2023 전공의 연수교육

ECMO for *Post-Cardiotomy Shock*

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Contents

Cardiogenic Shock after Cardiac Surgery

- **Epidemiology of cardiac arrest**
  - 0.7% - 8%
  - per 400,000 US open heart cases annually

- **Survival for in-hospital cardiac arrest - nearly 20%**
- **Survival post-cardiac surgery arrest - nearly 50%**
  - Survival for CABG 98-99%

Cardiogenic Shock after Cardiac Surgery

- Cardiac surgery patients are different !
- Standard AHA resuscitation ACLS may not be ideal
- Recent sternotomy has implications on external cardiac massage
  - Different effectiveness & safety issues
- Causes of cardiac arrest are different → ***Highly Reversible !!***
  - Ventricular fibrillation
  - Tamponade
  - Bleeding

Cardiogenic Shock after Cardiac Surgery

- Majority of PC-cardiac arrest
  - Within POD#3
  - Highly reversible – *Vfib, PM mediated, ischemia and electrolyte issues*
  - Likely to survival is much higher when **chest opens within 10 minutes**
- ECPR vs. Re-sternotomy
  - Pump failure? → *MCS / ECMO*
  - Other correctible reasons? → *CALS*

(cardiac surgical advanced life support)

ELSEVIER

European Journal of Cardio-thoracic Surgery 22 (2002) 421–425

EUROPEAN JOURNAL OF CARDIO-THORACIC SURGERY

www.elsevier.com/locate/ejcts

Six-year prospective audit of chest reopening after cardiac arrest☆

J.H. Mackay*, S.J. Powell, J. Osgathorp, C.J. Rozario

Papworth Hospital, Cambridge CB3 8RE, UK

Received 19 January 2002; received in revised form 29 April 2002; accepted 2 May 2002

Table 1
Characteristics of 79 chest reopenings

Chest opening characteristics		Survival to discharge
Location of arrest call	Patients	Survivors (%)
Critical care	58	19 (33)
Ward	21	1 (5)
Location of chest opening		
Critical care/theatre	58	19 (33)
Ward	12	0
Scooped from ward	9	1 (11)
Type of arrest		
VF/VT[a]	22	4 (18)
EMD[b]	36	13 (36)
Asystole	12	2 (17)
Other	9	1 (11)
Time since surgery to chest opening (h)		
<24	40	15 (39)
24–72	16	4 (25)
>72	23	1 (4)
Time from arrest to chest opening (min)		
<10	29	14 (48)
10–20	21	3 (14)
>20	29	3 (10)
Bypass utilised during resuscitation		
No	57	13 (23)
Yes	22	7 (32)

CARDIAC ARREST

assess rhythm

- ventricular fibrillation or tachycardia — DC shock (3 attempts)
- asystole or severe bradycardia — pace (if wires available)
- pulseless electrical activity

start basic life support

- amiodarone 300mg via central venous line
- consider external pacing
- if paced, turn off pacing to exclude underlying VF

prepare for emergency resternotomy

- continue CPR with single DC shock every 2 minutes until resternotomy
- continue CPR until resternotomy
- continue CPR until resternotomy

airway and ventilation

- If ventilated turn FiO_2 to 100% and switch off PEEP.
- Change to bag/valve with 100% O_2, verify ET tube position and cuff inflation and listen for breath sounds bilaterally to exclude a pneumothorax or hemothorax.
- If tension pneumothorax suspected, immediately place large bore cannula in the 2nd rib space anterior mid-clavicular line.

DO NOT GIVE EPINEPHRINE unless a senior doctor advises this.

If an IABP is in place change to pressure trigger.

Do not delay basic life support for defibrillation or pacing for more than one minute.

The Society of Thoracic Surgeons Expert Consensus for the Resuscitation of Patients Who Arrest After Cardiac Surgery

The Society of Thoracic Surgeons Task Force on Resuscitation After Cardiac Surgery

Fig 3. Recommended emergency resternotomy set.

STS EXPERT CONSENSUS STATEMENT

The Society of Thoracic Surgeons Expert Consensus for the Resuscitation of Patients Who Arrest After Cardiac Surgery

The Society of Thoracic Surgeons Task Force on Resuscitation After Cardiac Surgery

1. External CPR
2. Airway assessment and management
3. Defibrillator and pacer

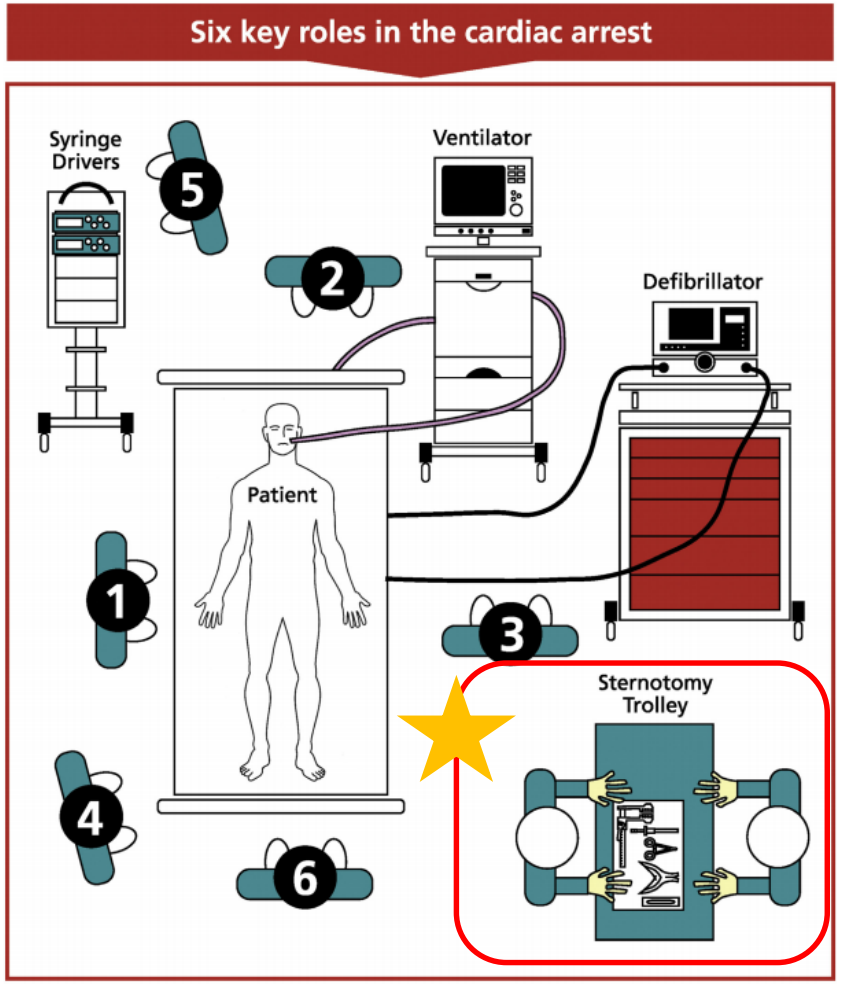
- during sternotomy, prepare sterile internal paddles

4. Senior code leader
5. Infusion provider
6. Unit leader

- *ensure resternotomy team preparing*
- *call others for assistance (ECMO, OR, additional equipment)*

7. Resternotomy team

- preparing before initial attempts fail
- **GOAL is 5 minutes from arrest!!**



Mechanical Circulatory Support

- MCS has evolved markedly over recent decades
- ECMO in particular has been more reliable with improving equipment, increased experience, reflected in improving results
- Newer percutaneous MCS options

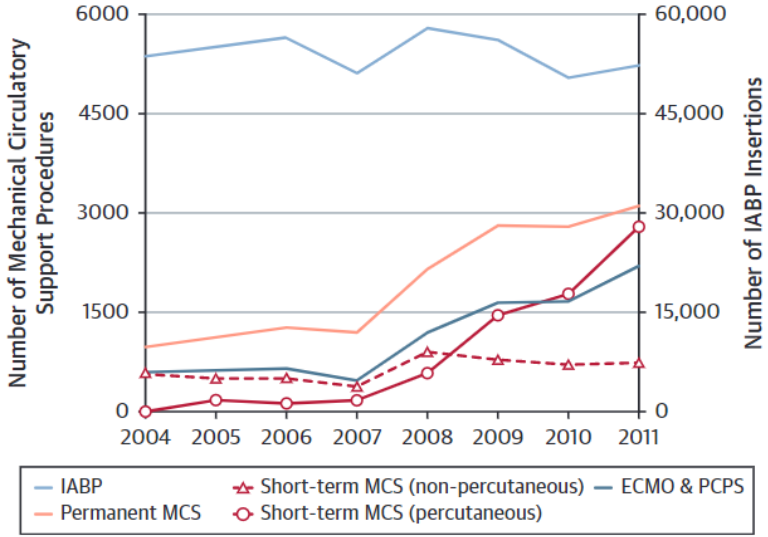


FIGURE 1 Use of MCS Devices Between 2004 and 2011

Use of percutaneous devices, permanent devices, extracorporeal membrane oxygenation (ECMO), and percutaneous cardiopulmonary support (PCPS) has grown considerably, whereas relatively little change in use has been observed for intra-aortic balloon pump (IABP) and nonpercutaneous devices. MCS = mechanical support device.

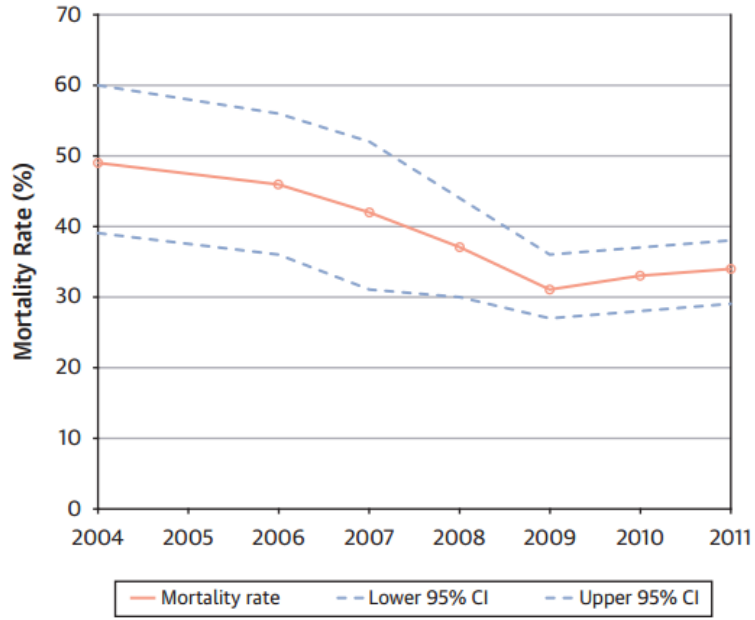


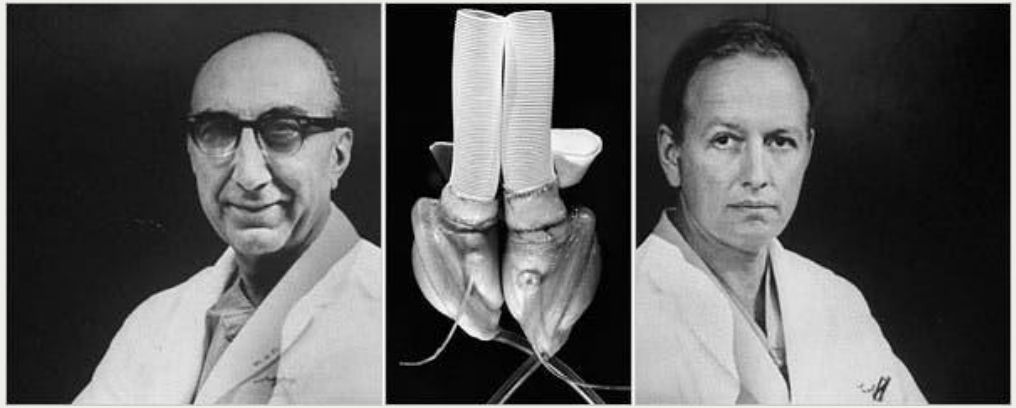
FIGURE 2 Mortality Rate Associated With Short-Term Mechanical Circulatory Support (2004 to 2011)

A trend toward decrease in mortality was observed over time for recipients of short-term circulatory assist devices. CI = confidence interval.

J Am Coll Cardiol 2014;64:1407–15

Post-cardiotomy shock MCS

- Started in 1966



ELSO Registry Data

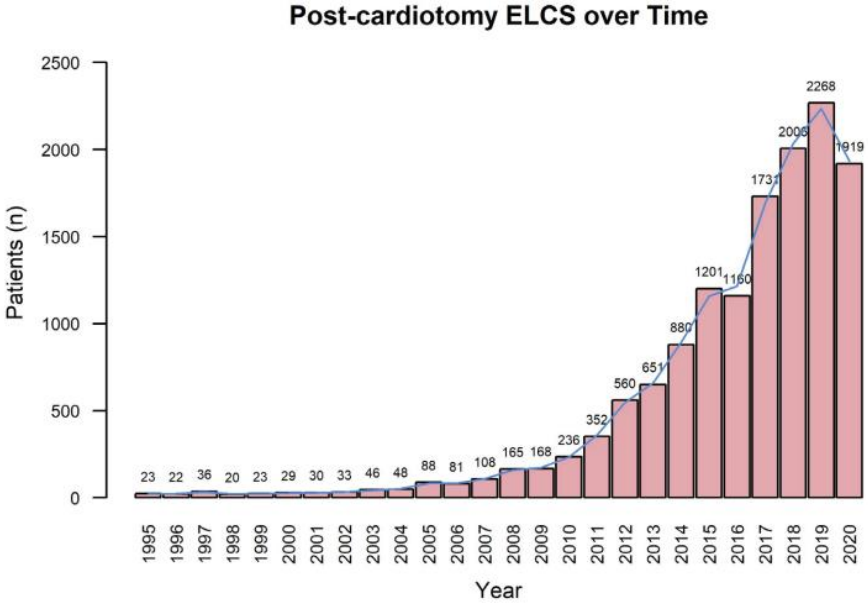


Figure 1. Post-cardiotomy extracorporeal life support (ECLS) reported in the ELSO Registry over time

ELSO Registry Data

- Weaning from PC-ECMO: 31-76% (mostly above 50%)
- Survival to hospital discharge: 16-52% (mostly above 40%)

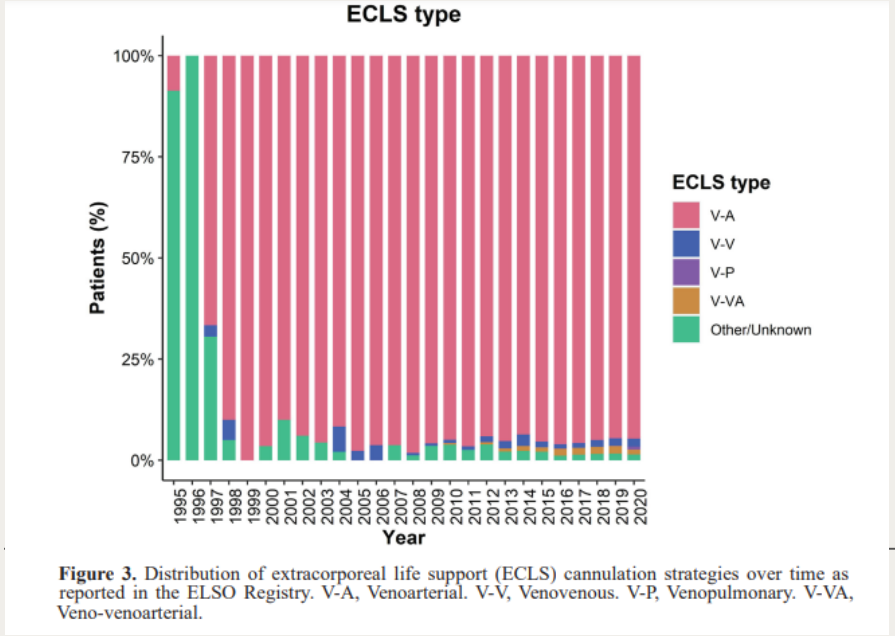


Figure 3. Distribution of extracorporeal life support (ECLS) cannulation strategies over time as reported in the ELSO Registry. V-A, Venoarterial. V-V, Venovenous. V-P, Venopulmonary. V-VA, Veno-venoarterial.

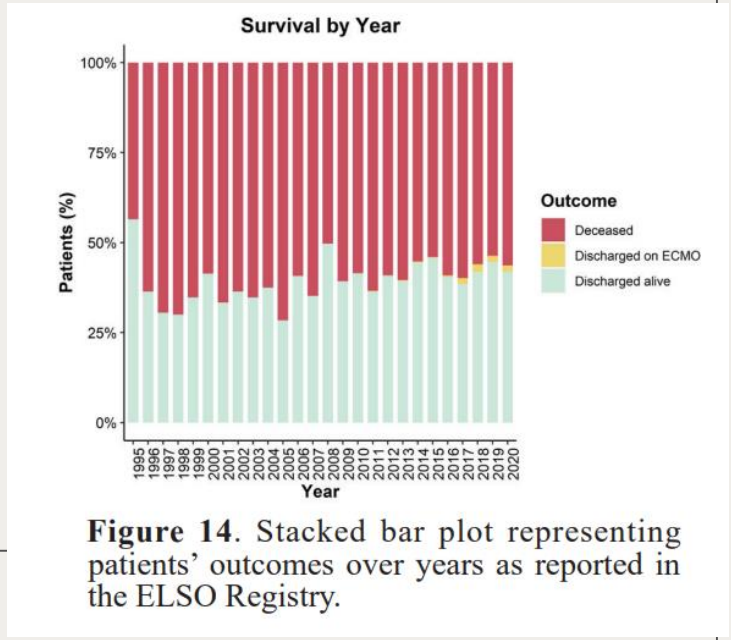
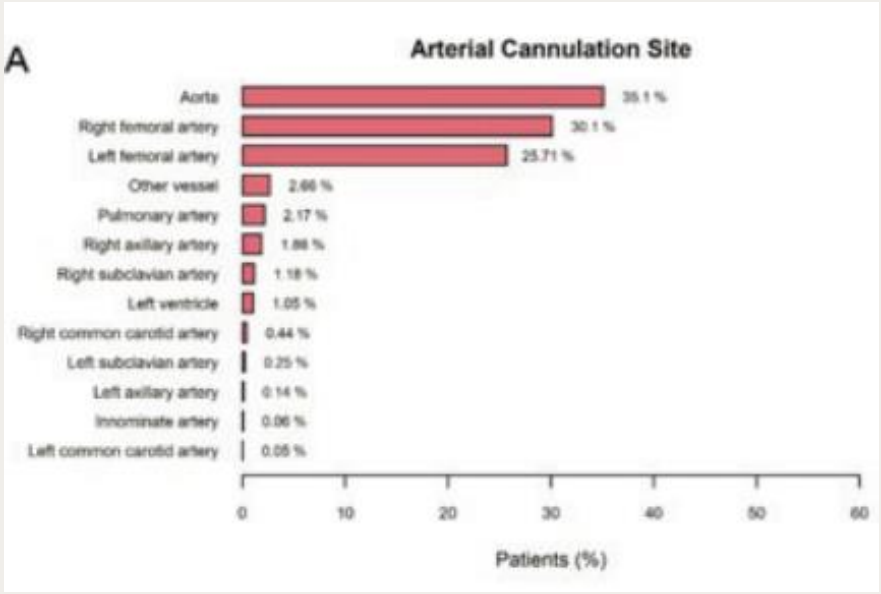


Figure 14. Stacked bar plot representing patients' outcomes over years as reported in the ELSO Registry.

ELSO Registry Data



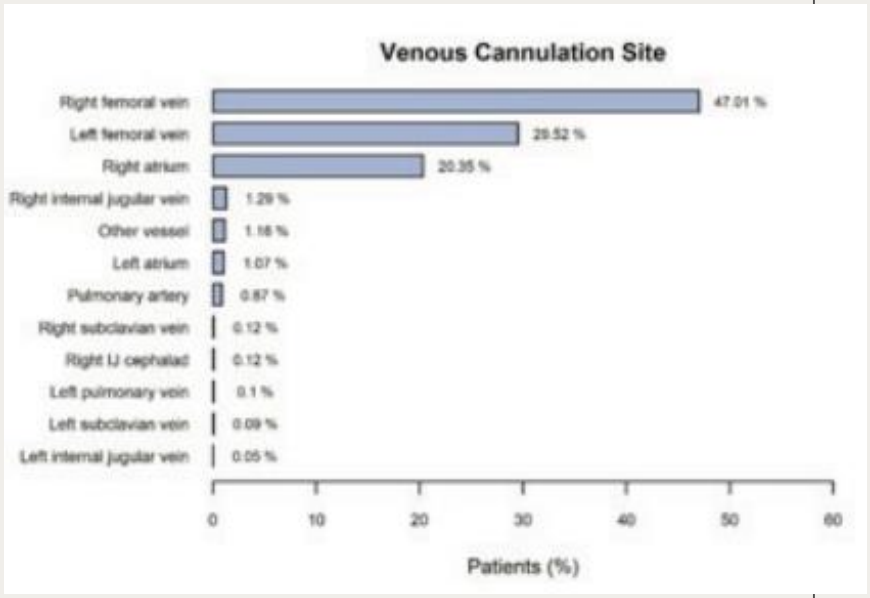


Figure 9. Arterial and venous cannulation sites in postcardiotomy ECLS as reported in the ELSO Registry. Data include possible configuration changes and multiple cannulation sites.

Questions for MCS for Post-Cardiotomy Shock

- What is “Ideal device”?
- Uni- or Bi-ventricular support?
- When to institute temporary support?
- Where to institute it? – OR / Cath lab / ICU
- For how long?
- What to do next?
    - STEP, not a STOP
    - Surgery may be needed

General GOALs of temporary MCS

- Immediate circulatory support
- Max. drainage w/o complications of venous obstruction
- Unobstructed inflow w/o distal ischemia
- Lowest risk of infection
- Mobilization of the patient when possible

Device Options

- IABP
- Impella
- ECMO
  - Central vs. Peripheral?
  - Vent or No vent?
- RVAD +/- oxygenator
- LVAD
- BiVAD +/- oxygenator

- ***Should chest be closed?***

Extracorporeal Membrane Oxygenation is Superior to Right Ventricular Assist Device for Acute Right Ventricular Failure After Heart Transplantation

Shahrokh Taghavi, MD, Andreas Zuckermann, MD, Jan Ankersmit, MD, Georg Wieselthaler, MD, Angela Rajek, MD, Günther Laufer, MD, Ernst Wolner, and Michael Grimm, MD

Departments of Cardiothoracic Surgery and Cardiothoracic Anesthesiology, University of Vienna, Vienna, Austria

- ECMO is superior to temporary RVAD for isolated RV failure post HTX

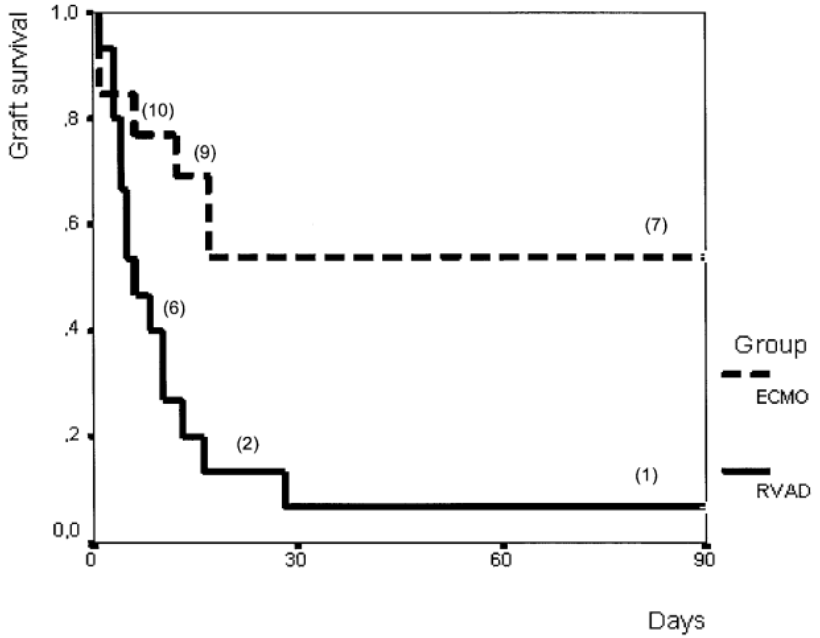


Fig 2. Kaplan-Meier analysis of graft survival in heart transplant recipients who required mechanical circulatory support (either right ventricular assist device [RVAD] or extracorporeal membrane oxygenation [ECMO]) for right ventricular failure. Numbers in brackets *represent patients at risk.* ($p = 0.005$ *by log-rank analysis.)*

Khorsandi *et al. Journal of Cardiothoracic Surgery* (2017) 12:55

Which Device?

Extracorporeal membrane oxygenation for primary graft dysfunction after heart transplant

Scott C. DeRoo, MD, Hiroo Takayama, MD, PhD, Samantha Nemeth, MA, MPH, A. Reshad Garan, MD, Paul Kurlansky, MD, Susan Restaino, MD, Paolo Colombo, MD, Maryjane Farr, MD, Yoshifumi Naka, MD, PhD, and Koji Takeda, MD, PhD

- Prompt ECMO is superior to Conservative ECMO for Primary graft dysfunction

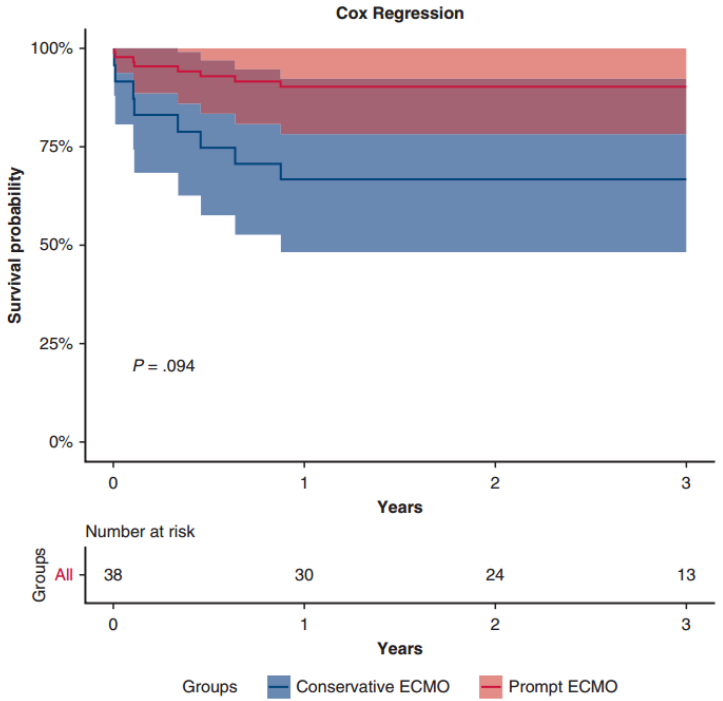


FIGURE 2. Cox proportional hazard model comparing survival between the conservative ECMO cohort and the prompt ECMO cohort. Cox regression suggested but did not prove a 74.6% lower risk of mortality in the prompt ECMO group ($P = .094$). *ECMO*, Extracorporeal membrane oxygenation.

J Thorac Cardiovasc Surg 2019;158:1576-84

ECMO for refractory crdiogenic shock after adult cardiac surgery: a systemiatic review and meta-analysis

- 2017, keywords “post cardiotomy”, “cardiogenic shock”, “extracorporeal membrane oxygenation” & “cardiac surgery”
- Identified 24 studies and a cumulative pool of 1926 patients form 1992 to 2016
- All the studies were retrospective cohort studies

- Meta-analysis revealed **overall survival rate to hospital discharge of 30.8%**
- Commonly reported **risk factors**: advanced **age** (>70years, P=0.058), **long ECMO support** (P=0.412)
- Other risk factors reported : Postoperative renal failure, high EuroSCORE (>20%), DM, obesity, rising lactate on ECMO, GI cx
- **Hemodynamic support with VA ECMO provides a survival benefit.**

Khorsandi *et al. Journal of Cardiothoracic Surgery* (2017) 12:55

When?

Journal of Artificial Organs (2021) 24:7–14

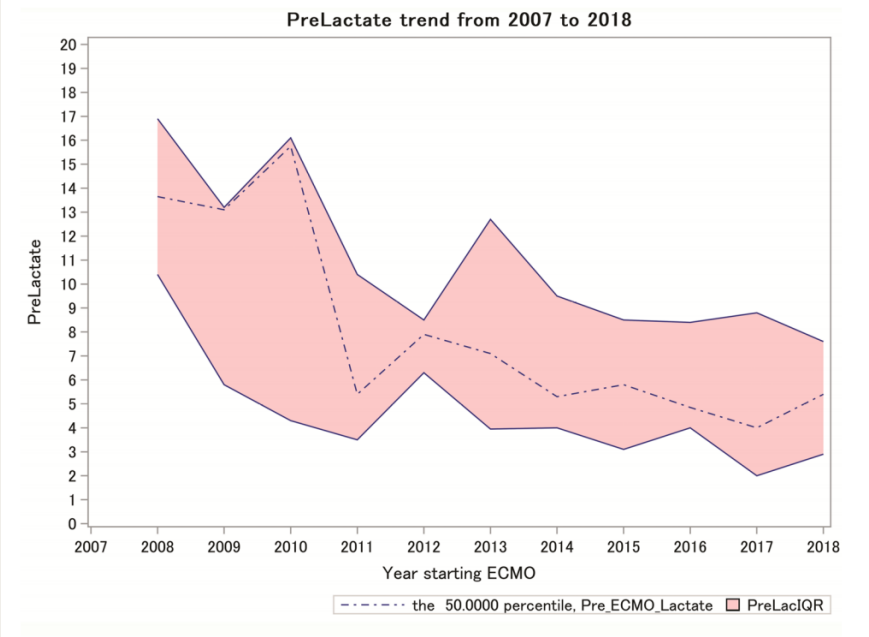
Early VA ECMO improves outcomes in post-cardiotomy shock

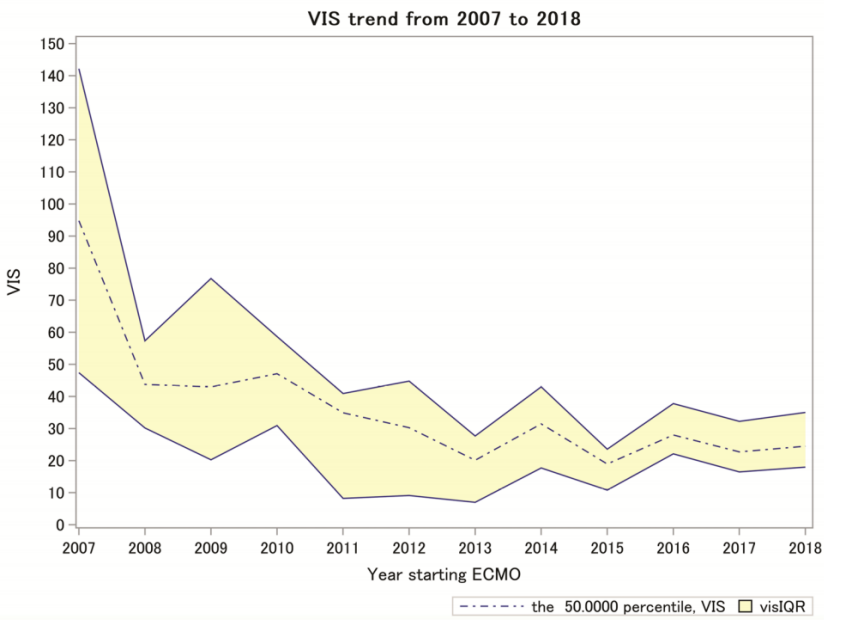
- 2007 – 2018, 156 patients underwent VA-ECMO for PCS
- Median 4.7 days of ECMO support
- 72 patients (46.1%) survived to discharge
- Survivors were cannulated **at lower serum lactate level** (5.3 vs 7.5, P=0.003) & **Vasoactive-inotropic score (VIS)** (P=0.017)
- Patients in Era 2 were more frequently cannulated **intraoperatively** (63.5% vs 34.6%, P=0.002), earlier in their hospital course, and at lower levels of serum lactate & VIS than in Era 1
- Independent RF for mortality – age, serum lactate at cannulation & VIS
- **Survival benefit – earlier ECMO initiation before prolonged hypo-perfusion**

When?

Journal of Artificial Organs (2021) 24:7–14

Early VA ECMO improves outcomes in post-cardiotomy shock



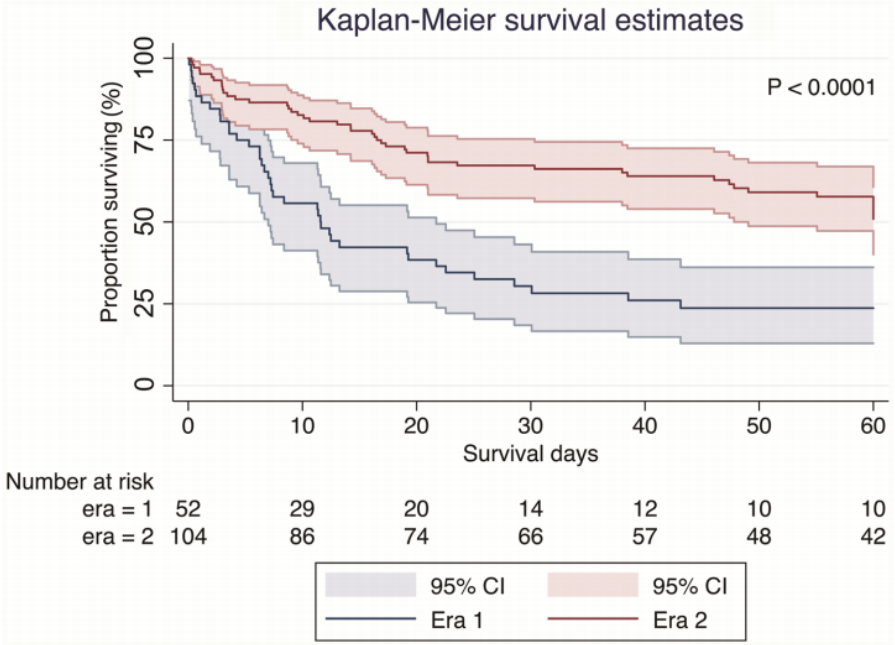


When?

Journal of Artificial Organs (2021) 24:7–14

Early VA ECMO improves outcomes in post-cardiotomy shock

Fig. 3 Sixty-day Kaplan–Meier survival estimates by era. CI, confidence interval



Next Step

Bridging to other therpaies

- Transitioning to VAD or Heart transplantation listing
  - Improve in-hospital survival
  - 75% early survival rate in ECMO pts bridged to a VAD after a short term ECMO run
- Despite this apparent effectiveness, only <20% of pts with PC-ECMO transition to other support (VAD or HTX, range 0% - 20%)

Postcardiotomy Mechanical Support: Risk Factors and Outcomes

Nicholas G. Smedira, MD, and Eugene H. Blackstone, MD

Department of Thoracic and Cardiovascular Surgery, The Cleveland Clinic Foundation, Cleveland, Ohio

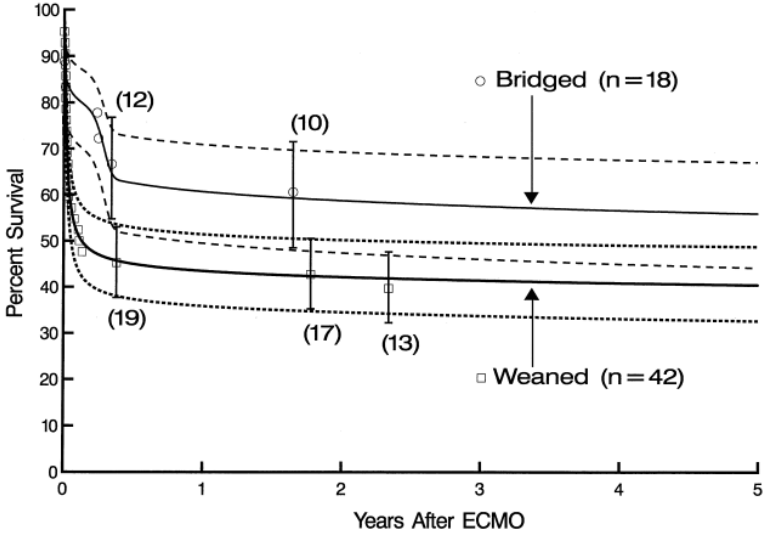
Background. The need for postcardiotomy mechanical support is uncommon, with an incidence of 0.5%.

Methods. Multivariable logistic regression analysis of factors associated with postcardiotomy extracorporeal membrane oxygenation (ECMO) support was investigated in 19,985 patients, of whom, 97 required ECMO.

Results. Younger age, number of reoperations, emergency operation, higher creatinine, greater left ventricular dysfunction, and history of myocardial infarction were significant predictors. Overall survival was 35%, but significantly better (72%) in the subgroup converted to an implantable system and then bridged to transplantation.

Conclusions. Patients at increased risk for mechanical support can be identified preoperatively and patient management modified as indicated. Improvement in postcardiotomy survival has been realized by bridging to transplantation. In nontransplant candidates, permanent support may be the only option for increasing survival.

(Ann Thorac Surg 2001;71:S60–6)



Next Step

LV unloading modalities

LV Unloading Procedures	Timing/ Setting	Approach	Extent of LV Unloading	Advantages	Disadvantages
Non-Catheter Based					
Reducing ECMO-Related Flow	Intraop/Postop	Conservative	Partial (indirect – enhanced LV ejection due to reduced afterload)	No intervention Modulated approach Change immediately modifiable	Reduced organ perfusion Risk of system thrombosis
Vasodilators	Intraop/Postop	Conservative	Partial (indirect – enhanced LV ejection due to reduced afterload)	No intervention Modulated approach Change immediately modifiable	Reduced organ perfusion
Moderate Inotropes	Intraop/Postop	Conservative	Partial (indirect – increased LV unloading due to enhanced ejection)	No Intervention Modulated Approach Change Immediately Modifiable	Risk of perpetuating or inducing myocardial ischemia Increased myocardial O2 consumption Tachycardia and vasoconstriction with some inotropes Reduced and delayed LV recovery
Increasing PEEP	Intraop/Postop	Conservative	Partial (indirect – increased right-sided unloading)	No Intervention Modulated Approach Change Immediately Modifiable	Increased RV Afterload (not advisable in case of acute or chronic RV dysfunction)

Catheter/Device-Based					Next Step
Right Superior Pulmonary Vein	Intraop	Surgical (minimally invasive procedure postop feasible)	Partial/Full (direct)	Full Drainage (direct) Drained Flow Modulated Independent of rhythm	Clots LV Perforation Re-Sternotomy for Catheter Removal
Pulmonary Artery Cathether/Cannula*	Intraop/Postop	Surgical or Percutaneous	Partial (indirect)	Partial Feasibility of drainage and subsequent perfusion (isolated RV support) Single or double-lumen cannula^^ Independent of rhythm	Vascular Complications Clots Not Easy Procedure (percutaneous)
Pulmonary Artery Suction Device^	Postop (intraop feasible)	Percutaneous (surgical feasible)	Partial LV Full RV (indirect)	Percutaneous Combination with Left Devices for Bi-Ventricular Failure Independent of rhythm	Not Easy Procedure Costs Availability Fluoroscopy
Trans-Atrial Catheter#	Postop (intraop. feasible)	Surgical or Percutaneous	Partial/Full (direct – LA drainage)	Percutaneous (via femoral vein) Bi-ventricular support by reduction of PCWP Independent of rhythm	Cost (for dedicated system*) Clots More complicated procedure (fluoroscopy for postop) Cost^^
LV Trans-Apical	Postop (intraop. feasible)	Surgical (minimally invasive procedure)	Partial/Full (depending on the catheter size)	Patient Mobility VAD Configuration (LV apex-Subclavian Artery for prolonged LV support) Independent of rhythm	Bleeding Clots Infection
Trans-Aortic Catheter	Postop (intraop feasible)	Percutaneous (surgical feasible) (minimally invasive procedure postop feasible)	Partial/Full (depending on the catheter size)	Percutaneous Independent of rhythm	Bleeding Clots Infection
Trans-Aortic Suction Device**	Postop/Intraop	Percutaneous/ Surgical (for 5.0 version)	Full Percutaneous (2.5 or CP version) Prolonged Support after ECMO	Complete LV unloading Easy management Percutaneous More prolonged support after ECMO feasible Independent of rhythm	Cost Availability Hemolysis Dislodgement
Intra-Aortic Balloon Pump	Intraop/Postop	Percutaneous	Partial (indirect – reduced LVEDP, enhance LV ejection due to reduced afterload)	Well-established system Perpetuating preop implant (critical CAD) Availability Cost Percutaneous	Limited Support Infection Vascular Complications (low rate) Rhythm-dependent

How?

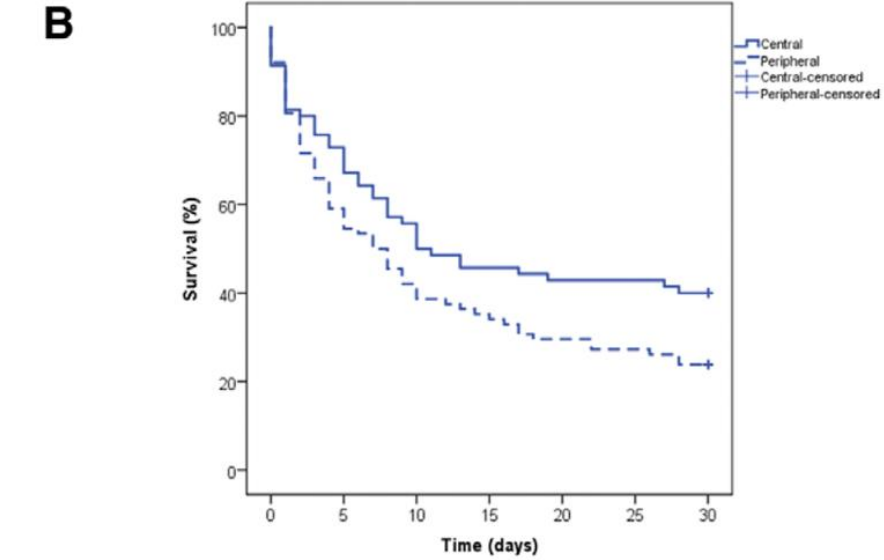
Central vs Peripheral Artieral Cannulation for VA ECMO in Post-Cardiotomy Shock

- 2010-2019, 158 pts with PCS requiring VA-ECMO
- 88 pts in group P (cannulated via axillary or femoral a.) & 70 pts in group C (centrally via ascending aorta)
- Demographics & operative parameters – similar
- Change of cannulation site for Harlequin's syn. or hypo-perfusion of extremity occurred in 13 pts in group P vs. never in group C (P=0.001)
- LV unloading – similar
- Cx: Stroke rates, renal failure – similar
- Weaning from ECMO (52.9% vs. 52.3%, P=NS) – similar
- **30 day mortality was higher in group P (60% vs 76.1%, P=0.029)**

How?

Central vs Peripheral Artieral Cannulation for VA ECMO in Post-Cardiotomy Shock

Central Cannulation for VA-ECMO provides antegrade flow w/o differential hypoxia, and better 30day survival



Patients at risk:

Central cannulation	70	47	35	31	30	29	27
Peripheral cannulation	88	48	34	30	26	23	20

Benefits of Central Cannulation

- Familiar to CT Surgeons
- Maximal flow possible
    - Larger cannula at larger blood vessels
- Avoid differential hypoxia
- Avoid retrograde blood flow
- **Possibly avoid LV vent**
    - **Heart is fully decompressed with higher flow**

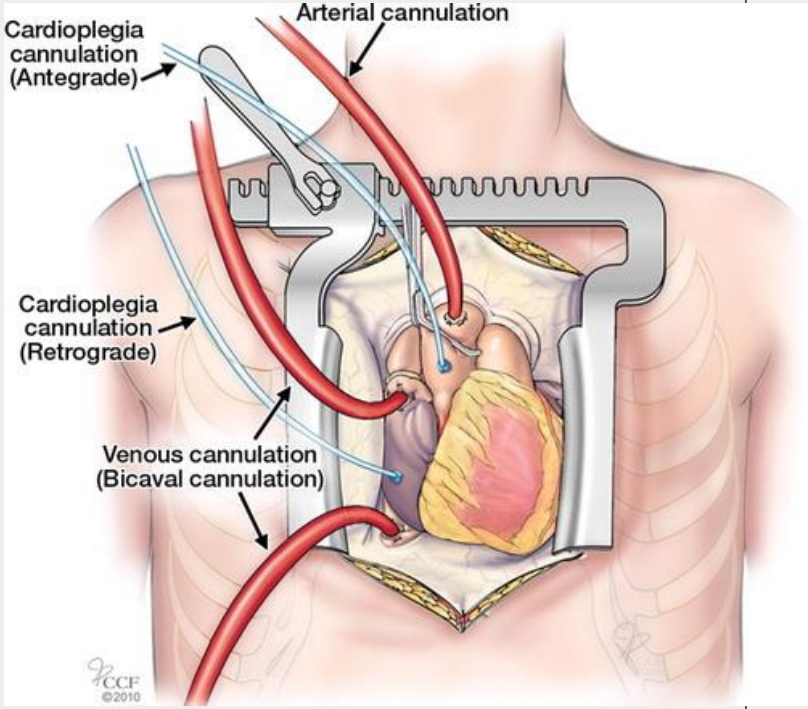
Using Operative Cannulas

- Distal Ascending Aorta
- RA or SVC/IVC

- Not placed anticipating prolonged use
- Difficult to secure cannulas
- Bleeding at cannulation sites
- Difficult to maintain sterility
- Potential for accidental decannulation
- No extra holes in the aorta/heart

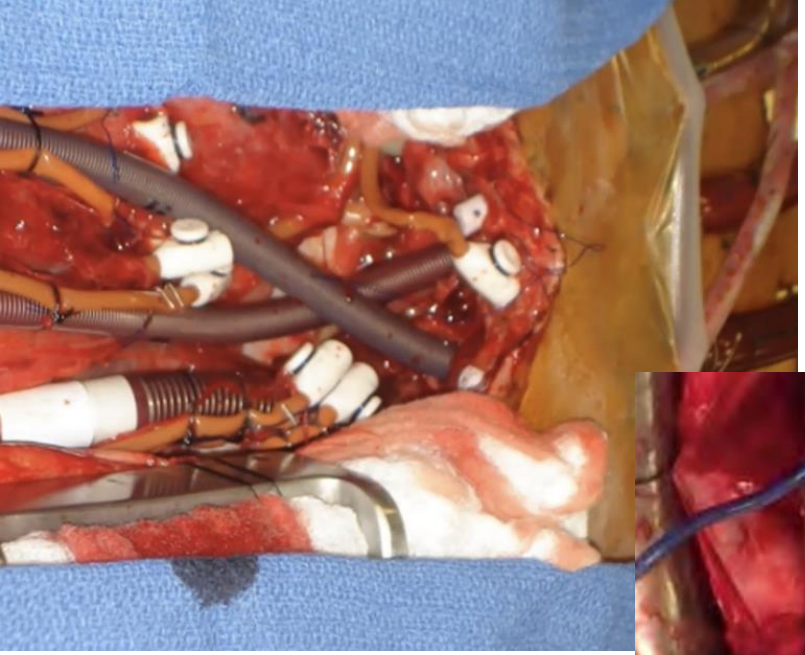
Using Operative Cannulas

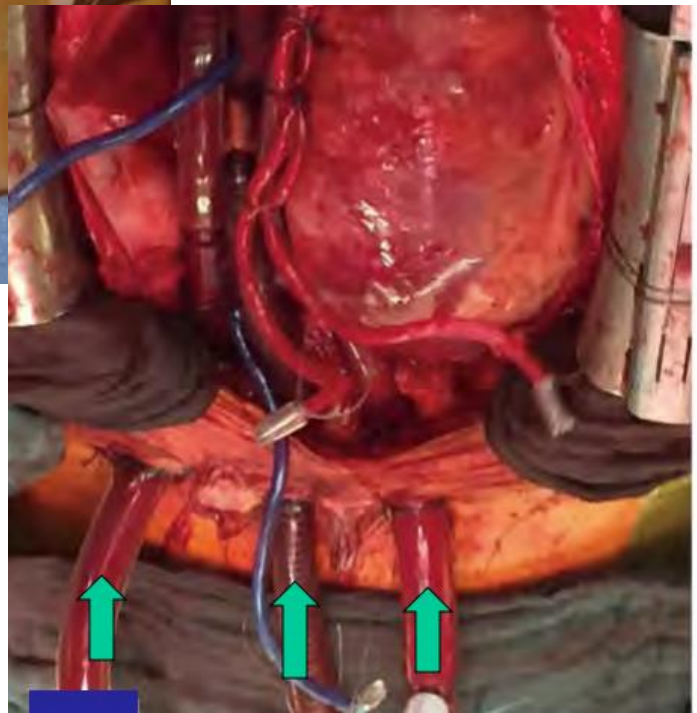
- Convert from Bypass to ECMO
  - clamp the circuit off bypass & convert to ECMO
- **Less than 1min**
- Existing open sternotomy incision
- Ao cannula; 1.5 – 2cm inside Aorta

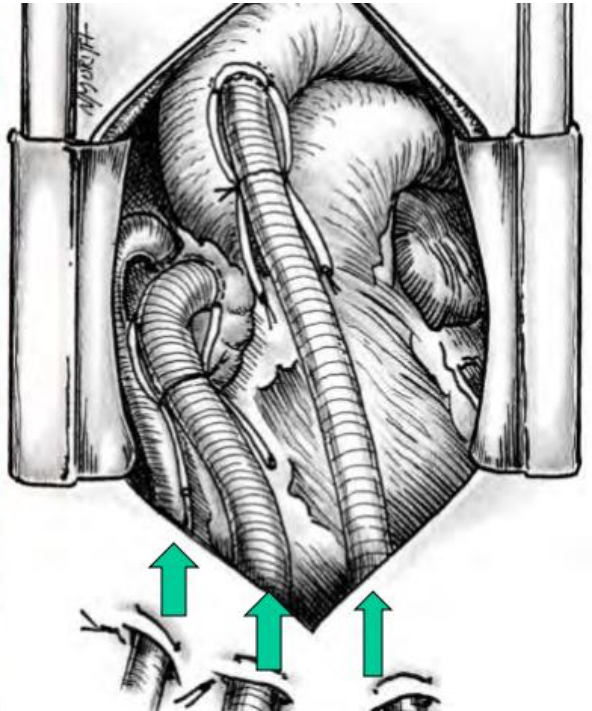


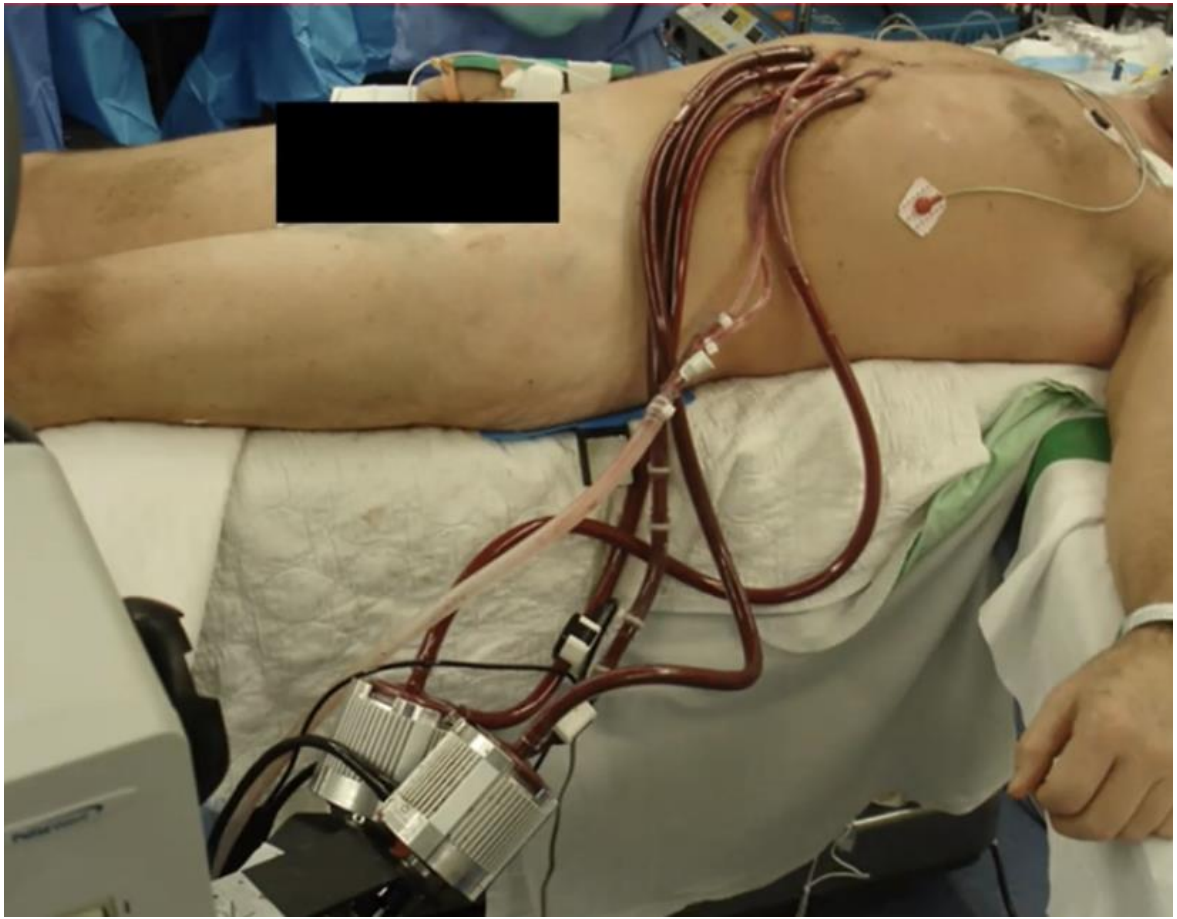
Tunneled New Cannulas

- Femoral arterial cannula inserted low into aorta
  - Seldinger technique (guidewire / dilator)
- Melleable cannula in SVC with tip in RA
  - More bleeding from atrial cannulation site than aortic cannula
- Lots of pledgets - pulse string hemostasis
- Locking snares - hold the cannula into space, lubber snares
- Exit similar to chest tubes
  - Through abdominal wall





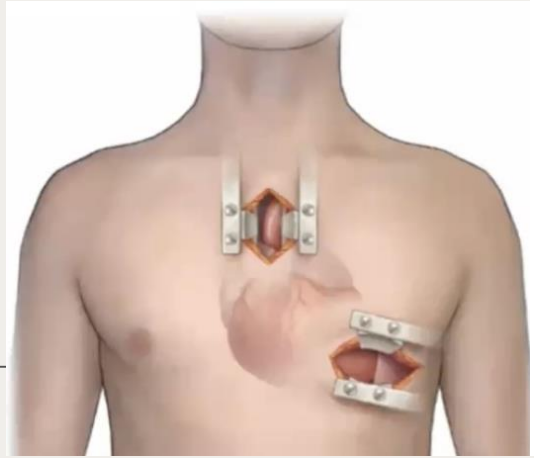




How?

Non-Sternotomy Approach

- Upper hemi-sternotomy or right 2nd interspace thoracotomy for aortic cannulation
  - Tunneled 2 or 3 ribs below incision
- Left 5-6th interspace thoracotomy for LV apex
  - LV venting
  - Larger apical cannula



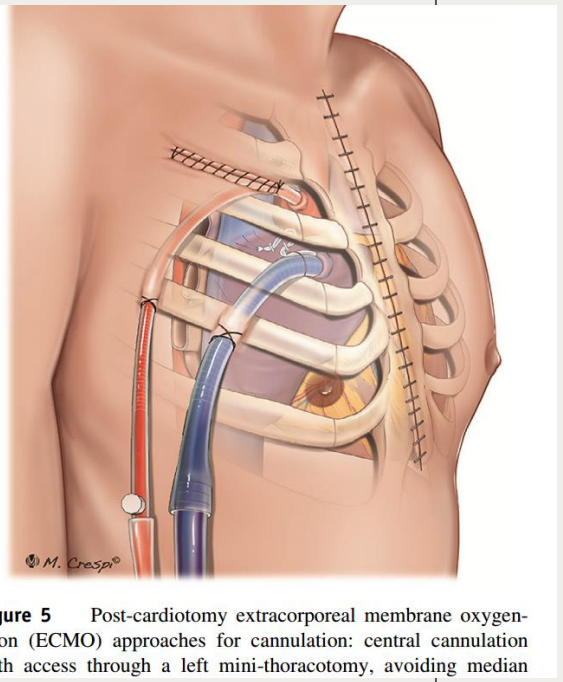
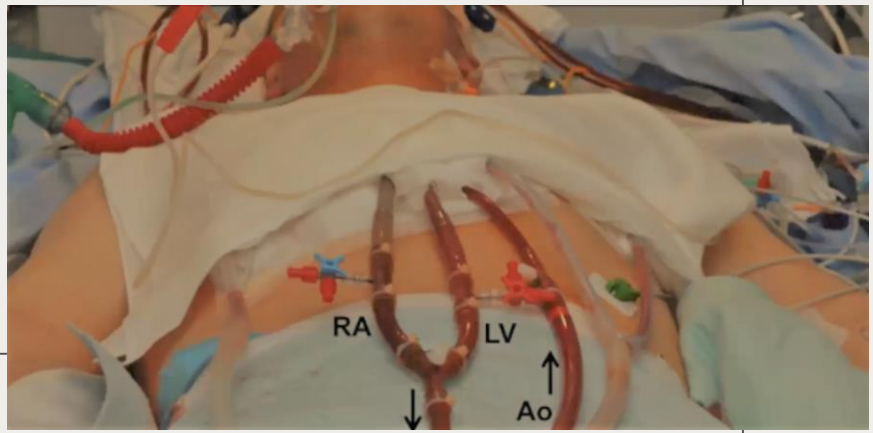


Figure 5 Post-cardiotomy extracorporeal membrane oxygenation (ECMO) approaches for cannulation: central cannulation with access through a left mini-thoracotomy, avoiding median

Central LV venting

- RUPV
  - Tends to bleed
  - Clot formation in LA over prolonged period time
- LV apex
- PA vent

- **Y into circuit with venous drainage**



- Avoid percutaneous femoral access while fully heparinized
- Open surgical cut down approach preferred

Tips

- In the OR, call a friend
- Support both ventricles
- Cannulation site bleeding won’t stop on its own
- Hold heparin until the bleeding stops
    - Hours to days
- Prosthetic mitral valves clot easily
    - LA clot as well

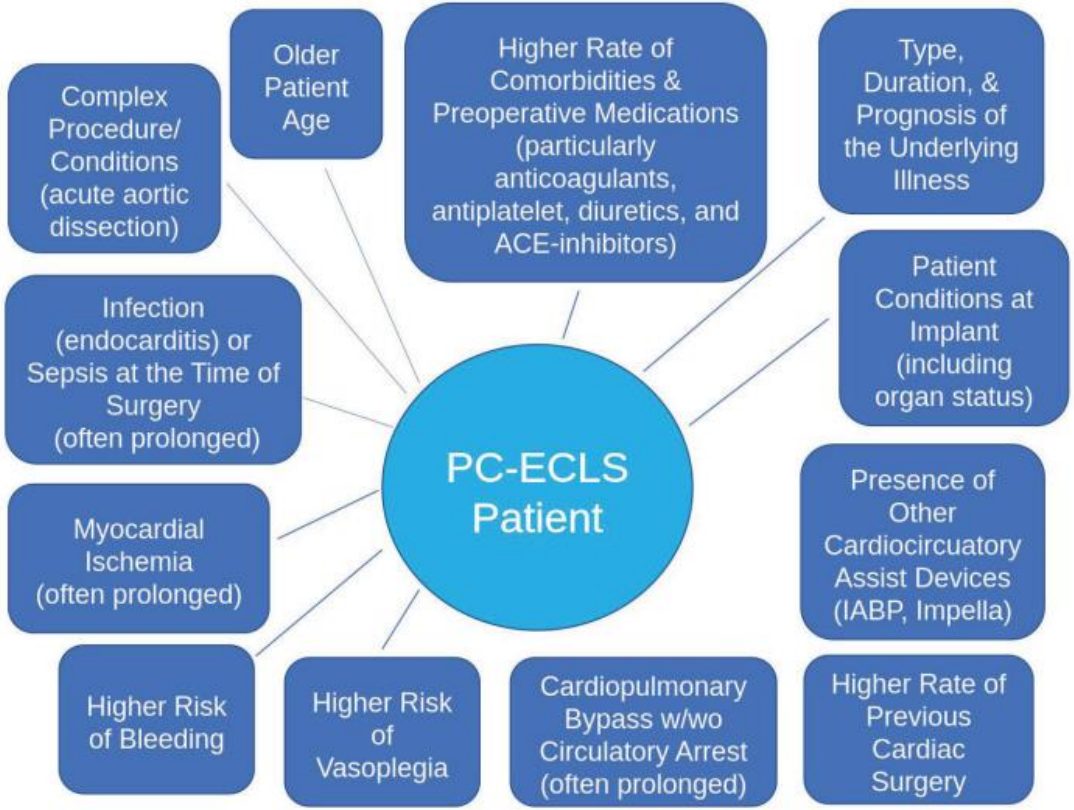


Figure 1. Peculiar characteristics of the Post-Cardiotomy Extra-Corporeal Life Support (PC-ECLS) patient which, in many instances, differ from other potential recipients, all of which impact outcome (from Lorusso et al[3]) ACEI, angiotensin-converting enzyme inhibitors; IABP, intra-aortic balloon pump.

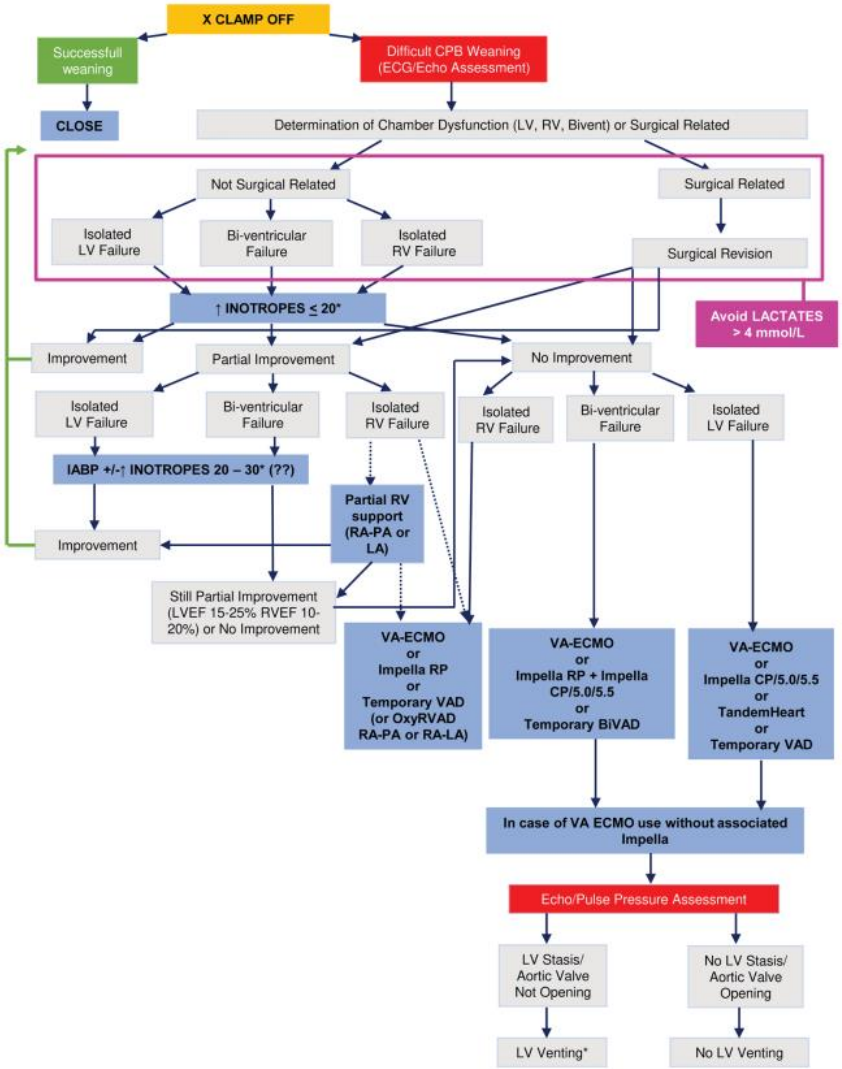


Figure 2. Decision algorithm for per-operative ECLS implantation.
* Inotropes doses according to the vasopressors conversion ratios published by Goradia S. et al, J Crit Care 2021, Feb;61:233-240.

Configuration		Advantages	Disadvantages
Central Cannulation	Right Atrium - Aorta	– Direct access to major vascular structures – Physiological arterial flow – Possibility of maintaining high ECLS flows	– Requires surgical approach via sternotomy – Difficult management of patient with open sternum
Peripheral Cannulation	Femoral Vein - Femoral Artery	– Easy access to the femoral vessels, even percutaneously – Can be used in emergencies	– Increased cardiac afterload – Risk of local complications – Risk of North-South (Harlequin) syndrome
	Femoral Vein - Axillary Artery	– Easy access to the femoral vein – "Pseudocentral" arterial flow	– Access to the axillary artery requires a surgical procedure which might be difficult in emergency situations – Upper limb hyperperfusion syndrome – Brachial plexus damage
	Left Internal Jugular Vein - Axillary Artery	– "Pseudocentral" arterial flow – Easy patient mobilisation	– Access to the axillary artery requires a surgical procedure which might be difficult in emergency situations – Upper limb hyperperfusion syndrome – Brachial plexus damage
Triple Cannulation	Veno-Venous - Arterial	– Improves venous drainage – Useful in case of intra-cardiac shunts or pulmonary hypertension – Reduces the risk of North-South (Harlequin) syndrome	– More complex circuit management
	Veno - Veno-arterial	– Used in cases of cardiac and lung failure – Prevents North-South (Harlequin) syndrome	– Less cardiac support – More complex circuit management

Table 1. Possible configurations for post-cardiotomy VA ECLS, advantages and disadvantages.

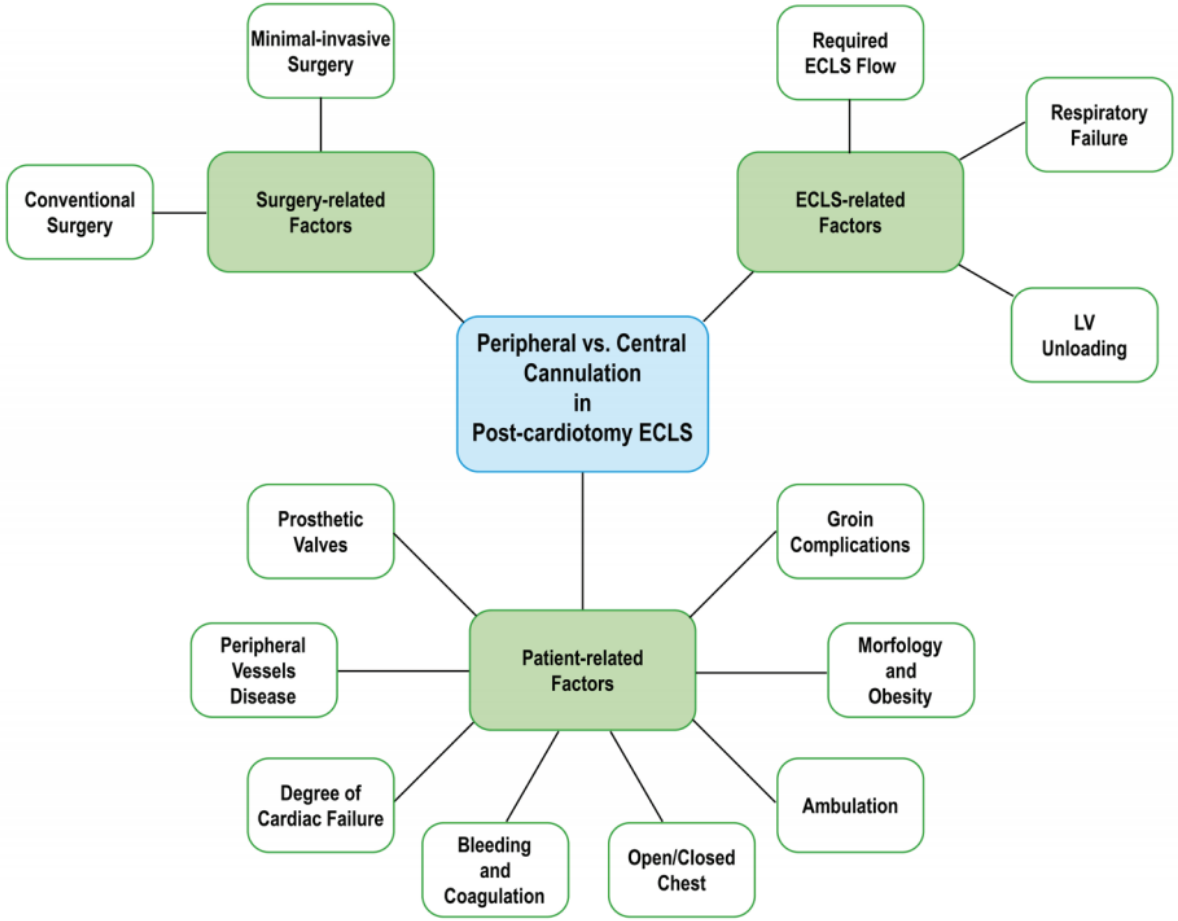


Figure 1. Diagram of decision for peripheral versus central approach in patients requiring post-cardiotomy extracorporeal life support (ECLS). LV, left ventricular.

Summary

- Most datas are retrospective single center data
  - No comparison of ECMO with temporary VAD (other than for post transplant shock)
- Imperative for early placement of ECMO in post-cardiotomy shock
  - Ideally in the Operating Room
  - Data supportive of this strategy
- Central ECMO probably preferable
- If diagnosis of post-cardiotomy shock occurs later or was missed, either percutaneous options or returning to OR is still an option

Summary

- Need to be versatile in “bridge-to-bridge” concept: ability to downgrade level of temporary MCS
- Success is defined as LV recovery
    - Negligible number of post-cardiotomy shock patients make it successful to durable LVAD

Final Thoughts

- Despite the encouraging results, there is clearly much room for improvement in this very sick group of patients
- Heart Team is critical to success
- Excellent percutaneous options in addition to existing surgical options

- ***“ If you are thinking about it, you probably should do it “***

Thanks!

Do you have any questions?

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