Hemodynamic Monitoring

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This Presentation is Approved for
1 CRCE Credit Hour

Learning Objectives

- Explain the rationale for selection of noninvasive hemodynamic monitoring techniques
- Explain the theory and application of the following noninvasive monitoring techniques
  - Impedance cardiography
  - Echocardiography
  - Partial CO_2 rebreathing
- Interpret data gathered by noninvasive monitoring techniques

Learning Objectives

- Explain the rationale for selection of invasive hemodynamic monitoring techniques
- Explain the theory and application of the following invasive hemodynamic monitoring techniques
  - Systemic arterial pressures
  - Central venous pressures
  - Pulmonary arterial pressures
  - Cardiac output
- Interpret data gathered by invasive monitoring techniques

Learning Objectives

- Diagnose complications of invasive monitoring techniques
- Explain the management of complications of invasive monitoring techniques

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

See link below to view impedance cardiography (ICG) lead placement and overview

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 see link below to view or download a PowerPoint presentation on impedance cardiography

Echocardiography - Types

- Transesophageal echocardiography (TEE)
- Stress echocardiography
- Three-dimensional

See link below for more information on echocardiography

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 CO_2 Rebreathing

- Description
  - Uses ratio of change in $PetCO_2$ and CO_2 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_2

Partial CO_2 Rebreathing

- Data obtained
  - Cardiac output – good correlation with thermodilution technique
  - Systemic vascular resistance
  - Pulmonary capillary blood flow
  - $EtCO_2$, VCO_2
  - Alveolar VE

Partial CO_2 Rebreathing

- Applications
  - Hemodynamic monitoring
  - Fluid management
  - Ventilator management
  - Ventilator weaning

Partial CO_2 Rebreathing

- Novametrix NICO™ monitor

See link below to view NICO Respironics

Invasive Monitoring

Overview

- Definition: invasive procedures to measure blood flow and pressures
- Indication
  - 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 gas analysis
  - Monitor arterial pressure
    - Titration of vasoactive drugs
    - Patients with extreme pressures

See link below to view arterial pressure waveform

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

FYI see link below for video of subclavian line placement (3) (requires sign-in for age verification)

Central Venous Line Sites

- External jugular vein

See link below to view illustration of external jugular vein
FYI see link below to view video of
external jugular vein cannulation (13 min)

Central Venous Line Sites

- Peripherally inserted central catheter (PICC)

See link below to view illustration of PICC line in place

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 see link below for article about central venous monitoring

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
  - Obtained mixed venous blood
  - Monitor mixed venous saturation
  - Provide atrial-ventricular pacing

Pulmonary Artery Catheter

See link below for images of different types of PACS

Pulmonary Artery Catheter

See link below for components of PACS

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 and proceed again

Pulmonary Artery Catheter

- Insertion

See link below for an illustration of PA catheter in place

Pulmonary Artery Catheter

- Insertion – confirmed by
  - Pressure wave form
  - Arterialized blood from wedge sample
  - Chest radiograph

See link below for pressure waveforms for PA catheter

Pulmonary Artery Catheter

- Insertion – confirmed by
  - Chest radiograph

See links below to view X-ray of PA catheter placed correctly and an X-ray of PA catheter placed distally

Pulmonary Artery Catheter

- Complications
  - Infection
  - Pneumothorax
  - Dysrhythmias
  - Air embolism
  - Perforation of vessels, heart

Pulmonary Artery Catheter

- Complications
  - Valve damage
  - Pulmonary thombosis, embolus, infarction
  - Looping, knotting of catheter

See link below for an article with X-ray of knotted PA catheter (click on thumbnails)

Pulmonary Artery Catheter

- Interpretation – PA pressures
  - Normal = 22/8 (mean = 13)
  - Decreased by
    - RV failure
    - Pulmonary vasodilation
    - Hypovolemia

Pulmonary Artery Catheter

- Interpretation – PA presssures
  - 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 SvO_2 monitoring – depends on constant SaO_2

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

Summary & Review

- Noninvasive Monitoring
  - Purposes
  - Parameters
  - Types
    - Impedance cardiography
    - Echocardiography
    - Partial rebreathing $ETCO_2$

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.