Caring for the Critically Ill Pregnant Patient

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Lecture Outline

- Review normal cardiopulmonary physiology of pregnancy
- Address management of critical illness during pregnancy
  - General supportive care
  - Critical illness & pregnancy
- The Case of the Particularly-Plagued Pregnancy

Physiologic Changes in Pregnancy: Cardiopulmonary System

Alterations in:
- Ventilation & respiratory drive
- Oxygen consumption
- Structural changes in chest wall and in airway mucosa
- Total body fluid and cardiac output
- Systemic vascular resistance

Hyperpnea of Pregnancy

- Early: $V_t$ increases, RR little change $\rightarrow$ increased $V_e$ (hyperventilation)
- Offsets ↑ metabolic rate
- Net result: ↓ PaCO₂ 40 $\rightarrow$ 28-32 $\rightarrow$ respiratory alkalosis

Hyperpnea of Pregnancy: Roles of Progesterone

- Progesterone $\rightarrow$ Direct stimulation of respiratory drive
- Progesterone $\rightarrow$ L shift, increased slope of CO2 response curve = ↑ “responsiveness”

Oxygen Exchange in Pregnancy

- Decreased maternal affinity for O2
- Increased O2 consumption (20%)
- Hypoxic ventilatory drive is twice normal (estrogen)
- Even so, pregnant women particularly susceptible to hypoxemia (low FRC, ↑ cardiac output)
Changes in Chest Wall Mechanics

- Diaphragm ascends 4 cm
- Subcostal angle increases 50% (relaxin)
- Lower rib cage widens 5-7 cm
- ↑ abdominal/end-expiratory pressure
- Decreased chest wall compliance (40%)
- ↓ total pulmonary resistance

ABG in pregnancy

- Respiratory alkalosis with mild metabolic acidosis
  - pH 7.40-7.47
  - pCO2 28-32 mm Hg
  - HCO3 18-21
  - PaO2 105-107 mm Hg (1st tm), ↓ by 5 mm by 3rd tm
  - ↓ total pulmonary resistance
  - Will see drop in PaO2 moving from sitting to supine of ± 13 mm
  - Increased A-a gradient by 3rd trimester

Hemodynamics of Pregnancy

- 50% increase total body volume
  - Results in decreased oncotic pressure, anemia
- Increase in cardiac output by 30-50%
  - ↑ preload, ↓ afterload, ↑ HR (15-20 bpm)
  - Central venous pressure and contractility unchanged
- Decreased systemic vascular resistance
  - High flow, low-resistance circuit (uteroplacental circulation is 30% of CO)
  - Increased venous capacitance
  - Increased arterial compliance
  - Factors driving this are incompletely understood

Hemodynamic change in pregnancy

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Nonpregnant value</th>
<th>Pregnant value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac output (l/min)</td>
<td>4.3 ± 0.9</td>
<td>6.2 ± 1.0</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td>73 ± 10</td>
<td>103 ± 10</td>
</tr>
<tr>
<td>Systemic vascular resistance (dynes x cm⁻² x s)</td>
<td>1550 ± 350</td>
<td>1210 ± 264</td>
</tr>
<tr>
<td>Mean arterial pressure (mm Hg)</td>
<td>86.4 ± 7.5</td>
<td>90.5 ± 8.8</td>
</tr>
<tr>
<td>Pulmonary capillary wedge pressure (mm Hg)</td>
<td>6.3 ± 2.1</td>
<td>7.5 ± 1.8</td>
</tr>
<tr>
<td>Central venous pressure (mm Hg)</td>
<td>3.7 ± 2.4</td>
<td>3.6 ± 2.5</td>
</tr>
<tr>
<td>Colloid oncotic pressure (mm Hg)</td>
<td>14.5 ± 2.5</td>
<td>13.5 ± 2.7</td>
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</table>

Table 1: Central hemodynamic changes in normal pregnancy


Positional Changes in Cardiac Output

Cardiovascular changes of pregnancy

A word on anemia….

Physiologic intravascular change
- Plasma volume increases 50-70% (begins wk 6)
- RBC mass increases 20-35% (begins wk 12)
- Disproportional increase in plasma volume > RBC volume → Hemodilution = “physiologic” anemia
- Typically Hgb shouldn’t fall below 10
- Anemia may contribute to dyspnea, due to increased O₂ requirements and decreased O₂ carrying capacity (somewhat compensated for by increased CO)

Physiologic Dyspnea of Pregnancy
- **Causes:** Increased respiratory drive, increased load (chest wall proprioceptors)
- **Other factors:** Increased pulmonary blood volume, anemia, nasal congestion
- **Note:** Exercise efficiency is unchanged, but ventilation at a given level of O₂ consumption increases → increased perception of respiratory effort
- Abnormal to have RR >20, PaCO₂<28 or >35 mm Hg

Fetal physiology
- Placental O₂ delivery affected by:
  1. Uterine artery blood flow
  2. O₂ content of uterine arterial blood
  3. Hb conc/sat
- **Protective mech:**
  - Higher fetal [Hb]
  - Left shifted Hb dissociation curve
  - Fetal “reserve”

Pregnancy and Critical Illness
- Need for ICU admission rare
- <1% of pregnancies in US; <2% of all ICU admissions involve pregnancy
- 75% of ICU admissions happen post-partum
- Maternal morbidity & mortality in the ICU is high (up to 20%)
- Management of pregnant patient often requires multidisciplinary approach
- Little in the way of formal research…

Adapting supportive care to the pregnant patient
- **Mechanical ventilation**
  - When intubating, anticipate difficult airway, poor reserve
  - Maintain PaCO₂ 30 - 32 mmHg, goal PaO₂ >70 mmHg
- **Sedation**
  - Opiates are safe; midazolam thought to be more safe than lorazepam. Avoid NSAIDs.
  - Minimal data re. paralytics (cisatracurium is B)
  - Vasopressors
    - Best to avoid, if possible (fluids, positioning)
    - Paucity of evidence regarding specific vasopressors (ephedrine preferred, neosynephrine is second)
  - Monitoring
    - Generally recommended; both maternal and fetal
  - **Prophylaxis**
    - VTE
    - HOB elevation
CPR in the pregnant patient

- Etiologies: PE (30%), hemorrhage (17%), sepsis (13%), cardiomyopathy or preeclampsia (10%); other
- Practicalities
  - Suspect magnesium toxicity: d/c infusions and give calcium
  - Left lateral decubitus with wedge under R hip or manual displacement of the uterus to the left
  - Continuous cricoid pressure, smaller ETT
  - Higher chest compressions
  - Remove fetal monitor before administering shocks
  - Early delivery (if >24 wks gestation or 4 finger breadths above umbilicus): “5 minute rule” for cardiac arrest

Critical Illness in Pregnancy: Causes

<table>
<thead>
<tr>
<th>Specific to Pregnancy</th>
<th>Causes</th>
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<tbody>
<tr>
<td>Peripartum cardiomyopathy</td>
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<tr>
<td>Preeclampsia/Eclampsia (HELLP)</td>
<td></td>
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<tr>
<td>Postpartum hemorrhage</td>
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<tr>
<td>Amniotic fluid embolism, tocolytic pulmonary edema</td>
<td></td>
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<tr>
<td>Nonspecific (but common)</td>
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<tr>
<td>Asthma</td>
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<tr>
<td>Pulmonary Embolism</td>
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<tr>
<td>Gastric Aspiration</td>
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<td>Infection/sepsis</td>
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<td>Other: pneumothorax, sleep apnea</td>
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Postpartum hemorrhage

- In US, occurs in 5% of births
- Accounts for 11-49% of admissions to ICU
- Causes: uterine atony (80%), trauma, coagulation problems
- Definition: any bleed that causes symptoms & results in signs of hypovolemia
- Management is typically multidisciplinary and related to cause of bleeding
  - Uterotonic agents
  - Balloon tamponade
  - IR embolization vs. surgery

Preeclampsia

- Definition: Hypertension and proteinuria after 20 wks gestation
  - Eclampsia: above, plus seizure
  - US: 5-8% (14% worldwide)
  - Pathogenesis not understood: “endothelial dysfunction”
  - Reasons for ICU admission:
    - refractory hypertension
    - neurological dysfunction (seizures, ICH, elevated ICP, AMS)
    - renal failure
    - liver rupture or liver failure
    - pulmonary edema
    - the HELLP syndrome
    - Disseminated intravascular coagulation (DIC)
  - Mortality 10%

Management of Preeclampsia

- Treat complications:
  - HTN (≥160 systolic or ≥ 110 diastolic)
    - Labetalol, hydralazine, nifedipine, nicardipine
  - Seizures (or risk of)
    - IV magnesium
  - Elevated ICP/ICH
    - Neurosurgical consult, mannitol, hyperventilation etc
  - Pulmonary edema
    - Usually blood pressure control, O2; rarely diuretics (patients usually intravascularly dry because of capillary leak)
    - DIC
  - Delivery!

HELLP Syndrome

- Hemolysis, Elevated Liver enzymes, Low Platelets
- Thought be a subset of Severe Preeclampsia (10-20%)
- Clinical manifestations
  - Usually 3rd TM
  - Abdominal pain, nausea/vomiting
  - 15% won’t have proteinuria or htn
- Management
  - Cornerstone is delivery of fetus
  - ICU level of care often indicated
  - Anti-hypertensives, platelet transfusions
Peripartum Cardiomyopathy

- Incidence: 1 in 3000 to 1 in 15,000

- Diagnostic criteria:
  - Onset within last month of pregnancy or 5 months after delivery
  - Absence of determinable cause
  - Absence of preexisting heart disease
  - LV systolic dysfunction

- Indications:
  - Usual signs/sx of heart failure
  - Cardiomegaly on CXR
  - Dilated cardiomyopathy on TTE

- Cause & pathogenesis remain obscure
  - Viral, autoimmune, familial, idiopathic
  - Posited “over-reaction” to normal alterations in cardiac physiology during pregnancy

- Treatment
  - ACE-inhibitors not safe; caution with beta blockers
  - Hydralazine, Digoxin, Furosemide, nitrates safe
  - Inotropes in severe cases
  - Consider anticoagulation, particularly if EF <30%

Outcome of Peripartum Cardiomyopathy

- Prognosis
  - Largest study of 123 women: 10% mortality, 4% transplanted. 50% had recovery of EF>50% by two years.
  - Predictors of persistent LV dysfunction:
    - LVEF ≤ 30%
    - LVH ejection ≤ 6% or fractional shortening <20%
    - Elevated troponin T
  - Risk of recurrence/worsening with subsequent pregnancy high

Amniotic Fluid Embolism (AFE)

- Poorly-understood
- High maternal/fetal mortality (60-90%)
- Incidence in US: 1 in 20,000-30,000 deliveries
- Pathophysiology: “Anaphylaxis of Pregnancy”
  - Intense inflammatory response to presence of amniotic fluid in maternal circulation
  - Lipid-rich material in AF activates complement → acute lung injury syndrome
  - Severe vasospasm → pulm htn → R then L heart collapse
  - Also has procoagulant factors → coagulation cascade → DIC

Amniotic Fluid Embolism

- Generally occurs during or soon after delivery, but can occur up to 48 hours later
- Clinical Presentation
  - Respiratory distress
  - Cyanosis
  - Cardiovascular collapse
  - Seizures (10-15%) or coma
  - Coagulopathy/hemorrhage
- No specific diagnostic tool
- No specific Rx available
  - Supportive care, restoration of uterine tone
  - 50% of patients die within one hour of onset
- Risk of recurrence is unknown

Tocolytic Pulmonary Edema

- Acute pulmonary edema during/within 24 hrs of receiving β-agonists
  - Terbutaline, Albuterol, Ritodrine
  - Estimated to occur in 6-15%
  - Pathogenesis: Likely multifactorial
    - Pulmonary vasoconstriction, Capillary “leak,” volume overload, reduced oncotic pressure
  - Risk factors
    - Multiple pregnancies
    - Infection
    - Preeclampsia
    - Simultaneous Mg Sulfate
    - Use of corticosteroids for >48 hrs
    - Presence of preexisting cardiac disease
  - Treatment
    - Discontinue tocolytic (if not already done)
    - O2, diuretics, nitrates
Asthma in Pregnancy

- Most common medical condition occurring during pregnancy (8%)
- Women with asthma have higher rates of:
  - Preeclampsia
  - Uterine hemorrhage, Placenta Previa, Hyperemesis
  - Preterm birth
  - IUGR or low-birth weight
  - Perinatal death
- Strong association between asthma control during pregnancy and fetal outcome
- Education is paramount

Thromboembolic Disease in Pregnancy

- Pulmonary embolism is leading cause of death among pregnant or peripartum women in the US
- Affects 1 in 1000 pregnancies in US
- Increased risk of VTE during/after pregnancy: 5-6X
- Risk is higher in post-partum period
- Risk factors:
  - Obesity
  - Older age
  - Personal/family history
  - Inherited thrombophilia
  - Anti-phospholipid antibody syndrome
  - Trauma
  - Cesarean delivery (2X risk of DVT)
  - Immobility
  - Increased parity

Clotting and Pregnancy

- Virchow’s Triad
  1. Stasis: Increased venous capacitance, compression on veins by gravid uterus
  2. Endothelial Injury: Particularly during delivery
  3. Hypercoagulability: Increases in “pro” clotting factors, decrease in protein S
- Diagnosis:
  - Clinical signs/sx non-specific
  - D-dimer not helpful
  - LE doppler Usd, spiral CT>VQ, potential use for MRI (safety not established)
  - DVT’s more likely to arise in the pelvic veins

Management of VTE in Pregnancy

- Treatment
  - Can’t use warfarin in pregnancy
  - Heparins, including LMWH, are safe
  - Prompt initiation of IV heparin with aPTT monitoring
  - Many advocate following anti-Xa level for LMWH
  - Should continue for minimum of three to six months
  - Timing of delivery and cessation of anticoagulation
  - Resume anticoagulation as soon as possible post-partum (6-12 hrs)
  - Role of IVC filters
  - Thrombolysis if life-threatening
Aspiration in Pregnancy

- "Mendelsson's Syndrome"
- Factors leading to aspiration during pregnancy:
  - ↑ abdominal pressure
  - Delayed gastric emptying
  - Relaxed GE sphincter tone
  - Peri-labor factors
- Usually chemical pneumonitis, but can lead to infection or ARDS

Pneumonia in Pregnancy

- 3rd leading cause of maternal death
- No difference in either incidence or mortality
- Decreased cell-mediated immunity may increase susceptibility to viral or fungal pathogens
  - Influenza
  - Varicella
  - Coccidiomyces
- Safe antibiotics in pregnancy: Penicillins, macrolides, cephalosporins, neuraminidase inhibitors, acyclovir
  - Avoid fluoroquinolones, tetracyclines, sulfa, chloramphenicol

When the lungs go bad: ARDS

- ARDS = Acute onset, severe impairment of gas exchange characterized by non-cardiogenic pulmonary edema
- Not common in pregnancy, but high mortality
  - Amniotic Fluid Embolism, aspiration, pneumonia/sepsis, preeclampsia, DIC
- Ventilator strategy adapted, if possible
  - Maintain higher PaO2
  - May be less tolerant of "permissive hypercapnia"
  - If critical, maternal over fetal health

The Particularly-Plagued Pregnancy

- 28 yo woman, 33 6/7 wks pregnant, presents to the ED with dyspnea, cough, and chest tightness.
- PMH notable for asthma, typically managed with albuterol inhaler
  - For last 3 months, describes using MDI 4-5 times a day
  - For last week has been using it “too much” (roughly every 2-3 hrs while awake)

Taking a history:
What do you want to know next?

- What do you need to know in order to categorize her asthma?
  - Frequency/timing of symptoms for previous 4 wks
  - Lung function (FEV1, FEV1/FVC, PFM)
  - Frequency of “rescue” inhaler use
  - Number of exacerbations requiring oral steroids/yr
- Other risk factors:
  - History of intubations/respiratory failure
  - ED visits, hospitalizations
  - Symptom “awareness”
  - Psychosocial factors

Classifying Asthma Severity

- She tells you that she has been having daily symptoms, and wakes at night 3-4 times a week to use her inhaler.
- She is unable to work.
  - FEV1 was 1.67 L (61%), and FEV1/FVC was 66% two weeks ago
  - She does not check her peak flows.
  - She was prescribed steroids but was afraid to take them
Categorizing asthma control

- How would you categorize her asthma control?
  A. Intermittent
  B. Mild persistent
  C. Moderate persistent
  D. Severe persistent

Asthma Severity

Before embarking on therapy....

- What else might you want to know?
  - What medication she's used in the past
  - Whether there are any co-existing risk factors
    - GERD
    - Infectious symptoms, history, contacts
    - Tobacco abuse
    - Allergies
    - Aspiration risk factors
  - What might you want to order?

Additional information

- + chills, +myalgias, green phlegm
- No smoking, GERD, or allergy
- No recent aspiration but intake has been poor
- VS: 38.3 134 140/55 24 94% on RA
  - Appears pale, fatigued
  - Mild "accessory" muscle use
  - Bilateral wheezing at end expiration
  - Regular tachycardia
  - Extremities cool, trace edema

Case, continued:

- WBC 13.9, nl diff
- ABG on 35% VM:
  - 7.40/29/80/18
- What would you do now?
  A. Intubate
  B. Order a CT scan
  C. BIPAP
  D. Albuterol nebs, IV steroids, fl/u ABG in 1 hour

Hospital course, con.

- She spikes a fever to 38.7
- Cultures are performed.
  Which of the following organisms is she at greatest risk for?
  A. Influenza
  B. Mycoplasma
  C. Varicella
  D. Streptococcus Pneumoniae
Gotta bug?

However, she really has Influenza!
Later that day, you note she has decreased wheezing but looks “tired.”
What is the next best step?
A. Let her get some sleep
B. Ask for an ABG
C. Request a CT scan of the chest
D. Ask respiratory to give her an extra nebulizer treatment

ABG shows 7.33/42/70/20 with 94% on 50% VM
Patient is sleeping and looks “comfortable.” Blood pressure is 95/60.
Now what do you do?
A. Increase the O2 back up to 100% NRB mask
B. Give an extra dose of albuterol
C. Call resident to order an additional antibiotic
D. Chest X-ray stat
E. Mobilize to intubate

Preoxygenate
Avoid too much bagging (or place NG)
Smaller ETT
Cricoid pressure
Positioning
Fluids, drugs

Your patient’s follow-up blood gas is 7.45/32/110/24 with 99% on FiO2 50%
The intern says, “We should give her more sedation; she’s breathing too fast.”
What do you say?
A. Yes
B. No
C. Can I call a friend?

Over the next week….
Happily, your patient’s infection improves and she is weaned from the ventilator after 5 days.
She is sent to the OB floor, but ICU is called 5 days later with the report that the patient is short of breath.
What would your differential diagnosis be?
The “Bounce Back”

- Your patient appears to be in acute respiratory distress, breathing 30 times per min
- Oxygen saturation is 93% on 6L NC
- Exam is notable for accessory muscle use, occasional wheeze, rales at the lung bases, and 1+ peripheral edema
- She is on continuous nebulizer treatment
- You convince the patient to have a chest x-ray

Differential Dx: 35 2/7 wks

[Images of chest x-rays]

Differential Diagnosis

<table>
<thead>
<tr>
<th>CXR A:</th>
<th>CXR B:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peripartum cardiomyopathy</td>
<td>Asthma</td>
</tr>
<tr>
<td>Preeclampsia</td>
<td>Venous thromboembolism</td>
</tr>
<tr>
<td>Volume overload</td>
<td>Other</td>
</tr>
</tbody>
</table>

Management, CXR A

- BP is 140/70, HR 133
- Patient is not on tocolytics and has not had any sign of aspiration
- What would you do now?
  A. Intubate and start antibiotics
  B. Immediate delivery
  C. Trial of BIPAP, nitrates, diuretics
  D. Order TTE

Management, CXR B

- BP is 140/70, HR 133
- Patient says “this doesn’t feel like asthma”
- What would you do now?
  A. Intubate
  B. Immediate delivery
  C. Heparin gtt and CT of the chest with PE protocol
  D. Stat albuterol nebs, trial of BIPAP

Particularly-Plagued Pregnancy, continued

- The patient’s CXR looked like “B”
- She received empiric heparin prior to scan
The Happy Ending….

- Our particularly-plagued pregnant patient delivered a healthy baby boy at term
- She continues on anticoagulation, asthma management (inhaled steroid-LABA combination)

Summary & Conclusions

- Complex physiologic alterations occur during pregnancy that serve to protect the mother and fetus from hemodynamic or respiratory derangements
- The spectrum of pulmonary disease in pregnancy is best understood in the context of alterations in cardiopulmonary physiology
- Although thankfully uncommon, pulmonary disease is an important cause of morbidity and mortality in pregnancy

Resources

UptoDate and Google online for figures

Questions?

There are cooler ways to die.