Hemodynamic Monitoring

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

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_2 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

Link to Cardiodynamics 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)

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

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

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

- Novametrix NICO (TM) monitor

Link to NICO respironics

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 view 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 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.immunesig.org/invivo_surgical.html

Central Venous Line Sites

- External jugular vein

Link to illustration of external jugular vein
http://focosi.immunesig.org/face_tx2.gif

Central Venous Line Sites

- Peripherally inserted central catheter (PICC)

Link to 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

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

Link to images of different types of PACs
http://www.edwards.com/products/pacatheters/

Pulmonary Artery Catheter

Link to components of PACs
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

Link to 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

Link to pressure waveforms for PA catheter
http://www.frca.co.uk/images/pac1.jpg

Pulmonary Artery Catheter

- Insertion- confirmed by:
  - chest radiograph

Link to radiographs of PA catheter placement correctly and distally
Click on to 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

Link to image 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 heparanized 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

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.