

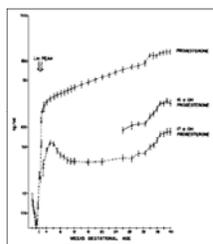
Caring for the Critically Ill Pregnant Patient

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Pulmonary & Critical Care
September 17, 2012

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

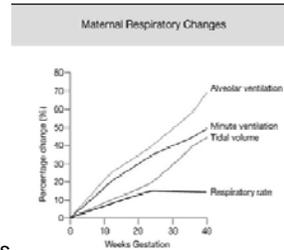
Physiologic Changes in Pregnancy: Cardiopulmonary System



- 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

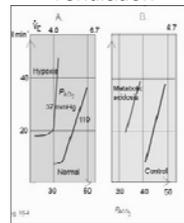
- Early: V_T increases, RR little change \rightarrow increased V_e (hyperventilation)
- Offsets \uparrow metabolic rate
- Net result: \downarrow PaCO₂ 40 \rightarrow 28-32 \rightarrow respiratory alkalosis



Hyperpnea of Pregnancy: Roles of Progesterone

- Progesterone \rightarrow Direct stimulation of respiratory drive
- Progesterone \rightarrow L shift, increased slope of CO₂ response curve = \uparrow "responsiveness"

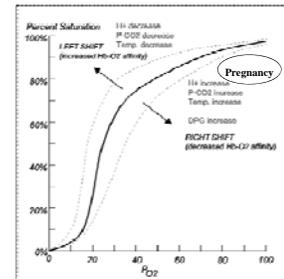
Change in minute ventilation



Red: pregnant patient
Blue: Non-pregnant control

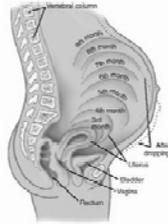
Oxygen Exchange in Pregnancy

- 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, \uparrow 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
 - 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

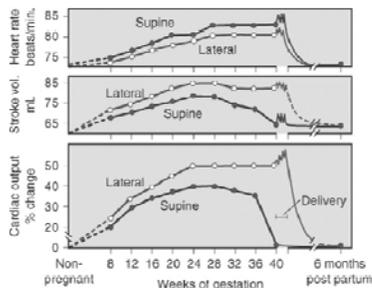
Table 1

Central hemodynamic changes in normal pregnancy

Measurement	Nonpregnant state	Pregnant state
Cardiac output (L/min)	4.3 ± 0.9	6.2 ± 1.0
Heart rate (beat/min)	71 ± 10	83 ± 10
Systemic vascular resistance (dyne × cm × s ⁻⁵)	1530 ± 520	1210 ± 266
Mean arterial pressure (mm Hg)	86.4 ± 7.5	90.3 ± 5.8
Pulmonary capillary wedge pressure (mm Hg)	6.3 ± 2.1	7.5 ± 1.8
Central venous pressure (mm Hg)	3.7 ± 2.6	3.6 ± 2.5
Colloid oncotic pressure (mm Hg)	14.5 ± 2.5	10.5 ± 2.7

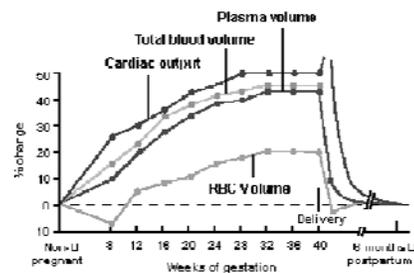
Adapted from Clark SL, Cotton DB, Lee W, Bishop C, Hill T, Southwick J, et al. Central hemodynamic assessment of normal term pregnancy. Am J Obstet Gynecol 1989;161:1441.

Positional Changes in Cardiac Output



Mason: Murray & Nadel's Textbook of Respiratory Medicine, 4th ed.

Cardiovascular changes of pregnancy

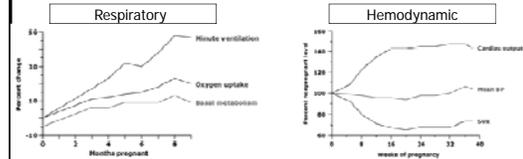


A word on anemia....

Physiologic intravascular change

- Plasma volume increases 50-70 % (begins wk 6)
- RBC mass increases 20-35 % (begins wk 12)
- Disproportionate 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)

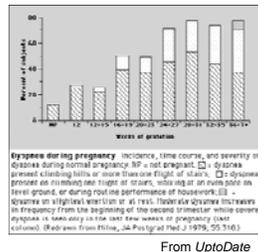
Summary: Changes in Maternal Physiology



- Increased respiratory drive to protect against acidosis, hypoxemia
- Heightened sensitivity to disruptions in CO₂, O₂ exchange
- Increased ability to unload oxygen to the placenta
- ↑ cardiac output & total body volume, ↓ SVR: to protect against hypovolemia (hemorrhage), inadequate nutrient to fetus

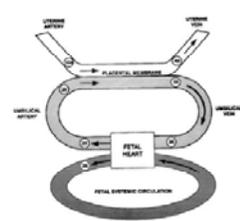
Physiologic Dyspnea of Pregnancy

- **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 is increased → 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

Circulation/AMA guidelines for resuscitation, 2010

Critical Illness in Pregnancy: Causes

Specific to Pregnancy	Peripartum cardiomyopathy
	Preeclampsia/Eclampsia (HELLP)
	Postpartum hemorrhage
Nonspecific (but common)	Amniotic fluid embolism, tocolytic pulmonary edema
	Asthma
	Pulmonary Embolism
	Gastric Aspiration
	Infection/sepsis
	Other: pneumothorax, sleep apnea

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

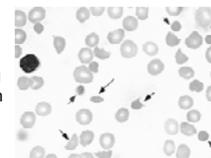
- Definition: Hypertension and proteinuria after 20 wks gestation
 - Eclampsia: above, plus seizure
- US: 5-8% (14% worldwide)
- Pathogenesis not understood: "endothelial dysfunction"
- Reasons for ICU admission:
 - refractory hypertension
 - neurological dysfunction (seizures, ICH, elevated ICP, AMS)
 - 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!

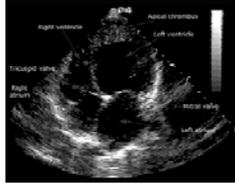
HELLP Syndrome

- 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

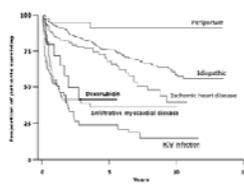
- **Incidence:** 1 in 3000 to 1 in 15,000
- **Diagnostic criteria:**
 - Onset within last month of pregnancy or 5 months after delivery
 - Absence of determinable cause
 - Absence of preexisting heart disease
 - LV systolic dysfunction
- **Indications:**
 - Usual signs/sx of heart failure
 - Cardiomegaly on CXR
 - Dilated cardiomyopathy on TTE



Peripartum Cardiomyopathy

- 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



Elkayam U et. al. Circulation 2005;111(16):2050-5

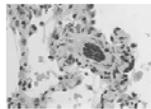
- **Prognosis**
 - Largest study of 123 women: 10% mortality, 4% transplanted. 50% had recovery of EF>50% by two years.
 - Predictors of persistent LV dysfunction:
 - LVEF ≤ 30%
 - LVED volume ≥ 6% or fractional shortening <20%
 - Elevated troponin T
 - Risk of recurrence/worsening with subsequent pregnancy 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**
 - Aspiration of amniotic fluid no longer felt to be diagnostic
- **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

Asthma in Pregnancy

- Most common medical condition during pregnancy
- Pre-pregnancy control is most important factor
- Rule of 1/3's
- Important factors:
 - Changes in physiology
 - Hyperpnea
 - Effects of weight gain
 - Changes in hormones, cortisol
 - Coexistence of GERD, sinusitis/rhinitis, pulmonary edema, PE
 - Medication adherence*
- Early recognition and treatment paramount
 - Early intubation; higher complications; delivery options

When asthma gets bad...

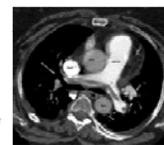


- Most acute exacerbations due to medication non-compliance (not using inhaled steroids: 18% vs. 4%)
- Initiation of inhaled steroids/ β -agonists during hospitalization led to 12% readmission rate vs. 33% in group discharged on β -agonists alone ($p < 0.047$)
- Combination of close maternal and fetal monitoring
- May need to follow PCO_2 and intubate early for impending respiratory failure
 - If RA O_2 saturation is $< 95\%$, if PEF $< 70\%$, or if fetal compromise, consider ICU
- Consider early delivery if fetal maturity permits

Pereira, A. and B. Krieger. Clin Chest Med 25 (2004)

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

Table 1. Assessment of Asthma Control in Pregnant Women.¹⁰

Variable	Well-Controlled Asthma	Asthma Not Well Controlled	Very Poorly Controlled Asthma
Frequency of symptoms	≤2 days/wk	>2 days/wk	Throughout the day
Frequency of nighttime awakening	≤2 times/mo	1-3 times/wk	≥4 times/wk
Interference with normal activity	None	Some	Extreme
Use of short-acting β-agonist for symptoms control	≤2 days/wk	>2 days/wk	Several times/day
FEV ₁ or peak flow (% of the predicted or personal best value)	>80	60-80	<60
Exacerbations requiring use of systemic corticosteroid (no.)	0-1 in past 12 mo		≥2 in past 12 mo

Schatz, et al. *NEJM*. 360:1862-1869, 2009

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, f/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?

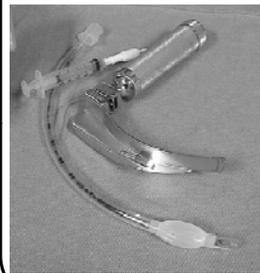
 - A. Influenza
 - B. Mycoplasma
 - C. Varicella
 - D. Streptococcus Pneumoniae

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



A.



B.

Differential Diagnosis

CXR A:

- Peripartum cardiomyopathy
- Preeclampsia
- Volume overload
- ARDS

CXR B:

- Asthma
- Venous thromboembolism
- Other

Management, CXR A

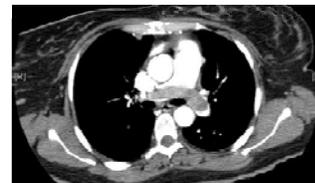
- BP is 140/70, HR 133
- Patient is not on tocolytics and has not had any sign of aspiration
- What would you do now?
 - A. Intubate and start antibiotics
 - B. Immediate delivery
 - C. Trial of BIPAP, nitrates, diuretics
 - D. Order TTE

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

Questions?



**There are cooler
ways to die.**

Resources

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