RADIATION EXPOSURE AND PREGNANCY: WHEN SHOULD WE BE CONCERNED?

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Introduction

Imaging the pregnant patient presents a unique challenge to the radiologist due to the concern of radiation risk to the conceptus (embryo/fetus). The goals of this exhibit include the following:

- To review fetal effects from in utero exposure to radiation
- To identify typical fetal doses from common radiological exams
- To summarize statements from national and professional organizations regarding the risk from diagnostic radiological exams
- To determine appropriate imaging exams for common imaging indications in pregnancy

Fetal Effects from Radiation Exposure

The fetal effects from in utero radiation exposure are based on animal studies and prior human exposures. In this latter case, the primary information source is from 1945 atomic bomb radiation in Hiroshima and Nagasaki, where approximately 2800 pregnant women were exposed to radiation, including 500 with conceptus dose of greater than 10 mGy.

Effects of radiation on the conceptus include prenatal death, growth retardation, small head size, mental retardation, organ malformations, and childhood cancer. These effects depend on the radiation dose to the conceptus and the stage of conceptus development.

- Prenatal death
  - Most sensitive period
    - 0-8 days post conception
    - If conceptus survives, it is thought to develop fully with no radiation damage
  - Threshold dose (based on animal studies)
    - 50-100 mGy, preimplantation
    - 250 mGy, after implantation
- Growth Retardation
  - Most sensitive period
    - 8-56 days post conception
  - Threshold dose
    - 200 mGy (human studies)
    - 10 mGy (animal studies)
  - Atomic bomb victims who received > 200 mGy were 2-3 cm shorter, 3 kg lighter and 1 cm smaller head circumference than controls
- Small Head Size
  - Most sensitive period
    - 14-105 days post conception
  - Most common defect seen in those exposed in utero to atomic bomb radiation
    - about 25% with small head size classified as mentally retarded
  - Incidence of 0.05-0.1% per mGy
  - No threshold seen in human studies
    - animal studies indicate a threshold dose of 100 mGy
- Mental Retardation
  - Most sensitive period
    - 56-105 days post conception
  - Severe mental retardation
    - Incidence of 0.04% per mGy
    - Threshold dose of 10 -100 mGy
  - Reduced IQ
    - Incidence of 25 IQ points per Gy
    - Threshold dose of 100 mGy
- Childhood Cancer (Table 1)
  - Leukemia likely most common
  - No apparent threshold dose
  - Absolute increase is small
  - Baseline risk in unexposed population is 1 in 1500
  - *Relative* increase in cancer incidence
    - 25% per mGy for 1st trimester
    - 6% per mGy for 2nd and 3rd trimester

Figure 1

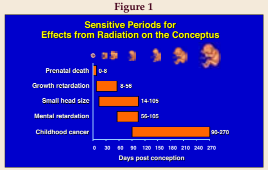


Table 1
Likelihood of NOT Developing Childhood Cancer after Prenatal Radiation Exposure (Adapted from Wagner, et al. 1997):

	0 mGy *	10 mGy	50 mGy	100 mGy
1st Trimester	99.93%	99.75%	99.12%	98.25%
2nd-3rd Trimester	99.93%	99.88%	99.70%	99.48%

* Baseline risk

Radiation Dose to Conceptus

The radiation dose to a conceptus due to a standard radiographic exam depends on the proximity of the uterus to the exposure, the thickness of the patient (i.e. the amount of tissue the x-ray beam penetrates), the projection (AP, PA, lateral), the depth of the conceptus from the skin surface, and x-ray technique factors. The dose can vary by a factor of 10 for a specific exam and projection.

The dose to the conceptus from radionuclide exams is variable, but depends principally on dose related to maternal uptake of the radiopharmaceutical, and dose due to passage of the agent across the placenta and uptake in the conceptus.

The CT exam is associated with high levels of radiation exposure. The dose to the individual conceptus varies with the proximity of the uterus to the anatomic location of the scan, the thickness of the patient, the depth of the conceptus, and x-ray technique factors. The conceptus dose can vary by a factor of 2-4 for a specific exam.

Recently, some vendors have introduced automated exposure control (AEC) capability with their CT scanners, allowing for real time x-ray tube current modulation to adjust technique based on tissue attenuation. Such mechanisms should help minimize radiation dose delivered to the patient and conceptus.

The scout image from CT delivers minimal radiation dose to the conceptus, and the benefits of its use (e.g. accurate localization of CT scan) outweigh the potential radiation risk. In addition, the scout image can be used to aid in properly making kVp and mA adjustments prior to the CT scan. The scout image is required when using AEC.

For all radiological studies, appropriate lead shielding of the abdomen and pelvis should be used if it will not interfere with imaging field.

The estimated conceptus doses from various radiological exams based on imaging protocols and equipment at our institution are detailed in Tables 2-7. These values can be compared with baseline environmental radiation dose to the conceptus of approximately 0.5mGy.

Estimated Conceptus Dose

Table 2
Extra-abdominal Radiography Examinations

Examination	Typical Dose (mGy)
C-spine (trauma series)	< 0.001
Extremities	< 0.001
Chest (PA-lat)	0.002
Thoracic spine (AP-lat)	0.0026

Table 5
Radiopharmaceutical Examinations

Examination	Typical Dose (mGy)	
	Early 1st Trimester	End of 1st Trimester
Bone scan (20 mCi Tc-99m MDP)	4.6	4.0
Whole body PET scan (15 mCi F-18 FDG)	15	9.5
Thyroid Scan/Uptake (0.2 mCi I-123)	0.15	0.10

Table 3
Abdominal Radiography Examinations

Examination	Typical Dose (mGy)
Abdomen (AP) - average	0.9
Abdomen (AP) - large	3.4
Lumbar spine (AP,lat,L5-S1 spot)	2.0
Intravenous pyelogram	3.4

Table 6
Extra-abdominal CT Examinations (one phase)

Examination	Typical Dose (mGy)
Head CT	0
Chest CT: Routine	0.2
Chest CT: PE	0.2
CT Angiogram: Coronaries	0.1

Table 4
Abdominal Examinations Including Fluoroscopy

Examination	Typical Dose (mGy)
Upper GI with small bowel	2
Barium enema (double contrast)	7
Renal angiogram	8
Pelvic arterial embolization	20

Table 7
Abdominal CT Examinations (one phase)

Examination	Typical Dose (mGy)
Abdomen: Routine	4
Abdomen/Pelvis: Routine	29
Abdomen/Pelvis: Stone protocol	20
CT Angiogram: Aorta (C/A/P)	34

Chest x-ray (PA/lat): 0.002 mGy to fetus. Essentially zero risk, if clinically necessary to perform. Lead shielding of abdomen/pelvis recommended.

Intravenous Pyelogram (IVP): 3.4 mGy to fetus, increasing with advanced gestation. Less appropriate in the evaluation of suspected urolithiasis. Ultrasound is first-line imaging modality, with renal stone CT only when necessary.

CT renal stone study: 20 mGy. Appropriate study to evaluate urolithiasis if transabdominal and endovaginal ultrasounds inconclusive and definitive diagnosis is necessary. (arrow – stone in mid right ureter)

CT pulmonary embolism study: 0.02 mGy to fetus. First-line imaging modality for making definitive diagnosis of pulmonary embolism (if lower extremity ultrasound insufficient).

CT Abdomen/Pelvis: 29 mGy to fetus. First-line imaging choice in setting of trauma. In other circumstances, abdomen/pelvis CT to be performed if ultrasound and/or MRI inconclusive or unavailable. (arrow – thickened, inflamed appendix)

Policy Statements

There have been several well recognized documents that have been published, providing guidance when imaging the pregnant patient.

- National Council on Radiation Protection and Measurements, 1977

  "The risk [of abnormality] is considered to be negligible at 50 mGy or less when compared to other risks of pregnancy, and the risk of malformations is significantly increased above control levels only at doses above 150 mGy. Therefore, exposure of the fetus to radiation arising from diagnostic procedures would very rarely be cause, by itself, for terminating a pregnancy."
- International Commission on Radiological Protection, 1999

  "Prenatal doses from most properly done diagnostic procedures present no measurable increased risk of prenatal death, malformation, or impairment of mental development over the background incidence of these entities."
- American College of Obstetricians and Gynecologists, Policy #299, September, 2004

  "Women should be counseled that x-ray exposure from a single diagnostic procedure does not result in harmful fetal effects. Specifically, exposure to less than 5 rad [50 mGy] has not been associated with an increase in fetal anomalies or pregnancy loss."
- American College of Radiology, 1988, 1998 (Res. 39-a)

  "The interruption of pregnancy is rarely justified because of radiation risk to the embryo or fetus from a radiologic examination…"

Clinical Guidelines

Pneumonia
- Chest x-ray delivers trivial radiation dose to the fetus

Suspected pulmonary emboli
- CT is better exam than VQ scan, with less radiation dose to conceptus
- Risk is negligible for both CT and VQ scan
- Caudal extent of the CT scan is the top of the diaphragm
- Circumferential shielding of abdomen/pelvis

Abdominal Trauma
- Benefit outweighs risk
- Standard trauma CT scan of abdomen/pelvis with intravenous contrast

Acute abdominal pain
- Suspected kidney stone
  - Transabdominal and transvaginal ultrasound
  - Observation
  - Repeat ultrasound
  - Renal stone protocol CT if patient's condition mandates despite US findings
- Suspected appendicitis
  - Ultrasound
  - Consider MRI, if available
  - Following surgical consultation, CT with intravenous contrast

Figure 2
Fetal Dose from Renal Stone CT Compared to 4-film IVP

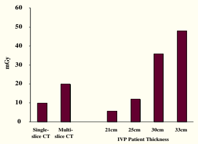
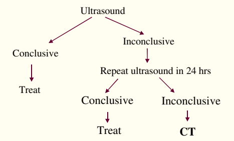


Figure 3
Evaluation of Urolithiasis in Pregnancy



Developing Practice Policy and Guidelines

Developing a practice policy at one's institution should be a data driven process. Such guidelines should be derived after review of available literature and societal guidelines (ACR, ACOG, etc.), as well as a critique of best recognized practices.

We have undertaken such an approach in creating a guideline for the imaging of the pregnant patient for several common presenting scenarios. An example of one of these analyses is given here for the situation of suspected urolithiasis in the pregnant patient. Recognizing the value of ultrasound as the initial imaging tool in these patients, we considered the situation where the ultrasound examination is inconclusive or suggests the need for further evaluation. The value of unenhanced CT for the detection of urolithiasis is well established. However, the concern for radiation dose to the fetus suggested to some that a limited 4-film intravenous pyelogram (IVP) was more appropriate than the use of CT. Thus, the fetal dose was determined in a quantitative manner for these two imaging scenarios. It was essential that this analysis be performed for patients of varying thickness (Figure 2), as the dose from a radiographic examination increased dramatically with increasing patient girth, as is expected in later pregnancy. For CT, this increase in dose is not necessary to obtain diagnostic images. Using these data, and considering the incremental value of CT in screening the remainder of the abdomen and pelvis, we were able to reach a consensus algorithm for the evaluation of pregnant patients with suspected urinary calculi (Figure 3).

Take Home Messages

- Radiological examinations outside of the abdomen/pelvis typically deliver negligible radiation dose to the fetus
- Diagnostic radiological examinations of the abdomen/pelvis rarely deliver fetal doses > 20 mGy
- The absolute risks of fetal effects, including childhood cancer induction, are still very small for fetal doses as large as 100 mGy.
- As with any drug or intervention in pregnancy, keep risks As Low As Reasonably Achievable (ALARA)
- Conservative clinical management is best.
- Perform radiological exams only when necessary.

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