

Radiology Procedures in Pregnancy

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Nursing

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Objectives

1. Discuss the potential risks of radiation exposure (x-ray usage) during pregnancy and the time period of most concern for these procedures.
2. Define the limits of ultrasound energy output that is recommended for use in pregnancy and explain the various ways in which magnetic resonance might be used.
3. Describe the types of nuclear medicine studies that might be utilized in women of childbearing age and the limitations that should be observed.

Article

Diagnostic Imaging in Pregnancy

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Introduction:

Diagnostic imaging procedures are frequently used during pregnancy, especially ultrasound. Use of other modalities, however, is controversial and often results in significant concern over damage to the developing fetus. The purpose of this article is to discuss the various forms of radiologic evaluation and their potential effect (if any) on pregnancy. These include the use of x-rays, magnetic resonance, and radioisotope procedures.

X-ray Imaging:

X-ray exposure involves ionizing radiation, which is something that could adversely affect a pregnancy. However, for practical purposes, the stigmas surrounding x-ray procedures during pregnancy has been somewhat blown out of proportion. Radiation can be harmful but is dose dependent. In theory, x-ray exposure in pregnancy can lead to three potential problems, which are the development of birth defects (teratogenic effect), an increased risk for developing cancer in the future (carcinogenic risk), and mutation of germ cells (genetic risk).

Regarding the genetic risk, radiation exposure to germ cells (the egg and the sperm) has been shown to cause damage to chromosomes (genetic material). However, the damage is such that the cells become nonfunctional and therefore could not result in a successful conception or pregnancy. Unfortunately, at this point in time, there is no way to know if subtle changes can occur, which could effect the genetics of future generations. In an overview perspective, x-ray imaging has been around for many years, but the incidence of chromosomal abnormalities identified in the general population has not changed. Therefore, in a general sense, x-ray exposure would not appear to substantially increase future genetic problems; however, this is an area that definitely needs further study.

The carcinogenic risk to the fetus from in utero exposure to radiation is also unclear. Several studies have been performed on the development of childhood leukemia after x-ray exposure, many of which show no increase. However,

an equal number of studies have demonstrated an increase in risk, though this risk is at most only doubled. Therefore, if the baseline risk for a child developing leukemia is 1 in 3000, this risk could be 1 in 2000 at the most. It has been suggested that the development of cancer following radiation exposure may be higher in children when compared to adults; however, it is unlikely that this increase is any higher than 1 in a 1000.

X-ray exposure does have the potential for producing birth defects (teratogenic risk). This risk is dose dependent. The traditional method for describing radiation dosage is the rad and roentgen equivalent man (rem). Gray units and Sievert units are more modern definitions for dosage, but have not really been used as terms in defining an effect on a fetus. Exposure is defined as Roentgen (R) and is the number of ions produced by x-rays in a kilogram of air. Dosage is defined as Rad (rad) or the amount of energy deposited per kilogram of tissue. Roentgen equivalent man (rem) is defined as the amount of energy deposited per kilogram of tissue normalized for biological effectiveness, which is the relative effective dose. For purposes of discussing diagnostic x-rays, one rad is equal to one rem.

Much of the data on radiation exposure during pregnancy comes from the atomic bomb survivors in Japan. High doses of radiation can cause damage to the central nervous system, especially between 8 and 15 weeks gestation. It is believed, that significant exposure resulting in cell death or damage prior to 8 weeks gestation (which is the first 6 weeks after conception) produces an all or none effect, meaning that the pregnancy will usually be lost (miscarried).

At this point, it is important to discuss the dating of a pregnancy and the significance of the first trimester. In most instances, the due date of a pregnancy is based upon a woman's last menstrual period. This is usually the case if the woman had regular menstrual cycles and she remembers or she wrote down the first day of her last period. A normal pregnancy lasts about 40 weeks from the first day of the last menstrual period to the due date (assuming the woman has menstrual cycles every 28 days). However, obviously, a woman is not pregnant during menstruation. When a woman becomes pregnant, the conception (joining of the egg and sperm) occurs about 14 days after the first day of the woman's last menstrual period. Therefore, on average, the length of a pregnancy from the time of conception to the due date is actually 38 weeks. The reason 38 weeks is not used is because not all women know when conception occurred, but they usually remember the date of their last menstrual period.

Therefore, when examining the issue of radiation exposure during pregnancy, the first two weeks of gestation are not a concern because the woman is NOT pregnant yet. Week three is the first week after conception. In most cases, the egg and sperm join together in the fallopian tube and the embryo then travels into the uterus and implants. This entire process takes about five to seven days to complete. At this point the embryo only consists of about 32 to 64 cells, and the body parts and organs have not yet started to form. The fourth week of the pregnancy is the second week after conception. During this week, some of the cells of the tiny embryo develop into what will become the placenta (or afterbirth). The remaining cells start to develop into what will eventually become the baby or fetus. These fetal cells basically evolve into three main tissue types. One form of tissue (the ectoderm) makes up the skin, brain, spinal cord, and nerves. The second tissue type (the mesoderm) makes up the muscles and connective tissue of the body, and the third tissue type (called endoderm) makes up the majority of the internal organs, such as the liver, kidneys, lungs, and intestines.

A gestational age of more than 4 weeks (or after the first two weeks of conception) through 12 weeks is when the major body parts and organs of the fetus form. Some examples are as follows: the central nervous system is the first organ system to develop starting at 4 ½ weeks gestation and is basically finished by 10 weeks; the forming of the heart also begins at 4 ½ weeks gestation and is also basically finished by 10 weeks; the intestinal tract starts to develop at about 6 to 7 weeks gestation, the small and large intestines actually form outside the body of the baby, they rotate, and then move to the inside of the body by 11 to 12 weeks gestation; the eyes and the ears start to form at around 5 to 6 weeks and are basically finished by 10 weeks; and the arms and legs start to develop at about 6 weeks, they have an upper portion, a lower portion, and hands and feet by 9 weeks, and are usually complete with fingers and toes by 10 weeks gestation. Therefore, the first trimester is the most concerning regarding the issue of birth defects because that is the time period in which most of the fetus is formed.

It is also important to know that many pregnancies are actually dated and given a due date by ultrasound. The gestational age of a pregnancy given by an ultrasound examination adds in the same two-week fudge factor that is seen when using the last menstrual period. Therefore, if a first trimester ultrasound states that a pregnancy is at 8 weeks gestation, in reality that pregnancy is 6 weeks from conception.

In humans, the most common adverse effects seen from high-dose radiation are intrauterine growth restriction, microcephaly, and mental retardation. The risk of mental retardation appears to take at least a dose of 20 rads. This risk is 40% following a dose of 100 rads and increases to 60% with a dose of 150 rads. Microcephaly and fetal growth

restriction have been reported at doses between 10 and 20 rads; however, no adverse effects have really been seen below 10 rads. Therefore, the American College of Obstetricians and Gynecologists (ACOG) and the American College of Radiology (ACR) both state that exposures of less than 5 rads do not increase the risk for anomalies (which leaves the range of 5 to 10 rads as being the gray zone). This threshold is well above the range for the majority of diagnostic procedures in use today. If any question exists regarding the amount of rads the fetus was exposed to, the radiology department physicist can calculate the fetal dosage based on the type of procedure performed and the machine that was used. The following list gives some examples of common procedures and the estimated fetal exposure:

1. Chest x-ray (AP and lateral) = 0.05 millirads
2. Flat plate of the abdomen = 100 millirads
3. Mammography = 5 to 20 millirads
4. Barium enema or small bowel series = 2 to 4 rads
5. Intravenous pyelogram (IVP) = 1 to 2 rads (based on # of films)
6. Computed tomography (CT) of the head = less than 1 rad
7. CT of the chest = less than 1 rad
8. Ct of the abdomen and lumbar spine = 3 to 4 rads

Remember, we are exposed to small amounts of radiation from the atmosphere on a daily basis and this is increased with altitude (for example, a higher dose during airplane travel or at the top of a mountain when compared to sea level). Also small amounts of exposure occur when passing through metal detectors at airport terminals and entrances to courthouses, etc.

Therefore, radiation exposure is a daily occurrence. Because radiation exposure has the potential for harm, the use of x-ray procedures during pregnancy should be closely evaluated. Likewise, if a woman discovers that she was pregnant after she already underwent a procedure, she should be advised on the amount of fetal exposure that occurred and the gestational age of exposure should be determined. In the majority of cases, the potential risk will be negligible.

Ultrasound Imaging:

Ultrasound utilizes sound waves to create an image and therefore is not a form a radiation. No studies have ever documented that ultrasound usage in human pregnancy can lead to fetal harm. Therefore, it has become the main modality for imaging during pregnancy. However, in theory and in animal experiments, ultrasound at certain levels can produce certain bioeffects, which include an increase in tissue temperature and the ability to produce cavitation.

ACOG and the American Institute of Ultrasound in Medicine (AIUM) initially set the upper limit for energy exposure with obstetrical ultrasound at $100\text{mW}/\text{cm}^2$. The FDA lowered this level to $94\text{mW}/\text{cm}^2$ in 1996. Therefore, ultrasound machines are now required to have output display screens that predict tissue heating (the thermal index or TI) or the potential for cavitation (the mechanical index or MI). Thermal index is a calculation that is determined by the ratio of the total acoustic power to the acoustic power required to raise the tissue temperature by 1°C . The area that has the greatest potential for a temperature rise is between the transducer and the focal region and is affected by the power output of the machine and the tissue being examined. Bone has the highest absorption, whereas fluid has the least. Therefore, amniotic fluid, blood, and urine absorb very little ultrasound energy.

The potential mechanical effects of ultrasound are the result of compression and decompression of tissue as the ultrasound beam passes through, which could produce microbubbles or cavitation. The MI is a mathematical calculation of dividing the spatial peak value of the peak rarefactional pressure by the square root of the center frequency. Based on current standards, if an ultrasound machine is capable of achieving an MI or TI of 1.0, then the output display should show the value. Some ultrasound machines are capable of power outputs at $720\text{mW}/\text{cm}^2$, therefore, it is important to recognize that the recommended upper level for obstetrics be kept below $94\text{mW}/\text{cm}^2$. Of note, increasing the "gain" of the ultrasound machine does not increase the energy delivered, whereas increasing the "power" output will.

Magnetic Resonance Imaging:

Magnetic resonance imaging (MRI) employs the use of magnets that alter the energy state of hydrogen protons and again is not ionizing radiation. The use of MRI in pregnancy was initially approached with caution because of uncertainty regarding fetal effects. However, the use of this modality has greatly increased in the past 3 to 4 years with multiple publications regarding its usage in diagnosing inutero fetal CNS abnormalities. It has also been described in

the evaluation of fetal neck masses, fetal chest disorders (differentiating between congenital diaphragmatic hernia, congenital cystic adenomatoid malformation, and pulmonary sequestration) and fetal urinary tract abnormalities.

Ultrasound imaging is at its best when a good amount of amniotic fluid is present, but is hampered by oligohydramnios (very low amniotic fluid volume). MRI usage, on the other hand, is not affected by oligohydramnios and may be a modality that could be of some benefit when presented with a potential fetal anomaly and low fluid. One problem that sometimes occurs with MRI usage in obstetrics is the difficulty in obtaining clear images when fetal movement occurs.

The majority of studies that have utilized MRI in pregnancy have been performed after the first trimester. One study analyzed the assessment of 20 infants at 9 months of age after they experienced MRI in utero after 20 weeks gestation. No difference was seen when compared to 20 controls. Even though no adverse effects have been reported, the National Radiological Protection Board has arbitrarily advised that MRI not be performed in the first trimester if at all possible until further studies are performed. A few recent reports have described Fast MRI imaging, which decreases exposure but still obtains quality images. This approach may show promise for further usage in obstetrics.

Nuclear Medicine Studies:

The most common nuclear medicine study performed on women of childbearing age is the pulmonary ventilation-perfusion (VQ) scan. Macro-aggregated albumin that is labeled with technetium Tc 99 is used for the perfusion part of the study and inhaled Xenon gas is used for the ventilation part. The amount of radiation exposure to the fetus with a typical study is very small, estimated to only be about 50 millirads. In a recent survey of over 300 hospitals that responded to whether or not they perform these studies on pregnant women, 67% responded yes and of these, 50% modify their approach, usually involving a reduction in the perfusion dose. Because pulmonary embolism (PE) is one of the major causes for maternal death during pregnancy, if there is a high clinical suspicion for PE, then a VQ scan is an accepted diagnostic modality according to ACOG. Other nuclear medicine studies include scans of the brain, bone, and kidneys (also using technetium 99, thallium, or gallium as the most common isotopes).

Women have a higher rate of thyroid abnormalities when compared to men. A common non-surgical treatment for significant hyperthyroidism is the radioactive isotope of iodine (Iodine 131 or I^{131}). Because iodine readily crosses the placenta, I^{131} treatment is not recommended during pregnancy. In reality, the fetal thyroid gland develops at about 8 weeks gestation and does not begin to concentrate iodine until about 11 to 12 weeks. Therefore, usage prior to 10 weeks would be of no consequence. Therefore, if a woman undergoes treatment for hyperthyroidism, and later she discovers that she was pregnant, timing the exposure in the first trimester is of utmost importance. If it occurred prior to 10 weeks gestation, she can be reassured that the fetus was probably unaffected.

References or Suggested Reading:

1. Hall EJ. Scientific view of low-level radiation risks. *Radiographics* 1991;11:509-518
2. National Council on Radiation Protection and Measurements. Exposure of the U.S. population from diagnostic medical radiation. Bethesda, Maryland: NCRPM, 1989. 26; report #100.
3. Russell JR, Stabin MG, Sparks RB. Placental transfer of radiopharmaceuticals and dosimetry in pregnancy. *Health Phys* 1997;73:747-55.
4. Balan KK, Critchley M, Vedavathy KK, et al. The value of ventilation-perfusion imaging in pregnancy. *British J Radiology* 1997;70:338-40.
5. Boiselle PM, Reddy SS, Villas PA, et al. Pulmonary embolus in pregnant patients: survey of ventilation-perfusion imaging policies and practices. *Radiology* 1998;207:201-6.
6. Simon EM, Goldstein RB, Coakley FV, et al. Fast MR imaging of fetal CNS anomalies in utero. *American J Neuroradiology* 2000;21:1688-98.
7. Clements H, Duncan KR, Fielding K, et al. Infants exposed to MRI in utero have a normal paediatric assessment at 9 months of age. *British J Radiology* 2000;73:190-4.
8. Vimercati A, Greco P, Vera L, et al. The diagnostic role of in utero magnetic resonance imaging. *J Perinatal Medicine* 1999;27:303-8.
9. Hubbard AM, Harty MP. MRI for the assessment of the malformed fetus. *Baillieres Best Pract Res Clin Obstet Gynaecol* 2000;14:629-50.
10. The American College of Obstetrics and Gynecology: Committee Opinion #158, Sept. 1995. Guidelines for Diagnostic Imaging during Pregnancy. Washington, DC.
11. Shope TB, Gagne RM, Johnson GC. A method for describing the doses delivered by transmission x-ray computed tomography. *Med Phys* 1981;8:488-95.
12. Ragazzion MW, Breckle R, Hill LM, et al. Average fetal depth in utero: data for estimation of fetal absorbed

- radiation dose. *Radiology* 1986;158:513-15.
13. Schull WJ, Otake M. Neurological deficit among the survivors exposed to the atomic bombing of Hiroshima and Nagasaki: a reassessment and new directions. From *Radiation Risks to the Developing Nervous System*; Editors: Kriegel H, Schmahl W, Gerber GB, Stive FE. New York: 1986:399-419.
 14. Ginsberg JS, Hirsh J, Rainbow AJ, et al. Risks to the fetus of Radiologic procedures used in the diagnosis of maternal venous thromboembolic disease. *Thrombosis Hemostasis* 1989;61:189-96.
 15. Committee on Biological Effects of Ionizing Radiation; from the National Research Council. *Health Effects of exposure to low levels of ionizing radiation: BEIR V*. Washington, DC. National Academy Press 1990:352-370.
 16. Otake M, Yoshimaru H, Schull WJ. Severe mental retardation among the prenatally exposed survivors of the atomic bombing of Hiroshima and Nagasaki; a comparison of old and new dosimetry systems. *Radiation Research Foundation Technical Report # 16-87 Hiroshima, Japan* 1987.
 17. Oppenheim BE, Briem ML, Meier P. The effects of diagnostic x-ray exposure on the human fetus: An examination of the evidence. *Radiology* 1975;114:529.
 18. Bross IDJ, Natarajan N. Leukemia from low level radiation. *New England J. Med* 1972;287:107.

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Dr. Towers is currently Professor and Vice Chair of the Department of Obstetrics & Gynecology at University of Tennessee Medical Center Knoxville in the Division of Maternal-Fetal Medicine. He is still clinically active managing numerous high-risk pregnancies. He is also actively involved in research with over 90 publications in major medical journals. Though his research has spanned many areas in obstetrics, he has primary interests in drugs in pregnancy, infections in pregnancy, fetal heart monitoring, bleeding in pregnancy, and fetal lung maturity.

He has authored a book for consumers regarding the safety of over-the-counter medications that are used in treating the common cold entitled "I'm Pregnant & I Have a Cold - Are Over-the-Counter Drugs Safe to Use?" published by RBC Press, Inc. He is also one of the new Editors of the reference book for clinical care providers entitled "Drugs in Pregnancy and Lactation, published by Wolters & Kluwer.

