Cardiogenic Shock- New Cardiopulmonary Support Devices

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Objectives

- Why cardiogenic shock relevant?
- What is the pathophysiology?
- What is the history of mechanical circulatory support?
- What are the various types of ventricular assist devices (VADs)?
- How and when are VADs used?
- What is the next generation of VADs?
CVD deaths vs. cancer deaths by age (US)

Deaths in Thousands

Ages

CVD deaths vs. cancer deaths by age (US)

Deaths in Thousands

<45 45-54 55-64 65-74 75-84 85+ Total

CVD Cancer

25 21 48 50 81 101 120 138 242 165 85 315 831 560

Total

CVD Cancer

Graph showing the comparison of CVD (red) and cancer (blue) deaths by age group in the US.
CVD and other major causes of death for all males and females

A CVD
B Cancer
C Accidents
D Chronic Lower Respiratory Diseases
E Diabetes Mellitus
F Alzheimer’s Disease
Cardiac and systemic vascular function curves combined. Point A is the normal, stead-state operating point under these particular physiological conditions.

Changes in cardiac output (CO) and right atrial pressure (PRA) in response to cardiac failure and compensatory increases in blood volume (Vol) and systemic vascular resistance (SVR), and decreased venous compliance (Cv). A, normal operating point; B, decreased cardiac performance; C, compensatory increase in SVR coupled with increased Vol and reduced Cv.
Cardiogenic shock - Definition

- **Clinical Criteria**
  - Pale, cool, and clammy peripheries
  - Prolonged capillary refill times
  - Altered mental status/confusion
  - Oliguria/anuria
  - Pulmonary congestion
  - Tachycardia/recurrent tachyarrhythmia
Cardiogenic Shock - Definition

- Hemodynamic criteria
- Systolic blood pressure (SBP) < 80-90 mm Hg for greater than 30 minutes
- MAP < 65 mmHg or 30 mmHg below baseline for greater than 30 mins with inotropic and pressor support
- Use of 2 high dose inotropes and vasopressors to keep SBP greater than 90 mm Hg
- Dobutamine > 5 mcg/kg/min, Epinephrine > 10 mcg/min, Milrinone > 0.5 mcg/kg/min
- Levophed > 10 mcg/min & Vasopressin > 4 units/hr.
- Cardiac index of less than 2 L/min/m² with support
- PCWP > 18 mmHg
- Continued hemodynamic instability despite presence of IABP
Corraborating Lab Values

- Elevated/rising lactate (>5 mmol/L)
- Metabolic acidosis (pH <7.35)
- Mixed venous saturation of less than 55%
- Rising ALT/AST (>1000 IU/L)
- Creatinine X 2.0 times baseline
INDICATIONS

- Post cardiectomy shock with inability to wean from CPB
- Primary graft dysfunction after heart transplantation
- Myocarditis
- Decompensated heart failure as bridge to VAD or transplantation
- ACS with cardiogenic shock (Bridge to decision/Recovery)
- Selective cases of septic shock with overwhelming cardiac depression
- Cardiogenic shock of any etiology
- Adjunct to CPR
ABSOLUTE CONTRAINDICATIONS

- Severe neurological injury or ICH
- Unrepaired aortic dissection
- Severe aortic insufficiency
- Refusal by surrogate decision maker if there is no living will or advanced directives from patient
- Non-recoverable disease and patient not a candidate for advanced therapies
RELATIVE CONTRAINDICATIONS

1. Age > 70 years
2. Weight > 140 kg (300 lbs.)
3. Inability to anti coagulate or refractory bleeding
4. Jehovah’s witness or refusal to accept blood or blood product transfusion
5. Unwitnessed cardiac arrest or CPR for >60 minutes
6. Advanced multi-organ failure
**Cardiogenic Shock Definition**

**Hemodynamic Parameters**
- SBP < 90 mmHg or MAP < 70 for > 30 min
- PCWP > 18 mm Hg
- CI < 2.0
- Lactic/metabolic acidosis

**Clinical Parameters**
- Oliguria
- Pulmonary edema
- Mixed venous O2 Sat < 55%
- Cold extremities
- Tachycardia / recurrent tachyarrhythmia

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**MCS Decision Pathway for Cardiogenic Shock Post MI**

1. **Cardiogenic Shock Complicating MI**
   - **Cath Lab**
   - **Immediate Revascularization**

2. **Echocardiogram**

3. **IABP and MCS Contraindicated**
   - Yes
   - **Severe AR**
   - No
   - **Initiate IABP Support**
   - Place Swan Ganz Cath

4. **No Contraindications to MCS**

5. **Progressive Shock**
   - Optimal Fluids & Ventilation
   - High Inotropes* (See Table)

6. **Contact Transplant Surgical team**

7. **Initiate ECMO**

* 2 High Dose Inotropes and Vasopressors on IABP Needed to Keep SBP > 90
  - Dobutamine > 5 mcg/kg/min
  - Epinephrine > 10 mcg/min
  - Milrinone > 0.5 mcg/kg/min
  - Levophed > 10 mcg/kg/min
  - Vasopressin > 4 units/hr.
Postinfarction cardiogenic shock with multisystem organ failure and uncertain neurological status

Initiate ECMO

- End-organ recovery
  - Neurologically intact
  - Preserved LV function
    - Wean from ECMO
    - Explant Temporary MCS

- End-organ recovery
  - Neurologically intact
  - Poor LV contractility
    - Long-term LVAD

- No neurological recovery
  - End-organ dysfunction (hepatic failure)
    - (dialysis dependence)
    - Withdraw Support
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Historical Events

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Historical Events

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1967: Barnard performs first heart transplant

1968: Shumway performs first heart transplant in US

1969: Cooley implants VAD as bridge to transplant
Who’s First

LIFE A BITTER FEUD
Two great surgeons at war over the human heart

Dr. Denton Cooley
Dr. Michael DeBakey
Dr. De Bakey has called that first-ever use of a total artificial heart a *theft*, a *betrayal*, *unethical* and "a *childish act*" to claim a medical first.

"*I didn't steal* anything," Cooley recalled. "But he made it seem like that. He *organized* the whole sort of *attack* on me with the aid of his two sisters and his publicists."
Short term Device options

IABP

ECMO

Tandem Heart

AbioMed 5000

Centrimag

Impella

Bridge to recovery
Bridge to decision
Intraaortic Balloon Pump (IABP)

- Developed in late 1960s
- Counterpulsation is synchronized to the EKG or arterial waveforms
- Increase coronary perfusion
- Decrease left ventricular stroke work and myocardial oxygen requirements
- Most widely used form of mechanical circulatory support
- Indications for its use include
  - Failure to wean from cardiopulmonary bypass
  - Cardiogenic shock after MI
  - Heart failure
  - Refractory ventricular arrhythmias with ongoing ischemia
Impella

- Axial flow pumps
- Acute hemodynamic support
- Miniaturized impellar pump in catheter
- Helical catheter tip placed across aortic valve and left ventricle
- Percutaneous or direct placement
- Flow 2.0 to 4.5L/min
- Bridge to recovery
• Recover LD 5.0
• Recover LP 5.0
• 4.5 liters per minute at a speed of 33,000 rpm.
• The pump is located at the distal end of a 9 Fr catheter. At its largest outside diameter, which contains the pump housing, the Impella measures 21 Fr.
Impella RP is designed for short-term right ventricular support.

The device requires single vascular access through a sheath in the femoral vein.

It aspirates blood from the inferior vena cava and expels it into the pulmonary artery at the maximum rate of up to 4.4 liters per minute.
What is ECMO???

- Extra Corporeal Membrane Oxygenation
- This simply means oxygenating the blood outside of the body
  - First pump oxygenator used in 1953 was a system that used bubbles of oxygen
CARDIOHELP (VA ECMO)
Centrifugal pumps

- Acute hemodynamic support
- Continuous flow
- Extracorporeal
- LV, RV or biventricular support
- Wide availability
- Ease of use
- Relatively low cost
- Limited duration of support
- Bridge to recovery
- Bridge to decision

Oxygenator
V-A ECMO

Complication of Peripheral Cannulation in Larger patients (Y off Art Line w/ Sheath)

Hypoxic blood may be delivered to the brain and the heart (V-A-V)

Possible limb ischemia

Monitor pulse-ox in upper extremity
ECMO..How does it work?

- Oxygenation occurs through a semi-permeable membrane oxygenator
- This means the ECMO circuit is capable of gas-exchange functions
- The physiologic goal of ECMO is to improve oxygen delivery to the tissues
  - Also removes carbon dioxide
  - Allows normal aerobic metabolism to continue while the lungs “rest.”
Complications

- Bleeding (30% of all cases), (Thrombocytopenia)
- Oxygenator Failure (Transfuse PLTs POST O2er)...
- Tubing Rupture
- Runaway pump head
- Power failure
- Centrifugal pump decoupling
Complications Cont.

- Clots in the circuit
- Water to blood leak
- Gas supply failure
- Line separation
- Cannula dissection
- Air emboli
  1. Retrograde venous perfusion
  2. Hyperbaric chamber
  3. Pharmacological management
- Neurological injury
- Renal failure
Tandem hearts

- Acute hemodynamic support
- Centrifugal pump
- Percutaneous placement
- LV support via transseptal cannula
- Used in high risk cardiac catheterization procedures
- Risk of vascular injuries due to cannula size
Levitronix Centrimag

- Newer generation
- Centifugal pump
- Continuous flow
- Extracorporeal
- Impellar within the pump rotates in contact-free manner
- Increased durability
- Minimal thrombus formation and hemolysis of RBCs
Abiomed 5000

- Extracorporeal
- Pneumatic pulsatile pumps
- Uni- or biventricular support
- Bridge to transplant
- Easy to insert and operate so used in community hospitals
- Flows 6L/min

Heartmate II

- Axial flow
- LV support
- Flows 10L/min
- Long term durability
- Bridge to transplant
- Approved January 2010 for destination therapy
- Over 4000 devices implanted to date
Implantation of device