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

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I have no conflicts of interest to disclose
Learning objectives

Hemodynamic Monitoring
  - Background
  - Types

Mechanical Ventilation
  - Background & Definitions
  - Indications
  - Means & Modes
  - Goals & Other Considerations

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: Background
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
  - 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
  - Limitations

- 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
    - \( \text{CO} = \text{SV} \times \text{HR} \)
  - SV changes in fluid therapy
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
  - Multiple possible sites
  - Accurate pressure information, facilitates blood sampling
  - Local infection, hemorrhage, thrombosis
  - Allen test
Central Venous Pressure (CVP)

- Intravascular pressure in the great veins relative to atmospheric pressure
- Influenced by central blood volume and compliance
- Infusion of medications, nutrition, volume
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
Case Scenario
30yo G1 P0 admitted to ICU in septic shock. Which types of vascular access would be appropriate initially? What is the utility of each?

- Peripheral IV (PIV)
- Arterial line (A-line)
- Hemodialysis catheter (HD)
- Central venous catheter (CVC)
- Pulmonary artery catheter (PAC)
Hemodynamic Monitoring

- PIV
  - Medications, hydration
  - Few contraindications

- A-line
  - Continuous access to arterial blood
  - Continuous BP measurement
Hemodynamic Monitoring

- HD
  - Large-bore, double lumen venous access

- CVC
  - Types
  - Medications
  - Monitoring
  - Plasmapheresis, hemodialysis, CRRT
  - Poor venous access
  - Device placement
Hemodynamic Monitoring

- PAC
  - Few true indications
  - No survival benefit
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
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
Helpful Definitions

- 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
Case Scenario
30yo G1 P0 EGA 28w admitted to the hospital for worsening pneumonia.

VS RR 31 P 110 O2sat 91% RA BP 120/78 mmHg

What is an appropriate means of respiratory assistance?

- Observation
- Nasal prongs
- Nonrebreather facemask
- Volume/assist control mechanical ventilation
- Airway pressure release ventilation
• **Observation**
• Nasal prongs
• Nonrebreather facemask
• Volume/ assist control mechanical ventilation
• Airway pressure release ventilation
• Observation

• Nasal prongs
• Nonrebreather facemask
• Bilevel ventilation
• Volume/assist control mechanical ventilation
• Airway pressure release ventilation
Noninvasive Ventilation
General

- 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 Ventilation

Over the last decade, noninvasive ventilation—now used almost exclusively with positive pressure—has seen a revival. It’s safer, more comfortable, and more convenient than ventilation involving an artificial airway. But it’s not for everyone.

During the early 20th century, ventilatory assistance generally was invasive and involved the delivery of negative pressure. The prime example is the iron lung, used to treat patients with polio syndrome. By the 1950s, with advances in artificial airways and positive-pressure application, mechanical ventilation using artificial airways became the standard of care for patients in acute respiratory failure.

Although it’s not suitable for every patient, noninvasive positive-pressure ventilation reduces many of the risks of mechanical ventilation.

By Mark Bauman, MS, RN, CORN

Respiratory failure may result from central nervous system failure, primary lung disease (such as chronic obstructive pulmonary disease [COPD]), infection, neuromuscular disease, or traumatic injury (such as pulmonary contusion, hemor-

Noninvasive ventilation makes a comeback

LEARNING OBJECTIVES
1. Identify the indications for noninvasive positive pressure ventilation (NIPPV).
2. Discuss the use of NIPPV, including modes and settings, patient ventilator interface, and complications.
3. Describe nursing management of a patient receiving NIPPV.
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
Noninvasive Ventilation


-Image from UpToDate 2014.
• Observation
  • Nasal prongs
  • Nonrebreather facemask
  • Bilevel ventilation
  • Volume/assist control mechanical ventilation
  • Airway pressure release ventilation
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, decreased CO, increased pulmonary artery pressures
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
  - 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 $V_T$
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
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$_2$ level 60 mmHg)
  - Positive End-Expiratory Pressure (PEEP)
    - Added to mitigate end-expiratory alveolar collapse, usually 5 cm H$_2$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
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 O₂ saturation > 90% with FIO₂ > 0.60 (PaO₂ <55 mmHg)
- PaCO₂ > 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
- pH 7.40 to 7.47
Thank You for Your Attention!

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