OBJECTIVES

• Discuss the effects of ionizing radiation on the fetus
• Evaluate specific risks of each imaging modality
• Discuss the use of contrast agents in CT and MR in pregnant and lactating patients
• Review current recommendations for the diagnostic work-up of common clinical scenarios encountered in pregnancy
INTRODUCTION

• Use of radiologic examinations in pregnant women has more than doubled in the past decade in the US (Kwan JAMA 2019)
• Most of what we know about radiation effects is based on atomic bomb survivors and radiation disasters
• Widespread confusion about the safety of imaging modalities in pregnancy amongst ordering providers and radiologists
• Results in the unnecessary avoidance of useful diagnostic tests or interruption in breastfeeding
• **Spontaneous abortion**
  • Radiation exposure greater than 50-100 mGy before implantation may cause embryonic demise.
  • If successful implantation, no consequence to fetus (all-or-none effect)

• **Teratogenesis**
  • Fetal malformation, microcephaly, IUGR, decreased IQ
  • Deterministic (nonstochastic) – **threshold** radiation must be crossed, around 100 mGy
  • Highest risk from radiation between 8-15 weeks gestation due to rapid neuronal development and migration
Carcinogenesis

- Stochastic (nondeterministic) – random DNA mutations, can occur at any radiation dose
- Linear no-threshold model – no minimum dose, with increased risk for higher radiation doses
- Difficult to predict cancer risk at radiation doses less than 100 mGy
- Relative risk of fatal cancer may be doubled after 50 mGy fetal exposure
  - Baseline risk is low – odds go from 1 in 2000 (baseline) to 2 in 2000
Table 1: Summary of Suspected In Utero Induced Deterministic Radiation Effects*[4,5]

<table>
<thead>
<tr>
<th>Menstrual or Gestational age</th>
<th>Conception age</th>
<th>&lt;50 mGy (&lt;5 rad)</th>
<th>50–100 mGy (5–10 rad)</th>
<th>&gt;100 mGy (&gt;10 rad)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–2 weeks (0–14 days)</td>
<td>Prior to conception</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>3rd and 4th weeks (15–28 days)</td>
<td>1st–2nd weeks (1–14 days)</td>
<td>None</td>
<td>Probably none</td>
<td>Possible spontaneous abortion.</td>
</tr>
<tr>
<td>5th–10th weeks (29–70 days)</td>
<td>3rd–8th weeks (15–56 days)</td>
<td>None</td>
<td>Potential effects are scientifically uncertain and probably too subtle to be clinically detectable.</td>
<td>Possible malformations increasing in likelihood as dose increases.</td>
</tr>
<tr>
<td>11th–17th weeks (71–119 days)</td>
<td>9th–15th weeks (57–105 days)</td>
<td>None</td>
<td>Potential effects are scientifically uncertain and probably too subtle to be clinically detectable.</td>
<td>Risk of diminished IQ or of mental retardation, increasing in frequency and severity with increasing dose.</td>
</tr>
<tr>
<td>18th–27th weeks (120–189 days)</td>
<td>16th–25th weeks (106–175 days)</td>
<td>None</td>
<td>None</td>
<td>IQ deficits not detectable at diagnostic doses.</td>
</tr>
<tr>
<td>&gt;27 weeks (&gt;189 days)</td>
<td>&gt;25 weeks (&gt;175 days)</td>
<td>None</td>
<td>None</td>
<td>None applicable to diagnostic medicine.</td>
</tr>
</tbody>
</table>

*A determined by the radiation dose received to the fetus during the specific gestational period.*

ACR Practice Guidelines: Imaging Pregnant or Potentially pregnant adolescents and women with radiation. 2018.
IMAGING MODALITIES USED IN PREGNANCY
ULTRASOUND

• Imaging technique of choice in pregnant patients
• No reports of adverse fetal effects
• Theoretical increase in temperature in fetus, up to 2 degrees Celsius, though unlikely to be sustained
• Risk of temperature elevation lowest in B-mode and M-mode, higher with color and spectral Doppler
MAGNETIC RESONANCE IMAGING

• Safe in pregnancy
• Theoretical concerns of acoustic damage, though no cases identified
• Gadolinium contrast – FDA category C drug
  • Water soluble, can cross placenta into fetal circulation and amniotic fluid
  • Administered in a chelated form as free gadolinium is toxic
  • One prospective study demonstrated no adverse neonatal outcomes among 26 women who received gadolinium in first trimester
  • If lactating woman receives gadolinium, breastfeeding should NOT be interrupted
• If no direct fetal or abdominopelvic exposure, dose to fetus is negligible
• Pregnancy should not alter decision to perform examination

COMPUTED TOMOGRAPHY (CT)

- Most commonly used in the setting of trauma or suspected pulmonary emboli
- Dose reduction techniques such as single phase contrast, increasing pitch, automated exposure control, and limiting image length should be used
- Abdominal shielding does not lead to dose reduction – most of fetal dose from internal scatter

TABLE 4: Estimated CT Conceptus Doses From Single Acquisition

<table>
<thead>
<tr>
<th>Examination</th>
<th>Dose Level</th>
<th>Typical Conceptus Dose (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraabdominal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head CT</td>
<td>Standard</td>
<td>0</td>
</tr>
<tr>
<td>Chest CT</td>
<td>Standard</td>
<td>0</td>
</tr>
<tr>
<td>Routine</td>
<td>Standard</td>
<td>0.2</td>
</tr>
<tr>
<td>Pulmonary embolus</td>
<td>Standard</td>
<td>0.2</td>
</tr>
<tr>
<td>CT angiography of coronary arteries</td>
<td>Standard</td>
<td>0.1</td>
</tr>
<tr>
<td>Abdominal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abdomen, routine</td>
<td>Standard</td>
<td>4</td>
</tr>
<tr>
<td>Abdomen/pelvis, routine</td>
<td>Standard</td>
<td>25</td>
</tr>
<tr>
<td>CT angiography of aorta (chest through pelvis)</td>
<td>Standard</td>
<td>34</td>
</tr>
<tr>
<td>Abdomen-pelvis, stone protocol§</td>
<td>Reduced</td>
<td>10</td>
</tr>
</tbody>
</table>

Note—Reprinted with permission from [7].
§Anatomic coverage is the same as for routine abdominopelvic CT, but the tube current is decreased and the pitch is increased because standard image quality is not necessary for detection of high-contrast stones.

CT CONTRAST AGENTS

• Oral contrast is safe during pregnancy and lactation
• Iodinated IV contrast is FDA category B – no risk in animal studies, no controlled studies in pregnant women
• Breastfeeding can be continued without interruption after iodinated contrast
  • <1% of administered dose excreted into breast milk, less than 1% of that absorbed by infant’s GI tract.
NUCLEAR SCINTIGRAPHY

- Small amount of radioactive material is injected into patient to evaluate organ function and structure
- Ventilation/Perfusion study most commonly performed study
- Fetal exposure is from radioactivity accumulating in maternal organs and transport of radiopharmaceuticals across the placenta
- Treatment with sodium iodide 131 is contraindicated due to risk of permanent hypothyroidism in fetus
- Breastfeeding cessation suggested after use of gallium 67 and $^{131}$I-NaI
RECOMMENDATIONS FOR COMMON CLINICAL SCENARIOS
ACUTE PULMONARY EMBOLISM

- Increased risk of PE/DVT in pregnancy due to hypercoagulability and venous stasis
- Leading cause of maternal mortality in developed world – 15% mortality rate
- Isolated pelvic DVT more common (may present with abdominal pain)
- D-dimer less useful as often elevated during pregnancy
ACUTE PULMONARY EMBOLISM

• Start evaluation with lower extremity doppler ultrasound if leg symptoms are present
  • If positive, further testing usually not necessary
• Choice between CT-PA and V/Q is still controversial
  • Fetal radiation dose for both studies is minimal (0.1-0.4 mGy)
  • In general, CT-PA is lower dose to fetus when fetus is small and further from field of view
  • Maternal breast dose is higher with CT-PA (10 mGy vs 0.25 mGy)
IMAGING OF PULMONARY EMBOLISM

• If V/Q performed, ventilation and SPECT/CT portions often omitted to reduce radiation

• CT-PA studies in pregnancy are more frequently of poor quality due to cardiac output directed toward fetus

• CT has the advantage of detection of other thoracic pathology
  • Pneumonia, aortic abnormality, pericardial disease
  • Tend to have less inter-reader variability

• ACOG, ACR, Fleischner Society, PIOPED, American Thoracic Society, and Society of Thoracic Radiologists all have statement paper

• Cochrane review in 2017 noted both CT-PA and V/Q are reasonable options, with low quality of evidence
ACUTE APPENDICITIS

• Most common nonobstetric indication for surgery in pregnant patients
• Location of appendix changes during pregnancy as displaced by uterus
• Graded compression ultrasound often initial imaging modality
  • Initial studies demonstrate high sensitivity and specificity (85-100% sens and 92-96% spec), though more recent studies show much lower sensitivity (20-36%)
  • High rate of indeterminate studies
  • Utility of sonography decreases as pregnancy progresses

Baer et al. Appendicitis in pregnancy. JAMA 1932; 98:1359-1364
ACUTE APPENDICITIS

- MRI is preferred second line modality
  - NPV of 98-100%
- CT with contrast can be performed if MRI unavailable

Wieseler et al. Imaging in pregnant patients: Examination appropriateness. Radiographics 2010; 30(5)

Spalluto et al. Radiographics 2012
APPENDICITIS CASE

• 19 year old female 9 weeks pregnant presents with one week of right lower quadrant pain and elevated WBC count
• Pelvic Ultrasound ordered
UROLITHIASIS

• Obstructive renal stones occur in 1 in 3300 pregnant patients
• Most (70-80%) pass spontaneously
• Renal ultrasound is preferred initial study
  • Limited by difficulty distinguishing pathologic hydronephrosis and physiologic dilation of the collection system
    • Occurs in 60-94% of pregnant patients, more common on right
• CT of the abdomen without contrast (CT KUB) or MR urography second line
• IV pyelogram not recommended – dose similar to CT with decreased sensitivity
Wieseler et al. Imaging in pregnant patients: Examination appropriateness. Radigraphics 2010; 30(5)
Wieseler et al. Imaging in pregnant patients: Examination appropriateness. Radiographics 2010; 30(5)
MR urography

- Uses heavily T2 weighted sequences to show collecting system
- Physiologic ureteral dilatation shows midureteral narrowing with gradual tapering of the ureter to sacral promontory
- Pathologic dilation – abrupt caliber change, perirenal edema, ureteral filling defects
- More sensitive for ureteral dilatation than CT, less sensitive for stones

Wang et al. Imaging of Pregnant and Lactating Patients. AJR:198, April 2012
ACUTE CHOLECYSTITIS

• Gallbladder disease is second most common nonobstetric indication for surgery during pregnancy
• Increased risk due to decreased gallbladder contractility, increased cholesterol synthesis, and increased bile stasis
• Dedicated right upper quadrant ultrasound is most appropriate imaging study
• MRI/MRCP – second line imaging study
  • Heavily T2 weighted sequence depicts biliary tree
  • Gadolinium contrast unnecessary
  • Sensitive for evaluation of choledocholithiasis
  • If negative, can generally forgo ERCP
TRAUMA IN PREGNANCY

- Leading cause of non-obstetric maternal death
- Motor vehicle accidents most common form of trauma (66%)
- Study in Melbourne, Australia 2015 – only 19% of pregnant patients received recommended radiologic evaluation
- Priority is given to maternal survival – all imaging and procedural protocols for stabilization should be followed regardless of pregnancy status
IMAGING IN TRAUMA

• Focused abdominal sonography
  • Highly specific, but may have false negative in pregnancy
• CT should not be withheld due to pregnancy status
• IV Contrast SHOULD be given
• Placental abruption is most common uterine traumatic injury
  • 70-80% of abruptions are not seen on ultrasound
  • Marginal (most common), retroplacental, or preplacental (rare)
  • Appearance of hemorrhage depends on size and age of hematoma
25 YEAR OLD FEMALE 19 WEEKS PREGNANT WITH FALL PRESENTING WITH VAGINAL BLEEDING
24 YEAR OLD FEMALE 26 WEEKS PREGNANT WITH ABDOMINAL PAIN AFTER MOTOR VEHICLE ACCIDENT
‘With few exceptions, radiation exposure through radiography, computed tomography (CT) scan, or nuclear medicine imaging techniques is at a dose much lower than the exposure associated with fetal harm. If these techniques are necessary in addition to ultrasonography or MRI or are more readily available for the diagnosis in question, they should not be withheld from a pregnant patient.’

-ACOG Committee Opinion Guidelines for Diagnostic Imaging in Pregnancy and Lactation
Please do not hesitate to come down and talk to or call your friendly radiologist!
ACOG Committee Opinion: Guidelines for diagnostic imaging during pregnancy and lactation. Oct 2017;130(3)
Parker et al. Female breast radiation exposure during CT pulmonary angiography. AJR 2005;185(5):1228-1233