Pregnancy, CT & Radiation Risk
33 week gestation
Acute abdominal pain
Case # 1

28 y/o woman in 10th week of pregnancy
Hx: Acute shortness of breath

Request: **CT pulmonary angiogram**
Case # 2

35 y/o woman pregnant at 32 weeks GA

Hx: Severe abdominal pain

Suspect appendicitis

Request: CT abdomen/pelvis
Case # 3

42 y/o woman pregnant at 22 weeks GA
Hx: Right flank pain
    Suspect kidney stone
Request: Stone Protocol CT
Case # 4

20 y/o woman pregnant at 8 weeks GA
Hx: Fell and injured right knee

Request: Radiographs - right knee series
Case # 5

31 y/o woman pregnant at 12 weeks GA
Hx: High speed motor vehicle collision

Request:  
- CXR & AP Pelvis radiographs
- Cervical spine
- Left hip & left femur
- Rt shoulder, humerus, elbow, wrist
- CT Head
- CTA Chest
- CT Trauma Abd/Pelvis
Medical Care during Pregnancy

• 2 patients: Mother & Fetus
• No fetal survival without maternal survival
• Perceived risk vs.
• Perceived benefit
• We may not always agree with the ER physician
Harmful Effects of Radiation to the Fetus

- Prenatal death
- Intrauterine growth restriction
- Mental retardation
- Organ malformation
- Cancer during childhood
Harmful Effects of Radiation to the Fetus

• Risk of each effect depends on:
  – Gestational age at time of exposure
  – Total fetal dose throughout gestation
Radiation Risk to the Fetus

Highest in the First Trimester

Less in the Second Trimester

Least in the Third Trimester
Radiation Dose

• A measurement of the energy absorbed by tissue from a beam of radiation

• Absorbed dose to the fetus
  – Measured in gray (Gy) or rad
  – 1 gray = 100 rads

• Measurements that consider the type of radiation
  – Sievert (Sv) or rems
  – 1 Sievert = 100 rem
  – 1 Sievert = 1 gray for x-ray & gamma radiation
Radiation Dose to the Fetus

• **Uterus is outside the field of view:** the fetus is exposed to scattered radiation only and the radiation dose is minimal

• **Uterus within the field of view:** dose depends on:
  - Thickness of the patient
  - Depth of the conceptus from skin
  - X-ray technique
  - Direction of the beam
# Radiation Dose to the Fetus

## CT Examination (16s MDCT)

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Dose Range</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head CT (routine)</td>
<td>0-0.1</td>
<td>mGy</td>
</tr>
<tr>
<td>Chest CT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Routine</td>
<td>0.2</td>
<td>mGy</td>
</tr>
<tr>
<td>CTPA</td>
<td>0.2-0.6</td>
<td>mGy</td>
</tr>
<tr>
<td>Abdomen CT (routine)</td>
<td>4</td>
<td>mGy</td>
</tr>
<tr>
<td>Abdomen/pelvis CT</td>
<td>12-25</td>
<td>mGy</td>
</tr>
<tr>
<td>Stone protocol (Low dose)</td>
<td>10-12</td>
<td>mGy</td>
</tr>
<tr>
<td>CTA aorta (CAP)</td>
<td>34</td>
<td>mGy</td>
</tr>
</tbody>
</table>

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**References**

- Hurwitz AJR 2006;186:871-876
- Wedegartner Rofo 2003;175:234
- Moore AJR 2006;187:498-502
- www.safety.duke.edu
- Patel RadioGraphics 2007;27:1705
### Radiation Dose to the Fetus

**Radiography in the Pregnant Patient**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Dose (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremities</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Chest (PA, Lat)</td>
<td>0.002</td>
</tr>
<tr>
<td>Cervical spine (AP, Lat)</td>
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<tr>
<td>Thoracic spine (AP, Lat)</td>
<td>0.003</td>
</tr>
<tr>
<td>Lumbar spine (AP, Lat)</td>
<td>1-3.4</td>
</tr>
<tr>
<td>Abdomen (AP) 21-cm</td>
<td>1</td>
</tr>
<tr>
<td>33-cm thick patient</td>
<td>3</td>
</tr>
<tr>
<td>Pelvis</td>
<td>1.7</td>
</tr>
<tr>
<td>Hip</td>
<td>1.3</td>
</tr>
<tr>
<td>Barium enema</td>
<td>7-39</td>
</tr>
<tr>
<td>Small bowel study</td>
<td>7-39</td>
</tr>
</tbody>
</table>
# Threshold Fetal Doses

**Best Estimates**

**No radiation dose is proven absolutely safe.**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Most Sensitive</th>
<th>Threshold Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prenatal death</td>
<td>0-8 days</td>
<td>No data</td>
</tr>
<tr>
<td>Growth retardation</td>
<td>1-8 weeks</td>
<td>200 mGy</td>
</tr>
<tr>
<td>Organ malformation</td>
<td>2-8 weeks</td>
<td>250 mGy</td>
</tr>
<tr>
<td>Mental retardation</td>
<td>8-15 weeks</td>
<td>100 mGy</td>
</tr>
<tr>
<td>Reduced IQ</td>
<td>8-15 weeks</td>
<td>100 mGy</td>
</tr>
<tr>
<td>Childhood cancer</td>
<td>0-13 weeks</td>
<td>No threshold</td>
</tr>
</tbody>
</table>

1 childhood cancer/500 fetuses exposed to 30 mGy

McCollough RadioGraphics 2007;27:909
Patel RadioGraphics 2007;27:1705
“Acceptable Dose to Fetus”

- National Council on Radiation Protection and Measurement (1977)
- American College of Obstetrics & Gynecology

< 50 mGy
< 5 rads

*Cumulative maximum fetal dose during pregnancy
No single study exceeds 5 rads
American College of Radiology

- No routine radiographic diagnostic study exceeds the “acceptable” dose for the fetus.
- Therapeutic radiographic procedures commonly exceed 5 rad fetal dose.
- Cumulative exposure from multiple radiographic studies may exceed 5 rads.
Additional Considerations

Lead Shielding

• Radiography
  – Less collimation
  – More scattered radiation in the room
  – Shield the pelvis whenever possible

• CT
  – Tightly collimated beam
  – Very little scattered radiation in the room
  – Radiation exposure to the fetus comes from scatter of radiation within the mother
Radiography
- External scattered radiation is very low
- Lead shielding is routinely recommended

CT
- External scattered radiation is minimal
- ? Lead shielding may increase fetal dose by impairing exit of internal scattered radiation
- Some institutions recommend shielding, many do not (MGH does, Duke does not)

Lead shielding offers the patient a sense of protection & reassurance
Additional Considerations

**Contrast Agents**

- Both iodinated contrast & gadolinium cross the placenta
- Agents appear in the fetal bladder within 11 min of maternal IV injection
- Excreted into urine > amniotic fluid > swallowed by the fetus
- Cycled innumerable times
Additional Considerations

Iodinated Contrast Agents

- Limited number of investigations on safety
- No proven teratogenic effect
- Risk of contrast-induced hypothyroidism in fetus
  - Screen exposed fetus for hypothyroidism after birth
- Not proven to be safe
- Document need for the study
  - Risk of radiation
  - Risk of contrast
- ACR recommends obtaining informed consent
Additional Considerations

Gadolinium

- Safety of use for the fetus is not proven
  - Even less experience & research than with iodinated agents
  - No mutagenic or teratogenic effects have been demonstrated
- FDA: Gadolinium agents are not recommended during pregnancy
- European Society of Radiology: Gadolinium agents are probably safe in pregnancy but should be used only when the diagnostic study is important to the health of the mother.
- “Should be used only if critical to the health of the mother"
Case # 1

Pulmonary Embolism in Pregnant Patient

• Pulmonary embolism is a leading cause of maternal death in pregnancy.
• Pulmonary embolism is 5x more common in pregnancy
• Treatment with anticoagulants is associated with maternal & fetal morbidity
• D-dimer values are not useful in pregnancy
• Accurate diagnosis is critical

Hurwitz AJR 2006;186:871-876
Matthew Br J Rad 2006;79:441-444
Case # 1

Pulmonary Embolism in Pregnant Patient

- Compression US of lower extremities is recommended as the initial study.
- 95% sensitive, 98% specific for DVT in the thigh
- Treatment for DVT & PE are the same
- Does not evaluate pelvic veins
- DVT in pelvic veins is more common in pregnant patients
- Negative DVT-US warrants further testing
Case # 1
Pulmonary Embolism in Pregnant Patient

Dose to Fetus

CTPA  0.6 mGy
V/Q scan  0.2-0.36 mGy

Dose to the Breasts

CTPA  14-20 mGy
(≈25-50 mammograms)

Hurwitz AJR 2006;186:871-876
Matthew Br J Rad 2006;79:441-444
Case # 1

Pulmonary Embolism in Pregnant Patient

Conclusions

• 1st: Perform DVT-US of lower extremities
• If negative, CTPA can be performed with minimal radiation exposure to the fetus
  – Limit radiation dose
  – Terminate scan at xiphoid process
  – Exclude upper abdomen from scan
• Obtain informed consent for contrast administration
• Do not perform CT venography of pelvis and lower extremities
Case # 2

Appendicitis in Pregnant Patient

• Undiagnosed appendicitis may be devastating to both the mother & the fetus
  – Increased rate of perforation
  – Associated with premature labor
  – Increased fetal morbidity & mortality

• Surgery for appendicitis also has risks
  – Preterm labor
  – Fetal loss
  – Decreased birth rate

Patel RadioGraphics 2007;27:1705
Hurwitz AJR 2006;186:871-876
Case # 2

Appendicitis in Pregnant Patient
Diagnostic Options

- US of the appendix is difficult in the 1st trimester and may be impossible in the 3rd trimester
  - Superior migration of appendix in pregnancy
  - May provide alternative diagnosis (Ov cyst)
- MR (without gadolinium) is a preferable alternative
  - High sensitivity (~100%) & specificity (94%)
- CT is second line study
  - If MR is contraindicated
  - Dose to fetus: 20-40 mGy
  - 1 cancer/500 fetuses exposed to 30 mGy

Patel RadioGraphics 2007;27:1705
Hurwitz AJR 2006;186:871-876
Renal Stone Disease in Pregnant Patient

- Most common of abdominal pain in pregnant patient
  - 70-80% of ureteral stones will pass spontaneously
  - Complications: pyelonephritis, premature labor
- US usefulness is limited
  - Insensitive in the diagnosis of ureteral stones
  - Difficult to differentiate obstruction from physiological hydronephrosis of pregnancy
  - RI > 70%, unilateral absence of ureteral jet
- MR urography - limited experience
  - Perirenal fluid & renal enlargement differentiate obstruction from physiologic hydronephrosis
  - Insensitive to detection of small calculi

Patel RadioGraphics 2007;27:1705
Hurwitz AJR 2006;186:871-876
Case # 3
Renal Stone Disease in Pregnant Patient

• Low dose non-contrast CT is highly accurate in diagnosis of ureteral calculi
  – 95% sensitivity, 98% specificity
  – Low dose protocol with 16-row MDCT
  – 160 mA, 140 kVp
  – Dose to the fetus = 10-12 mGy
Case # 3
Renal Stone Disease in Pregnant Patient
Conclusions

- Start with US
  - Look for signs of appendicitis or alternate diagnosis
  - Ureteral jets, RI > 70%
- Low dose protocol non-contrast CT is 2nd line imaging test
- ? MR urography

Patel RadioGraphics 2007;27:1705
Hurwitz AJR 2006;186:871-876
# Case # 4

Radiography in the Pregnant Patient

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</tr>
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</table>
Case # 4
Radiography in the Pregnant Patient
Conclusions

- Routine radiography that does not include the fetus (maternal pelvis) within the field of view causes very little radiation exposure to the fetus.
- Lead shielding of the pelvis should routinely be used.
- Requested radiographic studies that include the fetus within the field of view should be carefully reviewed for imaging alternatives.
Case # 5

Trauma in the Pregnant Patient

31 y/o woman pregnant at 12 weeks GA
Hx: High speed motor vehicle collision

Request:  
CXR & AP Pelvis radiographs
Cervical spine
Left hip & left femur
Rt shoulder, humerus, elbow, wrist
CT Head
CTA Chest
CT Trauma Abd/Pelvis
Case # 5

Trauma in the Pregnant Patient

• 7% of pregnant patients sustain an accidental injury
• Trauma is the leading nonobstetric cause of maternal death - No fetal survival without maternal survival
• Fetal death rate is 80% in setting of maternal shock
• Common obstetric complications:
  ▪ Uterine contractions
  ▪ Premature labor
  ▪ Placental abruption
Case # 5
Trauma in the Pregnant Patient
Approach - US

- Use US to assess the status of the pregnancy
  - Fetal number, cardiac activity, heart rate
  - Gestational age
  - Status of the placenta (abruption)
  - Free fluid in maternal abdomen
  - Limited use in assessing maternal organ injury
Case # 5

Trauma in the Pregnant Patient
Approach - Radiography

• Keep total combined radiation exposure as low as possible (< 50 mGy)
• Shield the fetus for maternal radiography
• Requested radiography
  – CXR  0.002 mGy
  – AP Pelvis  1.7 mGy (? necessity)
  – Extremities  <0.001 mGy
  – C-spine  <0.001 mGy (? necessity)
  – T-spine  0.003 mGy (? necessity)
  – L-spine  1-3.4 mGy (? necessity)
Case # 5

Trauma in the Pregnant Patient

Approach - CT

- Keep total combined radiation exposure as low as possible (< 50 mGy)
- Use CT as needed to assess the extent of maternal injuries
  - Limit range of scan
  - Limit scout views
  - Use lowest practical dose
- Shielding of the fetus is optional
Case # 5

Trauma in the Pregnant Patient
Approach - CT

- Requested CT
  - Head CT 0-0.1 mGy
  - Chest CT 0.2-0.6 mGy (Recon T-spine)
  - Abdomen CT 10-20 mGy (Recon L-spine)
  - Pelvic CT 20 mGy (Recon Pelvis)
  - Extremity CT 0-0.1 mGy
Summary

• Both the mother & the fetus are your patients
• Confirm definite need for study
• ALARA - As Low As Reasonably Achievable
  – Consider alternative study
  – Limit radiation dose each study - Use 16 slice MDCT
  – Limit total number of studies
• Avoid IV contrast administration if possible
  – Advise thyroid function study in neonate if used