and pulmonary aspiration of gastric contents with the proceduralist/surgeon and the patient.
- If the patient has no GI symptoms, and the GLP-1 agonists have been held as advised, proceed as usual.
- If the patient has no GI symptoms, but the GLP-1 agonists were not held as advised, proceed with 'full stomach' precautions or consider evaluating gastric volume by ultrasound, if possible and if proficient with the technique. If the stomach is empty, proceed as usual. If the stomach is full or if gastric ultrasound inconclusive or not possible, consider delaying the procedure or treat the patient as 'full stomach' and manage accordingly. Discuss the concerns of potential risk of regurgitation and pulmonary aspiration of gastric contents with the proceduralist/surgeon and the patient.
- There is no evidence to suggest the optimal duration of fasting for patients on GLP-1 agonists. Therefore, until we have adequate evidence, we suggest following the current ASA fasting guidelines.[15,16]

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Anesthetic Success

1) Team Sport: Multi-disciplinary discussions
    a) Specialized training and high volume center
        i) Abbott training for TEER
        ii) Chosen for MedAxiom Watchman Best Practices
        iii) COE for HCM
2) Understanding complex pathophysiology
3) Setting expectations - what is considered a success for this patient?

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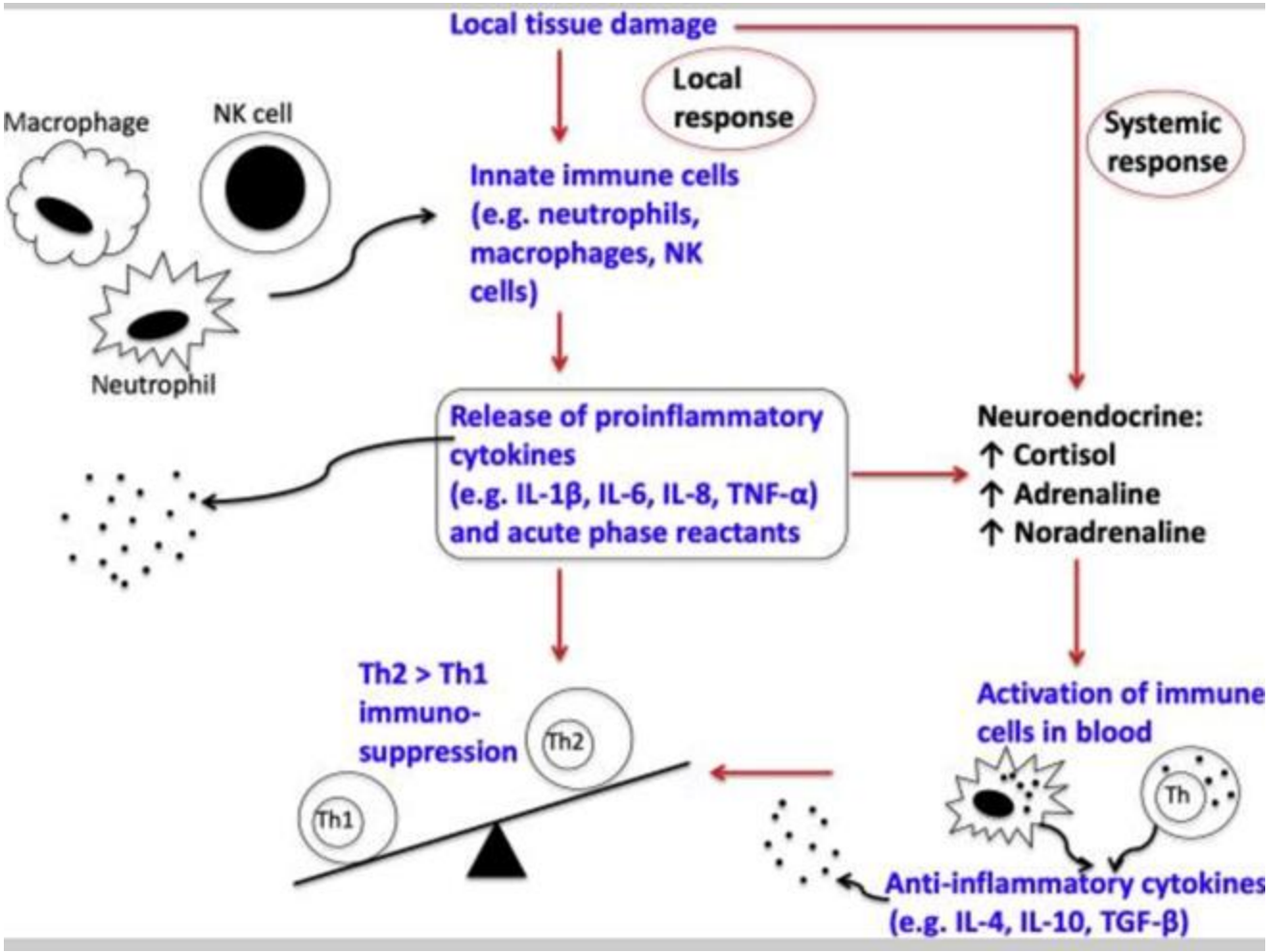
1) **Type of Procedure**
   a) Non-cardiac surgery
   b) PCI with impella
   c) TEER
   d) Open-heart
   e) AFib ablation
   f) VT ablation on ECMO
2) **Pre-existing Conditions**
   a) Cardiopulmonary
   b) Renal, Hepatic, etc.
3) **Medications**
   a) Amnesia
   b) Pain
   c) Muscle relaxants
   d) Vasopressors
   e) Vasodilators



Cusack, et al. (2020)

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Vasopressors

	Mechanism of action				Cardiac		Peripheral Vasculature	
Drug	**α1**	**β1**	**β2**	**Dopaminergic**	**Heart rate**	**Contractility**	**Vasoconstriction**	**Vasodilation**
Epinephrine	–/+*	++	+	0	+ + ++	+ + ++	+ + ++	+ + +
Norepinephrine	++	++	–	0	+	++	+ + ++	0
Dopamine	–/+*	–/+ +*	–/+*	++	+/+ +*	+/+ +*	0/+ +*	+/0*
Dobutamine	–	+ +	+	0	++	++ +/+ + + +*	0	++
Milrinone	Phosphodiesterase inhibitors				+	+ + +	0	++
Vasopressin	V1 receptor agonist				0	0	+ + ++	0

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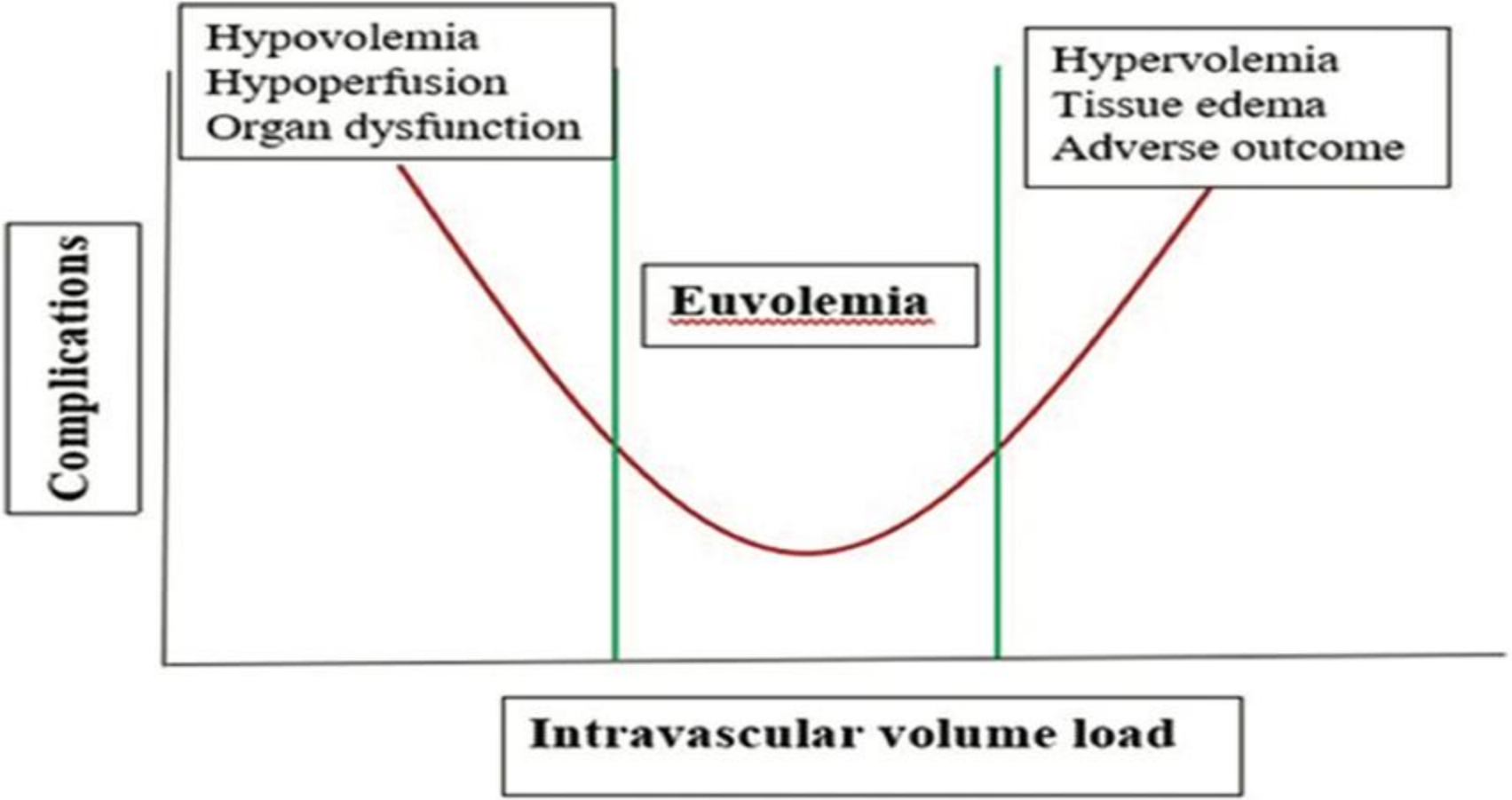

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Kendrick, et al. (2019)

Intraoperative Monitoring

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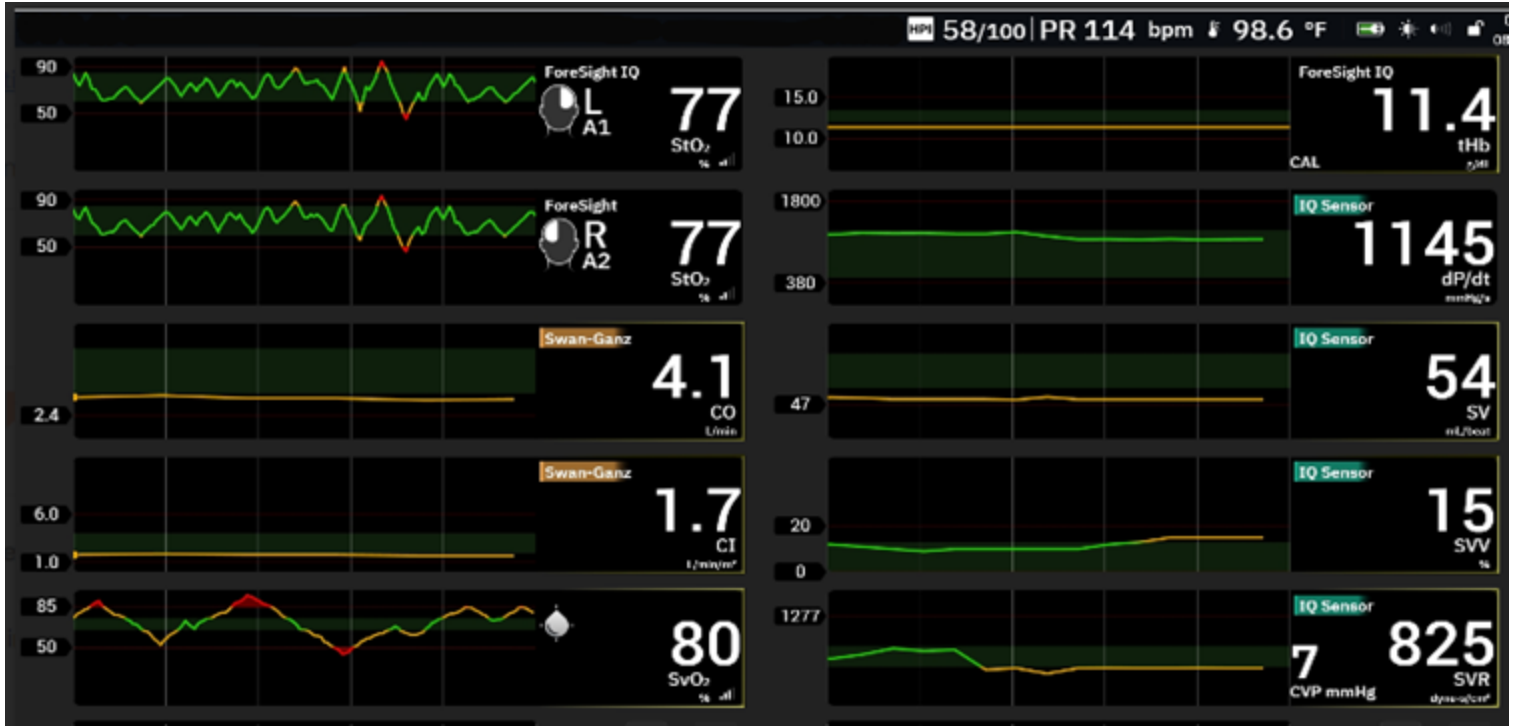
Cerebral Oximetry, CO/CI, SvO_2, SVR



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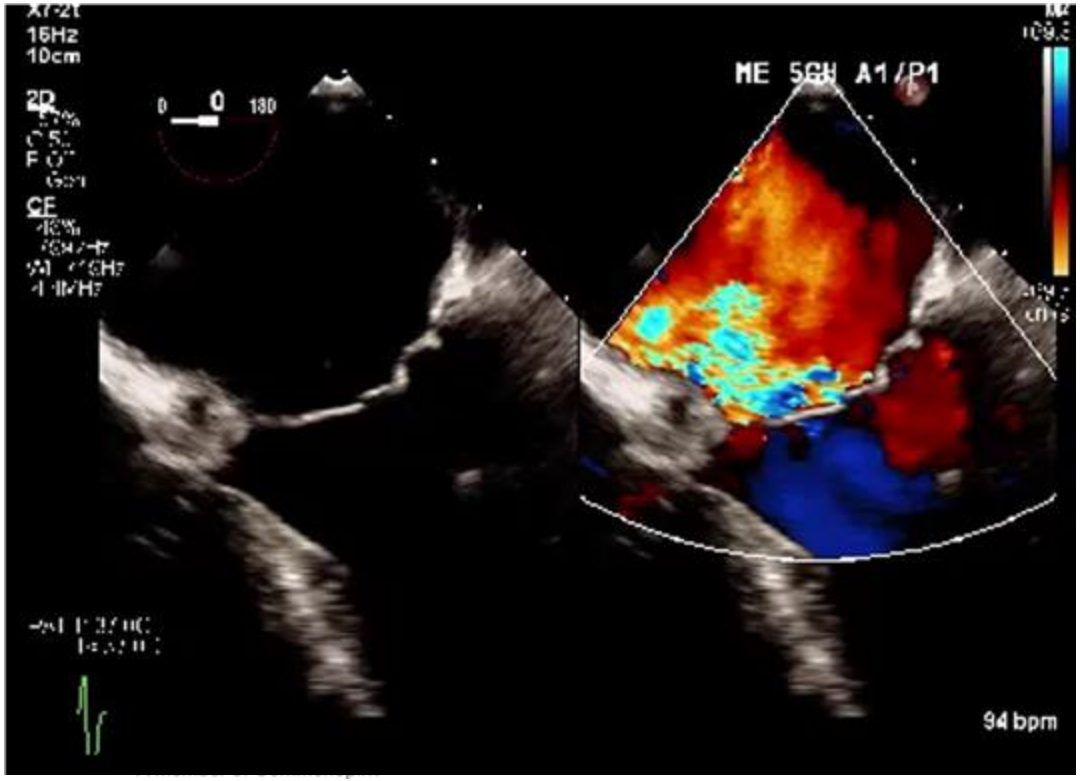
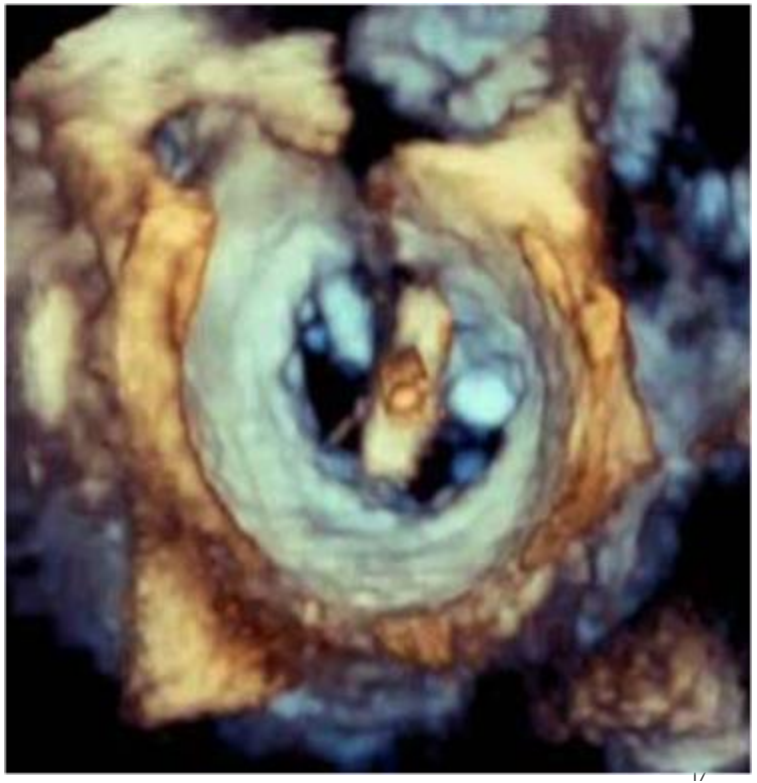
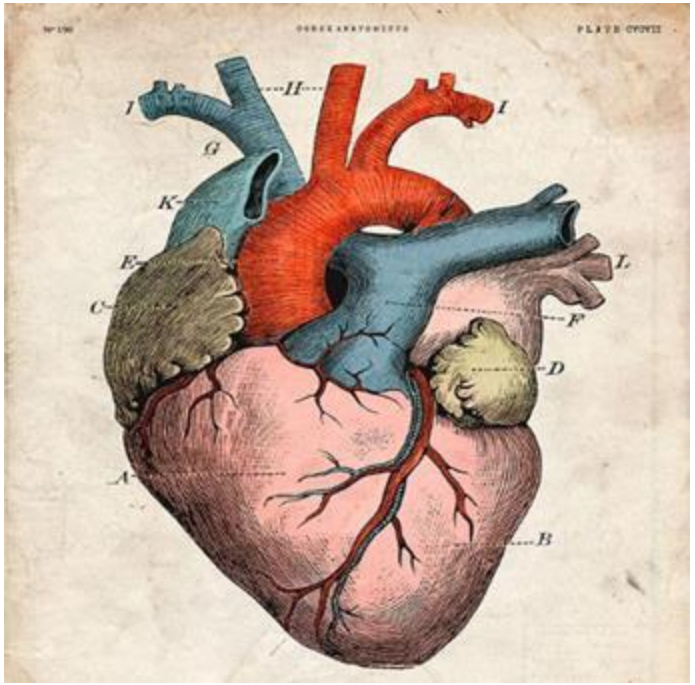
Transesophageal Echocardiography (TEE)





Thank You

Ricky.Harika@Commonspirit.org



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