TITLE: UNDERSTANDING FETAL RISK FROM MEDICAL IMAGING EXAMINATIONS

DEPARTMENT: Lower Mainland Medical Imaging Service

MODALITY: Mammography, Radiography, Fluoroscopy/ Interventional/Angiography, Computed Tomography, Nuclear Medicine

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This document is intended to provide medical practitioners and imaging specialists with a concise description of fetal risk from medical imaging examinations, and provide an estimate of fetal dose from common examinations.

General Fetal Risk

The following quote succinctly states the scientific community's current understanding of fetal risk association with diagnostic imaging examinations that use ionizing radiation.

"The radiation dose to the embryo or fetus that is likely to result from any diagnostic procedure in current use should present no risk of causing fetal death, malformation, growth retardation or impairment or mental development." (1).

Most diagnostic examinations are associated with little, if any, known significant fetal risks. Furthermore, the American College of Radiology (ACR) has stated that no single diagnostic procedure results in sufficient radiation that would threaten the well-being of a developing pre-embryo, embryo or fetus (1). As a general rule, there is no increased fetal risk for radiation doses below 50 mGy, a dose threshold which covers *all single* diagnostic exams (2) (3). An increase in risk to the fetus has been stated for doses above 100 mGy as a 1% increase in the natural incidence of malformation and cancer. A summary of fetal risk based on dose and fetal age is provided in Table 1, this information can be used by clinicians when deciding whether to proceed with an examination, or during patient counseling.

Although fetal risk is considered negligible for a single diagnostic procedure, applying the ALARA principle to reduce dose is warranted, this includes:

1. Screening all female patients of child bearing age (ages:11-55) for pregnancy,
2. Adjusting protocols or delaying the examination,
3. Documenting the entire process from screening responses to final dose *in the patient's record*.

4. Advising a pregnant patient to inform all future medical practitioners (during the current pregnancy) of all past imaging exams performed during the *current* pregnancy.
5. In the event a patient has multiple examinations during pregnancy, the doses can be considered additive to provide a conservative risk estimate.

Regulatory requirements (via the Diagnostic Accreditation Program of BC – DAP, CNSC, or Health Canada Safety Code 35) mandate specific screening questions and documentation for pregnancy prior to imaging a female of child bearing age.

The majority of diagnostic x-ray procedures will expose the fetus to less than 1 mGy of absorbed dose. At this level of exposure the excess absolute risk (or attributable risk) of cancer is estimated at 1 in 10,000, an estimate below the natural rate of childhood cancer (1 in 500 children). Some imaging procedures can lead to fetal doses between 1-10 mGy. Fetal risk of childhood cancer increases proportionally with dose from 1 in 10,000 (@ 1 mGy exposure) to 1 in 1,000 (@ 10 mGy exposure).

High dose diagnostic examinations are considered when the potential fetal dose **exceeds 10 mGy** and a low dose procedure if the potential fetal dose is **below 10 mGy.**

Risk specific to Nuclear Medicine Exams:

Fetal absorbed doses for nuclear medicine procedures depend on the isotope, chemical form and activity administered to the mother. In particular, it is important to avoid administering large activities and avoiding radiopharmaceuticals that can cross the placenta (such as iodine and gallium). In Table 5 we list the most common radiopharmaceuticals and the associated activities that can deliver fetal absorbed doses higher than 10 mGy. In addition, infants can be exposed to doses higher than 1 mGy through ingested breast milk and by being in close contact with the patient after the administration of a radiopharmaceutical. In Table 6 we list recommendations for periods during which patients should interrupt breastfeeding and restrict close contact with an infant.

Sample strategies to reduce fetal and infant dose due to nuclear medicine procedures include:

- Reduce the administered activity - the scan time can be increased to preserve image quality,
- Use radiopharmaceuticals that will reduce the fetal dose.

For patients currently breast feeding, breast milk can be discarded for the time duration stated in Table 6. For patients who have close contact with infants, recommended minimum contact distance and duration of contact restriction is provided in Table 6.

General Guidelines on Counseling Pregnant Patients:

It is the physician's and/or radiologist's role to counsel pregnant patients prior to the examination, after emergency diagnostic imaging in which pregnancy screening was not possible due to patient state (i.e. emergency trauma) or if patient confirmed pregnancy after an examination. The physician/radiologist may request support from a Medical Physicist to prospectively estimate the *in utero* dose for a planned examination or determine the *in utero* dose from a completed exam. It is also the physician/radiologist responsibility to file all reports in the patients file.

When counseling patients only carcinogenic effects need to be considered since there is no known deterministic effect under 100 mGy. As shown in tables 1-5, the excess absolute risk of childhood cancer related to *in utero* radiation exposure is low compared to the natural rate of childhood cancer (1 in 500) and other fetal risks during pregnancy (Table 7).

In general, diagnostic imaging examinations are safe for pregnant patients. However, due to the use of radiation and the negatively perceived effects some patients may be apprehensive towards the examination. In these situations the following statements may be helpful with patient counseling:

1. State the radiation dose to the embryo or fetus that is likely to result from any diagnostic procedure in current use should present **no** risk causing fetal death, malformation, growth retardation or impairment of mental development;

2. radiation doses resulting from diagnostic procedures in pregnancy present a negligible risk of causing radiation-induced hereditary disease in the descendents of the unborn child;

3. compare the excess absolute risk of this examination vs. other general risk factors (examples provided in Table 7).

4. and advise the patient to inform all physicians of prior imaging exams obtained during the current pregnancy.

Table 1 – Summary of Suspected In-Utero Induced Deterministic Radiations Effects

Menstrual or Gestational Age	Conception Age	Dose < 50 mGy	Dose 50-100 mGy	Dose > 100 mGy
0-2 weeks (0-14 days)	Prior to conception	None	None	None
3rd and 4th weeks (15-28 days)	1st-2nd weeks (1-14 days)	None	Probably None	Possible spontaneous abortion
5th -10th weeks (29-70 days)	3rd-8th weeks (15-56 days)	None	Potential effects are scientifically uncertain and probably too subtle to be clinically detectable	Possible malformations increasing in likelihood as dose increases
11th-17th weeks (71-119 days)	9th-15th weeks (57-105 days)	None	Potential effects are scientifically uncertain and probably too subtle to be clinically detectable	Increased risk of deficits in IQ or mental retardation that increase with increasing dose
18th-27th weeks (120-189 days)	16th-25th weeks (106-175 days)	None	None	IQ deficits not detectable at diagnostic doses
> 27th week (>189 days)	>25 weeks (>175 days)	None	None	None applicable to diagnostic medicine.

*ICRP 84 and ICRP 90.

Table 2 – Low Dose Fetal Imaging Examinations

Modality	Examination	Estimated Fetal Dose (mGy)	Risk of Childhood Cancer per examination (excess absolute risk)
Radiography	Skull	**0.001 - 0.1**	**< 1 in 1,000,000 To 1 in 100,000**
Radiography	C-Spine		
Radiography/CT	Extremities		
Radiography	Thoracic Spine		
Mammography	Breast (Screening)		
CT	Head, Head/Neck		
CT	Pulmonary Angiogram		
Nuclear Medicine	^{99m}Tc sulfur colloid (SC, <60 MBq)		
Nuclear Medicine	^{99m}Tc ventilation scan (Technegas, < 370 MBq inhaled)		
Nuclear Medicine	^{99m}Tc perfusion scan (MAA, <340 MBq)		

Table 3 – Medium Fetal Dose Examinations

Modality	Examination	Estimated Fetal Dose (mGy)	Risk of Childhood Cancer per examination (excess absolute risk)
Radiography	Abdomen	**0.1-1.0**	**1 in 100,000 To 1 in 10,000**
Radiography	Barium Meal		
Radiography	Hip		
CT	Chest & Liver		
Nuclear Medicine	^{99m}Tc Thyroid Scan (TcO4, < 111 MBq)		
Nuclear Medicine	^{99m}Tc Renogram (DTPA, <111 MBq)		
Nuclear Medicine	^{99m}Tc Renal Scan (DMSA, <200 MBq)		
Nuclear Medicine	^{99m}Tc White Cell Count (WBC, <370 MBq)		

Table 4 – Medium-High Fetal Dose Examinations

Modality	Examination	Estimated Fetal Dose (mGy)	Risk of Childhood Cancer per examination (excess absolute risk)
Radioscopy	Barium Enema	**1.0-10**	**1 in 10,000 To 1 in 1,000**
Radioscopy	Intravenous Urography		
Radiography	Lumbar Spine		
CT	Lumbar Spine		
CT	Abdomen		
Bone Density	All Exams		
Nuclear Medicine	^{99m}T Bone Scan (MDP, <1000 MBq)		
Nuclear Medicine	^{99m}T Red Blood Cells (RBC, <1000 MBq)		
Nuclear Medicine	^{111}In White Blood Cells (WBC, < 75 MBq)		
Nuclear Medicine	^{99m}T Renal scan (DTPA, < 800 MBq) (MAG3, < 500 MBq)		
Nuclear Medicine	^{123}I Tumor Scan (MIBG, < 550 MBq)		
Nuclear Medicine	^{99m}Tc Brain scan (HMPAO, <1100 MBq)		
Nuclear Medicine	^{18}F Tumor Scan (FDG, <370 MBq)		

Table 5 –High Fetal Dose Examinations

Modality	Examination	Estimated Fetal Dose (mGy)	Risk of Childhood Cancer per examination (excess absolute risk)
Computed Tomography	Pelvis	**10-50 (high dose)**	**1 in 1,000 To 1 in 200** *Natural risk of childhood cancer ~ 1 in 500*
Computed Tomography	Abdomen/Pelvis		
Computed Tomography	Chest/Abdomen/Pelvis		
Nuclear Medicine	^{99m}Tc Myocardial (SPECT rest-exercise protocol) (MIBI, >700 MBq) (Tetrofosmin, > 600 MBq)		
Nuclear Medicine	^{99m}Tc pertechnetate (TcO_4, > 900 MBq)		
Nuclear Medicine	^{201}Tl Thallus chloride ($TlCl_2$, > 100 MBq)		
Nuclear Medicine	^{67}Ga Tumor scan (Citrate, >100 MBq)		
Nuclear Medicine	^{111}In receptor scan (Octreotide, > 120 MBq)		
PET/CT	^{18}F Whole Body Scan (FDG, > 370 MBq)		

Table 6 –Recommendations for nuclear medicine procedures for interruption of breastfeeding and for limiting close contact with an infant after the administration of a radiopharmaceutical

Radiopharmaceutical	Administered Activity (MBq)	Time to interrupt breastfeeding*	Time to limit close contact (<30 cm) with an infant*
^{99m}Tc-MDP	740	No interruption	Restrict contact for 2 hrs
^{99m}Tc DMSA	150	No interruption	No restrictions
^{99m}Tc-SC	450	No interruption	No restrictions
^{99m}Tc-MIBI, Tetrofosmine	1100	No interruption	Restrict contact for 4 hrs
^{99m}Tc-MAG3	400	No interruption	No restrictions
^{111}In-WBC	20	No interruption	No restrictions
^{99m}Tc-MAA	200	12 hours	No restrictions
^{99m}Tc-DTPA	740	No interruption	Restrict contact for 2 hrs
^{99m}Tc-RBC	740 MBq *In-vivo*	12 hours	Restrict contact for 2 hrs
	740 MBq *In-vitro*	No interruption	
$^{99m}TcO_4$	<450	4 hours	No restrictions
	450 –1100	12 hours	Restrict contact for 4 hrs
	>1100	24 hours	Restrict contact for 8 hrs
^{123}I-NaI**	20	24 hours	No restrictions
^{201}Tl chloride	111	96 hours	No restrictions
^{67}Ga citrate	50	2 weeks	Restrict contact for 3 days
	185	Complete Cessation	
^{131}I-NaI	200	Complete Cessation	Restrict contact to 6 hrs within 24 hr period
^{123}I-MIBG**	150	12 hours	No restrictions
	370	48 hours	
^{99m}Tc Technegas	37	No interruption	No restrictions
^{99m}Tc-WBC	60	12 hours	No restrictions
	185	24 hours	
^{111}In Octreotide	200	48 hours	Restrict contact for 48 hrs
^{18}F-FDG	400	2 hours	No restrictions

* In the case where no recommendations are needed, if a patient is concerned about radiation exposure they can be advised to feed the infant formula or previously expressed breast milk for one feeding and/or to limit close contact with the infant for 2-4 hours following the administration of the pharmaceutical.

** Complete CESSATION is recommended if radioactive contaminates (such as ^{124}I and ^{125}I) are present in the radiopharmaceutical. Contact the Regional Medical Physicist in Nuclear Medicine or vendor if unsure whether radiopharmaceutical contains contaminants.

Table 7 – General excess absolute risk for different environmental condition

Risk Factor	Pregnancy Outcome	Risk of Occurrence
Maternal German Measles	Defects of Heart, lens, muscles, etc…	2 in 3
Cigarette Smoking < 1 pack/day >1 pack/day	Low birth weight, premature infant death	1 in 5 1 in 5 1 in 3
Alcohol Consumption 2 drinks/day 2-4 drinks/day Chronic alcoholic	Low birth weight Fetal Alcohol Syndrome (growth Deficiency, brain dysfunction)	1 in 5 1 in 5 1in 3
Age: 20 >35	Down's Syndrome	 1 in 2,300 1 in 64
Altitude: 100 m 2, 000 m 3, 0000 m	Low birth weight	 1 in 15 1 in 10 1 in 4
*Round Trip Flight: Vancouver- Toronto (45 uGy/trip)	Childhood Cancer	1 in 500,000

* Risk of fetal exposure to radiation from a diagnostic exam is easily comparable to the fetal received with flying above 40,000 ft. It would take 8 round trips from Vancouver to Frankfurt, Germany for a fetus to receive a total radiation dose of 1 mGy.

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