BASIC HEMODYNAMICS
DISCLOSURES

• In order to complete this course you will be required to pass a test and complete a course evaluation. You must attend the whole session in order to receive credit and you must sign in.

• There are no conflicts of interest to disclose. We may mention names of commercial products; we have no vested interest in these companies.

• We are receiving no commercial support.
COURSE OBJECTIVES

• Identify non-invasive indicators of Hemodynamic status
• List three indications for invasive hemodynamic monitoring
• Describe the relationship among preload, afterload, contractility, compliance, and cardiac output
• Describe pharmacological strategies that manipulate heart rate, preload, contractility, and afterload to improve cardiac output
• Discuss the theory of counter pulsation and analyze associated waveforms
HEMODYNAMICS

- What are Hemodynamics?
- Are Hemodynamics use *just* in the Intensive Care Unit (ICU)?
- Invasive v. non-invasive Hemodynamics
INVASIVE HEMODYNAMIC MONITORING
NON-INVASIVE HEMODYNAMIC MONITORING

- Capillary Refill
- Skin Temperature/Color
- Pulse Rate and Quality
- Blood Pressure
- UOP
- Mentation
CAPILLARY REFILL

- < 3 sec

Blood returned to tissue

Pressure is applied to nail bed until it turns white
SKIN TEMPERATURE
PULSE RATE AND QUALITY
BLOOD PRESSURE
MEAN ARTERIAL PRESSURE (MAP)

- MAP = [(2 x diastolic)+systolic] / 3
- Diastole counts twice as much as systole because 2/3 of the cardiac cycle is spent in diastole.
- A MAP of about 60 is necessary to perfuse coronary arteries, brain, kidneys.
- Usual range: 70-110
MENTATION

"HEY! I THINK HE JUST MOVED! ADD ONE MORE!"
Utilization of Hemodynamics in Clinical Practice

Basic Hemodynamics

Figure 2: This is a typical waveform progression as the pulmonary artery catheter floats through the cardiac chambers. Monitoring these waveforms tells clinicians where in the heart the catheter is as it advances.
THE HEART IS A PUMP
CARDIAC OUTPUT

- The amount of blood ejected from the ventricle in one minute
- 4 – 8 liters per minute
CARDIAC INDEX

- Cardiac index is an adjusted cardiac output for the patient's body surface area.

- \( \frac{C.O.}{BSA} = CI \)

\[
\begin{align*}
6 / 2.5 &= 2.4 \\
6 / 3.347 &= 1.8
\end{align*}
\]
CARDIAC OUTPUT

• Cardiac Output = Heart Rate x Stroke Volume
C.O. = \( \text{HR} \times \text{SV} \)  

**HEART RATE**

- The number of heartbeats per unit of time usually expressed as beats per minute.
- Normal: 60 – 100 bpm
- Chronotropy
**CO** = **HR** × **SV**

**STROKE VOLUME**

- Ventricular Stroke Volume is the difference between the ventricular end-diastolic volume (EDV) and the end-systolic volume (ESV)
- 65 – 130 ml/beat
- Factors that affect SV
  - Preload
  - Afterload
  - Contractility
SV = PRELOAD, AFTERLOAD, CONTRACTILITY

- The *volume* of blood in the ventricle at the end of diastole (EDV).
CENTRAL VENOUS PRESSURE (CVP)

- Central venous pressure (CVP) describes the pressure of blood in the thoracic vena cava, near the right atrium of the heart.
- Normal Value: 2-6 mmHg
PULMONARY CAPILLARY WEDGE PRESSURE

- An indirect indication of left atrial pressure
- obtained by wedging a catheter into a small pulmonary artery tightly enough to block flow from behind and thus to sample the pressure beyond.
- 5 – 10 mmHg
PULMONARY ARTERY PRESSURE

- Pulmonary artery is always venous blood because it is leaving the right ventricle on its way to the lungs to receive oxygen
- PA: 25/10 mmHg
THE RULE!

PAD > PAWP > CVP

Normal Heart
SV = PRELOAD, **AFTERLOAD**, CONTRACTILITY

- **Afterload** is the pressure or **RESISTANCE** the ventricles must contract against or overcome to eject the blood or create **systole**.
- **Amount of pressure needed to open each semi-lunar valve.**
SYSTEMIC VASCULAR RESISTANCE (SVR)

- Systemic vascular resistance (SVR) refers to the resistance to blood flow offered by all of the systemic vasculature, excluding the pulmonary vasculature.
- \[ \text{SVR} = \frac{\text{MAP} - \text{CVP}}{\text{CO}} \]
- SVR: 900-1400 dynes/sec/cm$^5$
PULMONARY VASCULAR RESISTANCE (PVR)

- PVR is the resistance against which the right ventricle has to pump to eject its volume.
- The PVR is about 1/6th of the SVR or approx. 150 – 300 dynes/sec/cm$^5$
LETS MANIPULATE SVR AND PVR

SVR 800
200/100
125/60
125/10
200/10

SVR 2600

PVR 200

PVR 10
25/10
15/5
25/10
5/0
Myocardial contractility is the intrinsic ability of the heart to contract independent of preload and afterload.

- Ventricle size
- Myocardial Fiber
- Stretch/Shortening ability (Starling’s Law)
- Calcium availability
- Good indicator is the Ejection Fraction
- Normal: 60-75% of blood/heart beat
PULMONARY ARTERY CATHETER
PULMONARY ARTERY CATHETER

The purpose of this catheter is to:

- Indirectly measure the left ventricular end-diastolic pressure.
- Evaluate the hemodynamic treatments and measure the patient’s hemodynamic status
- Draw mixed venous blood samples
- Obtain central vascular pressures measurements

Measure cardiac output:

- There are certain indications for using a PA catheter.
- They are:
  - Conditions of shock such as septic and hypovolemic shock
  - Evaluation of fluid volume status
  - Evaluation of cardiac output in complex medical situations
  - Prophylactic insertion for high-risk surgeries
PULMONARY ARTERY CATHETER PORTS
THERMISTOR PORT

- Thermistor and connector port
- Wire within the lumen transmits blood temperature
- Core temperature is most accurate reflection of the body temperature
DISTAL PA PORT

- Distal port – opening is at the tip (end) of the catheter.
- PA port
- Lies directly in the pulmonary artery measures the pulmonary artery pressures (PAP), (PCWP) when balloon is inflated
- PA pressures should always be monitored continuously
- NEVER USE for medication infusion
- Usually color coded yellow
PROXIMAL PORT (CVP)

- Proximal Port – approximately 30 cm from tip of catheter
- Also known as CVP port (central venous pressure)
- Lies in the right atrium and measures CVP can be used for infusion
- Used for injecting cardiac output boluses
- Usually color coded blue
BALLOON PORT

- Located about < 1 cm from tip of the catheter when the balloon is inflated with approximately 0.8 to 1.5 cc of air
- Catheter will become lodged (wedged) in the pulmonary artery given a wedge tracing
- When deflated, turn stopcock to off position and leave syringe connect to port color coded red
“FLOATING A SWAN”
LEFT VENTRICULAR FAILURE

Pumping Efficiency
LV Volume & Pressure
Baroreceptors Activate
HR
Release of Catecholamines
Afterload (SVR)
O₂ Demand
Preload (LVEDP)

Vasoconstriction

Demand

Supply

MVO₂
Hypervolemia

Glomerular Filtration Pressure

Activation of Renin-Angiotensin-Aldosterone-ADH

Na\(^+\) & H\(_2\)O Reabsorption

Preload (LVEDP)

Afterload (SVR)

O\(_2\) Demand

C.O.

HR

O\(_2\) Supply

Pulmonary Artery Pressure

MVO\(_2\)