A Health Care Personnel Guide For Assessing Radiation Risk And Selecting Imaging Procedures In Pregnant Women

Introduction

Pregnant patients are occasionally exposed to ionizing radiation in the course of their treatment. When a diagnostic imaging procedure is being considered, the benefits of that procedure, i.e., the value of the diagnostic information gained, should be weighed against the risk of radiation exposure received by the fetus and mother. Radiation exposure information is often limited, outdated, unavailable, or confusing. This undoubtedly leads to uninformed decisions on the appropriateness/risks of the exam, and apprehension for both patient and staff. The purpose of this guide is to educate and inform referring physicians contemplating a radiology exam that involves ionizing radiation in a pregnant patient.

Estimating Risk to the Fetus - Effects of Irradiation

Significant doses of radiation have been shown to cause latent leukemia and various cancers in adults and children which become manifest years after the exposure. The fetus is assumed to have the same risk for potential radiocarcinogenic effects as children, which is 2 to 3 times higher than the adult risk. A study of prenatal and childhood cancer studies showed a relative risk (RR) of 1.4 (40% increase above the normal incidence) following a fetal dose of ~ 10 mGy. The normal incidence of childhood cancer is ~ 0.2-0.3 %, so a 10 mGy fetal dose would increase this incidence to ~0.35%.

A fetal dose of 10-20 mGy raises the incidence of childhood leukemia to 5/10,000 from a baseline rate of 3.6/10,000.

Fetal Risk Categories

To determine the radiation dose to the fetus, the cumulative radiation exposure from all the radiation exams the patient receives needs to be totaled. The fetal radiation recommendations of the National Council on Radiation Protection and Measurements (NCRP) were published in 1971. Essentially this report concludes that the risk of fetal abnormality is a function of the stage of development irradiated, and the total radiation dose received.

Radiation-related risks throughout pregnancy vary according to gestational age. For a given radiation dose, the risk to the fetus is most significant during the first trimester, somewhat less in the second trimester, and least in the third trimester. Malformation of organs (3rd - 8th weeks after conception) appears to have a threshold of 100 mGy. The risk for severe mental retardation (8th - 15th weeks) has a threshold of 100 mGy. These are considered to be acute radiation effects.

The fetal dose is considered negligible at less than 50 mGy when compared with the other risks of pregnancy. The risks of organ malformations during organogenesis (3rd to 8th week) is significantly increased above control levels only at doses above 150 mGy. Therefore, the radiation dose received from a diagnostic imaging procedure should not be the sole determinant when contemplating the

termination of a pregnancy. Other risks, such as acute viral disease, teratogenic drug use, or when life of the mother is threatened, should also be considered in this regard.

The following table lists the fetal radiation risk categories according to fetal radiation dose and post-conception age:

Table 1: Fetal Risk Categories*

Gestational Age	< 100 mGy	≥100 mGy
< 2 weeks	I	III†
3 - 8 weeks	I	III‡
8 - 15 weeks	I	III§
> 15 weeks	I	II§

I = negligible risks
II = potential association with adverse birth outcome, especially with other teratogenic risk factors
III = highest risk condition.

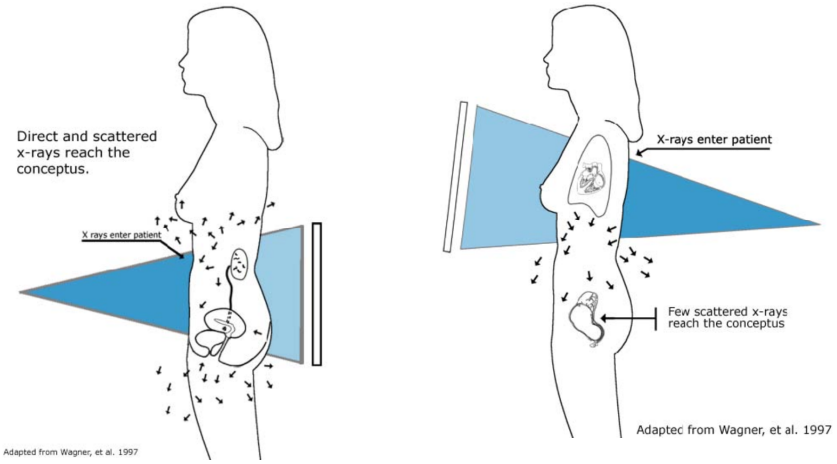
* Adapted from United Nations Scientific Committee on the Effects of Atomic Radiation.2
† At 0-2 weeks post-conception, doses ≥100 mGy have an "all or none effect"
potentially causing embryologic demise, surviving fetus will progress to term
without associated effects
‡ At 3-8 weeks post-conception, doses ≥100 mGy have potential for organ malformation
§ 100 mGy threshold dose for mental effects

Diagnostic Exposure to the Fetus

To determine the radiation dose to the fetus, the cumulative radiation exposure from all the radiation exams the patient receives needs to be totaled.

Potential radiation effects are proportional to the tissues exposed, either directly or indirectly by the radiation. This means a x-ray beam that includes the fetal site, or substantial scattered radiation from a site near the fetus, produces the greatest dose.3

The following tables list mean fetal radiation exposures for single x-ray, CT, and nuclear medicine procedures at Brigham and Women's Hospital, as well as the fetal risk category as described in Table I.



Please keep in mind the following:
1. These are average doses estimated from a heterogenous range of patients.
2. Multiple exams result in an additive or cumulative dose.
3. For patient-specific dose estimates or additional information, please contact Medical Physics 858-534-1433).

The radiation dose, as defined with other terms in the Glossary, may be expressed with either conventional or international (SI) units. In this guide the fetal doses are expressed in SI units.

Table 2: Estimated Dose to the Fetus During Selected Radiographic Exams

Exam	BWH Fetal Dose (mGy)	Fetal Risk Category
Dental	<0.0001	I
Skull (3 views)	<0.0001	I
C-Spine (trauma series)	<0.0001	I
Shoulder (AP, LAT)	<0.0001	I
Chest (PA, LAT)	<0.0001	I
Femur (AP)	<0.0001	I
Femur (LAT)	<0.0001	I
Thoracic Spine (AP)	0.0008	I
Thoracic Spine (LAT)	0.0008	I
Cardiac Catheterization	0.074	I
Hip (LAT)	0.42	I
KUB (LAT)	0.43	I
Lumbar Spine (LAT)	0.59	I
Hip (AP)	0.63	I
Pelvis (AP)	0.93	I
Lumbar Spine (AP)	1.36	I
Upper GI series	1.75	I
KUB (AP)	2.08	I
ERCP	3.1	I
Pulmonary Angiogram	3.00-7.00	I
Intravenous Urogram (IVU)	37.0	I

Table 3: Estimated Dose to the Fetus During Selected CT Exams

Exam	Fetal Dose (mGy)	Fetal Risk Category
Chest	0.062	I
Pulmonary Embolism		
lungs only	0.062	I
lungs and pelvis	0.211	I
Abdomen	1.4	I
Pelvis	15.4	I
Ureter	15.4	I
Urography		
unenhanced	1.4	I
nephrographic	15.4	I
pyelographic	15.4	I
Total	32.2	I

In nuclear medicine studies, fetal radiation exposure is a function of: 1) the tracer's ability to cross the placental barrier; 2) concentrate in fetal tissue; or 3) the result of radiation emanating from a nearby organ, e.g., the urinary bladder5.

Please also note that certain radionuclides can be expressed in breast milk. Nursing mothers should consult with the nuclear medicine physician.

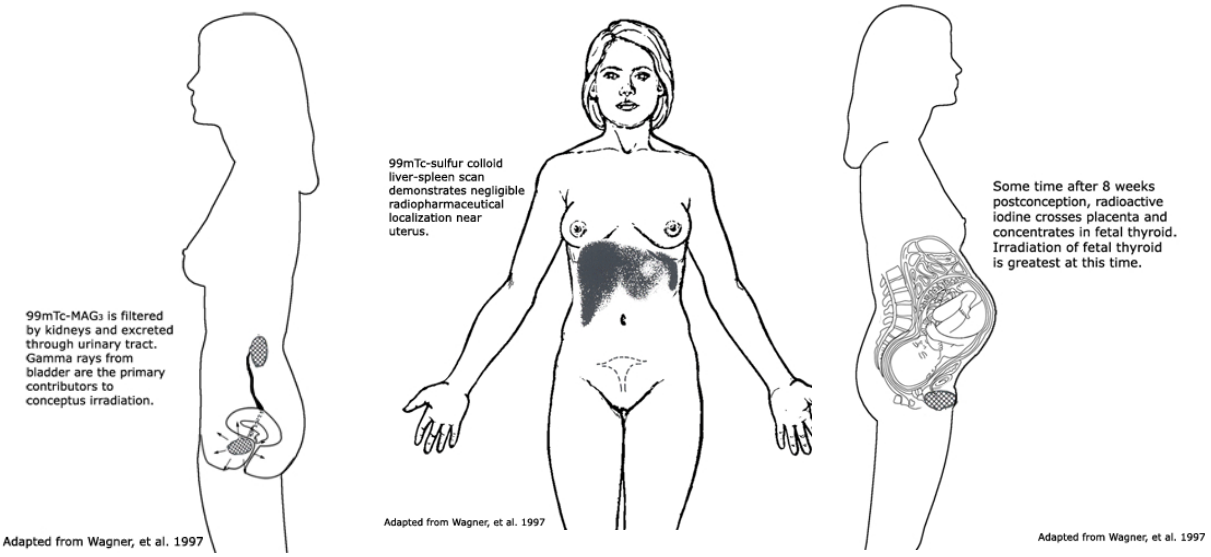
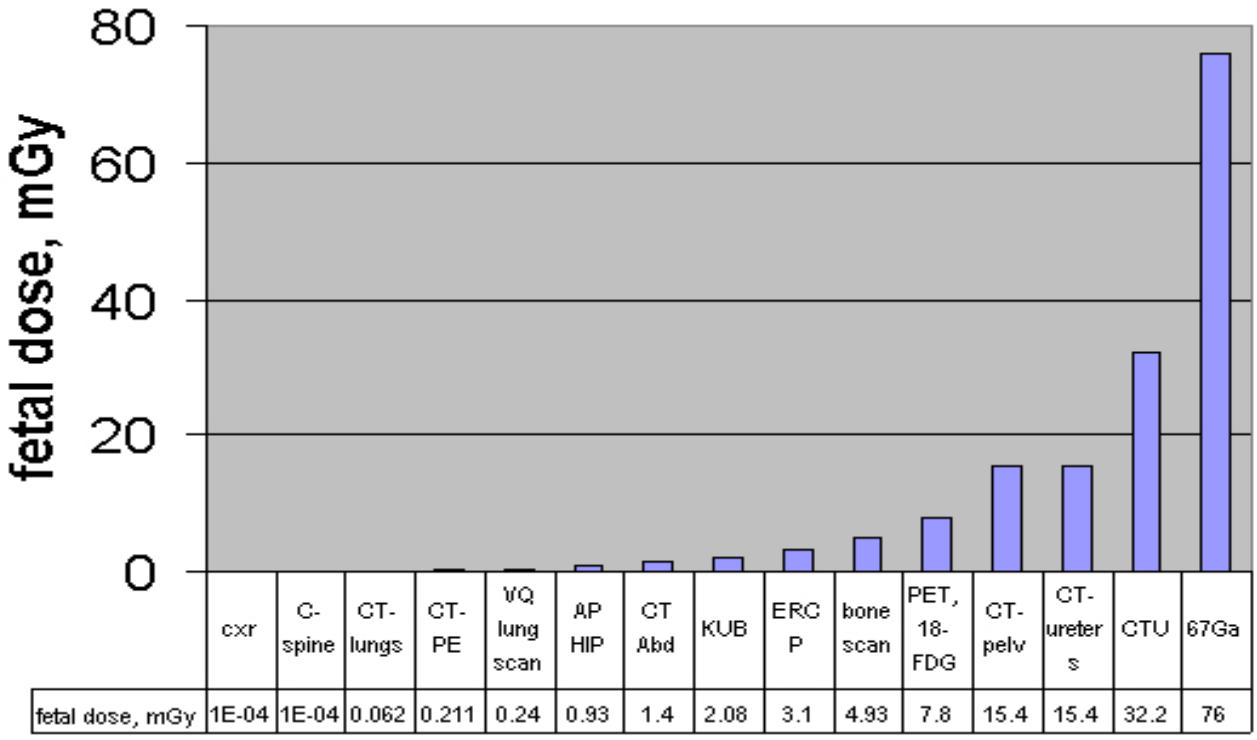


Table 4: Estimated Dose to Fetus During Selected Nuclear Medicine Studies

Exam	Agent	Mean admin'd dose (MBq)	Fetal Dose (mGy)*	Fetal Risk Category
Ventilation lung scan	Xe-133 (gas)	740	0.02	I
Perfusion lung scan	Tc-99m MAA	74	0.22	I
Myocardial perfusion	Tc-99m MIBI	1110	1.30	I
Renal Scan	Tc-99m MAG3	370	4.44	I
Bone Scan	Tc-99m MDP	925	4.93	I
PET scan	F-18 FDG	370	7.8	I
Myocardial perfusion	Tc-99m tetrofosmin	1110	8.44	I
Myocardial viability	T1-201 chloride	148	8.70	I
PET/CT scan	F-18 FDG & CT	370	18.5	I
Gallium scan - infection	Ga-67 citrate	185	38.0	I
Gallum scan - tumor	Ga-67 citrate	370	76.0	I

* Assumes radiopharmaceutical is administered at the 3-month gestational age, while administration before or after 3 months post-conception results in a lesser fetal dose.



	cxr	C-spine	CT-lungs	CT-PE	VQ lung scan	AP HIP	CT Abd	KUB	ERCP	bone scan	PET, 18-FDG	CT-pelv	CT-ureters	CTU	67Ga
fetal dose, mGy	1E-04	1E-04	0.062	0.211	0.24	0.93	1.4	2.08	3.1	4.93	7.8	15.4	15.4	32.2	76

For a summary dose display of sample procedures, see the following chart:

Summary and Recommendations

The question of whether to proceed with a procedure that imparts ionizing radiation to the fetus, rather than an alternative strategy, is a decision that should be based on each individual patient's clinical condition.

Most medical imaging studies produce fetal absorbed doses below those considered to pose a major risk. We recommend, however, that alternative diagnostic imaging tests which do not involve ionizing radiation, e.g., sonography or MRI, be first considered in the care of pregnant patients.

It is possible that multiple diagnostic imaging exams, or radiotherapy procedures, performed during a particular fetal development period can produce higher risks.

References

1. National Council on Radiation Protection. Medical Radiation Exposure of Pregnant and Potentially Pregnant Women. Report Number 54. Washington, DC: NCRP; 1977.

2. United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and Effects of Ionizing Radiation. New York, NY: United Nations; 1977.

3. International Commission on Radiological Protection. Protection of the patient in diagnostic radiology. Publication 34. Annals of the ICRP. 1982;9.

4. Wagner L, Lester R, Saladana L. Exposure of the Pregnant Patient to Diagnostic Radiation. Madison, WI: Medical Physics Publishing; 1997.

5. International Commission on Radiological Protection. Doses to the Embryo and Fetus from Intakes of Radionuclides by the Mother. Publication 34. Annals of the ICRP. 2001;31.

Glossary of Radiation Units

Absorbed Dose:The energy imparted by ionizing radiation per unit mass of irradiated material.

Becquerel (Bq): A SI unit of radioactivity. One Bq=1 disintegration per second. One million Bq=1 MegaBecquerel (MBq).

Curie (Ci): A traditional unit expressing the quantity of radioactivity. One Ci=3.7E+10 nuclear disintegrations per second. A milliCurie (mCi)=1/1000 Ci

Gray (Gy): A SI unit of absorbed dose. One Gy=100 rads. One milliGray (mGy)=1/1000 Gy.

Ionizing Radiation: Any radiation capable of displacing electrons from an atom, thereby producing ions. Examples: alpha, x-rays, gamma, beta, positron, and neutrons.

mCi vs. MBq: The conversions between the two radioactivity units are;
1 mCi = 37 MBq, and, 1 MBq = 0.027 mCi.

mrad vs. mGy: The conversions between the two absorbed dose units are;
1 mGy = 100 mrad, and, 1 mrad = 0.01 mGy.

Rad: A traditional unit of absorbed dose. One millirad (mrad) = 1/1000 rad.

Rem: A traditional unit of effective dose. A rem = (rad)(quality factor), where the quality factor (QF) is an indication of the potency of each type of radiation. Photons and beta particles have a QF=1, alpha particles=20.

Sievert: When the absorbed dose in grays is multiplied by the radiation QF, the result is the equivalent dose in sieverts (Sv). One Sv=100 rem. One milliSievert (mSv)=1/1000 Sv.

Credits and Disclaimer

The information in this summary is based on a document prepared by the Brigham and Women's Hospital. It is designed to inform your decision-making as you determine individual risks associated with medical imaging and communicate with your patients. It should not be interpreted as medical advice and dose estimates will vary with specific protocols. Patients with questions regarding these issues should speak directly with their caregivers. An additional resource is the Ask the Experts-Pregnancy and Radiation module of the Health Physics Society: http://www.hps.org