Doses from Medical Radiation Sources

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Introduction

Radiation exposures from diagnostic medical examinations are generally low and are almost always justified by the benefits of accurate diagnosis of possible disease conditions. There is no direct evidence of radiation ever causing any harm at the exposure levels encountered with diagnostic radiological examinations. Therapeutic uses of radiation naturally involve higher exposures and physicians will consider the risks of the treatment against the potential benefits. In diagnostic uses, we have only theoretical models that suggest the possibility of cancer risks, but these models all extrapolate results from higher exposures to these low levels, and no one is certain about whether or not any real risks are involved. The exposures are usually comparable to those that we receive routinely from natural radiation all around us, and the benefits of the medical exams are of course very significant.

Standardized radiation dose estimates can be given for a number of typical diagnostic medical procedures. It is impossible to give accurate radiation dosimetry for procedures involving radiation therapy; these need to be handled very carefully on a case-by-case basis. Doses are thus suggested below for some *typical* diagnostic radiology and nuclear medicine studies. It is important to note that these are only typical values. Doses will change, depending on a number of variables, including the specific machine and manufacturer (in the case of radiology), study techniques (in the case of radiology on the settings of the machine used to produce the radiation, in nuclear medicine on the amount of activity administered and the patient's metabolism), and other issues.

Typical Doses from Diagnostic Radiology Exams

As noted above, the tables below give dose estimates for typical diagnostic radiology exams. For comparison, we all receive about 300 mrem (3 mSv) of exposure annually to natural background radiation.

Plain Film X Rays

Single Radiographs	Effective Dose, mrem (mSv)
Skull (PA or AP)[1]	3 (0.03)
Skull (lateral)[1]	1 (0.01)
Chest (PA)[1]	2 (0.02)
Chest (lateral)[1]	4 (0.04)
Chest (PA and lateral)[5]	6 (0.06)
Thoracic spine (AP)[1]	40 (0.4)
Thoracic spine (lateral)[1]	30 (0.3)
Lumbar spine (AP)[1]	70 (0.7)
Lumbar spine (lateral)[1]	30 (0.3)
Abdomen (AP)[1]	70 (0.7)

Abdomen[6]	53 (0.53)
Pelvis (AP)[1]	70 (0.7)
Pelvis or hips[6]	83 (0.83)
Bitewing dental film[6]	0.4 (0.004)
Limbs and joints[6]	6 (0.06)

The following table shows the dose an individual might receive if undergoing an entire procedure, e.g., a lumbar spine series typically consists of five films.

Doses Received Undergoing an Entire Procedure

Complete Exams	Effective Dose, mrem (mSv)
Intravenous Pyelogram (kidneys, 6 films)[1]	250 (2.5)
Barium swallow (24 images, 106 sec fluoroscopy)[1]	150 (1.5)
Barium meal (11 images, 121 sec fluoroscopy)[1]	300 (3.0)
Barium follow-up (4 images, 78 sec fluoroscopy)[1]	300 (3.0)
Barium enema (10 images, 137 sec fluoroscopy)[1]	700 (7.0)
CT head[1]	200 (2.0)
CT chest[1]	800 (8.0)
CT abdomen[1]	1,000 (10)
CT pelvis[1]	1,000 (10)
CT (head and chest)[5]	1,110 (11)
PTCA (heart study)[6]	750-5,700 (7.5-57)
Coronary angiogram[6]	460-1,580 (4.6-15.8)
Mammogram[6]	13 (0.13)
Lumbar spine series[6]	180 (1.8)
Thoracic spine series[6]	140 (1.4)
Cervical spine series[6]	27 (0.27)

The following table shows typical doses from nuclear medicine exams.

Typical Doses from Nuclear Medicine Exams

Nuclear Medical Scan	Activity, mCi (MBq)	Radiopharmaceutical	Effective Dose, mrem (mSv)
Brain[2]	20 (740)	^{99m}Tc DTPA	650 (6.5)
Brain[3]	50 (1,850)	^{15}O water	170 (1.7)
Brain[4]	20 (740)	^{99m}Tc HMPAO	690 (6.9)
Hepatobiliary[2]	5 (185)	^{99m}Tc SCO	370 (3.7)
Bone[2]	20 (740)	^{99m}Tc MDP	440 (4.4)
Lung Perfusion/Ventilation[2]	5 & 10 (185 & 370)	^{99m}Tc MAA & ^{133}Xe	150 (1.5)
Kidney[2]	20 (740)	^{99m}Tc DTPA	310 (3.1)
Kidney[3]	20 (740)	^{99m}Tc MAG3	520 (5.2)
Tumor[2]	3 (110)	^{67}Ga	1,220 (12.2)
Heart[3]	30 (1,100)	^{99m}Tc sestimibi	890 (8.9)

	30 (1,100)	^{99m}Tc pertechnetate	1,440 (14.4)
Heart[4]	2 (74)	^{201}Tl chloride	1,700 (17)
	30 (1,100)	^{99m}Tc tetrofosmi	845 (8.45)
Various[3]	10 (370)	^{18}F FDG	700 (7.0)

The Pregnant or Breast-Feeding Patient

Special attention is paid to the pregnant, potentially pregnant, or breast-feeding patient. The developing embryo or fetus is particularly sensitive to radiation. If an examination that involves radiation exposure can be postponed or replaced with another study, this is always desirable. If the study is needed, precautions to eliminate or reduce the dose to the embryo/fetus should be followed. Most radiation therapy studies are contraindicated in pregnancy, but at times may be necessary. Any women of childbearing years should be given a pregnancy test before any therapeutic study involving radiation is undertaken. Breast-feeding patients are of concern in nuclear medicine studies (diagnostic or therapeutic), because the compounds given to the mother may be taken up and excreted into the breast milk, and thus possibly ingested by the nursing infant.

Doses from some important nuclear medicine exams for exposures to the fetus occurring in early pregnancy are shown in the following table. An article by Russell et al.[7] give doses at other stages of pregnancy and for other radiopharmaceuticals.

Doses from Nuclear Medicine Exams for the Fetus

Nuclear Medical Scan	Activity, mCi (MBq)	Radiopharmaceutical	Early Pregnancy Fetal Dose, mrem (mSv)
Bone	20 (740)	^{99m}Tc MDP	460 (4.6)
Lung Perfusion	5.5 (200)	^{99m}Tc MAA	56 (0.56)
Thyroid	0.8 (30)	^{123}I NaI	60 (0.6)
	0.015 (0.55)	^{131}I NaI	4 (0.04)
Tumor	5 (190)	^{67}Ga Citrate	1,800 (18
Lung Ventilation	30 (1,100)	^{133}Xe Gas	0.54 (0.0054)
Heart	1.5 (55)	^{201}Tl chloride	530 (5.3)
Kidney	20 (740)	^{99m}Tc MAG3	1,400 (14)
	20 (740)	^{99m}Tc DTPA	900 (9)
Heart	30 (1,100)	^{99m}Tc sestimibi	1,700 (17)
Liver	9.5 (350)	^{99m}Tc disofenin / mebrofenin	600 (6)
Infection	5.4 (200)	^{99m}Tc White Blood Cells	76 (0.76)
	0.5 (20)	^{111}In White Blood Cells	260 (2.6)
Liver/Spleen	8 (300)	^{99m}Tc Sulfur Colloid	54 (0.54)
Bone	20 (740)	^{99m}Tc HDP	390 (3.9)
Brain/Thyroid	30 (1,100)	^{99m}Tc Pertechnetate	1,200 (12)
Heart/blood flow	25 (930)	^{99m}Tc Red Blood Cells	600 (6.0)

** This is for diagnostic use of ^{131}I for thyroid scanning. ^{131}I is widely used for therapy of hyperthyroidism and thyroid cancer. Its use is generally contraindicated in pregnancy, as large doses to the fetus and fetal thyroid may result.

The following table shows estimated fetal radiation dose for 0, 3, 6, and 9 months gestational age based upon "typical" exposure values.

Estimated Fetal Radiation Dose Based on "Typical" Exposure Values

Study	Fetal Dose mrem, (mSv)			
	Early Pregnancy	3-Month	6-Month	9-Month
AP Pelvis	144 (1.44)	131 (1.31)	127 (1.27)	157 (1.57)
PA Pelvis	40 (0.40)	16 (0.16)	232 (2.32)	100 (1.00)
Lateral Pelvis	53 (0.53)	32 (0.32)	48 (0.48)	52 (0.52)
AP T-Spine (wide FOV)	1.8 (0.018)	1.1 (0.011)	6.9 (0.069)	13 (0.13)
AP T-Spine (narrow)	1.2 (0.012)	0.8 (0.008)	4.6 (0.046)	8.9 (0.089)
Lateral T-Spine	0.6 (0.006)	0.6 (0.006)	1.7 (0.017)	3.2 (0.032)
AP Lumbar Spine	225 (2.25)	197 (1.97)	394 (3.94)	926 (9.26)
Lat Lumbar Spine	113 (1.13)	62 (0.62)	84 (0.84)	85 (0.85)

In the case of the breast-feeding mother who receives a radiopharmaceutical, an article in 2000 in the *Journal of Nuclear Medicine*[8] discussed the issues associated with possible exposures of the nursing infant. The authors noted that individual levels of activity in breast milk vary widely and that the best approach is to make individual measurements of breast milk activity and individual-specific projections of dose and suggested interruption schedules. Nonetheless, they also offered a general set of recommendations for possible interruption of breast-feeding for a number of compounds, for which some experience with breast milk excretion had been reported in the literature. The following table summarizes these recommendations.

Summary of Recommendations for Radiopharmaceuticals Excreted in the Breast Milk[8] Administered

Pharmaceutical	Activity, mCi (MBq)	Counseling?*	Advisory
^{67}Ga Citrate	5.0 (185)	Yes	Cessation
^{99m}Tc DTPA	20 (740)	No	
^{99m}Tc MAA	4 (148)	Yes	12 hr
^{99m}Tc Pertechnetate	30 (1,110)	Yes	48 hr
^{131}I NaI	150 (5,550)	Yes	Cessation
^{51}Cr EDTA	0.05 (1.85)	No	
^{99m}Tc IDA agents	8 (300)	No	
^{99m}Tc Glucoheptonate	20 (740)	No	
^{99m}Tc HAM	8 (300)	No	
^{99m}Tc MIBI	30 (1,110)	No	
^{99m}Tc MDP	20 (740)	No	
^{99m}Tc PYP	20 (740)	No	
^{99m}Tc Red Blood Cells *in vivo*	20 (740)	Yes	12 hr
^{99m}Tc Red Blood Cells *in vitro*	20 (740)	No	
^{99m}Tc Sulfur Colloid	12 (444)	No	
^{111}In White Blood Cells	0.5 (18.5)	No	
^{123}I NaI	0.4 (14.8)	Yes	Cessation**
^{123}I OIH	2 (74)	No	
^{123}I mIBG	10 (370)	Yes	48 hr
^{125}I OIH	0.01 (0.37)	No	
^{131}I OIH	0.3 (11.1)	No	

^{99m}Tc DTPA Aerosol	1 (37)	No	
^{99m}Tc MAG3	10 (370)	No	
^{99m}Tc White Blood Cells	5 (185)	Yes	48 hr
^{201}Tl Chloride	3 (111)	Yes	96 hr

* "No" means that no interruption of breast-feeding need be suggested, given the criterion of a limit of 1 mSv effective dose to the infant and these amounts of administered activity. "Yes" means that some interruption is required, as noted in the next column.

** This requirement may be unduly restrictive, but was recommended because of documented cases in which significant levels of radioactive contaminants (^{124}I, ^{125}I and others) were found in commercial products. If no contaminants are present, little or no interruption of feeding may be necessary.

Doses in Radiation Therapy

In radiation therapy, much higher doses are given, with the intent of destroying cancer tissues. The trick is to give enough dose to kill the unhealthy tissues while not giving too much to normal, healthy tissues. This is accomplished in a number of ways. With external radiation, many techniques are used to focus the radiation dose in the area of interest and give lower doses to normal tissues. Small sources may be placed very near to or in direct contact with cancer tissues (brachytherapy) and only left in place for defined periods of time. Therapy is also performed with internal radioactive sources, like are used in diagnostic nuclear medicine. These sources are labeled to special molecules that are designed to be taken up preferentially by cancer cells, and less by other organs and tissues, and thus lead to a positive outcome without compromising the health of the patient. It is not possible to give specific dose calculations for these cases. Each situation is studied carefully by a radiation physicist before the therapy is given, and a specific dose plan is devised. Doses are typically on the order of hundreds or thousands times higher than in the diagnostic studies described above.

References

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