

Hemodynamic Monitoring

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<http://www.geocities.com/jonesapjr/index.html>

Learning Objective:

- ▲ Describe hemodynamic monitoring techniques and explain the implications of values for 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 CO₂ rebreathing

Impedance Cardiography

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

Impedance Cardiography**▲ Lead placement**

Click to see Cardiodynamics^(TM) lead placement and overview
<http://www.impedancecardiography.com/icgover10.html>

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)

FYI - Link to download a PowerPoint on impedance cardiography
<http://www.cdic.com/cdclin80.html>

Echocardiography- Types

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

FYI - 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

Echocardiography**▲ Data obtained**

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

Partial CO₂ Rebreathing**▲ Description**

- ◆ uses ratio of change in PetCO₂ and CO₂ 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 SpO₂.

Partial CO2 Rebreathing**^ Data obtained**

- ◆ cardiac output- good correlation with thermodilution technique
- ◆ systemic vascular resistance
- ◆ pulmonary capillary blood flow
- ◆ EtCO₂, VCO₂
- ◆ Alveolar VE

Partial CO2 Rebreathing**^ Applications**

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

Partial CO2 Rebreathing**^ Novamatrix NICO (TM) monitor**

Link to NICO respironics
<http://nico.respironics.com/>

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**

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

Click to see arterial pressure waveforms

http://www.bg.ic.ac.uk/Staff/khparker/homepage/Arterial_Waveforms_01.jpg

Click to see a different view of arterial pressure waveforms

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 arterial pressure (MAP)
 - ◆ 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- best to use artery with collateral flow

Central Venous Line

▲ **Description-** insertion of line that goes to 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 Line Sites

- ▲ **Subclavian vein**

Click to see line placement in subclavian vein
http://focosi.immunessig.org/invivo_surgical.html

Central Venous Line Sites

- ▲ **External jugular vein**

Click to see illustration of external jugular vein
http://uwmedicine.washington.edu/NR/rdonlyres/A63C48A2-F69B-4DEA-80EB-03A1E208EDE3/0/Hickman_catheter.jpg

Central Venous Line Sites

- ▲ **Peripherally inserted central catheter (PICC)**

Click to see illustration of PICC line in place
http://www.cancerhelp.org.uk/cancer_images/picc.gif

Central Venous Lines

- △ Advantages (compared to peripheral sites):
 - ◆ accommodate high flows
 - ◆ easier to place with hypotension
 - ◆ permit monitoring

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

FYI - Link to central venous access, monitoring
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

Pulmonary Artery Catheter

Click to see different types of PACs
<http://www.edwards.com/products/pacatheters/>

Pulmonary Artery Catheter

Click for information and images of PAC components
<http://www.rnceus.com/hemo/pacath.htm>

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
 - ▶ fluoroscopy- in catheterization lab
 - ▶ 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**

Click to see illustration of PA catheter in place
<http://cvphysiology.com/Heart%20Failure/HF008%20pulmonary%20capillary%20wedge%20pressure.g>

Pulmonary Artery Catheter

- ▲ Insertion- confirmed by:
- ◆ pressure wave form
 - ◆ arterialized blood from wedge sample
 - ◆ chest radiograph

Click to see pressure waveforms for PA catheter
<http://www.frca.co.uk/images/pac1.jpg>

Pulmonary Artery Catheter

- ▲ Insertion- confirmed by:
- ◆ chest radiograph

Click to see x-rays of PA catheter placement correctly and distally
 Click on 'lines and tubes;' then, 'Swan-Ganz catheter;' then, 'next'
<http://www.med-ed.virginia.edu/courses/rad/chest/index.html>

Pulmonary Artery Catheter

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

Pulmonary Artery Catheter

- ▲ Complications
- ◆ valve damage
 - ◆ pulmonary thrombosis, embolus, infarction
 - ◆ looping, knotting of catheter

Click for article with x-ray of knotted PA catheter
<http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1768215>

Pulmonary Artery Catheter

- ▲ Interpretation- PA pressures
- ◆ Normal = 22/8 (mean = 13)
 - ◆ Decreased by:
 - ▶ RV failure
 - ▶ pulmonary vasodilation
 - ▶ hypovolemia

Pulmonary Artery Catheter

- ▲ Interpretation- PA pressures
- ◆ Increased by:
 - ▶ pulmonary embolism
 - ▶ pulmonary vasoconstriction- (PADP - PAOP) >5 ==> increased PVR
 - ▶ LV failure
 - ▶ 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 =
 - ▶ 4-12 mm Hg, or
 - ▶ 2 mm less than PADP

Pulmonary Artery Catheter

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

Pulmonary Artery Catheter

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

Pulmonary Artery Catheter

- △ Interpretation- PAOP
 - ◆ Optimal PAOP- for maximal CO
 - ▶ 12- without PEEP
 - ▶ 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 SvO₂ monitoring- depends on constant SaO₂

Cardiac Output Parameters

- △ Normals
 - ◆ CO = 4-8 L/min
 - ◆ CI (CO/BSA) = 2.5-5.0 L/min/m²
 - ◆ SVR = 900-1400 dynes/sec/cm⁵
 - ◆ PVR = 110-250 dynes/sec/cm⁵
 - ◆ 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 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

Summary & Review

- ▲ Noninvasive monitoring
 - ◆ purposes
 - ◆ parameters
 - ◆ types:
 - ▶ impedance cardiography
 - ▶ echocardiography
 - ▶ partial rebreathing ETCO₂

Summary & Review

- ▲ Invasive monitoring
 - ◆ purposes
 - ◆ parameters- values, significance
 - ◆ complications
 - ◆ types:
 - ▶ arterial pressure
 - ▶ central venous
 - ▶ pulmonary artery catheter
 - ▶ cardiac output

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