Critical Care in Obstetrics:
An Innovative and Integrated Model for Learning the Essentials
Hemodynamic Monitoring and Mechanical Ventilation

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Outline

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- Hemodynamic Monitoring
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  - Types
- Mechanical Ventilation
  - Background & Definitions
  - Indications
  - Means & Modes
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- Summary
- Evidence
Learning Objectives

- Identify methods of noninvasive and invasive hemodynamic monitoring
- Recognize indications for mechanical ventilation
- Identify different modes of mechanical ventilation
- Identify ventilator goals for a gravid patient
Hemodynamic Monitoring

- Intermittent or continuous observation of normal or altered physiologic parameters pertaining to the circulatory system
- Goal is early detection of need for therapeutic intervention
- Use of a particular type of monitoring dictated by the patient type, technical expertise, cost effectiveness, individual preference
Hemodynamic Monitoring

- Primary objective
  - Optimal tissue perfusion, oxygen delivery while maintaining mean arterial pressure (MAP)
- Routinely available monitors unable to assess tissue hypoxia
- Extrapolation from globally measured variables that provide likelihood estimate of underlying disturbance
- Aids in directing therapeutic decisions
Hemodynamic Monitoring: Types
Types of Monitoring

- Noninvasive
  - Minimally Invasive
- Invasive
Noninvasive Monitoring

- Intermittent sphygmomanometry
  - Inaccurate with inappropriate cuff size or with proximal occlusions
  - Hemodynamic instability, shock
  - Malignant hypertension
  - Oxygenation failure

- Suprasternal aortic Doppler velocimetry
  - CO measurement
Noninvasive Monitoring

- Doppler velocimetry using ultrasound of aortic blood flow
  - Transthoracic (TT) or transesophageal (TE) echocardiogram
    - Cardiac output (CO) values, contractility, filling status, structural assessment
    - Useful, validated in pregnancy

- TE Doppler velocimetry
  - Changes in stroke volume (SV), calculated CO
    - $CO = SV \times HR$
  - SV changes in fluid therapy
“Minimally Invasive”

- May involve arterial, venous catheter placement
- Pulse contour waveform analysis
  - 4 commercially available systems
  - SV, CO calculated from arterial pressure waveform with known arterial compliance and systemic vascular resistance (SVR)
- Provide beat-to-beat continuous real-time data
- Well-studied, validated in non-pregnant
- Studied in PEC and cesarean section
Invasive Monitoring

- Arterial
  - Radial, femoral sites
- Accurate pressure information, facilitates blood sampling
- Caution in elderly, hypotensive, underlying vascular disease
- Local infection, hemorrhage, thrombosis
- Allen test
Invasive Monitoring

- Central Venous Pressure (CVP)
  - Intravascular pressure in the great veins relative to atmospheric pressure
  - Measured at junction of SVC and RA
  - Volume status, preload
  - Influenced by central blood volume and compliance
  - Infusion of medications, nutrition, volume
Invasive Monitoring

- Pulmonary Artery Catheter (PAC)
  - Preload, contractility, afterload, mixed venous oxygen saturation
    - Oxygen supply and demand
  - Studies show no survival benefit or harm with use of PAC
- Risks
  - Arrhythmia, compete heart block
  - Catheter malposition, knotting
  - Pulmonary infarction, PA rupture
### Pulmonary Artery Catheter

#### Direct Data
- CO
- Mixed venous $O_2$ saturation
- Vascular pressures
  - Right atrium
  - Right ventricle
  - Pulmonary artery
  - Balloon occlusion (wedge)

#### Derived Data
- Vascular resistance
  - Pulmonary
  - Systemic
- Stroke-work index
- Arteriovenous $O_2$ content difference
Mechanical Ventilation: Background & Definitions
Key Points: Gravid Patient

- Respiratory changes in pregnancy
  - 20% increase in $O_2$ consumption
  - 15% increase in metabolic rate
  - $V_E$ increases, RR stable
  - VT increase by 40% over baseline
  - ABG: respiratory alkalosis compensated by metabolic acidosis
    - Stable pH
    - $PaCO2$: 28 to 32 mmHg
Key Points: Gravid Patient

- Functional residual capacity (FRC), residual volume, and total lung volume decrease
- Respiratory distress occurs more rapidly
Helpful Definitions

- **Minute Ventilation** \( (V_E) \)
  - Amount of gas that moves in or out of lung in one minute
  - \( V_T \times \text{rate} = V_E \)

- **Tidal Volume** \( (V_T) \)
  - Amount of gas that moves in or out of lung in one breath
Peak Inspiratory Pressure (PIP)

- Highest pressure in the lung during a ventilator breath

Volume ventilation: PIP changes with lung mechanics (compliance, resistance) and ventilator settings

Pressure ventilation: PIP determined by set pressure on ventilator
Helpful Definitions

- Plateau Pressure
  - Pressure obtained during inspiratory breath-hold
  - Represents pressure transmitted to alveoli during mechanical ventilation, stiffness of lung
Helpful Definitions

- Noninvasive positive-pressure ventilation (NIPPV)
- Bilevel PPV via facemask
  - Better tolerated, less sedation
  - May be associated with lower rates of ventilator-associated pneumonia (VAP)
- Improves oxygenation
  - Increase mean airway pressure, improves alveoli recruitment, reduces work of breathing (WOB)
- Improves ventilation
  - Higher effective $V_T$, improved $V_E$, reduces WOB
Mechanical Ventilation: Indications
Mechanical Ventilation

- Provides pressure and flow to airways to effect oxygen (O$_2$) and carbon dioxide (CO$_2$) transport between the environment and pulmonary capillary bed

- Indicated with inability to maintain airway or adequate oxygenation or ventilation
  - Respiratory rate (RR) > 30/min
  - Inability to maintain arterial O$_2$ saturation > 90% with FIO2 > 0.60
  - PCO2 > 50 mmHg with pH < 7.25
Noninvasive Methods

- **Indications**
  - Hypoxemic respiratory failure due to congestive heart failure
  - Hypercapnic failure due to exacerbations of chronic obstructive pulmonary disease
  - Varied results in other conditions

- **Criteria**
  - Awake, alert, able to tolerate therapy
  - Set defined treatment goals
Noninvasive Therapy

- Contraindications
  - Mental status changes caused by brain injury, stroke, seizure
  - Active hemorrhage
  - Hemodynamic instability
  - Active cardiac ischemia
  - Active GI issues that may lead to aspiration
  - Facial trauma
  - Respiratory secretions
  - Acute organ failure in 2 or more systems
Invasive

- Intubation in respiratory failure refractory to NIPPV or with contraindications

- Risks
  - Ventilator-induced lung injury, long-term parenchymal fibrosis
  - VAP rates increase with duration
  - Need for sedation
    - Anxiety, agitation, delirium
  - Cardiovascular effects
    - Reduced preload, reduced afterload, increased SV, increased pulmonary artery pressures
Mechanical Ventilation: Means & Modes
Means and Modes

- Volume-cycled ventilation
  - Ventilator delivers set $V_T$
  - Resultant airway pressure not fixed, varies with resistance and elastance of the respiratory system and with the selected flow rate
- Assist-control (A/C) mode
  - Patient initiates supported breath
  - If patient does not trigger breath, ventilator initiates breath
  - Minimum respiratory rate (RR) ensured
Volume-cycled ventilation

- Assist-control (A/C) mode
- Synchronized intermittent mandatory ventilation (SIMV)
- Delivers breaths at set rate and volume synchronized to patient’s effort
- Patient efforts above set RR are unassisted
- Does not provide full support nor assist in ventilator liberation
Means and Modes

- Pressure-cycled ventilation
  - Ventilator delivers set inspiratory pressure
  - $V_T$ varies depending on resistance and elastance of respiratory system
  - Changes in respiratory system mechanics can yield unrecognized changes in $V_E$
  - Limits distending pressure of lungs
- Pressure control ventilation (PCV)
- Pressure support ventilation (PSV)
Means and Modes

- **Pressure control ventilation (PCV)**
  - Similar to A/C
  - Each respiratory effort beyond set sensitivity threshold delivers full pressure support maintained for fixed inspiratory time
  - Minimum RR achieved

- **Pressure support ventilation (PSV)**
  - No minimum rate set, all breaths triggered by patient
  - Pressure cut off when flow drops below certain point
  - Longer/ deeper inspiratory effort yields larger $V_T$
Means and Modes

- Airway Pressure Release Ventilation (APRV)
  - Allows for increase in mean airway pressure without significantly increasing peak airway pressure
  - Improves alveolar recruitment, limits volutrauma and barotrauma
  - Patients spontaneously breathe
  - Less sedation and paralytics
  - Spontaneous breathing improves venous return and augments cardiac function
Mechanical Ventilation: Goals & Other Considerations
Goals

- Ventilator Settings
  - $V_E$ adjusted to maintain $\text{PaCO}_2$ 30 to 32 mmHg
  - pH 7.40 to 7.47
  - $\text{PaCO}_2 < 30$ mmHg may decrease uterine blood flow due to significant respiratory alkalosis
Other Considerations

- Gravid Patient
  - Permissive hypercapnia
    - Does not appear to adversely affect fetus (CO\textsubscript{2} level 60 mmHg)
  - Positive End-Expiratory Pressure (PEEP)
    - Added to mitigate end-expiratory alveolar collapse, usually 5 cm H\textsubscript{2}O
    - Higher levels may be required in third-trimester
Other Considerations

- Most medications for analgesia, sedation, paralysis reach fetal circulation
- Analgesia
  - Opioids acceptable, avoid NSAIDs
Other Considerations

- **Sedation**
  - Limited data on benzodiazepines versus other anxiolytics
  - Midazolam theoretically superior
- **Limited data on propofol**
  - Associated with neonatal respiratory depression
- **Unknown safety of dexmedetomidine**
Other Considerations

- Neuromuscular Blockade
- Should be avoided
- If necessary
  - Cisatracurium (Category B)
  - Vecuronium, pancuronium (Category C)
- Also consider metabolism
Summary
Summary

- Invasive hemodynamic monitoring has become less clinically indicated
- Echocardiography provides vital data that complements other monitoring modalities
- Acute respiratory failure requiring endotracheal intubation is notable for:
  - respiratory rate (RR) > 30/min
  - inability to maintain arterial $O_2$ saturation > 90%
    with $FIO_2 > 0.60$ (Pa$O_2 < 55$ mmHg)
  - Pa$CO_2 > 50$ mmHg with pH < 7.25
Multiple modes of ventilation may be used in pregnancy.

Ventilator goals for the gravid patient:

- $V_E$ adjusted to maintain $\text{PaCO}_2$ 30 to 32 mmHg
- $\text{pH}$ 7.40 to 7.47
Evidence
Echocardiogram use in hemodynamic monitoring- **Level I** (nonpregnant), **Level II-2** (pregnant)


Evidence

Pulse waveform analysis in pregnancy- Level II-1

- Pauca AL. Pressure wave analysis is useful to understand the pathophysiology of preeclampsia, but perhaps not the rapid changes during cesarean delivery. Anes 2008;108:773-774.


Utility of PAC- Level I.


Noninvasive positive pressure ventilation- Level I.

Evidence

- **APRV- Level I (nonpregnant), Level III (pregnant)**

- **Ventilator settings in pregnancy- Level III**
Permissive hypercapnia- **Level III**


**Sedatives, analgesics in pregnancy- **Level III**

Thank You for Your Attention!

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