Objectives

- Review current state of maternal mortality and morbidity in the United States
- Review of Physiologic Changes and Hemodynamics in Pregnancy
- Discuss recognition and management of respiratory compromise in the pregnant patient
- Review preeclampsia and management of acute hypertension
- Review recognition and management of the pregnant patient with sepsis

Introduction: Where Are We?
CCOB – Case Scenario

• 32 yo G5P5 005
• Postpartum hemorrhage
• EBL 3200 ml
• 72/38, 144, 28
• Agitated, disoriented
• Intake – 4500 ml crystalloid
• Urine output – 22 mL in 2 hours
• Difficult to palpate pulses

CCOB – Case Scenario

• 39 yo at 28 weeks gestation
• BP 174-196/112-120
• Hydralazine 50 mg IV given total dose
• Labetalol 120 mg IV given total dose
• Urine output 10-12 mL/hour
• EFM – late decelerations, decreased baseline variability

Rising Maternal Mortality Ratio
<table>
<thead>
<tr>
<th>Cause of Pregnancy Related Death</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiovascular Disease</td>
<td>15.1%</td>
</tr>
<tr>
<td>Non-Cardiovascular Diseases</td>
<td>14.1%</td>
</tr>
<tr>
<td>Infection/Sepsis</td>
<td>14%</td>
</tr>
<tr>
<td>Hemorrhage</td>
<td>11.3%</td>
</tr>
<tr>
<td>Cardiomyopathy</td>
<td>10.1%</td>
</tr>
<tr>
<td>Thrombotic pulmonary embolism</td>
<td>9.8%</td>
</tr>
<tr>
<td>Hypertensive Disorders of pregnancy</td>
<td>8.4%</td>
</tr>
<tr>
<td>Amniotic Fluid Embolism</td>
<td>5.6%</td>
</tr>
<tr>
<td>Cerebrovascular accidents</td>
<td>5.4%</td>
</tr>
<tr>
<td>Anesthesia complications</td>
<td>0.3%</td>
</tr>
</tbody>
</table>

http://www.cdc.gov/reproductivehealth/MaternalInfantHealth/Pregnancy-relatedMortality.htm

For Every Woman Who Dies In Childbirth In the U.S., 70 More Come Close

Timing of Maternal Deaths

- Before Delivery: 30.5%
- 1-6 Days PPM: 18.8%
- 7-41 Days PPM: 21.3%
- 42-365 Days PPM: 30.5%

Near-Miss Maternal Morbidity

75% increase

1998-9

2008-9


Severe Maternal Morbidity in U.S.

- Rate of severe complications have doubled in the last decade
- Pregnancy related strokes increased by 50% 2006-2007 compared to 1994-1996

http://www.cdc.gov/reproductivehealth/MaternalInfantHealth/PMSS.html

Preventable Maternal Mortality

Centers for Disease Control estimates that more than half of the reported maternal deaths in the U.S. could have been prevented by early diagnosis and treatment
“National Initiative for every birthing facility in the United States to have a safety program in place for the most common preventable causes of death and severe morbidity.”
Safety Bundles Every Facility Should Have

Obstetric hemorrhage
Severe hypertension in pregnancy
Peripartum venous thromboembolism

Unit Improvement Bundles

Structured approach for recognition of early warning signs and symptoms
Structured internal case reviews to identify systems improvement opportunities
Support tools for patients, families and staff that experience an adverse outcome

Most Common Causes for Admission to ICU Status During Pregnancy

- Respiratory compromise
- Pulmonary edema
- Pulmonary embolus
- Asthma
- Hypertension management
- Preeclampsia
- Cardiac
- Hemorrhage
- DIC
- Sepsis
- DKA
- Post-op Fetal Surgery
- Acute kidney injury
Levels of Maternal Care: Objectives

- Uniform designations for levels of maternal care that are complimentary but distinct from levels of neonatal care
- Develop standard definitions and nomenclature for facilities
- Provide consistent guidelines of service according to level of maternal care for use in quality improvement and health promotion
- Foster development and equitable geographic distribution of full-service maternal care facilities and systems that promote proactive integration of risk-appropriate antepartum, intrapartum and postpartum services

"Your level of care is not determined by how sick your patients are. It is determined by how prepared you are for those sick patients."

-Stephanie Martin, DO
Review of Physiologic Changes and Hemodynamics in Pregnancy

Physiologic Changes of Pregnancy

<table>
<thead>
<tr>
<th>System</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiovascular</td>
<td>High Flow Low Resistance</td>
</tr>
<tr>
<td>Respiratory</td>
<td>Compensated Respiratory Alkalosis</td>
</tr>
<tr>
<td>Hematologic</td>
<td>Hypercoagulable</td>
</tr>
</tbody>
</table>

Cardiovascular: High Flow

- Blood Volume ↑
  - 1600 cc singleton gestation
  - 2000 cc multiple gestation
  - Decreased Colloid Oncotic Pressure

- Stroke Volume ↑
  - Amount of blood ejected from the left ventricle with each myocardial contraction
  - 30% increase Normal 73.3 ± 9

- Blood volume increase beginning at 6 weeks, peaking 28-34 weeks, returns to pre-pregnancy values 6-8 weeks postpartum
- Adequate perfusion to uterus, fetus, maternal tissues
- Maintain BP
- Accommodate blood loss at birth
- Hormone stimulation of plasma renin activity and aldosterone levels: stimulates renal tubular reabsorption of Na and water (6-8 L in total body water)
Cardiovascular: High Flow

Hemodilution

- RBCs 20% Increase
- Plasma Volume 45-50% Increase
- Hematocrit
  - Non-Pregnant: 38.2
  - Pregnant: 34.7

Colloid Oncotic Pressure (COP)

1. Plasma proteins
   - Albumin 80%
   - Globulin 20%
   - Fibrinogen

2. Gibbs-Donnan effect
   - Osmotic pressure caused by Na, K, and other cations held in the plasma by proteins

Colloid Oncotic Pressure Values in Pregnancy

<table>
<thead>
<tr>
<th></th>
<th>Colloid Oncotic Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Pregnant</td>
<td>25.4 ± 2.3</td>
</tr>
<tr>
<td>Antepartum</td>
<td>22.4 ± 0.54</td>
</tr>
<tr>
<td>Postpartum</td>
<td>15.4 ± 2.1</td>
</tr>
<tr>
<td>Antepartum with Preeclampsia</td>
<td>17.9 ± 0.68</td>
</tr>
<tr>
<td>Postpartum with Preeclampsia</td>
<td>13.7 ± 0.46</td>
</tr>
</tbody>
</table>

*KEY POINT: Decline in COP = ↑ risk of pulmonary edema*
COP Measurement

**Oncometer**

\[ \text{COP} = 5.21 \times \text{total protein} - 11.4 \]

\[ \text{COP} = 8.1 \times \text{serum albumin} - 8.2 \]

---

Cardiovascular Changes

<table>
<thead>
<tr>
<th>Cardiac output</th>
<th>Heart Rate</th>
<th>Stroke Volume</th>
</tr>
</thead>
</table>


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Cardiac Output

Cardiac Output: Positional Effects

- Knee chest: 6.9 ± 2.1 L/min
- Right: 6.8 ± 1.3 L/min
- Left: 6.6 ± 1.4 L/min
- Sitting: 6.2 ± 2.0 L/min
- Supine: 6.0 ± 1.4 L/min
- Standing: 5.4 ± 2.0 L/min


Cardiac Output

- Preload: CVP-right, PCOP-left
- Afterload: PVR-right, SVR-left
- Contractility: LVSWI
- Heart rate

Stroke Volume

CO ~5-7 L/min

SV 80-85 mL

HR 80’s

Hill et al. The heart during pregnancy. Rev Esp Cardiol. 2011;64(15)
MAP Unchanged in Pregnancy

Hall et al. The heart during pregnancy. Rev Esp Cardiol. 2011;64(11)

Respiratory Alterations:
Compensated Respiratory Alkalosis

- Anatomic changes
  - Hyperemia of upper airway results in narrowing passages
  - Gravid uterus pushes diaphragm up 5-7 cm
  - Thoracic cage changes increase chest circumference

https://thoracickey.com/pregnancy/

Respiratory Alterations: Compensated Respiratory Alkalosis

Oxygen Consumption
- Increases by 15-20%
- 50% of this increase required by uterus

Dyspnea of pregnancy
- Common - up to 60-70% of women
**Pulmonary Function in Pregnancy**

<table>
<thead>
<tr>
<th>Pulmonary Function</th>
<th>Definition</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory rate</td>
<td>Breaths per minute</td>
<td>None</td>
</tr>
<tr>
<td>Tidal volume (TV)</td>
<td>Amount of air inspired &amp; expired/breath</td>
<td>+30-40%</td>
</tr>
<tr>
<td>Minute ventilation</td>
<td>Volume of gas inhaled or exhaled per minute</td>
<td>+20-50%</td>
</tr>
<tr>
<td>Functional residual capacity (FRC)</td>
<td>Amount of air in lungs at resting expiration (ERV + RV)</td>
<td>-20%</td>
</tr>
</tbody>
</table>

**Maternal Blood Gases**

**Compensated Respiratory Alkalosis**

<table>
<thead>
<tr>
<th></th>
<th>Pregnant</th>
<th>Non-Pregnant</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.4 – 7.45</td>
<td>7.35 – 7.45</td>
</tr>
<tr>
<td>(p_{aO_2})</td>
<td>104 – 108</td>
<td>90-100</td>
</tr>
<tr>
<td>(p_{aCO_2})</td>
<td>27 – 32</td>
<td>35-45</td>
</tr>
<tr>
<td>HCO(_3^-)</td>
<td>18 – 31</td>
<td>24 - 31</td>
</tr>
</tbody>
</table>

**Respiratory Alterations:**

**Compensated Respiratory Alkalosis**

- Minute ventilation increases 30-40% \((TV \times RR)\)
- \(PaCO_2\) levels decrease
- Fetal-maternal CO\(_2\) gradient increases

Facilitates transfer of CO\(_2\) from fetus to mother

Decreased maternal \(PaCO_2\) leads to chronic respiratory alkalosis
Hematologic Alterations: Hypercoagulable

<table>
<thead>
<tr>
<th>Clotting Factors</th>
<th>Non-Pregnant</th>
<th>Change</th>
<th>Pregnant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activated PTT (sec)</td>
<td>31.6 +/- 4.9</td>
<td>Increased</td>
<td>31.9 +/- 2.0</td>
</tr>
<tr>
<td>Thrombin time (sec)</td>
<td>18.9 +/- 2.0</td>
<td>Increased</td>
<td>22.4 +/- 4.1</td>
</tr>
<tr>
<td>Factor VII (%)</td>
<td>99.1 +/- 15.4</td>
<td>Increased</td>
<td>133.4 +/- 48</td>
</tr>
<tr>
<td>Factor X (%)</td>
<td>97.7 +/- 15.4</td>
<td>Increased</td>
<td>144.5 +/- 20.1</td>
</tr>
<tr>
<td>Fibrinogen (mg/dL)</td>
<td>105.5 +/- 34.1</td>
<td>Increased</td>
<td>130.2 +/- 19.5</td>
</tr>
<tr>
<td>Plasminogen (%)</td>
<td>256 +/- 58</td>
<td>Increased</td>
<td>473 +/- 72</td>
</tr>
<tr>
<td>Antithrombin III (%)</td>
<td>58.9 +/- 13.2</td>
<td>Decreased</td>
<td>47.5 +/- 33.3</td>
</tr>
<tr>
<td>Protein C (%)</td>
<td>27.2 +/- 12.0</td>
<td>Decreased</td>
<td>32.5 +/- 20.5</td>
</tr>
<tr>
<td>Total Protein S (%)</td>
<td>75.6 +/- 14.0</td>
<td>Increased</td>
<td>99.3 +/- 10.2</td>
</tr>
</tbody>
</table>

Hematologic Alterations

• Erythropoietin increases
• Human placental lactogen may stimulate hematopoiesis
• WBC count increases
  • Increase in polymorphonuclear leucocytes
  • Neutrophil number increases with estrogen
  • Peak at 33 weeks – Stabilize - Increase in labor
• Suppression of T and B lymphocytes

Respiratory Compromise
Oxygen Transport Components

- Oxygen Content
- Affinity
- Delivery
- Consumption

Oxygen Transport

- Oxygen dissolved in the blood plasma (PaO₂)
- Oxygen combined with hemoglobin (saturated) (SaO₂)

Oxygen Content

- Dissolved in Plasma 2%

Low PaO₂

High PaO₂

- Oxygen dissolved in the blood plasma (PaO₂)
- Oxygen combined with hemoglobin (saturated) (SaO₂)
Diffusion Barriers

1. Alveolar epithelium
2. Tissue interstitium
3. Capillary epithelium
4. Plasma layer
5. Red cell membrane
6. Red cell cytoplasm
7. Hgb binding forces

Hypoxemia → Tissue Hypoxia → Anaerobic Metabolism

Production of Lactic Acid → Decreased pH → Metabolic Acidosis
Hypoxemia: Reduced oxygen in blood ($\text{PaO}_2$)

- Low Alveolar Oxygen (reduced $\text{PaO}_2$)
  - Altitude
  - Hypoventilation (increased $\text{PACO}_2$)
  - Breathing of gas mixtures less than 21%
- Diffusion Impairment (pulmonary edema)
- Intrapulmonary Shunt (pneumonia)
- Ventilation/Perfusion Mismatch (PE)

<table>
<thead>
<tr>
<th>Altitude (feet)</th>
<th>Effective Oxygen %</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>21%</td>
<td>Los Angeles</td>
</tr>
<tr>
<td>5,000</td>
<td>17%</td>
<td>Boulder, CO</td>
</tr>
<tr>
<td>8,000</td>
<td>15%</td>
<td>Aspen, CO</td>
</tr>
<tr>
<td>14,000</td>
<td>12%</td>
<td>Pikes Peak</td>
</tr>
<tr>
<td>29,000</td>
<td>7%</td>
<td>Everest</td>
</tr>
</tbody>
</table>

Hypoxia: Reduced oxygen at the tissue level

1. Lack of oxygen in blood (hypoxemia)
2. Lack of oxygen carrying capacity (anemia)
3. Lack of delivery of oxygen (circulatory)
4. Lack of ability to extract oxygen (infection)
Quick Reference: Oxyhemoglobin Curve

<table>
<thead>
<tr>
<th>$pO_2$ mmHg</th>
<th>SpO$_2$ %</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>70</td>
</tr>
<tr>
<td>50</td>
<td>80</td>
</tr>
<tr>
<td>60</td>
<td>90</td>
</tr>
</tbody>
</table>

Etiology of Respiratory Compromise in Pregnancy

- Pulmonary Edema
- Pneumonia
- Pulmonary Embolism
- Asthma Exacerbation
- Aspiration
- ARDS

Pulmonary Edema
**Cardiogenic**

- Hydrostatic

**Non-Cardiogenic**

- Non-Hydrostatic
- Capillary Leak Syndrome

---

**Imbalance of Starling Forces**

- Hydrostatic (push)
- Oncotic (pull)
- Lymphatic (drain)

---

**Cardiogenic Pulmonary Edema**

- ↑ Edema pressure
- ↑ LA pressure
- ↑ PVR
- ↓ Ventricular emptying
- ↓ Ventricular relaxation
- ↓ Cardiac output
- ↑ Hydrostatic, oncotic pressure + lymphatic drainage
  Fluid accumulates in interstitium and alveoli

- ↑ Catecholamine release
- ↑ Drives, sympathetic, adrenergic activation
- ↑ SVR
- ↑ Preload
- ↑ Cardiac work and oxygen demand
- ↓ Ventricular emptying
- ↓ Ventricular relaxation
- ↓ Cardiac output
- ↓ Gas exchange
- ↓ Hypoxia
- ↓ Work of breathing
Non-Cardiogenic Pulmonary Edema

Common Causes of Pulmonary Edema

<table>
<thead>
<tr>
<th>Non-cardiogenic</th>
<th>Cardiogenic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-eclampsia</td>
<td>Congenital or acquired heart disease</td>
</tr>
<tr>
<td>Sepsis/Infection</td>
<td>- Ischemic heart disease</td>
</tr>
<tr>
<td>DIC</td>
<td>- Congestive Heart Failure/Cardiomyopathy</td>
</tr>
<tr>
<td>TRALI</td>
<td>- Ischemic heart disease/Myocardial infarction</td>
</tr>
<tr>
<td>Anaphylaxis</td>
<td>- Congestive Heart Failure/Cardiomyopathy</td>
</tr>
<tr>
<td>Amniotic fluid embolism</td>
<td>- Ischemic heart disease/Myocardial infarction</td>
</tr>
<tr>
<td>Aspiration pneumonia</td>
<td>- Congestive Heart Failure/Cardiomyopathy</td>
</tr>
<tr>
<td>Opiate overdose</td>
<td>- Ischemic heart disease/Myocardial infarction</td>
</tr>
<tr>
<td>Salicylate toxicity</td>
<td>- Congestive Heart Failure/Cardiomyopathy</td>
</tr>
<tr>
<td>Neurogenic pulmonary edema</td>
<td>- Ischemic heart disease/Myocardial infarction</td>
</tr>
<tr>
<td>High altitude pulmonary edema</td>
<td>- Congestive Heart Failure/Cardiomyopathy</td>
</tr>
</tbody>
</table>
Exudative

- Excessive accumulation of fluid in alveoli
- Protein and inflammatory cells enter air spaces from alveolar capillaries
- 1st-2-4 days after onset of lung injury

Fibroproliferative

- Connective tissue and other structural elements in lungs proliferate in response to injury
- Increased density of lung tissue
- Risk of pneumonia, sepsis, rupture of lung tissue causing leakage into surrounding areas

Resolution and Recovery

- Lung tissue reorganizes and recovers
- Improvement in lung function [may take 6-12 months]

Infiltrates on X-ray don’t appear until up to 24 hours later in ARDS

Making the Diagnosis of ARDS

- P/F ratio determines degree of intrapulmonary shunt
  \( \frac{\text{PaO}_2}{\text{FiO}_2} \times 100 = \text{P/F ratio} \)
- Normal person:
  \( (100 \text{ mmHg}/21\%) \times 100 = 476 \)
- In ARDS the P/F ratio is < 200, indicating severe difficulty delivery oxygen
  - mild ARDS 200-300
  - Higher numbers reflect better oxygen exchange
Management

<table>
<thead>
<tr>
<th>L/Min</th>
<th>% FiO₂ (%)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nasal Cannula</td>
<td>1 - 6</td>
<td>25 - 40%</td>
</tr>
<tr>
<td>Face Mask</td>
<td>6 - 10</td>
<td>40 - 60%</td>
</tr>
<tr>
<td>FM w/reservoir</td>
<td>6 - 10</td>
<td>60 - 100</td>
</tr>
<tr>
<td>Venturi Mask</td>
<td>4-15</td>
<td>40-50%</td>
</tr>
<tr>
<td>CPAP</td>
<td>Set</td>
<td>Titrate</td>
</tr>
</tbody>
</table>

What is a Non-rebreather Mask?

- Non-rebreather mask has a one-way reservoir (bag and valves)
  - Prevents patient from rebreathing exhaled air - bag does not allow exhaled air to enter the bag reservoir
  - In a partial rebreather, the bag contains about 1/3 of exhaled air which is rebreathed by the patient
Noninvasive Positive Pressure Ventilation (NIPPV)

- Positive pressure ventilation without intubation
- Indications:
  - Emergency intubation not needed, condition which would respond to NIPPV
  - Cardiogenic pulmonary edema
  - Acute hypoxemic respiratory failure
- Contraindications:
  - Cardiac or respiratory arrest
  - High aspiration risk, impaired consciousness, unable to clear secretions or protect airway

Indications for Intubation and Mechanical Ventilation

- Failure to Oxygenate
  - Cardiogenic Pulmonary edema
- Failure to Ventilate
  - Asthma
- Unable to Protect Airway
  - Eclampsia
  - Loss of consciousness

- BP elevation after 20 wks
- No proteinuria
- No severe features
- Close monitoring for progression, delivery at 37w0d

Gestational HTN
- BP elevation prior to 20 wks
- Delivery after 38w0d if no complications
- Antenatal testing including growth evaluation

Chronic HTN
- BP elevation AND
- Proteinuria OR severe features
- WITHOUT severe features, delivery at 37w0d
- WITH severe features (including HELLP syndrome), inpatient monitoring and delivery at 34w0d or time of diagnosis

Preeclampsia (with or without severe features)
- BP elevation AND
- Proteinuria OR severe features
- WITHOUT severe features, close monitoring for progression, delivery at 37w0d
- WITH severe features (including HELLP syndrome), inpatient monitoring and delivery at 34w0d or time of diagnosis

Chronic HTN with Superimposed Preeclampsia
- New severe features over baseline
- Inpatient hospitalization with delivery at 36w0d or time of diagnosis

Early treatment of severe hypertension is recommended at the threshold levels of 160 mm Hg systolic or 110 mm Hg diastolic.

Magnesium sulfate for seizure prophylaxis is indicated for severe preeclampsia and should not be administered universally for preeclampsia without severe features (mild).

Preeclampsia: Critical Thinking Pathophysiology
- Focus usually on BP
- Multisystem effects of preeclampsia

Cardiac Neurologic Renal
Pulmonary Liver Fetal
Placental release of factor(s) that alter endothelial function

- Endothelial cell dysfunction
- Decreased production of PG12
- Reversed PG12:TXA2 ratio
- Vasoconstriction → Increased SVR
- Hypertension

Placental release of factor(s) that alter endothelial function

- Endothelial cell damage
- Exposure of collagen – tissue factor
- Platelet aggregation activation
- Activation of clotting cascade
- Thrombocytopenia, DIC

Placental release of factor(s) that alter endothelial function

- Endothelial cell damage
- Exposure of collagen – tissue factor
- Leaky capillaries
- Proteinuria; decreased COP
- Edema

Placental release of factor(s) that alter endothelial function

- Endothelial cell dysfunction
- Decreased production of PG12
- Reversed PG12:TXA2 ratio
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- Hypertension

Placental release of factor(s) that alter endothelial function

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- Exposure of collagen – tissue factor
- Platelet aggregation activation
- Activation of clotting cascade
- Thrombocytopenia, DIC
Preeclampsia: Pathophysiology

<table>
<thead>
<tr>
<th>Vascular</th>
<th>Renal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endothelial damage</td>
<td>Decreased renal perfusion</td>
</tr>
<tr>
<td>• Leaky capillaries</td>
<td>• Endothelial damage</td>
</tr>
<tr>
<td>• Edema</td>
<td>• Proteinuria</td>
</tr>
<tr>
<td>• Platelet aggregation/ activation</td>
<td>• Decreased COP</td>
</tr>
<tr>
<td>• Excessive clotting, DIC</td>
<td></td>
</tr>
<tr>
<td>• Intravascular volume depletion</td>
<td></td>
</tr>
</tbody>
</table>

Oliguria

<table>
<thead>
<tr>
<th>Hemodynamic Profile</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low PCWP</td>
<td>Volume</td>
</tr>
<tr>
<td>Hyperdynamic LV</td>
<td></td>
</tr>
<tr>
<td>Moderate increase SVR</td>
<td></td>
</tr>
<tr>
<td>Normal or increased PCWP</td>
<td>Delivery</td>
</tr>
<tr>
<td>Normal LV function</td>
<td></td>
</tr>
<tr>
<td>Normal SVR</td>
<td></td>
</tr>
<tr>
<td>Marked increase PCWP</td>
<td>Volume restriction</td>
</tr>
<tr>
<td>Decreased LV function</td>
<td>Afterload reduction</td>
</tr>
</tbody>
</table>
Preeclampsia: Pathophysiology

**Hepatic**
- Hepatic swelling
- Subcapsular hematoma
- Liver rupture
- Focal ischemia
- Elevated transaminases
- Liver failure

**Neurologic**
- Headache
- Visual changes
- Cerebral edema
- Focal ischemia
- Hyperreflexia
- Eclamptic seizures
- Altered mental status
- Hemorrhage
- Posterior Reversible Encephalopathy Syndrome (PRES)

**DTR Assessment**
- 0: absent
- 1: sluggish
- 2: active / normal
- 3: brisk
- 4: transient clonus
- 5: sustained clonus

Hyperreflexia
- Degree not associated with severity of disease process
- Presence or absence should not be a factor in making or excluding diagnosis of preeclampsia
- Not a predictor for eclampsia
Posterior Reversible Encephalopathy Syndrome (PRES)

- Diagnosed with clinical symptoms and radiologic testing (CT or MRI)
  - Impaired consciousness
  - Seizure activity
  - Headaches
  - Visual abnormalities
  - Acute hypertension
  - Nausea/vomiting
- Pathophysiology is controversial
- Symptom management

Pulmonary Edema

- **Cardiogenic**
  - Fluid volume overload
  - Elevated SVR
- **Non-cardiogenic**
  - Pulmonary capillary permeability
  - Intravascular volume depletion

**Critical Thinking**

- What is the intravascular hydrostatic pressure?
- What is the intravascular colloid oncotic pressure?
- What is the extravascular colloid oncotic pressure?
- What is the extravascular hydrostatic pressure?
Preeclampsia: Clinical Management

Key Concepts
- Preeclampsia is a dynamic process
- Reevaluation for severe features

What is the Blood Pressure?

Cardiac Output

Pulse Pressure

Cardiac Output

Peripheral Resistance

Cardiac output

Heart Rate

Stroke Volume
Hypertension Assessment

- Vital sign trends
- Blood Pressure

\[ \text{BP} = \text{SVR} \times \text{CO} \]
\[ \text{BP} = \text{SVR} \times \text{SV} \times \text{HR} \]

<table>
<thead>
<tr>
<th>SVR</th>
<th>MAP</th>
<th>SV</th>
<th>HR</th>
<th>Treatment</th>
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</thead>
<tbody>
<tr>
<td>1800</td>
<td>135</td>
<td>74</td>
<td>96</td>
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Blood Pressure Measurement

Hypertension Assessment

- Vital sign trends
- Blood Pressure

\[ \text{BP} = \text{SVR} \times \text{CO} \]
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Hypertension Assessment

- Vital sign trends
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Hypertension Assessment

- Vital sign trends
- Blood Pressure

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<td>88</td>
<td>76</td>
<td>140</td>
<td></td>
</tr>
</tbody>
</table>
Laboratory Analysis

<table>
<thead>
<tr>
<th>Test</th>
<th>Description and Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemoglobin and hematocrit</td>
<td>Hemoconcentration supports diagnosis of preeclampsia and is an indicator of severity. Values may decrease with HELLP or abruption.</td>
</tr>
<tr>
<td>Serum Creatinine</td>
<td>Abnormal or rising levels, in association with oliguria, suggests preeclampsia with severe features.</td>
</tr>
<tr>
<td>Serum uric acid</td>
<td>Increased levels may suggest the diagnosis of preeclampsia.</td>
</tr>
<tr>
<td>Serum transaminase</td>
<td>Rising values suggests preeclampsia with severe features or HELLP.</td>
</tr>
<tr>
<td>Serum albumin</td>
<td>Indicate the extent of endothelial leak (hypoalbuminemia)</td>
</tr>
</tbody>
</table>

Magnesium Sulfate: Nursing Care

- Mixture: 4 or 6 grams in 100 mL (Bolus); 20 grams in 500 mL (maintenance)
  - 25 mL = 1 gram
- All IV lines on infusion pump; label lines and bags
- 2 RN check
- Staffing
  - 1:1 during 1st hour
  - Remain at bedside during bolus
  - 1:1 in labor
  - 1:2 postpartum
- Strict bed rest
- Strict I & O
  - Foley catheter
  - Assess hourly and totals
- Vital signs
  - O 15 minutes 1st hour
  - O 30 minutes 2nd hour
  - O 1 hour
- Other Assessments
  - Breath sounds O 2 hrs
  - SPO2 O 1 hour
  - DTRs O 1 hour
  - Continuous EFM
  - Calcium gluconate
  - Unplug from mainline after DC
  - Keep it going in OR
The Sepsis Continuum

- **SIRS**
- **Sepsis**
- **Severe Sepsis**
- **Septic Shock**

Sepsis is a clinical response arising from a nonspecific insult, with ≥ 2 of the following:

- T > 38°C or < 36°C
- HR > 90 beats/min
- RR > 20/min
- WBC > 12,000/mm³ or < 4,000/mm³ or > 10% bands

SIRS = systemic inflammatory response syndrome

SIRS with a presumed or confirmed infectious process


Sepsis SIRS Severe Sepsis Septic Shock

Sepsis with organ failure

Refractory hypotension

2016 Surviving Sepsis

Sepsis

Life threatening organ dysfunction caused by a dysregulated host response to infection

Any 2 of the following clinical criteria:

- SBP ≤ 100 mmHg
- RR ≥ 22/min
- Altered mental status
Septic Shock

Subset of sepsis patients with increased mortality (40%)

Profund underlying metabolic and circulatory derangements

- Severe shock with persistent hypotension requiring vasopressor to maintain MAP ≤ 65 mmHg
- Lactate level > 2 mmol/L despite adequate fluid resuscitation

Identifying Risk Factors in Obstetrics

- Existing infection
- AMA (over 40 years of age) particularly with co-morbidities
- Cesarean birth
- Reproductive technologies
- Multifetal pregnancy
- Obesity


Tissue injury caused by physical/chemical agent or pathogenic microorganism

- Capillary dilation
- Increased permeability
- Attraction of leukocytes
- Systemic response
- Increased blood flow
- Fluid release into tissues
- Edema formation
- Necrosis
- Fever and proliferation of leukocytes

Pathophysiology: Immune System

- Inflammation Key Concepts
  - Vasodilation
  - Vasopermeability
  - Activation of adhesion molecules
  - Coagulation
- Inflammation conducted by mediators
  - Beneficial unless not controlled
    - Damage to healthy tissue
    - Uncontrolled vasodilation and permeability – distributive shock
    - Uncontrolled activation of coagulation - coagulopathy

Pathophysiology of Sepsis and Septic Shock

Factors:
- Environment
- Genetics
- Age
- Gender
- Other illness or risk factors for organ dysfunction
- Medications
- Site of infection
- Causative organism
- Pathogen load
- Violence
- Time to treatment

Factors:
- Environment
- Genetics
- Age
- Gender
- Other illness or risk factors for organ dysfunction
- Medications
- Site of infection
- Causative organism
- Pathogen load
- Violence
- Time to treatment

Sequential (Sepsis-related) Organ Failure Assessment (SOFA) Score

<table>
<thead>
<tr>
<th>Variable</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>pO2/FiO2</td>
<td>&lt;400</td>
<td>401-600</td>
<td>601-1000</td>
<td>101-200</td>
<td>&gt;200</td>
</tr>
<tr>
<td>Platelet count (10^3/μL)</td>
<td>&lt;150</td>
<td>151-300</td>
<td>301-500</td>
<td>&gt;500</td>
<td></td>
</tr>
<tr>
<td>Serum bilirubin (mg/dL)</td>
<td>&lt;1.2</td>
<td>1.2-1.9</td>
<td>2.0-3.9</td>
<td>4.0-6.0</td>
<td>&gt;6.0</td>
</tr>
<tr>
<td>Hematocrit (%)</td>
<td>None</td>
<td>&lt;35</td>
<td>&gt;35</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>SOFA</td>
<td>NA</td>
<td>1-3</td>
<td>4-6</td>
<td>&gt;6</td>
<td>NA</td>
</tr>
<tr>
<td>Serum creatinine (mg/dL)</td>
<td>&lt;1.2</td>
<td>1.2-1.9</td>
<td>2.0-3.9</td>
<td>4.0-6.0</td>
<td>&gt;6.0</td>
</tr>
<tr>
<td>Urine output (ml/24h)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>50-80</td>
<td>&lt;50</td>
</tr>
</tbody>
</table>

Maternal Early Warning Criteria
A Proposal From the National Partnership for Maternal Safety

- Proposed in 2014
- Adapted from UK Modified Early Obstetric Warning System (MEOWS)
  - Red Triggers
    - Deleted temp, pain, added oliguria
    - Not specific to sepsis
    - Intended to identify triggers that require immediate bedside evaluation by physician or other clinician

Mhyre et al. Obstet Gynecol 2014;124:782-6

Prospective Study of Maternal Early Warning Triggers

<table>
<thead>
<tr>
<th>Maternal Triggers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp</td>
</tr>
<tr>
<td>≥ 38°C (100.4°F) or ≤ 36°C (96.9°F)</td>
</tr>
<tr>
<td>Pulse Oximetry</td>
</tr>
<tr>
<td>≤ 93%</td>
</tr>
<tr>
<td>Pulse</td>
</tr>
<tr>
<td>&gt; 110 or &lt; 50</td>
</tr>
<tr>
<td>RR</td>
</tr>
<tr>
<td>&gt; 24 or &lt; 12</td>
</tr>
<tr>
<td>SBP</td>
</tr>
<tr>
<td>&gt; 155 or &lt; 80</td>
</tr>
<tr>
<td>DBP</td>
</tr>
<tr>
<td>&gt; 105 or &lt; 45</td>
</tr>
<tr>
<td>Altered mental status anytime</td>
</tr>
<tr>
<td>Fetal HR &gt; 160 (infection pathway)</td>
</tr>
</tbody>
</table>


Figure

American Journal of Obstetrics & Gynecology
2016 214, 527.e1-527.e6DOI: (10.1016/j.ajog.2016.01.154)
Percentage of Maternal Early Warning Trigger positive results of each clinical pathway and ICU admission

<table>
<thead>
<tr>
<th>Clinical pathway</th>
<th>Screened positive (n = 260)</th>
<th>ICU admissions (n = 47)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sepsis</td>
<td>71.4%</td>
<td>38%</td>
</tr>
<tr>
<td>Cardiopulmonary</td>
<td>3.1%</td>
<td>6%</td>
</tr>
<tr>
<td>Hypertension</td>
<td>14.6%</td>
<td>15%</td>
</tr>
<tr>
<td>Hemorrhage</td>
<td>7.7%</td>
<td>31%</td>
</tr>
<tr>
<td>Multiple pathways</td>
<td>2.3%</td>
<td></td>
</tr>
<tr>
<td>Pathways follow correctly</td>
<td>82.3%</td>
<td></td>
</tr>
<tr>
<td>Physician intervention time points, &lt;30 and &lt;60 min</td>
<td>71.9% and 83.1%</td>
<td></td>
</tr>
</tbody>
</table>


Vaginal delivery 1 week prior complicated by symphyse separation
Readmitted 1 wk postpartum with lower abdominal pain, swelling of the labia and erythema across the lower suprapubic area.
Treated with antibiotics for cellulitis 12 hours later...

• Shock - mentally obtunded and intense abdominal pain
• Necrotizing fasciitis
• Multi-organ dysfunction (acute renal failure, hepatic derangement, and coagulopathy)
• Surgery
  • Necrotic tissue debrided
  • Day 12 – reconstructive surgery
  • Day 19 – reconstructive surgery
• Full recovery

Athanassopoulos NZ Med J 2006
The Sepsis Bundle
Application for Obstetrics

Surviving Sepsis Campaign
• Goal directed therapy
  • Statistically better outcomes in goal directed therapy group
• No RCT data during pregnancy, but use is recommended

www.survivingsepsis.org

3 Hour Bundle

Measure Lactate Level
Blood Cultures
Antibiotics
Volume Resuscitation and Manage Hypotension

http://www.survivingsepsis.org/News/ Pages/Surviving-Sepsis-Campaign-Releases-Hour-1-Bundle.aspx
3 Hour Bundle Volume Resuscitation

- **1st Priority** – Aggressive Volume Resuscitation
  - Initial Volume Resuscitation - Crystalloid 30 mL/kg for hypotension or lactate level > 4 mmol/L
  - Additional volume based on frequent reassessment

PRELOAD VOLUME

Cardiac Output

Heart Rate

Contractility

Afterload

Preload

3 Hour Bundle Volume Resuscitation

- Recommendations
  - Crystalloids over colloids for initial resuscitation
  - Against the use of hydroxyethyl starches (HES) for fluid resuscitation of severe sepsis and septic shock (grade 1B)
    - Increased mortality in several studies
  - Albumin use when "substantial" amounts of crystalloids are required for resuscitation
  - Increased expense
  - No proven benefit

3 Hour Bundle Obtain Cultures

- Culture all clinically relevant sites before antibiotics
  - NOTE: Don’t delay antibiotics if cultures can’t be obtained w/in 45 minutes
- Blood cultures
  - 2 with at least one draw percutaneously
  - 1 draw through each vascular access device unless device inserted < 48 hours
  - Aerobic and Anaerobic

Obtain Cultures

- Culture all clinically relevant sites before antibiotics
  - NOTE: Don’t delay antibiotics if cultures can’t be obtained w/in 45 minutes
- Blood cultures
  - 2 with at least one draw percutaneously
  - 1 draw through each vascular access device unless device inserted < 48 hours
  - Aerobic and Anaerobic
Common Sources of Infection in Pregnancy

- Uterus
- Triple I
- Endometritis
- Urinary tract (gram negative)
- Respiratory tract (pneumonia)
- Abdomen

NOTE: Infections in pregnancy are commonly polymicrobial

Ampicillin and Gentamycin cover ~90% of organisms that cause obstetric sepsis

<table>
<thead>
<tr>
<th>Time to (\text{ABX}^1), hrs</th>
<th>OR(^2)</th>
<th>95% CI</th>
<th>p-value</th>
<th>Probability of mortality(^3)</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.00</td>
<td>—</td>
<td>—</td>
<td>18.7</td>
<td>17.5</td>
</tr>
<tr>
<td>2</td>
<td>1.09</td>
<td>1.04</td>
<td>1.15</td>
<td>&lt; 0.001</td>
<td>20.0</td>
</tr>
<tr>
<td>3</td>
<td>1.14</td>
<td>1.06</td>
<td>1.23</td>
<td>&lt; 0.001</td>
<td>20.8</td>
</tr>
<tr>
<td>4</td>
<td>1.19</td>
<td>1.08</td>
<td>1.32</td>
<td>&lt; 0.001</td>
<td>21.5</td>
</tr>
<tr>
<td>5</td>
<td>1.32</td>
<td>1.13</td>
<td>1.51</td>
<td>&lt; 0.001</td>
<td>22.3</td>
</tr>
<tr>
<td>6</td>
<td>1.31</td>
<td>1.13</td>
<td>1.51</td>
<td>&lt; 0.001</td>
<td>23.1</td>
</tr>
</tbody>
</table>

\(^1\)Time to \(\text{ABX}\) is based on 15,948 observations that are greater than or equal to zero.

\(^2\)Hospital mortality odds ratio referent group is 6 hours for the time to \(\text{ABX}\) and is adjusted by the number of baseline organ failures, infection type (community vs. nosocomial), and geographic region (Europe, North America, and South America).

3 Hour Bundle
Serum Lactate

- Reflects decreased tissue perfusion and organ dysfunction
- N= 1,278 patients with infections in ED

<table>
<thead>
<tr>
<th>Lactate Level</th>
<th>Mortality Rate</th>
</tr>
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<tbody>
<tr>
<td>0-2.5 mmol/L</td>
<td>4.9%</td>
</tr>
<tr>
<td>2.5-4 mmol/L</td>
<td>9%</td>
</tr>
<tr>
<td>&gt;4 mmol/L</td>
<td>28.4%</td>
</tr>
</tbody>
</table>


NOTE: Newer studies:
Lactate > 4 with hypotension = Mortality 46%

3 Hour Bundle

- Imaging studies
  - Confirm potential source of infection
- Source control
  - Effective intervention (percutaneous, surgical drainage)
  - If intravascular device is possible source for consideration – remove after establishing new vascular access
- Infection prevention
- Oral and/or digestive decontamination

Septic Shock: Management of Hypotension After Initial Fluid Bolus

- Vaspressors to maintain MAP ≥ 65 mm Hg
  - Norepinephrine – 1st choice vasopressor
  - Epinephrine
  - Vasopressin 0.03 units/minute
  - Dopamine
    - Not used for renal perfusion
    - Phenylephrine not recommended
    - Exceptions: arrhythmia
Goals of Treatment

- Initiate antibiotics within 1st hour of recognizing sepsis or septic shock
- CVP ≥ 8-12 mm Hg
- MAP ≥ 65 mm Hg
- ScVO₂ ≥ 70%
- Normal lactate
- Urine output ≥ 0.5 mL/kg/hour

Factors

<table>
<thead>
<tr>
<th>Questions to Consider</th>
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<tbody>
<tr>
<td>Is fetus viable?</td>
</tr>
<tr>
<td>Can adequate monitoring be achieved?</td>
</tr>
<tr>
<td>Is the fetus appropriately grown?</td>
</tr>
<tr>
<td>Are there fetal anomalies or genetic conditions that will impact prognosis?</td>
</tr>
<tr>
<td>Is infections caused by a pelvic source?</td>
</tr>
<tr>
<td>Can source control be accomplished effectively while pregnant?</td>
</tr>
<tr>
<td>How aggressive is source therapy?</td>
</tr>
<tr>
<td>Is patient in septic shock?</td>
</tr>
<tr>
<td>Is patient requiring vasopressor support?</td>
</tr>
<tr>
<td>Does patient have AIDS or HIV?</td>
</tr>
<tr>
<td>Is patient requiring ventilator support?</td>
</tr>
<tr>
<td>Is patient improving or deteriorating in response to therapy?</td>
</tr>
<tr>
<td>What is the anticipated clinical course?</td>
</tr>
<tr>
<td>Is patient obese?</td>
</tr>
<tr>
<td>Is patient immunocompromised?</td>
</tr>
<tr>
<td>Is patient diabetic?</td>
</tr>
<tr>
<td>Does patient have other comorbidities which impact prognosis?</td>
</tr>
<tr>
<td>Does patient have prior uterine surgery?</td>
</tr>
<tr>
<td>Is patient afraid?</td>
</tr>
<tr>
<td>Is fetus non-vertex?</td>
</tr>
<tr>
<td>Is the cervix dilated?</td>
</tr>
<tr>
<td>Has the patient had a prior vaginal birth?</td>
</tr>
<tr>
<td>Is there an obstetric indication for cesarean section?</td>
</tr>
<tr>
<td>What are risks to general anesthesia?</td>
</tr>
<tr>
<td>Can patient tolerate labor without regional anesthesia?</td>
</tr>
<tr>
<td>What is the patient’s cardiac function?</td>
</tr>
<tr>
<td>What is the patient’s pulmonary function?</td>
</tr>
</tbody>
</table>

"Your level of care is not determined by how sick your patients are. It is determined by how prepared you are for those sick patients."

- Stephanie Martin, DO