Short Term Mechanical Circulatory Support for Advanced Cardiogenic Shock

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Disclosures

• I have no disclosures to report

Objectives

1. Pathophysiology
2. Epidemiology
3. Assessment
4. Management
   1. Medical
   2. Mechanical
Heart Failure

- A condition in which there is insufficient cardiac output to meet the metabolic demands of the body.
- Can be caused by a variety of conditions that decrease the ability of the heart muscle to pump blood; either by damaging and/or overloading.

Heart Failure

- Estimated 5.7 million people in the United States have heart failure.
- Heart Failure expected to increase to > 8 million by 2030.
- Acute Coronary Syndrome affecting nearly 700,000 people annually.
- One of the most frequent causes of unscheduled hospital admissions.

Heart Failure

- Divided into multiple sub-categories
  - Left sided
  - Right sided
  - Bi-Ventricular
  - Systolic
  - Diastolic
  - Acute
  - Chronic
  - Acute on Chronic
Acute Heart Failure (AHF)

- Can occur with either impaired or preserved ejection fraction
- Heart failure is categorized as a heart disorder but can lead to a systemic disorder affecting all vital organs
- Mechanisms of dysfunction:
  - Congestion and hypo-perfusion

Management of AHF

- Needs to be efficient, rapid and organized
- Multidisciplinary Care:
  - Intensivists, Heart Failure Cardiologist, Interventional Cardiologist, Cardiac Surgeon, Advance practice provider, Nurse, Respiratory therapist
- Goals of care
  - Restoring Cardiac Output
  - Identifying and treating the etiology

Clinical Presentation of AHF

- Importance of physical exam
  - Jugular Vein Distension (JVD)
  - Hepatomegaly
  - Peripheral Edema
  - Tachypnea
  - Rales
  - Orthopnea
  - Gallops (S3)
  - Heart Murmurs
  - Tachycardia
  - Pulsus alternans
  - Cool Extremities
  - Restlessness and/or confusion
Diagnostic Evaluation

- Blood laboratory tests:
  - Brain natriuretic peptide (BNP)
  - Troponins
  - Renal Function
  - Liver Function
  - Lactic acid
  - Blood gas analysis

- Studies:
  - Electrocardiogram (ECG)
  - Echocardiogram
  - Chest X-rays
  - Early cardiac catheterization
    • If indicated

Hemodynamic Profile

Warm & Wet

- Diuretics
  - Loop Diuretics are typical first line
    • Furosemide bolus (0.5 mg/kg)
  - Thiazide Diuretics, combination therapy or 2nd line
    • Diuril 250 mg to 500mg IV bolus

- Vasodilators
  - Nitrates
    • Nitroglycerin (10-20 mcg/min, up to 200 mcg/min)
    • Nitroprusside (0.3 mcg/kg/min, up to 5 mcg/kg/min)
Warm & Wet

- **Oxygen**
  - Often needed secondary to hypoxia related to pulmonary edema
- **Use of Non Invasive Ventilation**
  - Pulmonary edema often times can rapidly progress
    - Due to flooding of the alveoli secondary to increase in hydrostatic capillary pressure with the lung
- **Morphine**
  - Opiate that can help with anxiety related to air hunger
  - Can lead to increased rates of intubation

Cold & Wet
Cardiogenic Shock

- Clinically presents as hypotension with evidence of organ hypo-perfusion
  - Altered Mental Status
  - Cold, clammy skin and/or extremities (mottling)
  - Oliguria (< 0.5 ml/kg/hr or < 30 ml/hr)
  - Respiratory distress in the form of pulmonary congestion

Cardiogenic Shock

- The most severe form of acute heart failure
- Commonly a direct sequela of acute coronary syndrome
  - Complicating ~ 5%-8% of acute myocardial infarctions
- Non-ischemic Etiologies less common (1%)
  - Acute on chronic decompensations
  - Myocarditis
  - Takotsubo cardiomyopathy
  - Acute valvular disease

Cardiogenic Shock

- Hemodynamically defined as:
  - Persistent hypotension with systolic blood pressure < 90 mmHg or mean arterial blood pressure 30 mmHg below baseline
  - Inadequate Cardiac Output/Cardiac Index (CI < 2.2L/min/m²) despite normal or elevated pre-load
    - Pulmonary capillary wedge pressure > or = to 18 mmHg
    - Central venous pressure > or = to 10 mmHg

Medical Management

- Goal is to restore Cardiac Output and reverse end-organ dysfunction
- Hemodynamic Evaluation
  - Echocardiograms
  - Arterial line
  - Lactic acid
  - Blood gases
  - Liver function
  - Renal function
  - Central Venous Access (SVC vs PAC)
  - $SvO_2$, CVP, PCWP, PVR, SVR, Stroke volume

Inotropes

- Intravenous medications used to improve cardiac contractility
- Use for the shortest duration and at the lowest dose to maintain perfusion
- Adverse Risks:
  - Increased risk of atrial and ventricular arrhythmias
  - Systemic Hypotension
  - Increased Myocardial Oxygen Demand
**Dobutamine**

- Synthetic catecholamine that stimulates Beta\textsubscript{1} receptors
- Does not increase blood pressure; can stimulate peripheral Beta\textsubscript{2} receptors that can lead to hypotension
- Frequently associated with:
  - Tachycardia
  - Arrhythmias: supraventricular and ventricular
  - Increased myocardial oxygen demand
- Dosing:
  - 2 to 20 mcg/kg/min
- Short half life

**Milrinone**

- Phosphodiesterase inhibitor
  - Increases cyclic AMP levels thus increasing intracellular calcium levels
  - Net result is increased inotropy
- Vasodilation of both pulmonary and systemic circulatory systems
  - Often require combination vasopressor support
- No significant chronotropic affects
  - Can lead to arrhythmias due to increase in myocardial oxygen demand
- Dose:
  - 0.125 to 0.75 mcg/kg/min
- Long half life (2-6 hours)
  - Renally cleared

**Epinephrine**

- Catecholamine: non specific agonist of all adrenergic receptors Beta\textsubscript{1,2,3}, Alpha\textsubscript{1,2} – dose dependent
- Frequently associated with:
  - Tachycardia
  - Hypertension
  - Arrhythmias: supraventricular and ventricular
  - Increased myocardial oxygen demand
- Dosing:
  - 0.02 to 0.2 mcg/kg/min
- Short half life
Vasopressors

• Intravenous medications used to improve blood pressure
• Use for the shortest duration and at the lowest dose to maintain perfusion
• Adverse Risks:
  – Decreased peripheral tissue perfusion
  – Decreased microcirculation
  – Lead to tissue necrosis

Norepinephrine

• Catecholamine: potent vasoconstrictor $\alpha_1$ – agonist
• Frequently associated with:
  – Bradycardia
  – Hypertension
  – Arrhythmias: supraventricular and ventricular
  – Limb Ischemia
• Dosing:
  – 0.02 to 0.2 mcg/kg/min (higher doses used in sepsis)
• Short half life

Dopamine

• Catecholamine: non specific agonist of all adrenergic receptors $\beta_{1,2,3}$, $\alpha_{1,2}$, Dopa – dose dependent
• Frequently associated with:
  – Tachycardia
  – Arrhythmias: supraventricular and ventricular
  – Increased myocardial oxygen demand
• Dosing:
  – 2 to 20 mcg/kg/min
• Short half life
Failure of Medical Management

- Persistent hypotension & hypo-perfusion despite use of 2 or more inotropic and/or vasopressor agents
- Rising lactic acid
- Evolving organ dysfunction

Short Term MCS Devices

1. Intra Aortic Balloon Pump (IABP)
2. Impella
3. Tandem Heart
4. Extra Corporeal Membrane Oxygenation (ECMO)

Short Term MCS

- Optimal timing / early initiation of mechanical support
- Optimal level of support to restore adequate perfusion of end organs
- Optimal prevention and management of potential device related complications
IABP

- Helium filled balloon
- Inflates during diastole / Deflates during Systole
- Volume shifting ~ 40ml per heart beat (inc. SV)
- Can increase Cardiac Output ~ 0.5 to 1L
- During Diastole
  - Increase Coronary Perfusion
  - Improved reperfusion after intervention
- During Systole
  - Hallmark is afterload reduction
    - Reduction in LV end-diastolic pressure
    - Reduction in pulmonary capillary wedge pressure
    - Decrease in LV wall stress and myocardial oxygen demand

IABP

- Percutaneously placed via the femoral artery or left axillary artery (7 to 8 French)
- Placed in the descending thoracic aorta
  - Can be placed at the bedside, cath lab or OR
  - Quick initiation

Complications

- Bleeding
- Hemolysis
- Risk of limb ischemia
- Vascular compromise (dissection)

Management

- Low complexity
  - Trigger / Timing is automatic (1:1,1:2,1:3)
- Anticoagulation
  - Heparin drip (PTT goal 40-50)
- Vascular checks
Tandem Heart

• A continuous flow centrifugal pump
• Can supply up to 4L/min cardiac output
• Percutaneously placed via the femoral vessels:
  – 21 Fr inflow cannula: left atrium via femoral vein and then trans-septal puncture
  – 15-17 Fr outflow in the femoral artery
• Placed in the cardiac cath lab
Tandem Heart

- Superior to the IABP in improving hemodynamic endpoints:
  - Greater increase in cardiac output/cardiac index
  - Greater increase in mean arterial pressure
  - Greater decrease in cardiac filling pressures
    - Reduced PCWP, CVP, PAP
  - Reduced cardiac workload and oxygen demand

Tandem Heart

- Complexity of insertion limits the use
- Complications
  - Vascular compromise
  - Malposition of cannula
    - Can cause intra cardiac shunt
  - Bleeding / Coagulopathies
    - Insertion site
    - GIB
  - Limb Ischemia
  - Infection
    - SIRS/Sepsis
  - Stroke

Management

- Higher level of training required
  - Nursing, advanced practice providers, physicians
- Anticoagulation
  - PTT 50-60
- Vascular checks
- Device placement
  - X-ray and Echocardiograms
Impella

- Continuous Axial Flow Pump
- Positioned across the aortic valve via access from the femoral artery
- Typically placed in the Cath Lab or OR
  - Fluoroscopy and Echocardiogram guided
  - Interventional Cardiology and/or Surgeon

Impella

- 3 Impella Devices:
  1. Impella 2.5
     - 13Fr cannula percutaneously placed
     - 12Fr micro-axial catheter pump
     - Can provide up to 2.5 LPM cardiac output
  2. Impella CP
     - Percutaneously placed
     - 14Fr micro-axial catheter pump
     - Can provide up to 4.0 LPM cardiac output
  3. Impella 5.0
     - 22 Fr cannula placed by cut down of the femoral artery
     - 21 Fr micro-axial catheter pump
     - Can provide up to 5.0 LPM cardiac output
     - Needs Surgical repair for removal
     - Can also be placed via axillary artery
Complications

- Bleeding
- Hemolysis
- Risk of limb ischemia
- Aortic Insufficiency

- Vascular compromise (dissection)
- Malposition

Management

- Anticoagulation
- Vascular checks
- Placement
  - Echocardiogram and x-ray
Extracorporeal membrane oxygenation (ECMO)

- A technique of providing cardiac and/or respiratory support to patients whose heart and lungs are unable to function appropriately.
- Works by removing blood from the body, artificially removing carbon dioxide, and re-oxygenating red blood cells prior to returning blood back to the body.
Basic Principles of ECMO

- **Support for the failing heart and/or lungs**
  - Must meet metabolic demands:
    - Cardiac output (VA)
    - Adequate oxygenation and CO2 regulation

- **Veno-arterial (VA)**
  - Bypasses/rests the heart & lungs
  - Drains blood from venous system, returns oxygenated blood to arterial circulation

- **Veno-venous (VV)**
  - Rests the lungs, relying on native cardiac circulation
  - Drains blood from venous system, returns oxygenated blood to venous system (right atrium)

Circuit

- **CentriMag**
  - Magnetically levitated, centrifugal pump
  - 2-10LPM
  - Oxygenator & Blood pump are separate

- **CardioHelp**
  - Centrifugal pump
  - 2-10LPM
  - Blood pump & oxygenator are 1 piece
ECMO
- Percutaneous placement by any trained provider in any location:
  - Intensivist, Cardiologist, Surgeon, Emergency Room
- Arterial Access: 15 to 19 Fr
- Venous Access: 21 to 27 Fr
- Limb Perfusion catheter: 5 to 7 Fr
- Typical Flow 4-6 LPM
- Provides both cardiac and pulmonary support to the patient
  - Can increase Afterload (No AI)
    - Leading to increased myocardial wall stress
  - Decreased LV Pre-load
  - Decreased PCWP
- Decreased myocardial oxygen demand

Management
- Bedside Nurse vs Perfusion
- Arterial blood returned in retrograde direction
  - 2 Perfusion circuits
    - Native vs ECMO
    - Harlequin Syndrome –> need to monitor oxygenation from right radial artery
- Anticoagulation
  - Heparin drip with PTT goal 50-60
  - Hemorrhage vs embolic events vs hemolysis
- Vascular Checks

Complications
- Bleeding
- Hemolysis
- Limb ischemia
- Vascular compromise (dissection)
- Thromboembolic events
- Aortic Insufficiency
Summary

- Cardiogenic Shock continues to carry a high in-hospital mortality rate, 40-50% despite advances in early revascularization
- Early identification and initiation of therapy is paramount in preventing development of multi-system organ dysfunction
- Hallmark therapies with inotropes/vasopressor and early revascularization have led to the reduction of mortality, but rates remain high
- Advances in mechanical circulatory support offer innovative ways to restore circulation and rest the heart but further research is needed


Thank You