Guidelines for Diagnostic Imaging During Pregnancy

ABSTRACT: Undergoing a single diagnostic X-ray procedure does not result in radiation exposure adequate to threaten the well-being of the developing preembryo, embryo, or fetus and is not an indication for therapeutic abortion. When multiple diagnostic X-rays are anticipated during pregnancy, imaging procedures not associated with ionizing radiation, such as ultrasonography and magnetic resonance imaging, should be considered. Additionally, it may be helpful to consult an expert in dosimetry calculation to determine estimated fetal dose. The use of radioactive isotopes of iodine is contraindicated for therapeutic use during pregnancy. Other radiopaque and paramagnetic contrast agents have not been studied in humans, but animal studies suggest that these agents are unlikely to cause harm to the developing human fetus. Although imaging techniques requiring these agents may be diagnostically beneficial, these techniques should be used during pregnancy only if potential benefits justify potential risks to the fetus.

Various imaging modalities are available for diagnostic use during pregnancy. These include X-ray, ultrasonography, magnetic resonance imaging (MRI), and nuclear medicine studies. Of these, diagnostic X-ray is the most frequent cause of anxiety for obstetricians and patients. Much of this anxiety is secondary to a general belief that any radiation exposure is harmful and will result in an anomalous fetus. This anxiety could lead to inappropriate therapeutic abortion and litigation. Actually, most diagnostic radiologic procedures are associated with little, if any, known significant fetal risks. Moreover, according to the American College of Radiology, no single diagnostic X-ray procedure results in radiation exposure to a degree that would threaten the well-being of the developing preembryo, embryo, or fetus (1). Thus, exposure to a single X-ray during pregnancy is not an indication for therapeutic abortion (2, 3).

Some women are exposed to X-rays before the diagnosis of pregnancy. Occasionally, X-ray procedures will be indicated during pregnancy for significant medical problems or trauma. To enable physicians to counsel patients appropriately, the following information is provided about the potential risks and measures that can reduce diagnostic X-ray exposure.
X-Ray Exposure

Ionizing radiation can result in the following 3 harmful effects: 1) cell death and teratogenic effects, 2) carcinogenesis, and 3) genetic effects or mutations in germ cells (2, 3). There is little or no information to estimate either the frequency or magnitude of adverse genetic effects on future generations.

Units traditionally used to measure the effects of X-ray include the rad and roentgen equivalents man (rem). Modern units include the gray (Gy) and sievert (Sv). The definitions of these units of measure are summarized in Table 1.

The estimated fetal exposure from some common radiologic procedures is summarized in Table 2. A plain X-ray generally exposes the fetus to very small amounts of radiation. Commonly during pregnancy, the uterus is shielded for nonpelvic procedures. With the exception of barium enema or small bowel series, most fluoroscopic examinations result in fetal exposure of millirads. Radiation exposure from computed tomography (CT) varies depending on the number and spacing of adjacent image sections. Although CT pelvimetry can result in fetal exposures as high as 1.5 rad, exposure can be reduced to approximately 250 mrad (including fetal gonad exposure) by using a low-exposure technique (4).

Spiral (or helical) CT allows continuous scanning of the patient as the couch is moved through the scanner, providing superior speed and image quality. Radiation exposure is affected by slice thickness, the number of cuts obtained, and the “pitch,” a ratio defined as the distance the couch travels during one 360-degree rotation divided by the section thickness. The patient dose is proportional to 1 per pitch. Under typical use with a pitch of 1 or greater, the radiation exposure to the fetus from spiral CT is comparable to conventional CT (5).

<table>
<thead>
<tr>
<th>Measure</th>
<th>Definition</th>
<th>Unit</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure</td>
<td>Number of ions produced by X-rays per kilogram of air</td>
<td>Roentgen (R)</td>
<td>Roentgen (R)</td>
</tr>
<tr>
<td>Dose</td>
<td>Amount of energy deposited per kilogram of tissue</td>
<td>Rad (rad)*</td>
<td>Gray (Gy)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 Gy = 100 rad</td>
</tr>
<tr>
<td>Relative effective</td>
<td>Amount of energy deposited per kilogram of tissue</td>
<td>Roentgen equivalents</td>
<td>Sievert (Sv)</td>
</tr>
<tr>
<td>dose</td>
<td>normalized for biological effectiveness</td>
<td>man (rem)*</td>
<td>1 Sv = 100 rem</td>
</tr>
</tbody>
</table>

*For diagnostic X-rays, 1 rad = 1 rem


Cell Death and Teratogenic Effects

Data from an animal study suggest that exposure to high-dose ionizing radiation (ie, much greater than that used in diagnostic procedures) before implantation will most likely be lethal to the embryo (2). In other words, cell death is most likely an “all or none” phenomenon in early embryonic development.

Myriad teratogenic effects have developed in animals exposed to large doses of radiation (ie, 100–200 rad). However, in humans, growth restriction, microcephaly, and mental retardation are the most common adverse effects from high-dose radiation (3, 6, 7). Based on data from atomic bomb survivors, it appears that the risk of central nervous system effects is greatest with exposure at 8–15 weeks of gestation, with no proven risk at less than 8 weeks of gestation or at greater than 25 weeks of gestation (3, 8). Thus, at 8–15 weeks of gestation, the fetus is at greatest risk for radiation-induced mental retardation, and the risk appears to be a “non-threshold linear function of dose” at doses of at least 20 rad (3, 6, 8, 9). For example, the risk of severe mental retardation in fetuses exposed to ionizing radiation is approximately 40% at 100 rad of exposure and as high as 60% at 150 rad of exposure (3, 8). It has been suggested that a threshold for this adverse effect may exist in the range of 20–40 rad (7, 8). Even multiple diagnostic X-ray procedures rarely result in ionizing radiation exposure to this degree. Fetal risks of anomalies, growth restriction, or abortions are not increased with radiation exposure of less than 5 rad, a level above the range of exposure for diagnostic procedures (2).

Carcinogenesis

The risk of carcinogenesis as a result of in utero exposure to ionizing radiation is unclear but is prob-
ably very small. It is estimated that a 1–2 rad fetal exposure may increase the risk of leukemia by a factor of 1.5–2.0 over natural incidence and that an estimated 1 in 2,000 children exposed to ionizing radiation in utero will develop childhood leukemia. This is increased from a background rate of approximately 1 in 3,000 (2, 10). If elective abortion were chosen in every instance of fetal exposure to radiation, 1,999 exposed, normal fetuses would be aborted for each case of leukemia prevented (2, 11). It has been estimated that the risk of radiation-induced carcinogenesis may indeed be higher in children compared with adults, but such risks are not likely to exceed 1 in 1,000 children per rad (12). Thus, abortion should not be recommended solely on the basis of exposure to diagnostic radiation.

**Ultrasonography**

Ultrasonography involves the use of sound waves and is not a form of ionizing radiation. There have been no reports of documented adverse fetal effects for diagnostic ultrasound procedures, including duplex Doppler imaging. Energy exposure from ultrasonography has been arbitrarily limited to 94 mW/cm² by the U.S. Food and Drug Administration. There are no contraindications to ultrasound procedures during pregnancy, and this modality has largely replaced X-ray as the primary method of fetal imaging during pregnancy.

**Magnetic Resonance Imaging**

With MRI, magnets that alter the energy state of hydrogen protons are used instead of ionizing radiation (13). This technique could prove especially useful for diagnosis and evaluation of fetal central nervous system anomalies and placental abnormalities (eg, accreta, previa).

**Nuclear Medicine**

Nuclear studies such as pulmonary ventilation–perfusion, thyroid, bone, and renal scans are performed by “tagging” a chemical agent with a radioisotope. The fetal exposure depends on the physical and biochemical properties of the radioisotope (6).

Technetium Tc 99m is one of the most commonly used isotopes and is used for brain, bone, renal, and cardiovascular scans. In general, these latter procedures result in a uterus, embryo, or fetal exposure of less than 0.5 rad (6, 12).

One of the more common nuclear medicine studies performed during pregnancy is the ventilation–perfusion scan for suspected pulmonary embolism. Macroaggregated albumin labeled with Technetium Tc 99m is used for the perfusion portion, and inhaled xenon gas (127Xe or 133Xe) is used for the ventilation portion. The amount of radiation to which the fetus is exposed is extremely small (approximately 50 mrad) (14).

In a 2002 study, investigators calculated the mean fetal radiation exposure resulting from helical (spiral) CT in healthy pregnant women and compared it with reported fetal radiation doses for ventilation–perfusion lung scanning (approximately 100–370 μGy) (15). Although the exposure from ventilation–perfusion is relatively low, the study found that the mean fetal doses associated with helical CT were lower. Although exposure varied with gestational age (3.3–20.2 μGy for the first trimester, 7.9–76.7 μGy for the second trimester, and 51.3–130.8 μGy for the third trimester), 20 of 23 study patients exhibited a mean fetal dose of less than 60 μGy for all 3 trimesters.

Radioactive iodine readily crosses the placenta and can adversely affect the fetal thyroid, especially if used after 10–12 weeks of gestation. Radioactive isotopes of iodine used for treatment of hyperthyroidism are contraindicated during pregnancy, and such therapy should be delayed until after delivery. If a diagnostic scan of the thyroid is essential,

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**Table 2. Estimated Fetal Exposure From Some Common Radiologic Procedures**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Fetal Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest X-ray (2 views)</td>
<td>0.02–0.07 mrad</td>
</tr>
<tr>
<td>Abdominal film (single view)</td>
<td>100 mrad</td>
</tr>
<tr>
<td>Intravenous pyelography</td>
<td>≥1 rad*</td>
</tr>
<tr>
<td>Hip film (single view)</td>
<td>200 mrad</td>
</tr>
<tr>
<td>Mammography</td>
<td>7–20 mrad</td>
</tr>
<tr>
<td>Barium enema or small bowel series</td>
<td>2–4 rad</td>
</tr>
<tr>
<td>CT scan of head or chest</td>
<td>&lt;1 rad</td>
</tr>
<tr>
<td>CT scan of abdomen and lumbar spine</td>
<td>3.5 rad</td>
</tr>
<tr>
<td>CT pelvimetry</td>
<td>250 mrad</td>
</tr>
</tbody>
</table>

*Exposure depends on the number of films

†Abbreviation: CT, computed tomography

¹²³I or Technetium Tc 99m should be used in place of ¹³¹I (14).

**Contrast Agents**

A variety of oral and intravascular contrast agents are used with X-ray and magnetic imaging procedures. Most radiopaque agents used with CT and conventional radiography contain derivatives of iodine and have not been studied in humans; however iohexol, iopamidol, iothalamate, ioversol, ioxaglate, and metrizamide have been studied in animals and do not appear to be teratogenic (16). Neonatal hypothyroidism has been associated with some iodinated agents taken during pregnancy (17). For this reason, these compounds generally are avoided unless essential for correct diagnosis. Studies requiring views before and after the administration of contrast agents will necessarily have greater radiation exposure. Although some radiopaque agents pass into the breast milk, they have not been associated with problems in nursing babies (16).

Paramagnetic contrast agents used during MRI have not been studied in pregnant women. Animal studies have demonstrated increased rates of spontaneous abortion, skeletal abnormalities, and visceral abnormalities when given at 2–7 times the recommended human dose (18, 19). It is not known if these compounds are excreted into human milk. Generally, these agents should be used during pregnancy only if the potential benefit justifies the potential risk to the fetus as demonstrated in animal studies.

**Guidelines**

The following guidelines for X-ray examination or exposure during pregnancy are suggested:

1. 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 has not been associated with an increase in fetal anomalies or pregnancy loss.

2. Concern about possible effects of high-dose ionizing radiation exposure should not prevent medically indicated diagnostic X-ray procedures from being performed on a pregnant woman. During pregnancy, other imaging procedures not associated with ionizing radiation (eg, ultrasonography, MRI) should be considered instead of X-rays when appropriate.

3. Ultrasonography and MRI are not associated with known adverse fetal effects.

4. Consultation with an expert in dosimetry calculation may be helpful in calculating estimated fetal dose when multiple diagnostic X-rays are performed on a pregnant patient.

5. The use of radioactive isotopes of iodine is contraindicated for therapeutic use during pregnancy.

6. Radiopaque and paramagnetic contrast agents are unlikely to cause harm and may be of diagnostic benefit, but these agents should be used during pregnancy only if the potential benefit justifies the potential risk to the fetus.

**References**


