Incorporation of ECMO, cooling, and ventricular assist devices into cardiac resuscitation protocols

Joseph M Delehanty MD

Goals

- Discuss targeted temperature management in the post-arrest patient
- Discuss the role of circulatory support including ECMO and E-CPR in the cardiac arrest patient
- Discuss the role of ventricular assist devices in the management of the post-cardiac arrest patient
- Implementation of these strategies into practice

Medicine of the Highest Order
UR Medicine

Case presentation

- 38 year old woman with history of tobacco use and familial hyperlipidemia presented to Elmira with anterior MI. Cardiac arrest in ED from which she was resuscitated
- Emergent cath revealed occlusion of the proximal LAD and severe disease of the RCA. Both lesions successfully treated with PCI but recurrent VF from which she could not be resuscitated
- Placed on VA ECMO from the groin with good blood pressure and distal flow. Transferred to URMC for further management

Medicine of the Highest Order
UR Medicine

- On arrival here she was in VF with MAP of ~75. Defibrillated multiple times and eventually had sinus bradycardia requiring temporary pacing.
- Being cooled to 33 degrees on ECMO circuit
- TEE done:

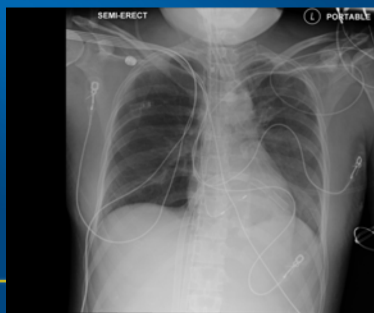
Medicine of the Highest Order
UR Medicine

Minimal flow thru aortic valve

Medicine of the Highest Order
UR Medicine

- TEE with LVEF of <10%, dilated LV
- Taken for placement of a sump in the LV placed through the atrial septum

Medicine of the Highest Order
UR Medicine



Medicine of the Highest Order

- Subsequently went on to have implantable LVAD and percutaneous RVAD placed.
- After a very prolonged course, was discharged to rehab facility
- Neurologically intact

Medicine of the Highest Order

Prognosis after cardiac arrest

- Meta-analyses have shown that survival to hospital discharge is only about 7.6% for out of hospital arrest and for in hospital arrest it is only marginally better at 20% survival discharge
- Of those who survive, 50% have good neurologic outcome

Medicine of the Highest Order

Reasons people die after cardiac arrest

- Loss of cerebral function secondary to anoxic damage
  - Attempt to minimize using "targeted temperature management"
- Loss of circulatory function from cardiac damage
  - Leads to multi-organ system failure
  - Need to interfere with the shock process that leads to MOSF

Medicine of the Highest Order

Targeted temperature management

- Therapeutic hypothermia has been the standard for the past 15 years
- Get patients to 32-33 degrees and maintain there for 24 hours
- Associated with ~50% survival with good neurologic outcome

Medicine of the Highest Order

Compare hypothermia to normothermia in a trial

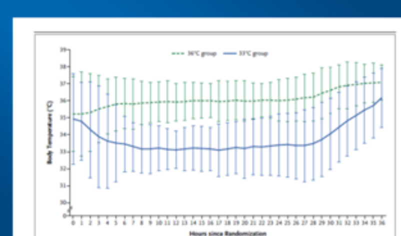


Figure 1. Body Temperature during the Intervention Period.
Shown are body-temperature curves in the 33°C and 36°C groups for the 860 patients in whom a bladder temperature was recorded. In the remaining 79 patients, the temperature was recorded with an intravascular or esophageal probe, with a similar temperature profile (data not shown). Rewarming was commenced at 28 hours after randomization. The temperature curves display the means, and the I bars indicate ±2 SD (95% of the observations are within the error bars).

Medicine of the Highest Order

No difference between the two strategies

Table 2. Outcomes.

Outcome	33°C Group	36°C Group	Hazard Ratio or Risk Ratio (95% CI)*	P Value
	no./total no. (%)			
Primary outcome: deaths at end of trial	235/473 (50)	225/466 (48)	1.06 (0.89–1.28)	0.51
Secondary outcomes				
Neurologic function at follow-up†				
CPC of 3–5	251/469 (54)	242/464 (52)	1.02 (0.88–1.16)	0.78
Modified Rankin scale score of 4–6	245/469 (52)	239/464 (52)	1.01 (0.89–1.14)	0.87
Deaths at 180 days	226/473 (48)	220/466 (47)	1.01 (0.87–1.15)	0.92

* The hazard ratio is shown for the primary outcome, and risk ratios are shown for the secondary outcomes. CI denotes confidence interval.
† The neurologic follow-up was specified in the protocol to be performed at 180 days ±2 weeks, but the time to follow-up was in some cases several weeks longer for logistic reasons. The Cerebral Performance Category (CPC) scale ranges from 1 to 5, with 1 representing good cerebral performance or minor disability, 2 moderate cerebral disability (function is sufficient for independent activities of daily life), 3 severe cerebral disability, 4 coma or vegetative state, and 5 brain death. Scores on the modified Rankin scale range from 0 to 6, with 0 representing no symptoms, 1 no clinically significant disability despite some symptoms, 2 slight disability (patient is able to look after own affairs without assistance), 3 moderate disability (patient requires some help but is able to walk unassisted), 4 moderately severe disability (patient is unable to attend to own bodily needs), 5 severe disability (patient is bedridden), and 6 death.

MEDICINE *of* THE HIGHEST ORDER — UR MEDICINE

- It is thought that perhaps the benefit is in prevention of hyperthermia
- Our institution and many others have not changed the temperature goal
- In some patients where hypothermia needs to be avoided, strict temperature control is probably as good

MEDICINE *of* THE HIGHEST ORDER — UR MEDICINE

Circulatory support

- For the patient with return of spontaneous circulation (ROSC), targeted temperature management is appropriate
- What about those patients in whom we cannot achieve ROSC? Are there any options available?

MEDICINE *of* THE HIGHEST ORDER — UR MEDICINE

Circulatory support options

- IABP
  - Easy to insert
  - Can be placed in ED setting
  - Doesn't work
- Impella
  - Provides more circulatory support
  - Needs to be placed in cath lab
  - Frequent complications

MEDICINE *of* THE HIGHEST ORDER — UR MEDICINE

ExtraCorporeal Membrane Oxygenation (ECMO)

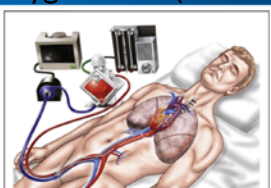


Figure 3 Femoral Venoarterial ECMO

When extracorporeal membrane oxygenation (ECMO) is implemented via femoral venous drainage and femoral arterial return in patients with residual native cardiac function and impaired lung function, reinfused oxygenated blood **(red arrow)**, flowing retrograde through the aorta, may meet resistance from poorly oxygenated blood flowing antegrade from the left ventricle **(purple arrow)**. Depending on the amount of cardiac function, the location of the interface between antegrade and retrograde flow will vary, and the reinfused oxygenated blood may not reach the cerebral and coronary vascular beds.

MEDICINE *of* THE HIGHEST ORDER — UR MEDICINE

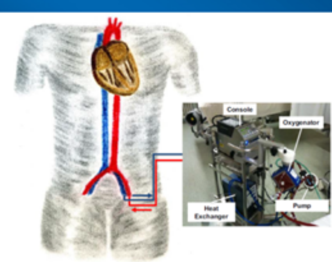


Figure 1. Peripheral venoarterial (va)-ECMO therapy breaks a vicious cycle of self-perpetuating myocardial ischemic injury. The extracorporeal membrane oxygenation supports the failing heart by draining blood from the inferior vena cava and returning oxygenated blood via the femoral artery (coronary perfusion). Beneficial effects unloading the heart include a reduced right ventricular preload, subsequently decreasing left ventricular filling and end-diastolic pressure, allowing reduced myocardial oxygen consumption as well as an increased coronary blood flow. ECMO indicates extracorporeal membrane oxygenation.

MEDICINE *of* THE HIGHEST ORDER — UR MEDICINE

E-CPR

- Incorporation of ECMO into the CPR regimen and the addition of ECMO support in the patient without ROSC or inadequate circulation

Saving life and brain with extracorporeal cardiopulmonary resuscitation: A single-center analysis of in-hospital cardiac arrests

Graham Peigh, BA, Nicholas Cavarocchi, MD, and Hitoshi Hirose, MD, PhD

- 23 inpatients underwent E-CPR at Thomas Jefferson Hospital. All were undergoing CPR at the time of ECMO institution
- Retrospective review of outcomes

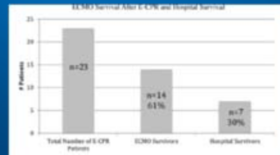


FIGURE 1. ECMO survival after E-CPR and hospital survival. *ECMO*, Extracorporeal membrane oxygenation; *E-CPR*, extracorporeal cardiopulmonary resuscitation.

MEDICINE of THE HIGHEST ORDER | UR MEDICINE

Refractory cardiac arrest treated with mechanical CPR, hypothermia, ECMO and early reperfusion (the CHEER trial)☆

Dion Stub[c,f,g], Stephen Bernard[a,b,d,*], Vincent Pellegrino[a], Karen Smith[b,d,e], Tony Walker[d], Jayne Sheldrake[a], Lisen Hockings[a], James Shaw[a,b,c], Stephen J. Duffy[a,b,c], Aidan Burrell[a,b], Peter Cameron[a,b], De Villiers Smit[a], David M. Kaye[a,b,c]

- Prospective study of patients with refractory cardiac arrest
- 26 patients
  - 15 in hospital arrest
  - 11 out of hospital arrest patients
- All appropriate patients underwent coronary angiography and revascularization after initiation of ECMO
- MAP maintained >70 mmHG with pressors as needed

MEDICINE of THE HIGHEST ORDER | UR MEDICINE

Table 2
Cardiac arrest and treatment details.

Arrest characteristics	All $N=26$	Survivors $N=14$	Non-survivors $N=12$	P value
ECMO inserted, n (%)	24(92)	12(86)	12(100)	0.41
Median time from ECPR team arrival to initiation of ECMO, min (IQR)	20(15–30)	16(15–19)	30(24–35)	0.01
Median time from collapse to initiation ECMO, min (IQR)	56(40–85)	40(27–57)	78(48–101)	0.02
Location of ECMO (n = 24)				
Emergency Department, n (%)	13(50)	6(43)	7(58)	
Intensive Care Unit, n (%)	7(27)	3(21)	4(33)	0.40
Coronary catheterization laboratory, n (%)	3(12)	2(14)	1(8)	
Hospital ward, n (%)	1(4)	1(7)	0(0)	
ST elevation on initial ECG, n (%)	9(35)	5(36)	4(33)	0.75
Initial post arrest laboratory values				
pH	6.9 (6.7–7.1)	7.0 (6.8–7.1)	6.8 (6.7–7.0)	0.02
PCO_2 mmHg	57 (43–85)	52(32–69)	77(48–91)	0.23
PO_2 mmHg	112(83–211)	114(101–159)	97(68–350)	0.51
HCO_3 mEq/L	10(6–16)	15(8–16)	8(6–13)	0.23
Lactate mEq/L	10(7–14)	8(6–12)	13(9–14)	0.18
INR	1.3 (1.2–1.4)	1.3 (1.1–1.4)	1.3 (1.2–3.1)	0.40
Troponin μgm/mL	1.5 (0.12–19)	0.16 (0.07–5.8)	3.5 (1.4–39)	0.02
Creatinine μmol/L	119(107–132)	114(97–123)	127 (110–146)	0.24
Subsequent intervention				
Coronary angiogram, n (%)	21(81)	13(93)	4(33)	0.61
PCI, n (%)	11(42)	6(43)	5(42)	
Pulmonary thrombectomy, n (%)	1(4)	1(7)	0(0)	
AICD, n (%)	5(19)	5(36)	0(0)	0.02
Extent of coronary disease				
No significant disease, n (%)	6(23)	6(43)	0(0)	0.07
Single vessel disease, n (%)	6(23)	3(21)	3(25)	
Multivessel disease, n (%)	9(70)	4(29)	5(42)	
LMCA involvement, n (%)	2(16)	0(0)	2(17)	
Culprit vessel				
Left anterior descending, n (%)	4(15)	2(14)	2(17)	0.71
Left circumflex, n (%)	4(25)	2(14)	2(17)	
Right coronary artery, n (%)	3(8)	2(14)	1(8)	

OHCA – out-of-hospital cardiac arrest, ECMO – extra corporeal membrane oxygenation, PCI – percutaneous coronary intervention, LMCA – left main coronary artery, AICD – automatic implantable cardiac defibrillator.

MEDICINE of THE HIGHEST ORDER | UR MEDICINE

Complications

- Ischemia to the leg
  - Routinely place cannula distal to the ECMO cannula to reperfuse
  - Arterial or venous injury
    - 16-24 F catheters
    - Meticulous attention to detail with placement
  - Need for systemic anticoagulation
    - Risk of cerebral embolization

MEDICINE of THE HIGHEST ORDER | UR MEDICINE

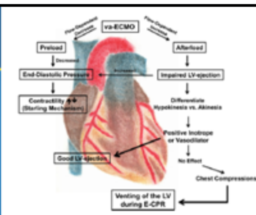
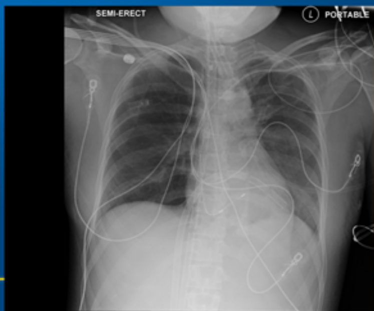


Figure 3. Circulatory changes associated with venoarterial (va)-ECMO therapy during cardiogenic shock requiring immediate venting of the left ventricle. Sophisticated pathophysiological mechanisms including a ECMO blood flow–dependent decrease in cardiac preload accompanied by a corresponding increase in afterload demand a higher contractile force from the left ventricle (LV) to open the aortic valve. If the failing LV is unable to exert sufficient pressure obstruction of coronary blood flow, pulmonary edema, hemorrhage, and even intracavity clot formation develops. Reducing va-ECMO flow may alleviate this problem and helps to distinguish left ventricular hypokinesia vs akinesia. However, because decreased afterload is accompanied by enhanced preload during va-ECMO, increased left ventricular filling pressures may worsen the situation in the failing heart via the Starling law. Inotropic or vasodilator support represents the next therapeutic step, respectively. Nevertheless if none of these measures suffice, immediate venting of the left ventricle is mandatory. At the bedside, this can be easiest accomplished via the resumption of chest compressions. ECMO indicates extracorporeal membrane oxygenation; and E-CPR, extracorporeal cardiopulmonary resuscitation.

MEDICINE of THE HIGHEST ORDER | UR MEDICINE



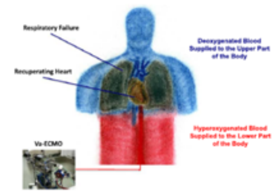


Figure 2. In case of respiratory failure, flow competition in the aorta between the recovering native heart and the extracorporeal circuit can lead to a "Harlequin" or "North–South" syndrome. Deoxygenated blood is supplied to the upper part of the body, whereas only the lower part benefits from the hyperoxygenated blood supplied by the venoarterial (va)-ECMO. The solution to this serious problem is additional venovenous (vv)-ECMO support (eg, via cannulation of the internal jugular vein). ECMO indicates extracorporeal membrane oxygenation.

Medicine of the Highest Order

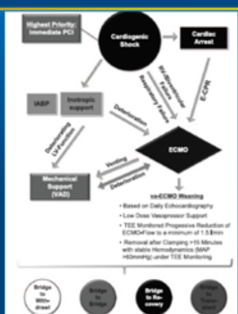
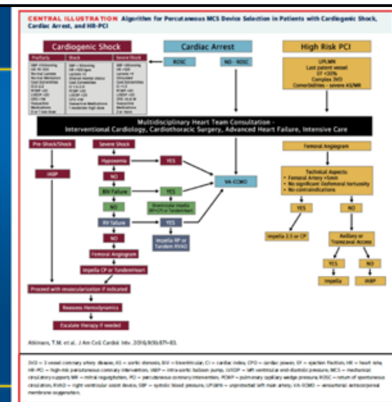


Figure 4. Support to the failing heart during cardiogenic shock must be considered early on to facilitate immediate revascularization as the number 1 priority. In this regard, extracorporeal cardiopulmonary resuscitation (E-CPR) represents the primary therapeutic option during cardiogenic shock requiring CPR. ECMO must also be considered early on during all cases refractory to inotropic support, in particular when right- or biventricular, as well as respiratory failure is impending. The extracorporeal circuit can be easily combined with other forms of left ventricular support, such as IABP, an Impella pump, or a Tandem Heart. The latter are prime choices in case of isolated left ventricular failure. All serve as bridges toward full recovery or definite therapeutic options depending on neurological and cardiac function. ECMO indicates extracorporeal membrane oxygenation; IABP, intra-aortic balloon pump; LV, left ventricle; and VAD, ventricular assist device.

Medicine of the Highest Order

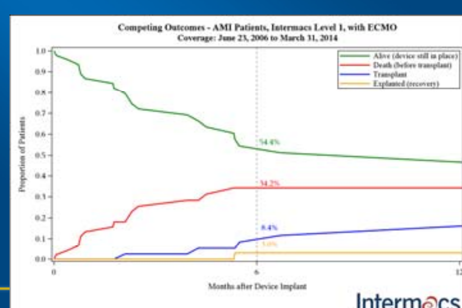


Medicine of the Highest Order

What to do after successful E-CPR

- Assess neurologic function
- Assess residual cardiac function
  - In those patients with good neurologic recovery who have return of cardiac function
  - Wean off ECMO
- Good neurologic function with no return of cardiac function:
  - Consideration of long term mechanical support

Medicine of the Highest Order



Medicine of the Highest Order

Summary

- With successful ROSC
  - Targeted temperature management
  - Not clear what the ideal temperature is but should definitely choose either 33 or 36 degrees
- Unable to achieve ROSC
  - E-CPR is a technique that can allow for meaningful recovery in some patients
  - Requires tremendous commitment in terms of time and resources

- Long-term mechanical support of the appropriate patient population is feasible in survivors
- Appropriate selection of patients for E-CPR is a very difficult subject as is how long to support the patient resuscitated thusly.
- In our patient one is left wondering what would have happened if she had been able to stop smoking and was on appropriate lipid lowering therapy