Physiologic Changes in Pregnancy

POS March 16, 2011

Presenters: Marisa Horniachek, Lea Luketic, Karen Macmillan and Jessica Rollings-Scattergood (OB GYN 1)
Case

28 year old G2T1L1 at 24\(^{+3}\) weeks GA presents to ER with nausea, vomiting and right lower quadrant pain,

- **Pregnancy history**- Uneventful, with early nausea treated with Diclectin, U/S at 18 weeks- normal, Blood type- A Rh+, VDRL/HbsAg/HIV- negative
- **PMHx**- Nil, no surgeries
- **Medications**- Prenatal vitamins, NKDA
- **Physical Exam**- AVSS, CVS and Resp- normal, Abdominal exam reveals tenderness and guarding in the right lower quadrant

- **Differential Diagnosis**- ?, During workup must understand what is normal in a pregnancy
Pregnancy is a normal healthy condition and simultaneously the most common altered physiologic state to which human beings are subject to.
Objectives

- Identify the common physiologic changes of each organ system in pregnancy
- Identify the pathologic vs. physiologic changes
- What to expect when ordering diagnostic tests
- Understand how to proceed with a pregnant surgical patient
- Special considerations
Introduction

• Maternal physiologic adjustments in pregnancy occur to support the requirements of fetal homeostasis without jeopardizing maternal well being

• Maternal systems remodel to deliver substantial energy to the fetus and remove inappropriate waste products

• The normal values for many hematologic, biochemical and physiologic indices during pregnancy differ markedly from those in the non-pregnant range

• Important to understand these changes as pregnant patients can present with non-pregnancy related surgical emergencies

• Unique challenge as two patients to be cared for
Cardiovascular System

- **Cardiac output** and **blood volume** increase to meet maternal and fetal metabolic demands
  - At term the blood volume has increased by 1000-1500 ml in most women
    - Each additional multiplet (twin/triplet) adds 500 cc of blood volume
  - Cardiac chambers enlarge and myocardial hypertrophy is often noted on echocardiogram
Cardiovascular System specifics

• Increased **cardiac output** (40 % at term) is due to both increase in **HR** (15-30%) and **SV** (30%)
  • Resting tachycardia needs assessment

• **Blood pressure** - increase in CO, but **decrease in systemic vascular resistance** will result in decrease in **mean arterial pressure**
  • Decrease in **systemic vascular resistance** by the second trimester decreases both diastolic and, to lesser degree, systolic blood pressure
  • Beware of a high blood pressure in pregnancy

• Enlarging uterus compresses IVC and pelvic veins
  • Decreased venous return (hypotension)
  • Increased venous pressure (varicose veins, **hemorrhoids** and leg edema)
CVS physical exam findings/Investigations

Physical Exam
- Decreased BP - postural hypotension can occur
- Increased HR
- Heart sounds
  - Systolic flow murmurs
  - Diastolic murmurs should be considered potentially pathologic
  - 3rd heart sound can occur after mid pregnancy
- Peripheral edema

EKG changes
- Increased HR, LAD, Inverted T waves in Lead III, Q waves in Lead III and AVF and unspecific ST changes

Echocardiogram
- Myocardial hypertrophy
Respiratory System

Major respiratory changes in pregnancy involve three factors:

1. **Mechanical**- Effects of the enlarging uterus with diaphragm displacement

2. **Consumption**- Increased need for oxygen

3. **Stimulation**- Progesterone acts as a respiratory stimulant
Respiratory mechanics in pregnancy

Diaphragm rises 4 cm
• Less negative intrathoracic pressure
• Decreased Functional Residual Capacity
• Decreased Expiratory Reserve Volume
• Decreased Residual Volume

No impairments in diaphragmatic or thoracic muscle motion
• Lung compliance remains unaffected
Consumption

- Oxygen consumption increases by 15-20%
- 50% of this increase is required by uterus
- Despite increase in oxygen requirements with the increase in CO and increase in alveolar ventilation oxygen consumption exceeds the requirements
- Arterial PCO₂ falls

Stimulation

- Progesterone directly stimulates ventilation
- It also increases the sensitivity of the respiratory centers to CO₂
Additional respiratory points

Minute ventilation = Respiratory rate x Tidal Volume

- Tidal volume increases and RR stays same, so therefore minute ventilation increases
- Vital capacity - remains unchanged

Dyspnea of pregnancy

- Common symptom in pregnancy
- Up to 60-70% of women will experience at some point in their pregnancy
- Mechanism not established but may involve increased sensitivity and lower threshold to PCO₂
Hematological System

Pregnancy leads to a **hypercoagulable state and increased risk of thromboembolic disease**, due to

- Increased factors VII, VIII, X and XII
- Increased fibrinogen and FDPs
- Decreased fibrinolytic activity
- Decreased antithrombin III

**Other hematologic changes:**

- Increased WBC (up to 21)
- Platelets decrease by 10-20%

*In addition to hypercoagulable state venous stasis occurs- DVT/PE*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Nonpregnant</th>
<th>Pregnant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activated PTT (sec)</td>
<td>31.6 +/- 4.9</td>
<td>31.9 +/- 2.9</td>
</tr>
<tr>
<td>Thrombin time (sec)</td>
<td>18.9 +/- 2.0</td>
<td>22.4 +/- 4.1</td>
</tr>
<tr>
<td>Fibrinogen (mg/dL)</td>
<td>256 +/- 58</td>
<td>473 +/- 72</td>
</tr>
<tr>
<td>Factor VII (%)</td>
<td>99.3 +/- 19.4</td>
<td>181.4 +/- 48.0</td>
</tr>
<tr>
<td>Factor X (%)</td>
<td>97.7 +/- 15.4</td>
<td>144.5 +/- 20.1</td>
</tr>
<tr>
<td>Plasminogen (%)</td>
<td>105.5 +/- 14.1</td>
<td>136.2 +/- 19.5</td>
</tr>
<tr>
<td>Antithrombin III (%)</td>
<td>98.9 +/- 13.2</td>
<td>97.5 +/- 33.3</td>
</tr>
<tr>
<td>Protein C (%)</td>
<td>77.2 +/- 12.0</td>
<td>62.9 +/- 20.5</td>
</tr>
<tr>
<td>Total Protein S (%)</td>
<td>75.6 +/- 14.0</td>
<td>49.9 +/- 10.2</td>
</tr>
</tbody>
</table>
Dilutional Anemia

- Increase in plasma volume

- **Increase in red blood cell mass** (lesser degree than increase in plasma volume)

- Results in a physiologically lowered hemoglobin, hematocrit and red blood cell count (no change in MCV)- different thresholds during pregnancy

**Fe deficiency anemia** - make up majority of causes of anemia in pregnant women - can start women on Fe replacement
Genitourinary System

Anatomical Changes

- Kidneys increase in length by 1-1.5cm
- Dilatation of renal calyces, renal pelvices and ureters
- Uterus can compress ureters at pelvic brim
- Due to dextrrotation of the uterus the right sided collecting system tends to be more dilated than left
- These changes lead to physiologic obstruction and urinary stasis, which results in an elevated risk for pyelonephritis, even in asymptomatic bacteriuria

*Pyelonephritis* is the number one cause of non-pregnancy related hospital admission in a pregnant patient

Copyright © The McGraw-Hill Companies, Inc. All rights reserved.

Hydronephrosis. Plain film from the 15-minute image of an intravenous pyelogram (IVP). Moderate hydronephrosis on the right (arrows) and mild hydronephrosis on the left (arrowheads) are both normal for this 35-week gestation.
Physiologic Changes

- GFR increases
- Decrease in BUN and CR
- Increase in **urinary protein excretion**
- Although filtered load of sodium increases, the increase in tubular reabsorption leads to a net retention of sodium
- Glucosuria occurs because of increased GFR and decreased distal reabsorption
- Significant water retention- intravascular volume expands by 1-2L and extravascular by 4-7L. This results in a decrease in plasma sodium and in plasma osmolality
Gastrointestinal System

- Anatomic alterations secondary to displacement from uterus
- Increased intragastric pressure resulting in heartburn and hiatus hernia
- Appendix displaced superiorly and laterally (T2/T3)
- Increased incidence of hemorrhoids

- Physiologic changes are mediated by the smooth muscle relaxant effects of **progesterone**
- Decreased LES tone --> GERD and heartburn
- Decreased gastric and small bowel motility resulting in delayed gastric emptying
- Increased anesthetic risk --> regurgitation and aspiration
Hepatobiliary Changes

Anatomic
- Liver is shifted up and posteriorly
- Spider nevi and palmar erythema may be normal findings
- Dilation of the gallbladder and biliary duct system caused by progesterone
- Progesterone also inhibits cholecystokinin resulting in decreased gallbladder motility and bile stasis
- Increased incidence cholelithiasis

Laboratory Changes
- AST, ALT, GGT, bili are normal or slightly decreased
- PT and LDH levels are unchanged
- Albumin levels are decreased
- ALP levels increase
Endocrine and Metabolic Changes

Pituitary Gland
- Enlarges up to 135%
- Increased production of plasma growth hormone and prolactin

Thyroid
- Relative **iodine deficiency**
- Glandular hypertrophy (frank goiter however is not normal)
- Thyroid binding globulin increases due to estrogen effects
- Increase in total and bound T3 and T4 (free remains normal)
- TSH levels fall slightly in 1st trimester then recover later in pregnancy (changes in TSH due to α-HCG subunit)
- Practically this means that T3 and T4 is less helpful during pregnancy, use TSH
Endocrine and Metabolic Changes

Adrenal Glands
• Increased serum cortisol
• Increased serum aldosterone
• Increased adrenal androgens

Pancreas
• Beta cells undergo hyperplasia resulting in increased insulin secretion
• Peripheral insulin resistance increases throughout pregnancy
Immune System

• Decreased cellular immunity, with increase in humoral, or antibody mediated immunity

• This results in increased susceptibility to intracellular pathogens

• Cell mediated auto-immune diseases often improve during pregnancy
Musculoskeletal Changes

• Average 25-35 pound weight gain (vary depending on pre pregnancy weight)
• Increased force across joints
• Low back lordosis, forward neck flexion, widened stance
• Joint laxity
• Fluid retention can result in compression of nerves (eg carpal tunnel syndrome)
• These changes frequently result in pain, especially in the lower back
"The Faberge Egg"
aka The pregnant patient requiring non-obstetrical surgery

• 2 patients with unique vulnerabilities

• Need a heightened sense of awareness and avoid indecision or delay in treatment

• Delay in treatment can be the greatest danger in relation to morbidity and mortality

• Need to be aware of unique circumstances associated with each trimester of pregnancy

• Weigh the possible adverse effects on the fetus against the maternal risks of delaying the surgery

• Preop consultation between surgeon, anaesthesiologist, obstetrician and neonatologist
Common Indications for Surgery

- Acute appendicitis
- Biliary Disease
- Trauma
- Breast
- Bowel obstruction
- Ureteric stenting
Diagnostic imaging during pregnancy

- Safety of radiation to fetus is often concern but risk of delayed diagnosis can be greater risk
- Ultrasound and MRI are preferred if appropriate for confirmation of diagnosis
- Effects on fetus depend on gestational age, dose of radiation and fetal cellular repair mechanisms
- Radiation exposure of up to 5 rads is not associated with increased fetal anomalies, intellectual disability, growth restriction, or pregnancy loss
## Fetal Radiation Exposure

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Fetal Dose (mrads)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest Xray (PA and lateral)</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Abdominal plain film</td>
<td>200 to 300</td>
</tr>
<tr>
<td>Intravenous pyelogram</td>
<td>400 to 900</td>
</tr>
<tr>
<td>Barium enema</td>
<td>700 to 1600</td>
</tr>
<tr>
<td>Cervical spine Xray</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Dorsal spine Xray</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Lumbar spine Xray</td>
<td>400 to 1600</td>
</tr>
<tr>
<td>Upper GI series</td>
<td>50 to 400</td>
</tr>
<tr>
<td>Hip and femur Xray</td>
<td>100 to 400</td>
</tr>
<tr>
<td>Dental Xray</td>
<td>0.01</td>
</tr>
<tr>
<td>Mammography</td>
<td>negligible</td>
</tr>
<tr>
<td>Cerbral angiography</td>
<td>&lt;10</td>
</tr>
<tr>
<td>CT of Chest</td>
<td>30</td>
</tr>
<tr>
<td>CT of the abdomen</td>
<td>250</td>
</tr>
<tr>
<td>Perfusion of Lung scan</td>
<td>6-12</td>
</tr>
<tr>
<td>Ventilation lung scan</td>
<td>1-19</td>
</tr>
<tr>
<td>Pulmonary angiography via femoral route</td>
<td>221 to 374</td>
</tr>
<tr>
<td>Pulmonary angiography via brachial route</td>
<td>&lt;50</td>
</tr>
</tbody>
</table>
Surgical Issues

- Potential concerns include teratogenesis, miscarriage, hemorrhage, infection, aspiration, preterm labor/delivery

- Data is based off of observational studies, expert opinion and extrapolation from trials in nonpregnant individuals

- If fetus is at viable gestation, staff should be on hand in case an emergent c-section be necessary
Timing

- If possible wait until pregnancy is over

- If not possible....
  - **Second trimester is optimal**
    - Uterus is smaller
    - Organogenesis is complete
    - Lower rate of pre-term labour - 1% vs 9% in third
  - **First trimester**
    - Risk of miscarriage
      - Not clear if risk is increased due to underlying process itself or surgery but delay if possible
    - Organogenesis is ongoing
    - Teratogenesis
  - **Third trimester**
    - Increased risk of pre-term labour and delivery
Glucocorticoids

- Any surgery performed between 24-34 weeks should be considered for antenatal glucocorticoids
- Reduce perinatal morbidity/mortality if pre-term delivery should occur
- 12 mg doses of betamethasone given IM 24 hours apart
- Avoid in systemic infection - sepsis or ruptured appendix *
Positioning

- Gravid uterus causes aortocaval compression
  - Decreases venous return
  - Cardiovascular compromise

- Over 18 - 20 weeks

- Keep patient in 15 percent lateral tilt if possible
  - or
- Right hip wedge
Surgical Approach

- Laparoscopic carries the same benefits as in the non-gravid patient (uterine perforation with veress and trochar a concern)
- If open to be preformed - vertical incision generally allows for better exposure
- Also depends on the skills of the surgeon
Fetal Heart Rate Monitoring

- In non-viable fetus
  - Document pre and post op FHR

- Viable fetus
  - Intraoperative FHR monitoring should be individualized (not used most often)
  - Recommend in those greater then 23-24 weeks

- Can be helpful for anesthesia to optimize uteroplacental oxygen
  - Ensure no aortocaval compression
  - Increase maternal hypoxia
  - Normocarbia
  - Correct hypovolemic and hypotension

- FHR shows decreased variability during anesthesia and may demonstrate baseline decrease in rate
Thromboprophylaxis

• Pregnancy is a hypercoagulable state

• Pneumatic compression devices

• Determine need for medical thromboprophylaxis based on specific case
  o surgery
  o thrombophilia
  o length of surgery
  o immobilization
  o previous history of DVT
  o malignancy
  o DM
  o varicose veins
  o paralysis
  o obesity
  o what would you do for a non-gravid patient?

  o Safe to use heparin/fragmin in pregnancy
Anesthesia Issues

• Regional if possible
• Avoid hypotension
• Maintain oxygentation
  o risk of desaturation
    ▪ 9 min vs 3 min (100%-90%), made worse with obesity 98sec
  o preoxygenate
• Avoid hypercarbia
• Higher rate of failed intubation due to changes in airway and edema
• Increased risk of aspiration
  o prophylaxis
    ▪ sodium citrate to maintain gastric pH >3
    ▪ histamine receptor antagonists
    ▪ metoclopramide
    ▪ nonparticulate antacids
  o no solid food x6h, liquids x2h
  o cricoid pressure and RSI
Appendicitis Case Considerations

- Most common cause of acute abdomen in pregnancy (1:1500)

- Typical presentation: colicky epigastric or periumbilical pain localizing to right side of abdomen

- Appendix migration during pregnancy needs to be considered when evaluating pain location

- Anorexia and vomiting are non-specific indicators and fever is often not present

- Laboratory values not reliably predictive but WBC <10 gives reassurance

- Ultrasound is accurate for diagnosis in 1st and 2nd trimester but technically difficult 3rd trimester

- If think that appendicitis has occurred - operate

- If perforation occurs, fetal loss rate may be as high as 36% allowing for a higher negative exploration rate
Conclusions

• Many changes occur in the pregnant patient- important to understand the normal changes so can workup patient and interpret investigations as well as provide optimal care

• Pregnant patients can definitely have non-pregnancy related issues- may have to provide care for pregnant patient!

• Multidisciplinary approach will be necessary
References

- Cox, S. Williams Obstetrics. 22nd ed. McGraw Hill, 2005


- [www.uptodate.com](http://www.uptodate.com)