FUNDAMENTALS OF ECPR

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INTRODUCTION

EXTRACORPOREAL MEMBRANE OXYGENATION (ECMO) IS AN ADVANCED FORM OF TEMPORARY LIFE SUPPORT, TO AID RESPIRATORY AND/OR CARDIAC FUNCTION.

IT WAS BEEN USED SINCE THE EARLY 1970'S AND IS BASED ON CARDIOPULMONARY BYPASS TECHNOLOGY AND DIVERTS VENOUS BLOOD THOUGH AN EXTRACORPOREAL CIRCUIT AND RETURNS IT TO THE BODY AFTER GAS EXCHANGE THOUGH A SEMI-PERMEABLE MEMBRANE. ECMO CAN BE USED FOR OXYGENATION, CARBON DIOXIDE REMOVAL AND HEMODYNAMIC SUPPORT.

ADDITIONAL COMPONENTS OF THE ECMO CIRCUIT ALLOWS FOR THERMOREGULATION AND HEMOFILTRATION.

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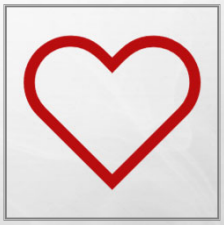
- THE TWO MOST COMMON FORMS OF ECMO ARE VENO-VENOUS (VV) AND VENO-ARTERIAL (VA).
- VV-ECMO ITS USED TO SUPPORT GAS EXCHANGE WHERE OXYGENATED BLOOD IS RETURNED TO A CENTRAL VEIN.
- VA-ECMO IS USED IN CASES OF CARDIAC OR CARDIORESPIRATORY FAILURE, OXYGENATED BLOOD IS RETURNED TO THE SYSTEMIC ARTERIAL CIRCULATION, BYPASSING BOTH THE HEART AND LUNGS.



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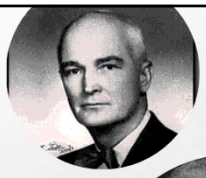
HISTORY OF ECMO



- DR. JOHN GIBBON
  - HELPED DEVELOPED THE FIRST HEART/LUNG MACHINE
  - FIRST SUCCESSFUL OPEN-HEART OPERATION USING A HEART-LUNG MACHINE IN 1954.
- DR. ROBERT BARTLETT "FATHER OF ECMO"
  - PIONEERED ECMO TECHNOLOGY, USAGE AND RESEARCH
  - FIRST NEONATAL ECMO SURVIVOR IN 1972.

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•1972 First successful adult ECMO patient
- Polytrauma patient with aortic transection who developed ARDS

Alain Vuylsteke , Daniel Brodie , Alain Combes , Jo-anne Fowles , Giles Peek. Cambridge University Press 978-1-107-68124-8 — ECMO in the Adult Patient
Hill JD, O'Brien TG, Murray JJ, Dontigny L, Bramson ML, Osborn JJ, et al. Prolonged extracorporeal oxygenation for acute post-traumatic respiratory failure (shock-lung syndrome). Use of the Bramson membrane lung. N Engl J Med. 1972;286:629–34. doi: 10.1056/NEJM197203232861204.

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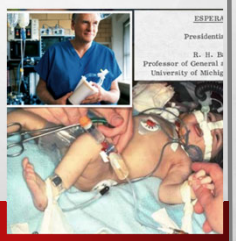
Brogan, Thomas V., et al. *Extracorporeal life support: the ELSO red book*. Extracorporeal Life Support Organization, 2017.

- 1975 NEONATE PLACED ON ECMO WITH SUCCESS
  - MECONIUM ASPIRATION
  - 72 HOURS ON ECMO
- NEONATES WITH END-STAGE LUNG DISEASE
  - 90% MORTALITY PRIOR TO ECMO —> 75% SURVIVAL AFTER ECMO



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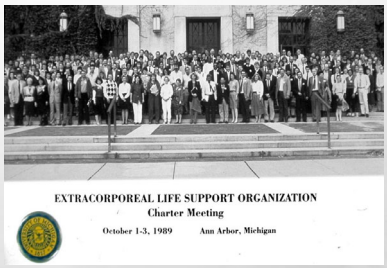
ELSO

- 1989 EXTRACORPOREAL LIFE SUPPORT ORGANIZATION FOUNDED



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2009 FLU PANDEMIC

- H1N1 INFLUENZA VIRUS
  - FIRST EVER WHO "PUBLIC HEALTH EMERGENCY OF INTERNATIONAL CONCERN"
  - CDC ESTIMATED 284,000 DEATHS GLOBALLY (MOSTLY IN AFRICA AND SOUTHEAST ASIA)
- 2009 CESAR TRIAL, H1N1 FLU EPIDEMIC
  - INCREASED ECMO USE IN ADULTS
  - INCREASED DEVELOPMENT OF NATIONAL ECMO PROGRAMS FOR ADULTS

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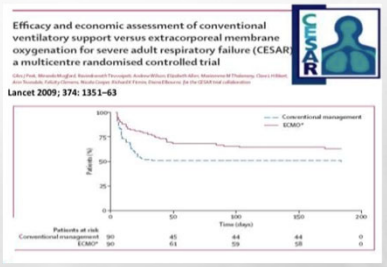
- 180 PATIENTS
- PRIMARY ENDPOINT: SURVIVAL W/O SEVERE DISABILITY AT 6 MONTHS
  - 63% ECMO VS 47% CM
- MOST PATIENTS HAD SEVERE ARDS (P:F <75)
- 30% OF THE CONTROL GROUP DID NOT RECEIVE LUNG-PROTECTIVE VENTILATION



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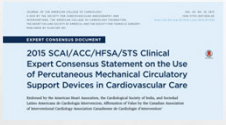

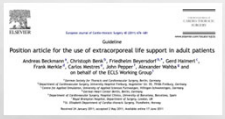

- WHILE THERE ARE NO WIDELY AGREED GUIDELINES ON THE INDICATIONS AND CONTRAINDICATIONS FOR ECMO SUPPORT, THERE ARE CONSENSUS STATEMENTS, AND ELSO HAS PUBLISHED RECOMMENDATIONS FOR THE USE OF ECMO IN CRITICALLY ILL PATIENTS.

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HOW DOES IT WORK?

- MEMBRANE LUNG/ OXYGENATOR
- CENTRIFUGAL PUMP
- CANNULAE
- HEATER/COOLER
- DIALYSIS CONNECTIONS

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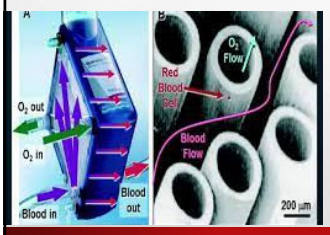
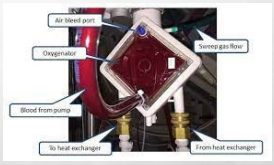
MEMBRANE LUNG/OXYGENATOR





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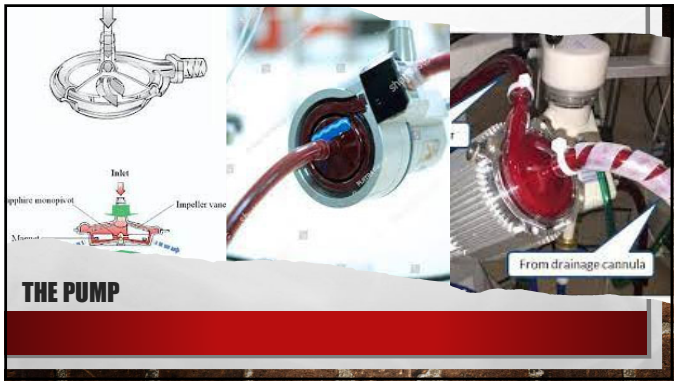

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Veno-arterial Extracorporeal membrane oxygenation

- VA-ECMO can support patients with cardiogenic shock that is refractory to maximal therapy.
- Bridge to further mechanical circulatory support, such as a ventricular assist device, or cardiac transplantation.
- VA-ECMO can also be a salvage treatment option in the setting of cardiac arrest with successful advanced life support. (eCPR)
- Acute severe heart or lung failure with high mortality risk despite optimal conventional therapy
  - Consider if mortality >50%
  - Indicated if mortality >80%

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Indications for cardiac VA-ECMO

- Acute myocardial infraction
- Fulminant myocarditis
- Acute exacerbations of chronic heart failure
- Cardiac failure due to intractable arrhythmias
- Post cardiotomy cardiac failure
- Primary graft failure following cardiac transplantation
- Acute heart failure secondary to drug toxicity
- Post cardiac arrest

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Veno-venous extracorporeal membrane oxygenation

- Support with VV-ECMO is indicated for patients with acute respiratory failure with refractory hypoxemia or hypercapnia despite optimal ventilation.
- Instituted in patients presumed to have a reversible cause for their respiratory failure.
- VV-ECMO allows to decrease the ventilatory insult caused by mechanical ventilation.
- In the setting of isolated respiratory failure VV-ECMO is preferred since lung perfusion maintains endocrine pulmonary function. VV-ECMO is simpler to use and has a lower rate of complications than VA-ECMO.

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Indications for cardiac VV-ECMO

- Reversible causes of acute respiratory failure
- Acute respiratory distress syndrome associated with viral or bacterial pneumonia.
- Graft dysfunction following lung transplantation
- Trauma with excessive pulmonary contusion
- Pulmonary embolism
- Inability to provide adequate gas exchange without risk of ventilatory injury
- Pulmonary hemorrhage
- Severe bronchospasm.

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Contraindications for ECMO therapy

- ECMO IS AN ADVANCED FOR OF LIFE SUPPORT WITH SIGNIFICANT INHERENT RISK AND THE DECISION TO COMMENCE THERAPY SHOULD NOT BE TAKEN LIGHTLY.
- A MULTIDISCIPLINARY TEAM SHOULD ALWAYS BE INVOLVED.
  - CARDIOLOGY
  - PULMONOLOGY
  - CARDIOTHORACIC SURGEONS
  - INTENSIVISTS
- THE USE OF ECMO IS CONTRAINDICATED IN PATIENTS WITH NON RECOVERABLE CARDIAC OR RESPIRATORY FAILURE WHO ARE NOT CANDIDATES FOR TRANSPLANTATION OR PERMANENT MECHANICAL SUPPORT.
- ECMO CAN BE USED AS A "BRIDGE TO DECISION" AND AS A "BRIDGE TO CANDIDACY" IF ITS BELIEVED THAT THE PATIENT MAY BECOME A CANDIDATE FOR TRANSPLANTATION.

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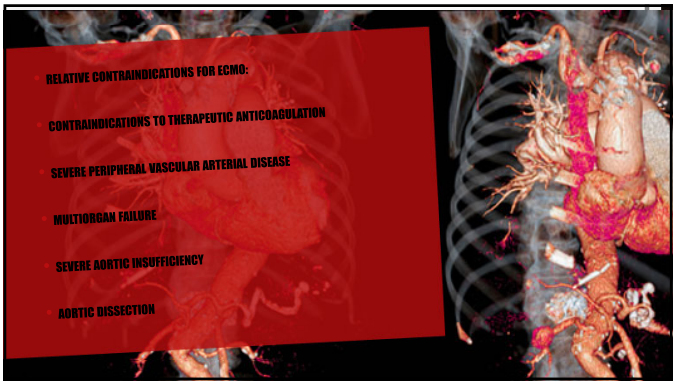

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SITUATIONS IN WHICH ECMO IS UNLIKELY TO BE SUCCESSFUL

Wrong choice of ECMO configuration
Chronic respiratory or cardiac disease with no hope of recovery or transplant
Out of Hospital cardiac arrest with prolonged low blood flow
Severe Aortic regurgitation or Type A aortic dissection if using VA ECMO
Refractory septic shock in adults with preserved left ventricular function
Advanced age in acute respiratory distress syndrome
Acute respiratory distress syndrome with advanced multiorgan failure

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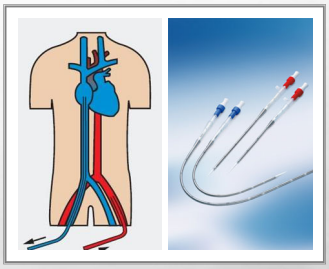
PERCUTANEOUS INSERTION

- PERCUTANEOUS PLACEMENT
  - VENOUS CANNULA (DRAINS DEOXYGENATED BLOOD)
  - ARTERIAL CANNULA (RETURNS OXYGENATED BLOOD)
- FEMORAL VESSELS ARE MOST COMMON BECAUSE THEY ALLOW FOR EASIER ACCESS
- CAN BE INSERTED AT BEDSIDE AND DURING CPR.
- NO RADIOLOGIC ASSISTANCE REQUIRED



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PERCUTANEOUS INSERTION

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ECMO FOR CARDIAC ARREST

"eCPR"

First described in 1966- series 8 patients

Time-sensitive veno-arterial ECMO cannulation to perfuse body during refractory cardiac arrest

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ECPR, also known as venoarterial extracorporeal membrane oxygenation, may be considered as an alternative to conventional CPR for select patients with refractory cardiac arrest when the suspected etiology of the cardiac arrest is potentially reversible during a limited period of mechanical cardiorespiratory support.

ECPR

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ECPR

- OHCA OCCURS 434K ANNUALLY THE UNITED STATES
- SURVIVAL TO HOSPITAL DISCHARGE
  - OUT OF HOSPITAL (OHCA): 9%
  - IN-HOSPITAL (IHCA): 15-24%
  - BY INITIAL RHYTHM:
    - VT/VF: 12-37%
    - PEA/ASYSTOLE: 12%
- PROLONGED CR: DISMAL PROGNOSIS 4%

AMERICAN HEART ASSOCIATION

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ECPR

Conventional CPR provides only 30% typical cardiac output

- **Some studies as low as 5%!**
- **ECMO circuit 3-5 lpm flow of oxygenated blood**

Circuit provides access for large volume resuscitation

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Outcome predictors in cardiopulmonary resuscitation facilitated by extracorporeal membrane oxygenation

Clin Res Cardiol (2016) 105: 196–205

ECMO Cardio-Pulmonary Resuscitation (ECPR), trends in survival from an international multicentre cohort study over 12-years

Resuscitation 112 (2017) 34–40

Advanced reperfusion strategies for patients with out-of-hospital cardiac arrest and refractory ventricular fibrillation (ARREST): a phase 2, single centre, open-label, randomised controlled trial

Lancet 2020; 396: 1807–16

Hyperinvasive approach to out-of hospital cardiac arrest using mechanical chest compression device, prehospital intraarrest cooling, extracorporeal life support and early invasive assessment compared to standard of care. A randomized parallel groups comparative study proposal. "Prague OHCA study"

Bělohlávek et al. Journal of Translational Medicine 2012, 10:103

Extracorporeal life support in cardiovascular patients with observed refractory in-hospital cardiac arrest is associated with favourable short and long-term outcomes: A propensity-matched analysis

European Heart Journal: Acute Cardiovascular Care 2016 Vol 5(7) 13–22

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Contents lists available at ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

EUROPEAN RESUSCITATION COUNCIL

Clinical paper

ECMO Cardio-Pulmonary Resuscitation (ECPR), trends in survival from an international multicentre cohort study over 12-years

Alexander (Sacha) C. Richardson, Matthieu Schmidt, Michael Bailey, Vincent A. Pellegrino, Peter T. Rycus, David V. Pilcher

- **IHCA SURVIVAL 15–17%; OHCA SURVIVAL 8–10%**
- **RETROSPECTIVE STUDY USING ELSO REGISTRY FROM 2003-2014 FOR ADULT E-CPR**
- **1796 E-CPR EPISODES WITH MEAN AGE 50 +/- 18.5, 69% MALE**
- **520 (29%) SURVIVED TO DISCHARGE**

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TABLE 6. Cohort studies with propensity analyses reporting the outcomes of patients treated with extracorporeal membrane oxygenation (ECMO) for extracorporeal cardiopulmonary resuscitation (E-CPR)

Study (y)	Setting (duration)	E-CPR group (No. patients)	C-CPR group (No. patients)	Primary survival analysis: ECMO group (%)	Primary survival analysis: Control group (%)	P value
Chen and colleagues (2008)	In hospital (to discharge)	59	113	28.8	12.3	<.0001
Shin and colleagues (2011, 2013)	In hospital (to discharge)	85	321	34.1	12.1	<.001
Maekawa and colleagues (2013)	Out of hospital (to 3-mo)	53	109	28.3	4.6	<.0001
Kim and colleagues (2014)	Out of hospital (to 3-mo)	55	444	14.5	9.9	.346*

All studies performed propensity matching, but the number of patients and survival reported in the Table represent the entire cohort included in each study, before propensity matching. In all studies demonstrating a significant difference in survival at the primary end point favoring E-CPR in the raw analysis, superiority of E-CPR was maintained after propensity matching. *E-CPR*, Extracorporeal cardiopulmonary resuscitation; *C-CPR*, conventional cardiopulmonary resuscitation; *ECMO*, extracorporeal membrane oxygenation. *E-CPR demonstrated superior survival with desirable neurologic outcomes at 3 months following cardiac arrest after propensity matching (E-CPR, 15.4% vs C-CPR, 1.9%; $P = .03$).

J THORAC CARDIOVASC SURG. 2016 JUL;152(1):20-32

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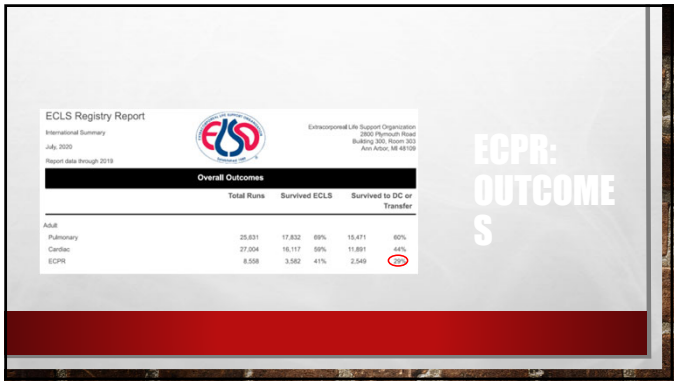

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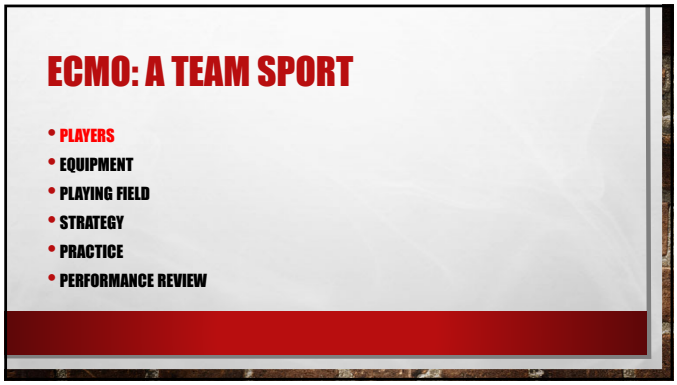

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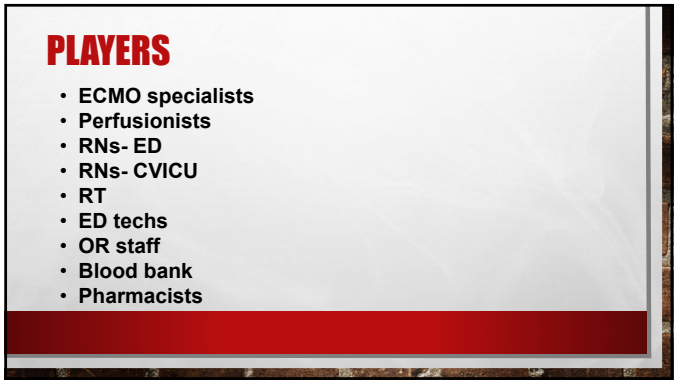

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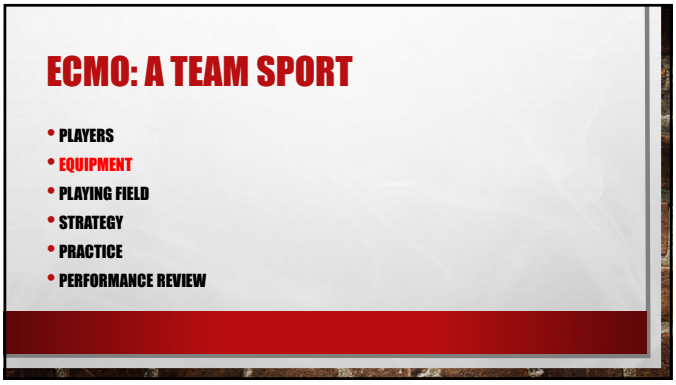

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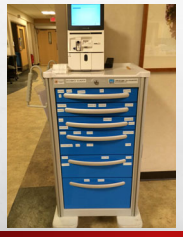

ECMO EQUIPMENT

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ECMO: A TEAM SPORT

- PLAYERS
- EQUIPMENT
- PLAYING FIELD
- STRATEGY
- PRACTICE
- PERFORMANCE REVIEW

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ECMO: PLAYING FIELD

- ED
  - TRAUMA BAY
- ICU
- OR
- WARDS

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ECMO: A TEAM SPORT

- PLAYERS
- EQUIPMENT
- PLAYING FIELD
- STRATEGY
- PRACTICE
- PERFORMANCE REVIEW

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ECMO STRATEGY

- REVERSIBLE UNDERLYING CAUSE OF ARREST
- RECOVERABLE ORGAN FUNCTION
- NO IRREVERSIBLE SEQUELAE
- NOT BLEEDING
- NOT SEPTIC

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ECMO: A TEAM SPORT

- PLAYERS
- EQUIPMENT
- PLAYING FIELD
- STRATEGY
- PRACTICE
- PERFORMANCE REVIEW

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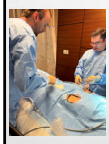
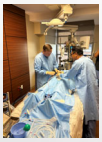
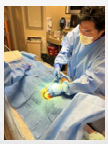
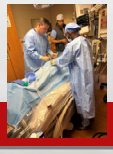
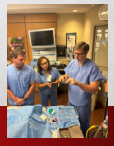
ECMO: Practice

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ECMO PERFORMANCE REVIEW

- REVIEW EACH CASE
- STANDARDIZE DATA COLLECTION FOR CASES
- IDENTIFY AREAS FOR IMPROVEMENT
  - STRATEGIZE
  - STANDARDIZE
  - PRACTICE

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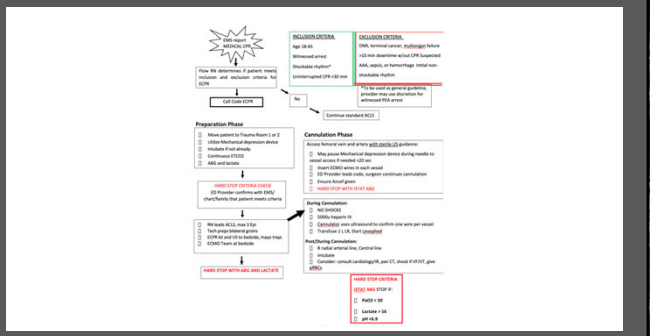

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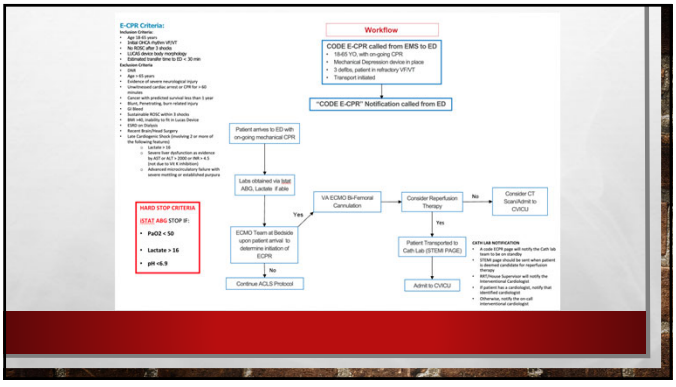

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