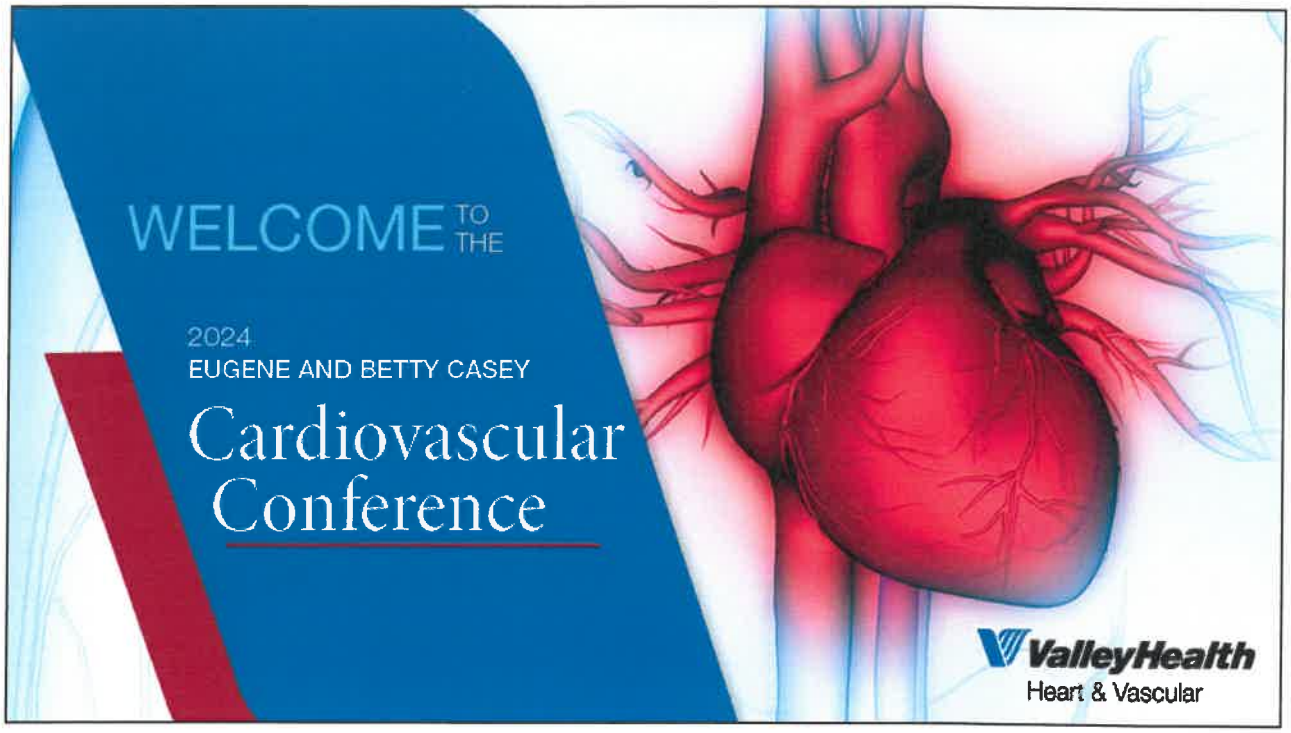

Cardiac Arrest : Mechanical Circulatory support options

Kayla Roberts, MHA, RT(R)(CI)

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Objectives:

CV Disease
OHCA arrest in US/ outcomes?
In Hospital Data
2023 AHA guidelines

MCS Devices & Indications Uses

Case Review

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Cardiovascular Disease

On the basis of NHANES 2017 to March 2020 data, the prevalence of CVD (comprising CHD, HF, stroke, and hypertension) in adults ≥20 years of age was 48.6% overall (127.9 million in 2020) and increases with age in both males and females.

- On the basis of 2020 mortality data, HD and stroke currently claim more lives each year than cancer and chronic lower respiratory disease combined.

2020, 19.05 million deaths were estimated for CVD globally, which amounted to an increase of 18.71% from 2010. The age-standardized death rate per 100 000 population was 239.80, which rep-resents a decrease of 12.19% from 2010. Overall, the crude prevalence of CVD was 607.64 million cases in 2020, an increase of 29.01% compared with 2010. However, the age-standardized prevalence rate was 7354.05 per 100 000, an increase of 0.73% from 20

Circulation. 2023;147:e93–e621. DOI: 10.1161/CIR.0000000000001123

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Out Of Hospital Cardiac Arrest

In the prehospital setting, among participating centers in the Resuscitation Outcomes Consortium (ROC) Epistry, survival from out-of-hospital arrest ranged from 3.0% to 16.3%.

In the United Kingdom, survival-to-discharge rates within the National Health Service ambulance system ranged from 2% to 12%.

Survival to hospital discharge after emergency medical services–treated out-of-hospital cardiac arrest was 9.3% in the 2022 CARES registry (Cardiac Arrest Registry to Enhance Survival) with significant variation among states reporting data (range, 5.5%–15.4%).

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Cardiac Arrest

- Survival to hospital discharge after emergency medical services–treated out-of-hospital cardiac arrest was 9.3% in the 2022 CARES registry (Cardiac Arrest Registry to Enhance Survival) with significant variation among states reporting data (range, 5.5%–15.4%).
- The median risk-adjusted in-hospital cardiac arrest incidence was 8.5 per 1000 admissions of Medicare beneficiaries. In-hospital cardiac arrest incidence varied across hospitals after adjustment for differences in case-mix index, from 2.4 per 1000 admissions to 25.5 per 1000 admissions.
- According to 2013 to 2019 CARES data, Black and Hispanic individuals with out-of-hospital cardiac arrest receive less bystander CPR at home (adjusted OR, 0.74) and in public (adjusted OR, 0.63).

Originally published24 Jan 2024https://doi.org/10.1161/CIR.0000000000001209Circulation. 2024;149:e347–e913

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GWTG – In-hospital Cardiac Arrest

- In the hospital setting, among participating centers in the Get With The Guidelines-Resuscitation quality improvement program, the median hospital survival rate from adult cardiac arrest is 18% (interquartile range, 12%–22%) and from pediatric cardiac arrest, it is 36% (interquartile range, 33%–49%).
- In a hospital setting, survival is >20% if the arrest occurs between the hours of 7 am and 11 pm but only 15% if the arrest occurs between 11 pm and 7 am. There is significant variability with regard to location, with 9% survival at night in unmonitored settings compared with nearly 37% survival in operating room/post anesthesia care unit locations during the day.

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Percutaneous Mechanical Support

- Cardiopulmonary Bypass
  - 1953
- IABP –
  - A Kantrowitz - 1968
- Impella
  - Approved 2008
- Tandem Heart – 2006
- ECMO – 1971 - 1976

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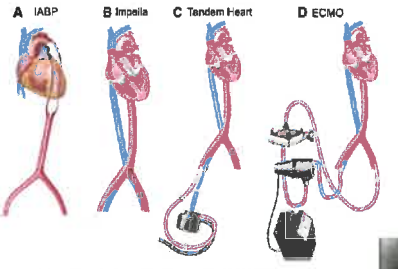
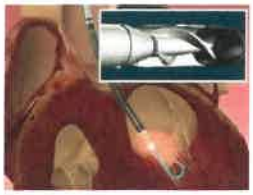
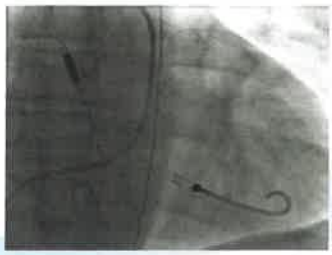
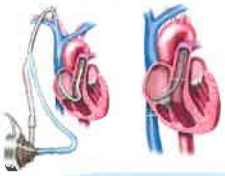
MCS Devices









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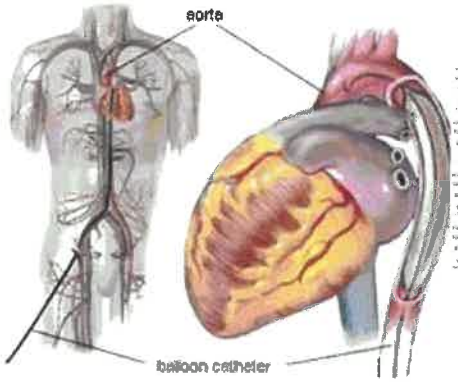
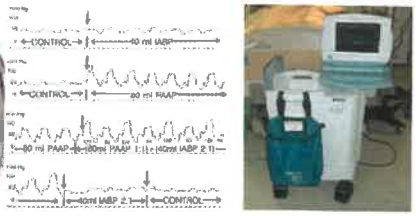
Intra-Aortic Balloon Pump





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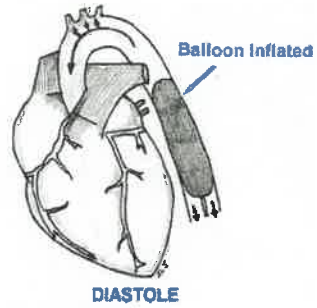
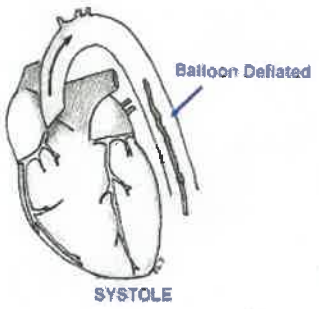
- ECG or pressure triggered
  - Inflation/Deflation of helium balloon
- Inflates in Diastole
  - Increases Coronary Perfusion Pressure
  - Increases Systemic Perfusion
- Deflates in Systole
  - Decreases afterload
  - Increases Cardiac Output
- Believed to augment flow up to 0.5 L.





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Intra-Aortic Balloon Pump

INDICATIONS

- Cardiogenic Shock
- Reversible Intracardiac mechanical defects
  - Acute MR, post MI septal perf
- Unstable Angina
- Post Cardiotomy
  - Weaning of pump, shock
- Percutaneous coronary Angioplasty
- High risk CABG

CONTRAINDICATIONS

- Absolute
  - Severe AI
  - Aortic Dissection
  - Severe aortoiliac occlusive diease
- Relative
  - Prosthetic vascular aortic graft
  - Aortic Aneurysm
  - Aortofemoral graft

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IABP Complications

Feature	Intra-aortic balloon therapy[4,7]
Duration of use	Short-term use: hours to days
How does it work?	Blood volume displacement Requires cardiac rhythm or arterial

Table 1. Inaccuracies of intra-aortic balloon pump inflation and deflation timing and possible consequences[1].

Timing inaccuracy	Potential complication
Late inflation	Attenuated inflation time, leading to lower peak diastolic augmentation and suboptimal IABP function
Early inflation	Balloon inflates before aortic valve closes – the left ventricle is therefore forced to empty against an inflated balloon. There is an increase in afterload, potentially raising myocardial oxygen demand
Late deflation	Balloon is still inflated at start of next systole, causing an increase in ventricular afterload. Similar to deleterious consequences of early balloon inflation
Early deflation	Reduced inflation time, leading to lower peak diastolic augmentation and suboptimal IABP function. Theoretically, this can cause retrograde coronary flow leading to angina and ischemic arrhythmias and retrograde carotid flow causing cerebral ischemia

[1]Refer to Figure 7 for corresponding waveforms.
IABP: Intra-aortic balloon pump.

Cost	$800-$1200 for cost of device and associated supplies plus cost of console
Potential complications	Limb ischemia Bleeding, hematoma at access site Vascular injury Embolization of thrombus or plaque Infection Balloon rupture

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IABP Kit

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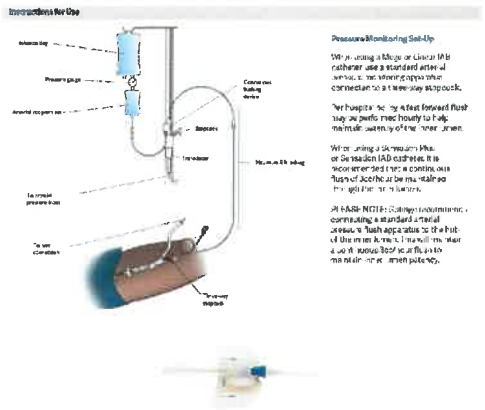
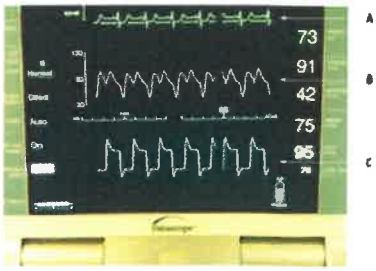
IABP Start Up





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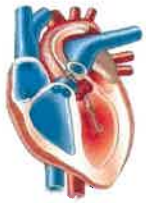
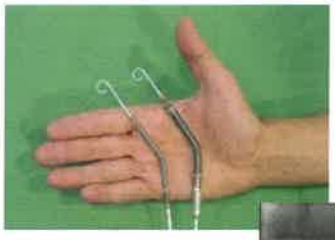
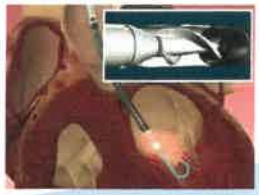
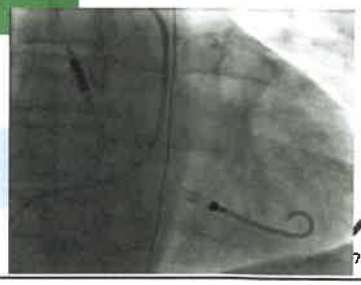
Micoraxial Support Devices









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CGS

Percutaneous Support with Impella

Catheter-mounted non-pulsatile axial flow pump unloads LV . Percutaneous CP device supplies up to 3.5L/M flow via 14F sheath. Surgically-placed Impella 5.0 device can provide 5L/m flow and can allow mobilization

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Impella

https://youtu.be/Ff4PcA2s0rs

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Impella LHC Support Indications

High-Risk PCI

The Impella 2.5®, Impella CP® and Impella CP® with SmartAssist® Systems are temporary (≤ 6 hours) ventricular support devices indicated for use during high-risk percutaneous coronary interventions (PCI) performed in elective or urgent, hemodynamically stable patients with severe coronary artery disease, when a heart team, including a cardiac surgeon, has determined high-risk PCI is the appropriate therapeutic option. Use of the Impella 2.5, Impella CP, and Impella CP with SmartAssist Systems in these patients may prevent hemodynamic instability, which can result from repeat episodes of reversible myocardial ischemia that occur during planned temporary coronary occlusions and may reduce peri- and post-procedural adverse events.

Cardiogenic Shock

The Impella 2.5®, Impella CP®, Impella CP® with SmartAssist®, Impella 5.0®, Impella 5.5® with SmartAssist® and Impella LD® Catheters, in conjunction with the Automated Impella Controller™ (collectively, "Impella® System Therapy"), are temporary ventricular support devices intended for short term use (≤ 4 days for the Impella 2.5, Impella CP, and the Impella CP with SmartAssist, and ≤ 14 days for the Impella 5.0, Impella 5.5 with SmartAssist and Impella LD) and indicated for the treatment of ongoing cardiogenic shock that occurs immediately (< 48 hours) following acute myocardial infarction or open heart surgery or in the setting of cardiomyopathy, including peripartum cardiomyopathy, or myocarditis as a result of isolated left ventricular failure that is not responsive to optimal medical management and conventional treatment measures (including volume loading and use of pressors and inotropes, with or without IABP). The intent of Impella System Therapy is to reduce ventricular work and to provide the circulatory support necessary to allow heart recovery and early assessment of residual myocardial function.

Emergency Use Authorization

Impella Left Ventricular (LV) Support Systems (Impella 2.5, Impella CP, Impella CP with SmartAssist, Impella 5.0, and Impella 5.5 with SmartAssist) are authorized for emergency use by HCPs in the hospital setting for providing temporary (≤ 4 days for Impella 2.5, Impella CP, and Impella CP with SmartAssist; and ≤ 14 days for Impella 5.0 and Impella 5.5 with SmartAssist) LV unloading and support to treat critical care patients (i.e. patients in the intensive care unit) with confirmed COVID-19 infection who are undergoing ECMO treatment and who develop pulmonary edema while on V-A ECMO support or late cardiac decompensation from myocarditis while on V-V ECMO support. The Impella LV Support Systems have neither been cleared or approved for the authorized indication for use. The Impella LV Support Systems have been authorized for the above emergency use by the FDA under an EUA. The Impella LV Support Systems have been authorized only for the duration of the declaration that circumstances exist justifying the authorization of the emergency use of medical devices under section 564(b)(1) of the Act, 21 U.S.C. § 360bbb-3(b)(1), unless the authorization is terminated or revoked sooner.

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Contraindications

Contraindications and Warnings

The Impella 2.5, Impella CP, Impella CP with SmartAssist, Impella 5.0, Impella 5.5 with SmartAssist and Impella LD are contraindicated for use with patients experiencing any of the following conditions: Mural thrombus in the left ventricle; Presence of a mechanical aortic valve or heart constrictive device; Aortic valve stenosis/calcification (equivalent to an orifice area of 0.6cm^2 or less); Moderate to severe aortic insufficiency (echocardiographic assessment graded as ≥ +2); Severe peripheral arterial disease precluding placement of the Impella System; Significant right heart failure*; Combined cardiorespiratory failure*; Presence of an Atrial or Ventricular Septal Defect (including post-infarct VSD)*; Left ventricular rupture*; Cardiac tamponade*

** This condition is a contraindication for the cardiogenic shock indication only.*

less...

Potential Adverse Events

Acute renal dysfunction, Aortic valve injury, Bleeding, Cardiogenic shock, Cerebral vascular accident/Stroke, Death, Hemolysis, Limb ischemia, Myocardial infarction, Renal failure, Thrombocytopenia and Vascular injury

In addition to the risks above, there are other

CONTRAINDICATIONS

No LV thrombus

No severe valvular stenosis or valvular regurgitation of tricuspid or pulmonary valve

Mechanical valves

Vena cava filter / unless it's a greenfield

Eustachian valve remnant @ RA - Caval junction

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Impella

Feature	Impella 5.5	Impella 5.0®
Catheter Length	70cm	135cm
Cannula Diameter	21Fr	21Fr
Motor Diameter	18Fr	21Fr
Rigid length (motor & outlet)	27mm	42mm
Pigtail	NO	YES
Sensor	Fiber optic	Differential Pressure

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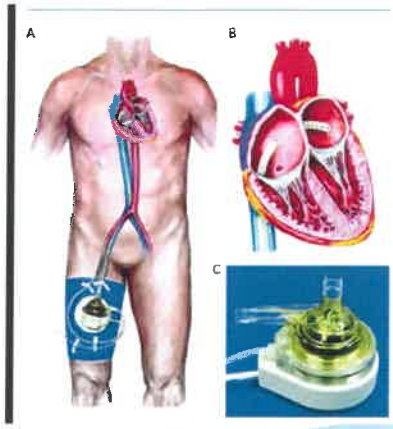
Tandem Heart



– TandemHeart Animation (youtube.com)

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What is ECMO?

- **Definition**
  - Extracorporeal membrane oxygenation (ECMO) is a *temporary mechanical support system* used to aid heart and lung function in patients with severe respiratory or cardiac failure
- **Types**
  - **Veno-Arterial and Veno-Venous**

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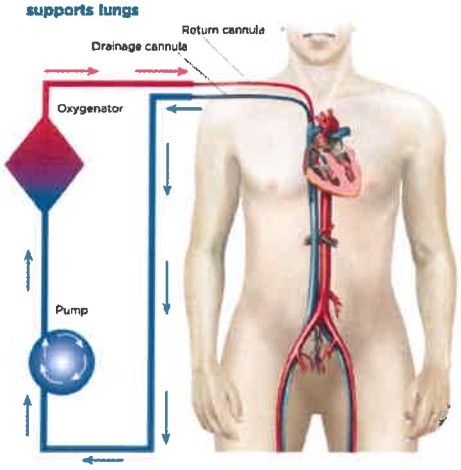
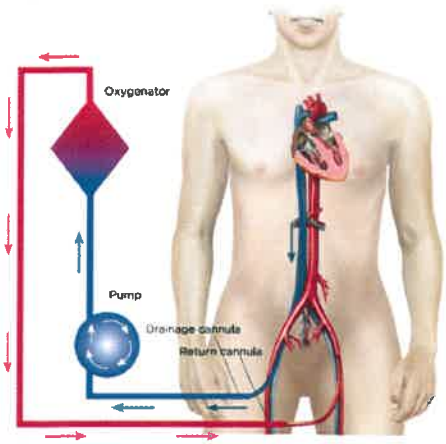
Veno-venous (VV) ECMO

supports lungs



Veno-arterial (VA) ECMO

supports both heart and lungs



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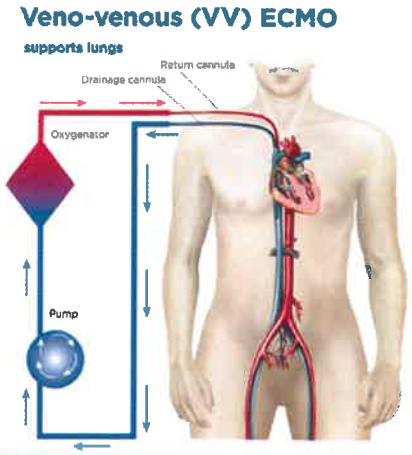
Veno-Venous ECMO

- Support the lungs
  - ARDS
  - Other refractory hypoxemia
- Utilizes native heart function
- Multiple cannulation strategies



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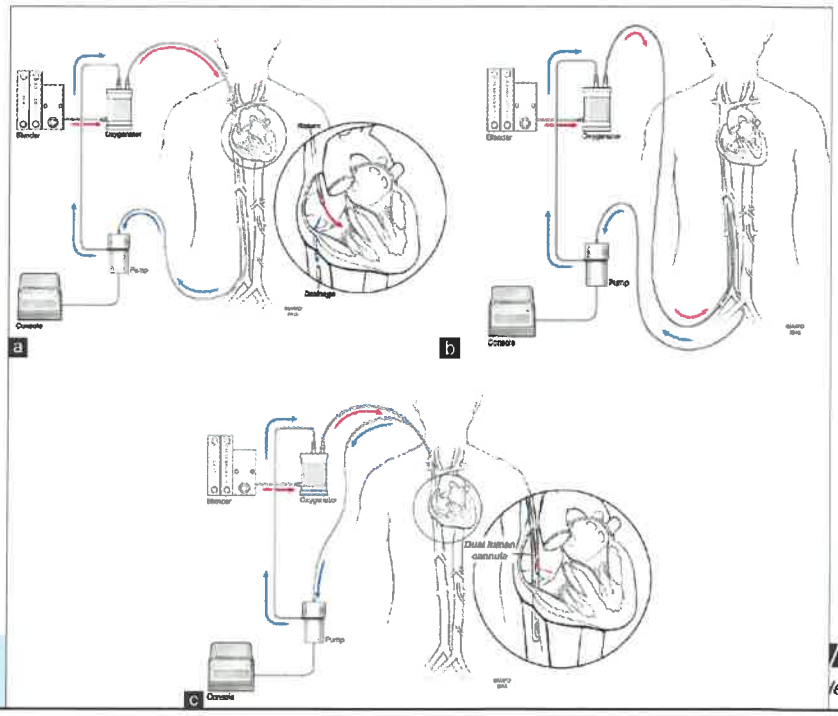
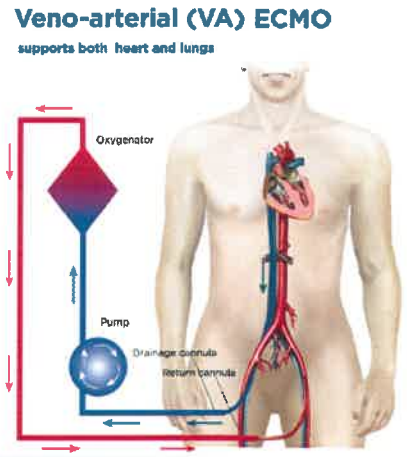


Veno-Arterial ECMO

- Supports heart and lungs
  - Cardiogenic shock
  - Post cardiac surgery
  - Bridge to transplant
- Provides Cardiac Output to the patient
- Peripheral and Central cannulation options



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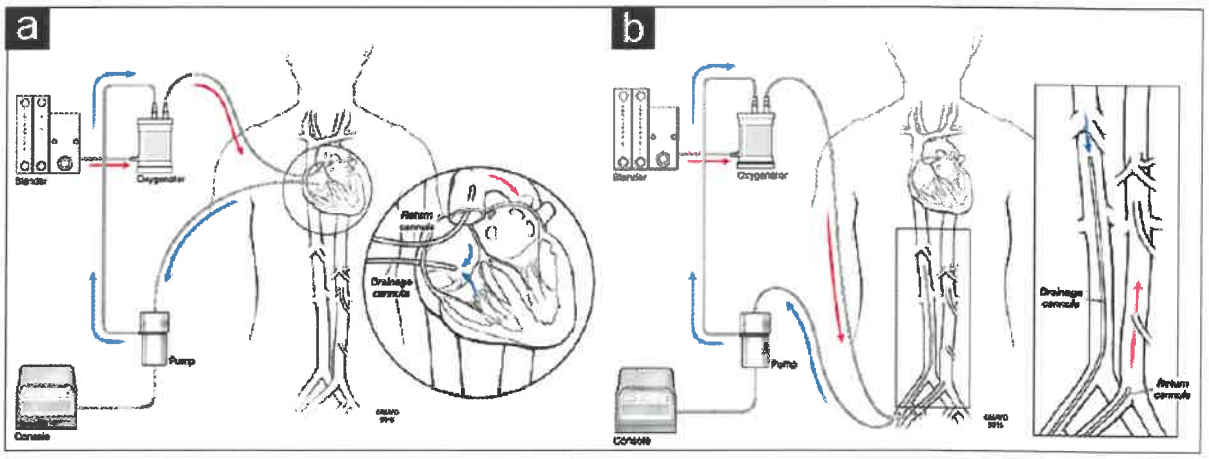

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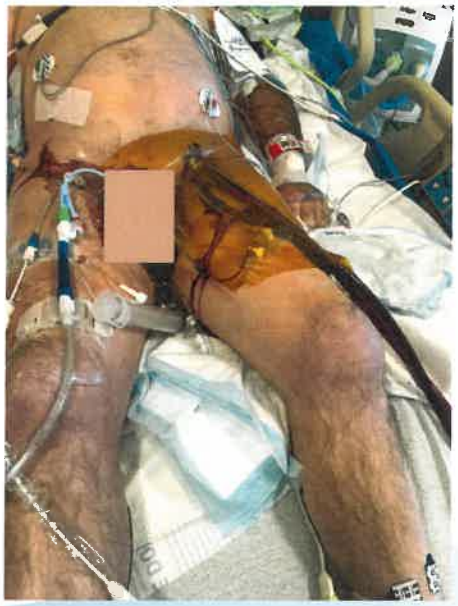

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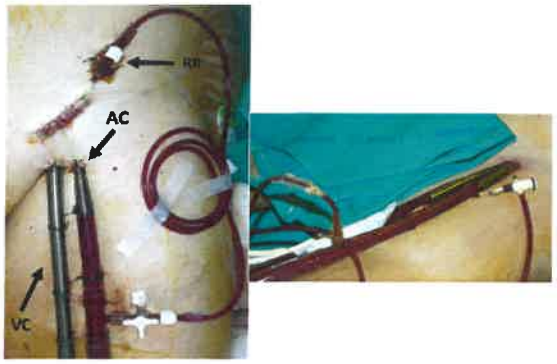
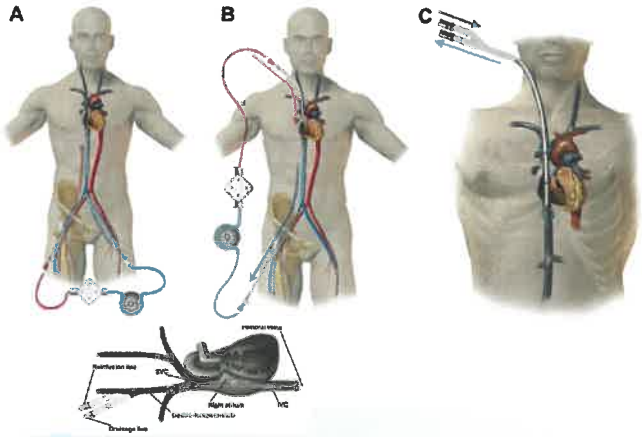
Cannulation Highlights



Distal Limb Perfusion for Percutaneous VA ECMO to avoid highly morbid Limb Ischemia. Cut-down vs Perc.



Options for VV Cannulation. Two-Cannula vs Dual Lumen single Cannulation.

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Selection and Exclusion

- ***Regardless of mode (VV or VA), ECMO is considered only when maximal conventional medical therapy has failed and where death is imminent without further intervention. In addition, the patient is thought to be suffering from a problem that is reversible, or treatable with a durable organ replacement, mechanical or transplant, AND there are no contraindications to proceeding.***
- ***As programs have matured and gained experience, indications have broadened and exclusions have narrowed considerably.***
- ***At WMC, final decisions on whether or not to proceed with life-saving ECMO will be at the discretion of the ECMO co-directors, in consultation with the referring provider.***
- ***Indications for ECMO are generally divided into two categories:***

1) Respiratory Failure (VV)
2) Cardiac Failure / cardiogenic shock (VA)

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Implementation

Selection and Exclusion - Indications for VV ECMO

- Reversible causes of severe respiratory failure with persistent severe hypoxemia (ARDS, pneumonia or trauma) or hypercapnia (asthma, COPD):
  - ***Difficult to Oxygenate:*** PaO2/FiO2 <80-100 despite high PEEP ***AND*** other state-of-the-art salvage therapies, such as VDR, prone position and paralysis lasting > 6 hrs, or shorter if P/F <50.
    - Screening for ECMO should be considered when P/F <200 and persistent plateau pressures >30mmhg despite low tidal volume strategy (4cc/kg)
  - ***Refractory Hypercapnia :*** acute exacerbation of COPD/Asthma or other reversible chronic lung conditions.

VV ECMO = gas exchange without circulatory support. Some patients with primary respiratory failure will also have secondary cardiac failure and may need VA support. Others ⇨ full and rapid recovery of cardiac dysfunction by simply correcting severe hypoxemia and associated organ dysfunction, and may improve dramatically with VV support alone.

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Implementation

Indications for VA ECMO

VA ECMO ***should be considered*** to provide both circulatory and respiratory support in ***Cardiogenic Shock,*** manifested by ***low CO***, with LV and/or RV failure with resultant poor tissue perfusion (elevated lactate) in the setting of:

- Acute MI (including complications of wall/PM rupture and refractory VF) unresponsive to conventional therapy including high dose inotropes, IABP or Impella support
- Post-Cardiotomy failure to wean from CPBP, or following wean with borderline hemodynamics despite high dose inotrope/pressor support.
- Myocarditis, post-partum and Takotsubo cardiomyopathy
- Sepsis with cardiac depression
- PE with RV failure and acute HD deterioration
- Acute decompensation of chronic LV failure
- Acute RV failure following LVAD
- Acute anaphylaxis
- Drug overdose with cardiac depression
- Refractory Ventricular Arrhythmia

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Implementation

Selection and Exclusion - Absolute Contraindications to ECMO of any type

- Disseminated or active malignancy (this envelope has been pushed)
- Intracranial bleed or other active bleeding in non-controllable site
- Known severe brain injury or irrecoverable neurologic dysfunction
- Advanced age >75
- Morbid obesity, weight >140kg (this envelope has been pushed)
- Inability to anticoagulate (some reported VV cases without anticoagulation)
- Unwillingness or inability to receive blood products
- Aortic dissection
- Unrecoverable heart failure and not a candidate for VAD or TX due to end-stage emphysema, cirrhosis, renal failure or compliance issues (cognitive, psych, social)

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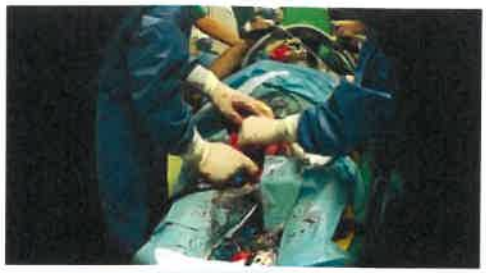
ECPR

VA ECMO ***can*** be considered for emergency cardio-respiratory support (eCPR) in the setting of:

- Refractory ***witnessed*** cardiac arrest in ED or en route
- …… or when repetitive arrests occur without sustained ROSC



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Overall Patient Outcomes

	Total Runs	Survived ECLS		Survived to DC	
Adult					
Pulmonary	51,093	33,932	66%	29,901	58%
Cardiac	47,917	29,012	60%	22,138	46%
ECPR	14,836	6,339	42%	4571	30%
Pediatric					
Pulmonary	12,885	9,438	73%	7,951	61%
Cardiac	16,598	12,146	73%	9,172	55%
ECPR	6,779	3,954	58%	2,842	41%
Neonatal					
Pulmonary	35,023	30,605	87%	25,552	72%
Cardiac	10,856	7,532	69%	4,882	44%
ECPR	2,636	1,840	69%	1,138	43%
Total	**198,623**	**134,798**	**67%**	**108,147**	**54%**

Data Through December 31, 2022

ELSO Registry

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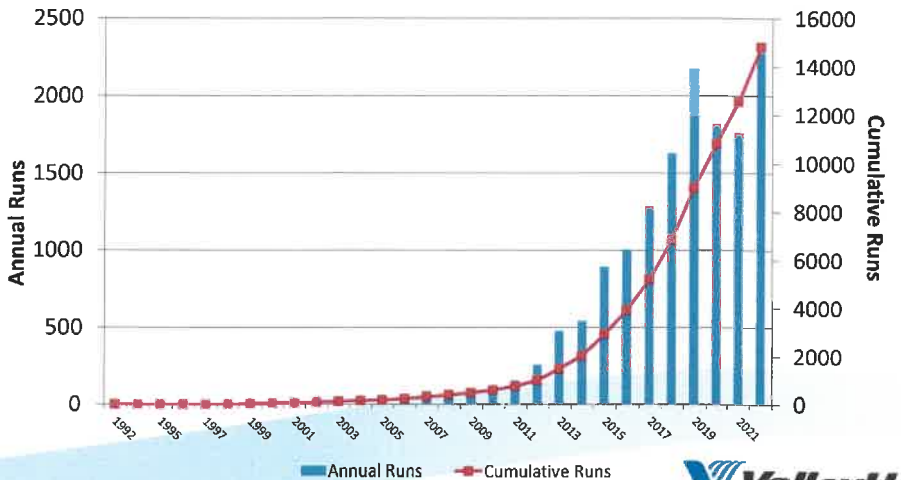
Adult ECPR Cases



Data Through December 31, 2022

ELSO Registry

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2023 American Heart Association Focused Update on Adult Advanced Cardiovascular Life Support: An Update to the American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care

Sarah M. Perman, Jonathan Elmer, Carolina B. Maciel, Anezi Uzendu, Teresa May, Bryn E. Mumma, Jason A. Bartos, Amber J. Rodriguez, Michael C. Kurz, Ashish R. Panchal, Jon C. Rittenberger and on behalf of the American Heart Association

Originally published 18 Dec 2023 | https://doi.org/10.1161/CIR.0000000000001194 | Circulation. 2024;149:e254–e273

EXTRACORPOREAL CPR

ECPR		
COR	**LOE**	**Recommendation**
2a	B-R	1. Use of ECPR for patients with cardiac arrest refractory to standard ACLS is reasonable in select patients when provided within an appropriately trained and equipped system of care.

The Hyperinvasive Trial

The ARREST trial (Advanced Reperfusion Strategies for Refractory Cardiac Arrest)

The ARREST trial (Advanced Reperfusion Strategies for Refractory Cardiac Arrest) demonstrated significantly improved survival to discharge and 6-month survival for patients receiving ECPR for refractory cardiac arrest with shockable presenting rhythms.

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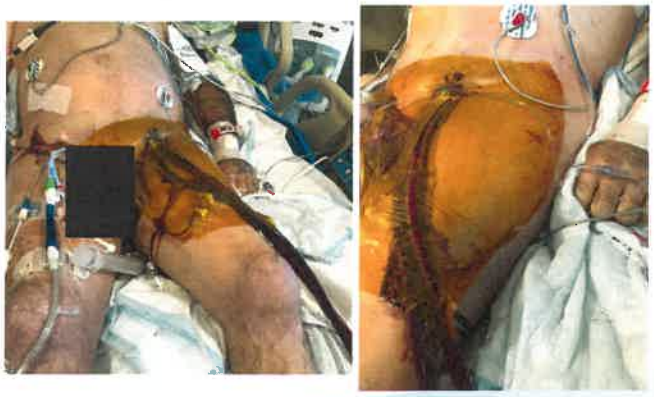
Cannulation Cath Lab



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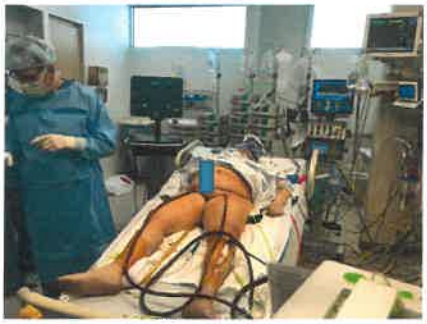
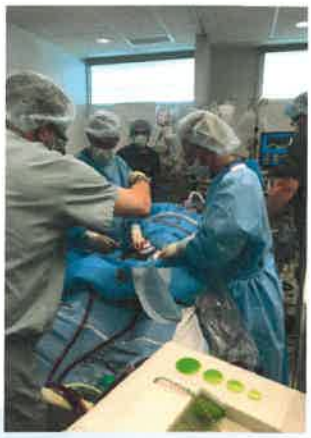
Cannulation ICU Bedside





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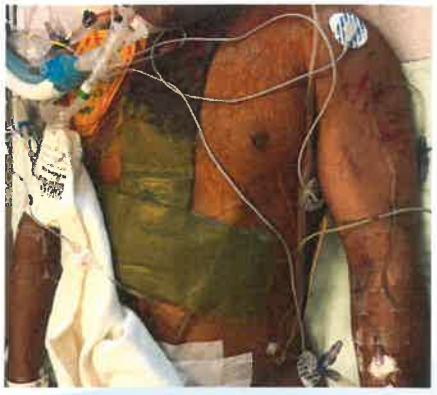
Central Cannulation ICU



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ECPR

- Video here https://youtu.be/UK0yBWypCrg

Bing Videos

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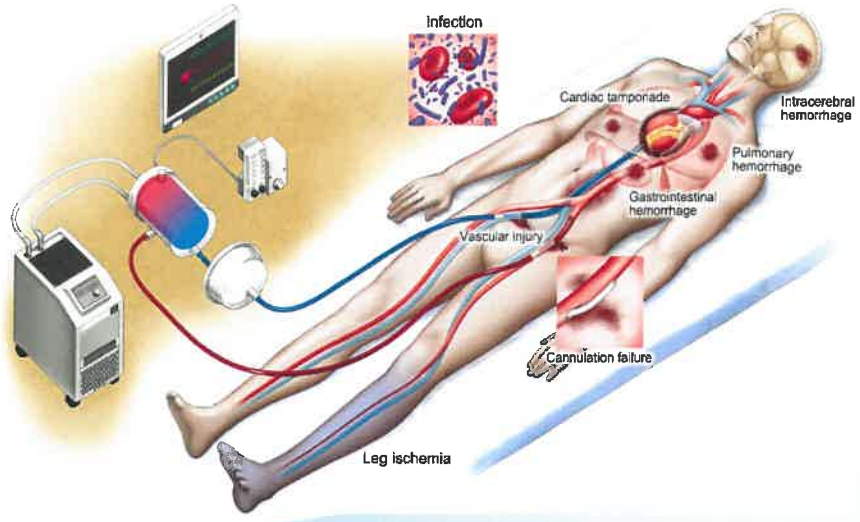

Akihiko Inoue Journal of the American Heart Association. Extracorporeal Cardiopulmonary Resuscitation for Out-of-Hospital Cardiac Arrest in Adult Patients, Volume: 9, Issue: 7, DOI: (10.1161/JAHA.119.015291)

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WMC ECPR Protocol

Inclusion Criteria : (All criteria need to be met)	Exclusion criteria: (any one item makes patient ineligible)
Patient Characteristics	
**Age > 18 and < 60	Hospital Record review finds major co-morbidity or major neurological deficit
No Major co-morbidities (second page for additional detail)	
Arrest Characteristics	
Out of hospital Cardiac Arrest – Presumed Cardiac- witnessed	ETCo2 < 10
In-house Cardiac Arrest – Presumed Cardiac	Lactate > 18
	Signs of life with CPR no longer present
Initial Rhythm Shockable	Initial non-shockable rhythm
Demonstrating Signs of life during Code (Moving or Gasping or Pupils < 5)	ROSC within 5 minutes of ACLS
Lactate < 18	ACLS ongoing >50 minutes *if periods of ROSC, minus from total time
ETCo2 > 10	Out of hospital cardiac arrest > 5 minutes of no CPR – Arrest must be witnessed with bystander CPR

***Comorbidities:*

(Non recoverable comorbidity such as major CNS damage or terminal malignancy, CNS hemorrhage, end stage organ failure, Greater than 60% TBSA burn, Inability to receive blood products , DNR , Unrecoverable respiratory or cardiac disease (unless candidate for durable VAD or transplant), Inability to be anticoagulated)

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Case Reviews

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Case Review

56-year-old gentleman with a history of tobacco use disorder who presented to the emergency department by private vehicle complaining of chest pain. In the emergency department, the patient reported that his chest pain started today to nursing staff. As soon as I walked into the patient's room, the patient went into ventricular fibrillation cardiac arrest.

Transferred from outside facility to WMC.

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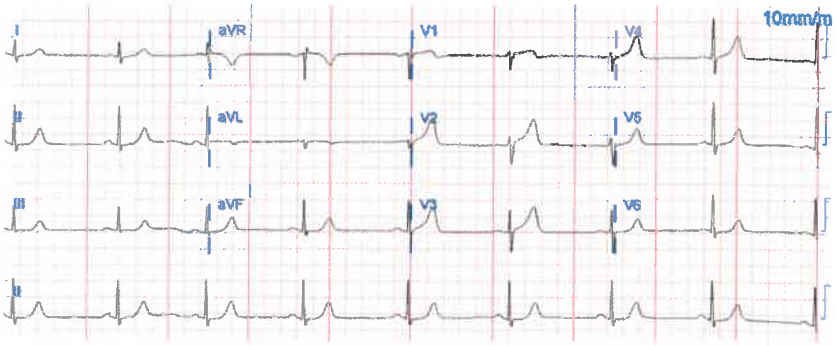
Case Review



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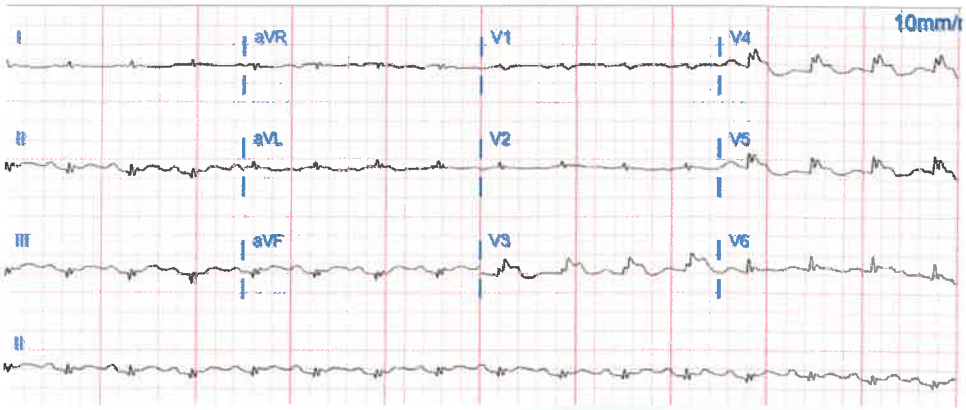
Case Review



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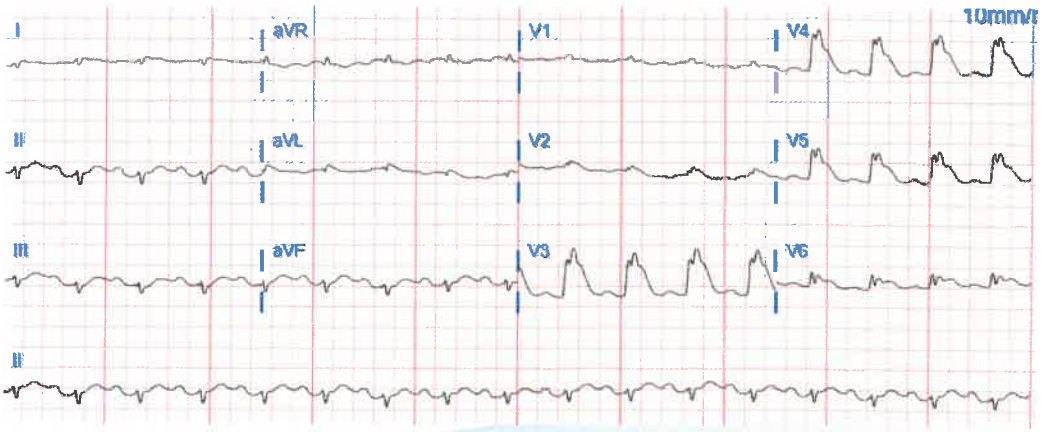
Case Review



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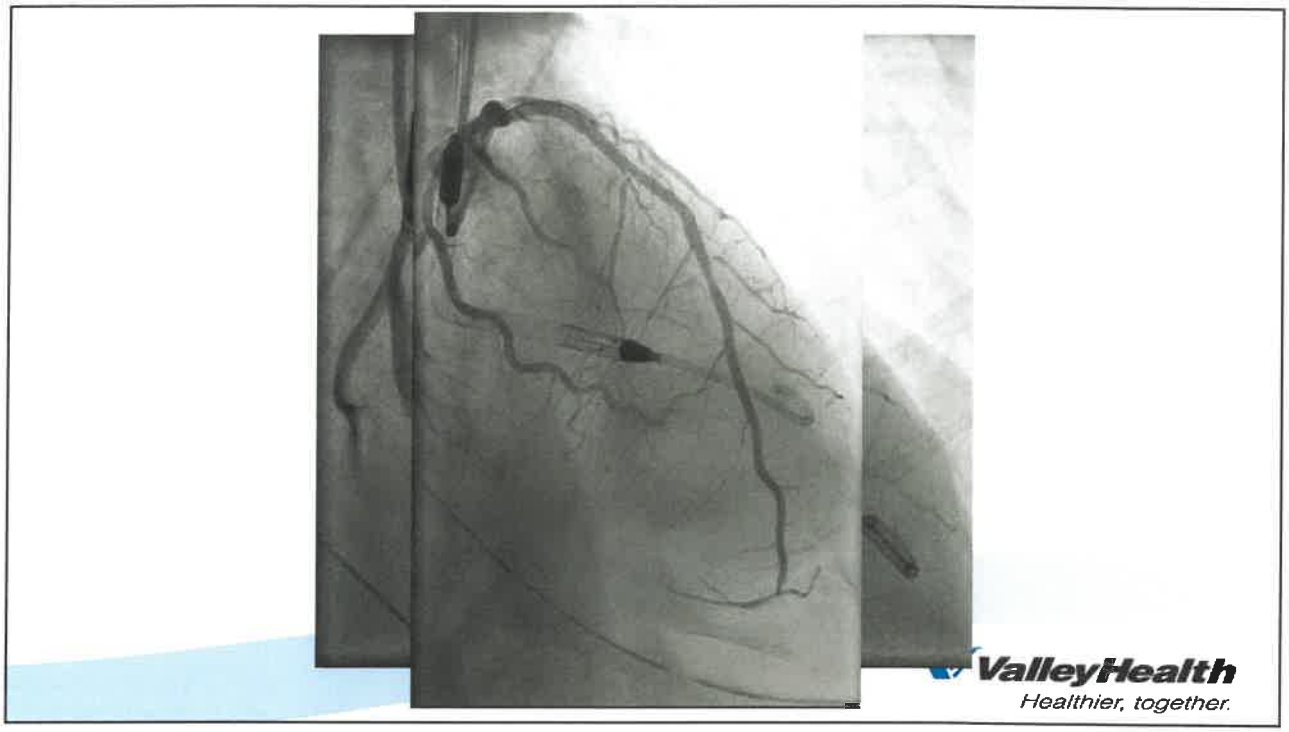

Case Review

Echo 9-8-2022

Conclusions 1: The left ventricular ejection fraction is severely decreased, estimated at 20%.
2: There is mid-to-distal anterior, inferior, lateral, septal and apical akinesis.
3: Grade I diastolic dysfunction of the left ventricle.
4: The right ventricle is normal in size and systolic function.
5: No significant valvular abnormalities.
6: The pulmonary arterial systolic pressure could not be estimated due to an incomplete tricuspid regurgitation velocity profile.
7: No prior study available for comparison.

Echo 11-7-2022

Conclusions 1: The left ventricle is normal in size and wall thickness. The systolic function is normal with an estimated
EF = 55-60%. No regional wall motion abnormalities detected. The diastolic function is normal.
2: The right ventricle is normal in size and systolic function.
3: No clinically significant valve disease.
4: Compared to prior, LVEF has normalized.

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Case Review

38 year old male:

Chest pain started at 6AM today, describes symptoms as racing. Symptoms are associated with shortness of breath. Patient has a history of palpitations. Patient stated that he took aspirin 2 tabs today.

Patient arrived via EMS -Adenosine 6mg and 12 mg given en route without improvement.

He has been nauseous and vomiting. He is diaphoretic. He says a history of cardiomyopathy does have a pacemaker. He is scheduled to have a cardiac cath by Dr. Gaither in the next few days. Patient has had trouble with chest pain off and on recently. He denies any recent illnesses. He had no fevers chills cough or COVID-19 exposure. He does have some peripheral edema. He said he feels terrible. He has been tired and weak. Patient continues to have nausea and vomiting. He has some mild abdominal pain.

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Case Review

SVT
- amiodarone per cardiology

CAD
- LHC/RHC per cardiology

Ischemic cardiomyopathy s/p BiV ICD
- cont coreg
- entresto was stopped due to side effects

Elevated BNP
- would prefer to diurese but just received fluid boluses for hypotension
- consider diuresis when BP stabilizes

HTN
- currently hypotensive

COPD
- cont inhaler

CKD Stage 3
- monitor BMP

significant history of ICM (EF 25-30%), CAD: LAD 100% and HTN, and CVA.

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Case Review

During ED admission – patient had a witnessed arrest. Patient stated he could not breathe had chest pain sat up and then collapsed. He went into a pulseless activity. CPR was begun. Epi was administered. Patient was in a PEA. He received epinephrine calcium and bicarbonate. Patient was intubated. CPR was continued dopamine drip was begun patient was on amiodarone. There was return of spontaneous circulation. Cardiology is at the bedside. The patient was taken directly to the Cath Lab for intervention.

Right Heart Catheterization:
PA: 68/30
PCWP: 38/40 mean 38

Arterial O2 saturation: 92%
Pulmonary Artery saturation:54%

Impression:
1. Two-vessel coronary disease with with patent stents in the left anterior descending occluded ostium circumflex
2. Acutely occluded ostial left circumflex with late stent thrombosis successfully treated with balloon angioplasty alone
3. Cardiogenic shock with Impella placement
4. Severely elevated right heart pressures
5. ECMO cannulation

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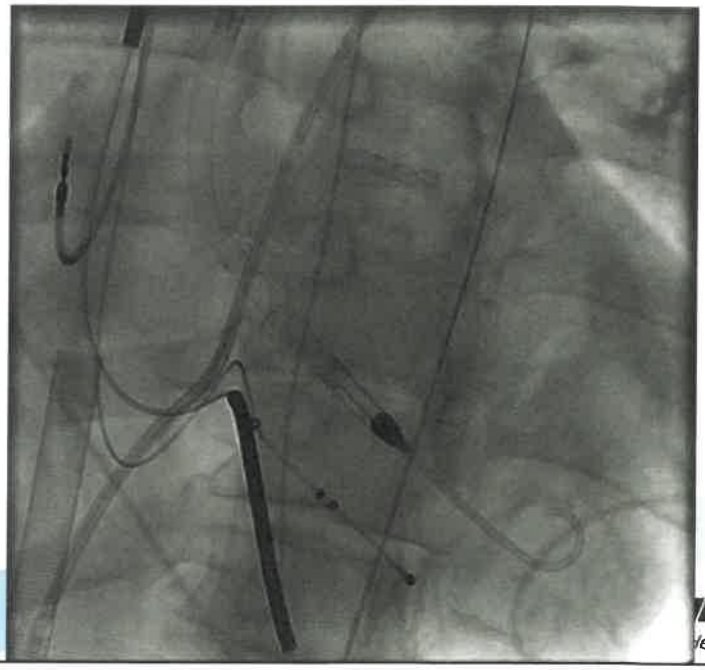
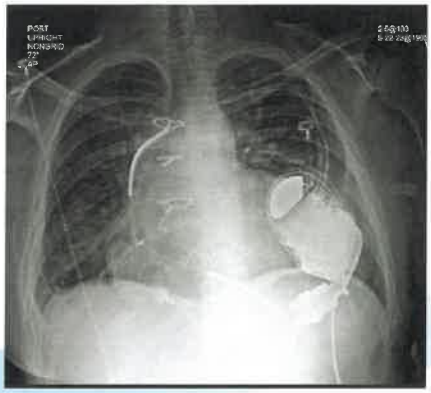


Patient was taken to the catheterization laboratory after having a cardiac arrest in the emergency department. He was in cardiogenic shock and an Impella was placed to support him during the procedure. He remained in cardiogenic shock requiring institution of VA ECMO. Transfer was set up to Washington Hospital Center, and he was sent there directly from the catheterization laboratory.

LVAD placed 3/15/2023



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Questions

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