

## **Hemodynamic Monitoring**

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### **Objectives:**

- ▲ Describe both invasive and noninvasive methods for hemodynamic assessment.
- ▲ Describe measurement techniques and explain the implications for values of hemodynamic parameters.

## **Noninvasive Monitoring**

### **Rationale**

- ▲ Hemodynamic data are crucial in diagnosis and management of many critically ill patients
- ▲ Gold standard for monitoring involves invasive techniques with complications
- ▲ Noninvasive monitoring would avoid complications, while providing necessary data

### **Methods:**

- ▲ Impedance cardiography
- ▲ Echocardiography
- ▲ Partial CO<sub>2</sub> rebreathing

### **Impedance Cardiography**

- ▲ Description- translates electrical conductivity in the thorax into blood flow data
- ▲ Presently, not a viable alternative to invasive procedures

### Impedance Cardiography

#### ^ Data obtained

- ◆ Cardiac Output (CO)
- ◆ Stroke Volume (SV)
- ◆ Systemic Vascular Resistance (SVR)
- ◆ Acceleration Index (ACI) initial acceleration of blood flow in aorta
- ◆ Thoracic Fluid Content (TFC)

### Echocardiography- Types

- ◆ transesophageal echocardiography (TEE)
- ◆ stress echocardiography
- ◆ three-dimensional

Link to more information on echocardiography  
<http://www.echoincontext.com/basicEcho.asp>

### Echocardiography

#### ^ Data obtained

- ◆ cardiac chamber size,
- ◆ wall thickness & motion,
- ◆ valve configuration & motion
- ◆ proximal great vessels
- ◆ pericardial effusions
- ◆ neoplasms
- ◆ congenital defects
- ◆ estimates cardiac output

### Partial CO2 Rebreathing

#### ^ Description

- ◆ uses ratio of change in PetCO<sub>2</sub> and CO<sub>2</sub> excretion, in response to 50 sec rebreathing, to calculate pulmonary capillary blood flow.
- ◆ CO is estimated by adding a correction factor for shunt flow, based on SpO<sub>2</sub>.

### Partial CO2 Rebreathing

#### ^ Data obtained

- ◆ cardiac output- good correlation with thermodilution technique
- ◆ systemic vascular resistance
- ◆ pulmonary capillary blood flow
- ◆ EtCO<sub>2</sub>, VCO<sub>2</sub>
- ◆ Alveolar VE

^ Reliability of data affected by condition of lungs

### Partial CO2 Rebreathing

#### ^ Applications

- ◆ hemodynamic monitoring
- ◆ fluid management
- ◆ ventilator management
- ◆ ventilator weaning

# Invasive Monitoring

## Overview

^ Definition- invasive procedures to measure blood flow and pressures

^ Indications

- ◆ hypovolemia
- ◆ septic shock
- ◆ pulmonary edema
- ◆ pulmonary hypertension
- ◆ cardiac failure
- ◆ cardiovascular surgery
- ◆ multiple organ system failure

## Measured Parameters

- ^ systemic arterial pressures
- ^ central venous pressure
- ^ cardiac output
- ^ pulmonary arterial pressure
- ^ pulmonary arterial occlusion (wedge) pressure
- ^ systemic vascular resistance
- ^ pulmonary vascular resistance

## Arterial Lines

^ Purposes

- ◆ monitor arterial pressures
- ◆ obtain blood for gas analysis
- ◆ monitor arterial pressure
  - f* titration of vasoactive drugs
  - f* patients with extreme pressures

Link to information on arterial wave forms  
<http://hemodynamics.ucdavis.edu/mustafa/Pulse.htm>

## Normal Arterial Pressures

- ^ systolic = 120 mm Hg
- ^ diastolic = 80 mm Hg
- ^ pulse pressure = 40 mm Hg
- ^ mean pressure = 100 mm Hg

## Abnormal Arterial Pressures

- ^ decreased systolic
  - ◆ hypovolemia
  - ◆ cardiac failure
  - ◆ vasodilation
- ^ decreased diastolic- important, because coronary flow occurs on diastole

### **Abnormal Arterial Pressures**

- △ decreased pulse pressure
  - ◆ first sign of hypovolemia
  - ◆ cardiac tamponade
- △ mean pressure- important, because decreased values precede multiple organ system failure
  - ◆ used to titrate vasoactive agents
  - ◆ used to reflect myocardial work

### **Error Sources For Arterial Pressures**

- △ air in lines- decreased pressure
- △ loose connections- decreased pressure
- △ clotting- decrease or eliminate pressure

### **Complications of Arterial Lines**

- △ hemorrhage
- △ infection
- △ ischemia

### **Central Venous Line**

- △ Description- insertion of line into vena cava
- △ Purposes:
  - ◆ measure central venous pressure (CVP)
  - ◆ venous access for infusion, when peripheral lines cannot be inserted

### **Central Venous Line**

- △ Purposes:
  - ◆ administration of vasoactive/ inotropic drugs that cannot be given peripherally
  - ◆ administration of hypertonic solutions including total parenteral nutrition
  - ◆ hemodialysis/plasmapheresis

### **Central Venous Line Sites**

- △ femoral vein
- △ internal jugular vein
- △ subclavian vein
- △ peripherally-inserted central catheter (PICC)

### Central Venous Lines

- △ **Advantages (compared to peripheral sites):**
  - ◆ accommodate high flows
  - ◆ easier to place with hypotension
  - ◆ permit monitoring
- △ **Disadvantages**
  - ◆ more complications
  - ◆ must interrupt CPR to insert (except PICC)

### Central Venous Lines

- △ **Complications**
  - ◆ cannulation of artery
  - ◆ damage to thoracic duct, nerves
  - ◆ infusion of fluids into mediastinum
  - ◆ pneumothorax- internal jugular, subclavian veins
  - ◆ air embolus
  - ◆ infection

Link to more information on central venous access, monitoring  
[http://www.nda.ox.ac.uk/wfsa/html/u12/u1213\\_01.htm](http://www.nda.ox.ac.uk/wfsa/html/u12/u1213_01.htm)

### Central Venous Pressure

- △ **Normal <5 mm Hg**
- △ **Decreased by:**
  - ◆ hypovolemia
  - ◆ decreased intrathoracic pressure
  - ◆ increased cardiac output

### Central Venous Pressure

- △ **Increased by:**
  - ◆ right ventricular or bi-ventricular failure
  - ◆ hypervolemia
  - ◆ increased intrathoracic pressure; e.g., PEEP
  - ◆ pulmonary hypertension
  - ◆ pulmonary embolism
  - ◆ tamponade

### Pulmonary Artery Catheter

- △ **AKA, Swan-Ganz catheter- inserted through heart, into pulmonary artery**
- △ **Purposes:**
  - ◆ measure PA pressures
  - ◆ measure cardiac output
  - ◆ obtain mixed venous blood
  - ◆ monitor mixed venous saturation
  - ◆ provide atrial-ventricular pacing

Link to more information on pulmonary artery catheter  
<http://www.manbit.com/PAC/chapters/PAC.cfm>

### Pulmonary Artery Catheter

- △ **Insertion**
  - ◆ peripheral veins- less complication
  - ◆ jugular veins- right jugular is most direct
  - ◆ subclavian veins- less chance of carotid puncture

### Pulmonary Artery Catheter

#### ^ Insertion

- ◆ guidance for insertion
  - f* fluoroscopy
  - f* pressures/pressure waveforms
- ◆ catheter advanced to right atrium, then balloon is inflated
- ◆ balloon floats catheter through ventricle to pulmonary artery

### Pulmonary Artery Catheter

#### ^ Insertion

- ◆ if catheter advanced to 50 cm and pulmonary waveform is absent, assume it is curling in atrium or ventricle ==> deflate, withdraw to atrium & proceed again

### Pulmonary Artery Catheter

#### ^ Insertion- confirmed by:

- ◆ pressure wave form
- ◆ arterialized blood from wedge sample
- ◆ chest radiograph

### Pulmonary Artery Catheter

#### ^ Complications

- ◆ infection
- ◆ pneumothorax
- ◆ dysrhythmias
- ◆ air embolism
- ◆ perforation of vessels, heart

### Pulmonary Artery Catheter

#### ^ Complications

- ◆ infection
- ◆ pneumothorax
- ◆ dysrhythmias
- ◆ air embolism
- ◆ perforation of vessels, heart
- ◆ valve damage
- ◆ pulmonary thrombosis, embolus, infarction
- ◆ looping of catheter- surgery

### Pulmonary Artery Catheter

#### ^ Interpretation- PA pressures

- ◆ Normal = 22/8 (mean = 13)
- ◆ Decreased by:
  - f* RV failure
  - f* pulmonary vasodilation
  - f* hypovolemia

### Pulmonary Artery Catheter

- △ Interpretation- PA pressures
  - ◆ Increased by:
    - f* pulmonary embolism
    - f* pulmonary vasoconstriction- (PADP - PAOP) >5 ==> increased PVR
    - f* LV failure
    - f* congenital heart disease with left-to-right shunt

### Pulmonary Artery Catheter

- △ Interpretation- PAOP (wedge)
  - ◆ Intended to reflect LV preload
  - ◆ Created by inflating balloon in small branch of PA
  - ◆ Normal =
    - f* 4-12 mm Hg, or
    - f* 2 mm less than PADP

### Pulmonary Artery Catheter

- △ Interpretation- PAOP
  - ◆ Increased by:
    - f* LV failure (>18 mm Hg)
    - f* PAOP > 25 mm ==> pulmonary edema, depending on colloid osmotic pressure (COP)

### Pulmonary Artery Catheter

- △ Interpretation- PAOP
  - ◆ Increased in:
    - f* mitral valve stenosis, regurgitation
    - f* pulmonary venous constriction or obstruction
    - f* high levels of PEEP- do not remove from PEEP to measure PAOP

### Pulmonary Artery Catheter

- △ Interpretation- PAOP
  - ◆ Optimal PAOP- for maximal CO
    - f* 12- without PEEP
    - f* 18- with PEEP

### Invasive CO Measurement

- △ Methods
  - ◆ dye dilution
  - ◆ Fick method
  - ◆ intermittent thermodilution- solution injected for measurement
  - ◆ continuous thermodilution- solution automatically injected by system
  - ◆ continuous SvO<sub>2</sub> monitoring- depends on constant SaO<sub>2</sub>

### Cardiac Output Parameters

- ^ Normals
  - ◆ CO = 4-8 L/min
  - ◆ CI (CO/BSA) = 2.5-5.0 L/min/m<sup>2</sup>
  - ◆ SVR = 900-1400 dynes/sec/cm<sup>5</sup>
  - ◆ PVR = 110-250 dynes/sec/cm<sup>5</sup>
  - ◆ EF = 65-75%

### Components of Monitoring System

- ^ Catheter- patency maintained by heparinized solution under pressure
- ^ Transducer- translates pressure to electronic signal
- ^ Computer for CO
- ^ Monitor- to display data

### Technical Aspects Of Monitoring

- ^ Transducers
  - ◆ calibrated with Hg manometer
  - ◆ zeroed at level of atria
- ^ Monitor sensitivity calibrated each shift

### Technical Aspects Of Monitoring

- ^ Transducers
  - ◆ calibrated with Hg manometer
  - ◆ zeroed at level of atria
- ^ Monitor sensitivity calibrated
- ^ Tubing tested for dampening
- ^ circuit must be air-free
- ^ patency confirmed by visibility of wave fluctuations with ventilation

### Reference

- ^ Hamelin G. Hemodynamic monitoring. Chap. 6 in Chang DW, Elstun LR, Jones AP. The multiskilled respiratory therapist: A competency-based approach, 2000: FA Davis; Phila.

**END**