Assessment of doses to embryo and fetus after incorporation of radionuclides

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'Fetal radiation risk: dose assessment in occupational, medical and emergency situations'

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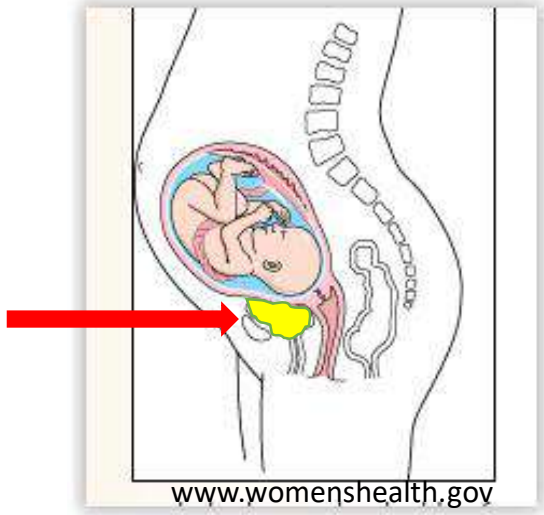
Pregnancy and medical radiation

- Thousands of pregnant women are exposed to ionizing radiation each year
- Lack of knowledge has probably led to abortion, unnecessarily
- For most patients radiation exposure is medically appropriate and the radiation risk to the embryo/fetus is minimal.
  - There are however exceptions….
  - There are occasions when the fetal exposure will result in significant harm to the embryo/fetus

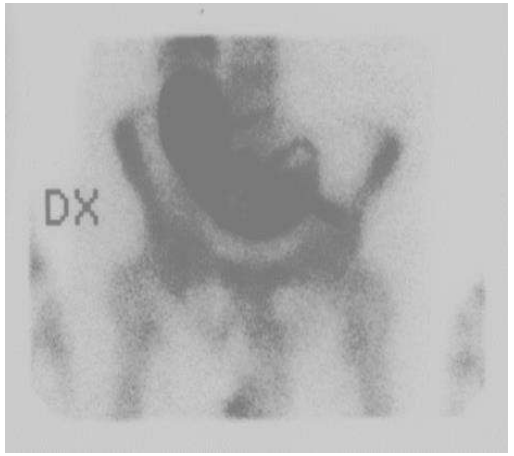
ICRP Publication 84. Ann. ICRP 30 (1).

Irradiation of the embryo/fetus in Nuclear medicine

- The embryo/fetus may be **irradiated externally** from activity in the mother



- Some radiopharmaceuticals may cross the placenta and concentrate in fetal tissue i.e. **internal exposure** of the fetus



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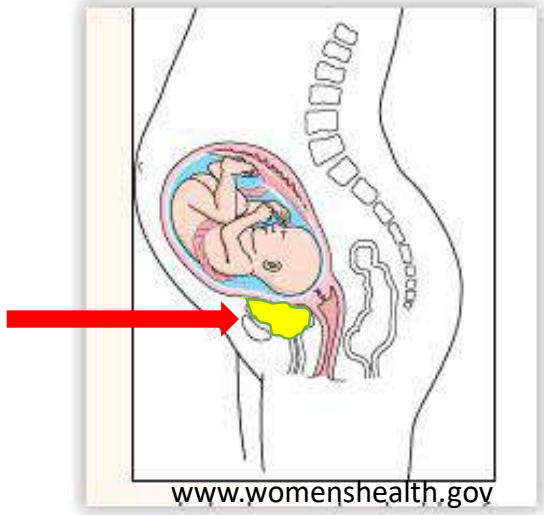

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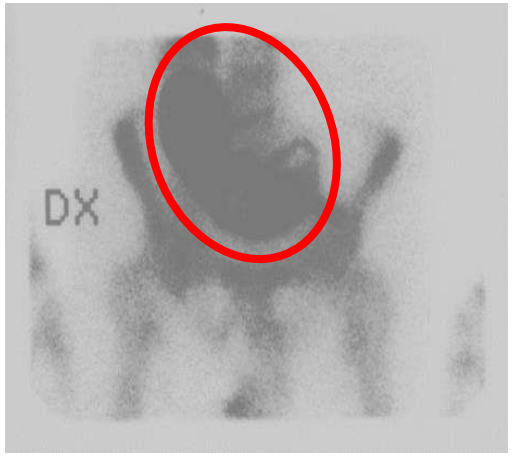


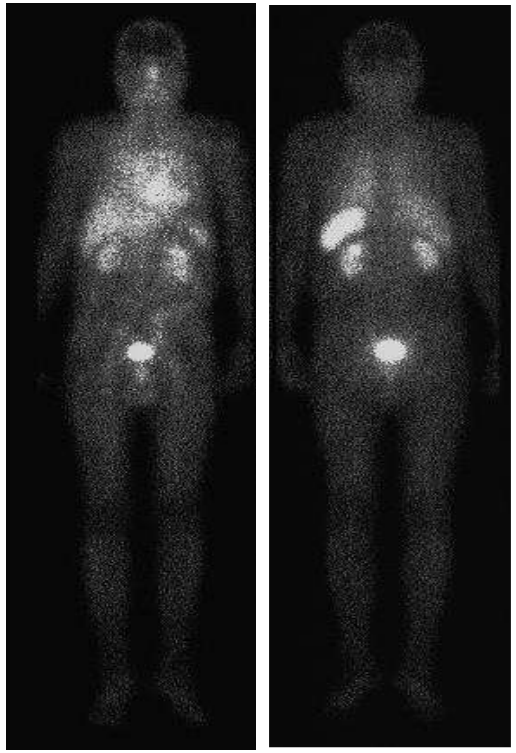
Pregnancy and radiopharmaceuticals - Assessment of fetal dose

- Biodistribution and retention in organs and tissues
- Excretion routes
- Radionuclide
- Placental crossover

^{99m}Tc-diphosphonate

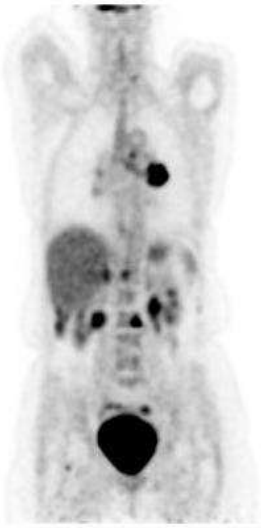
Anterior Posterior

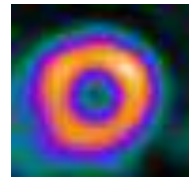
^{111}In-octreotide



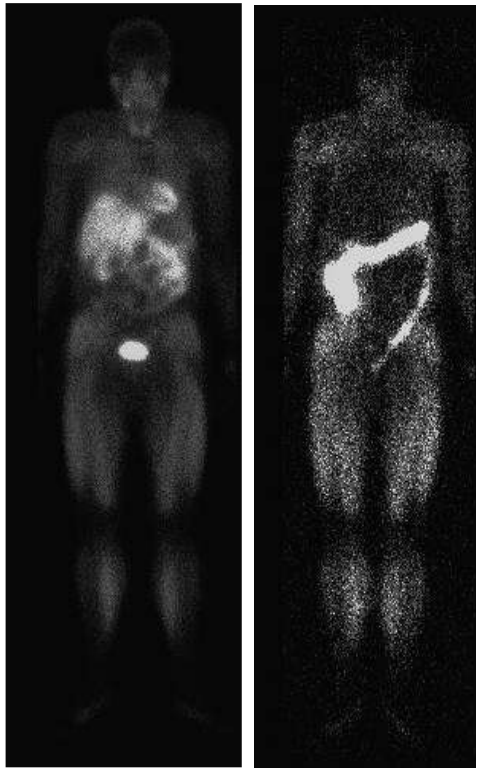
Anterior Posterior

^{18}F-FDG

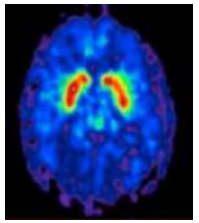




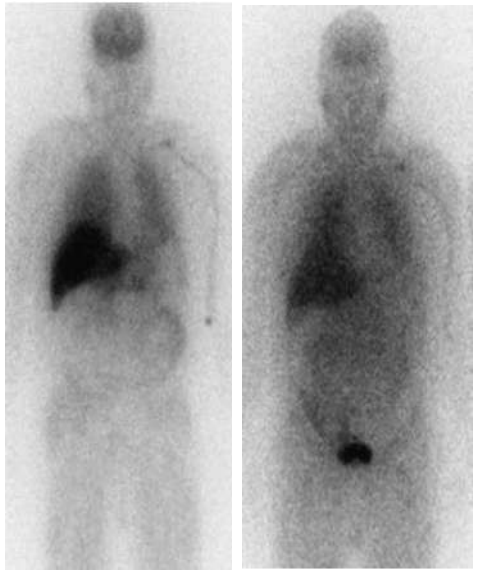
^{99m}Tc-MIBI



15 min p.i. 24 h p.i.



^{123}I-ioflupane



10 min p.i. 6 h p.i.

Sigrid Leide-Svegborn 2021

Radiation-related risks throughout the pregnancy is related to the:

- The absorbed dose to the embryo/fetus (mGy)
- The stage of pregnancy at the time of irradiation

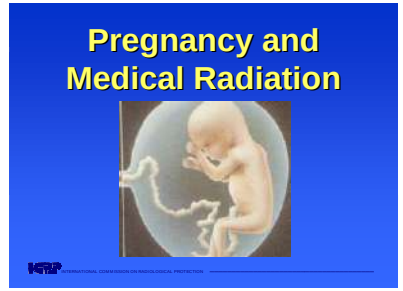
The radiation risk is most significant during the organo-genesis and in the early fetal period, somewhat less in the second trimester and least in the third trimester

Most risk

Less risk

Least risk

ICRP publication 84



ICRP publication 84

Radiation-related effects in embryo/fetus

- Early effects

- Effects on embryo/fetus during growth

  - lethal effects – threshold dose 100 mGy

  - malformations – threshold dose 100-200 mGy or higher

  - mental retardation – threshold dose 100 mGy

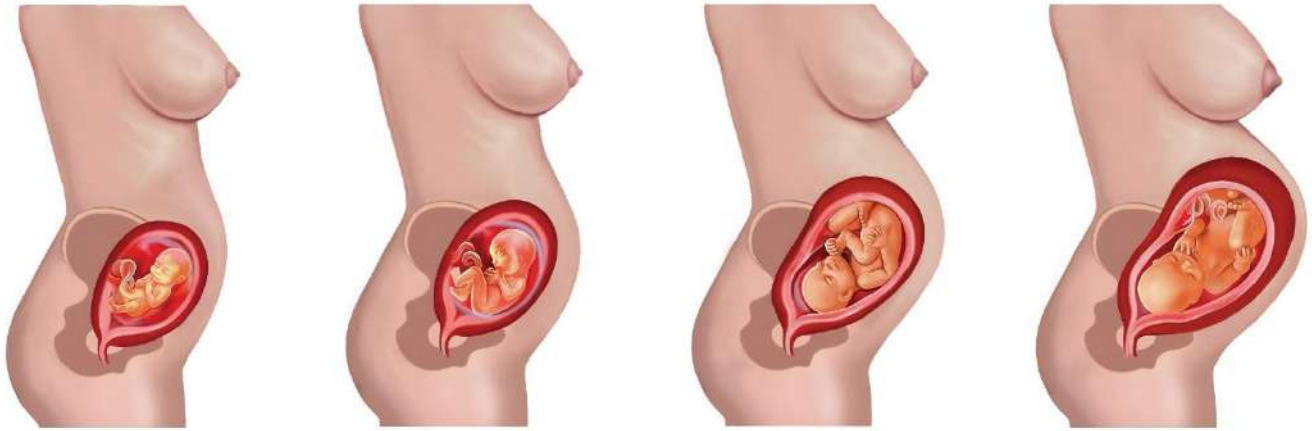
    - High risk 8-15 w post-conception
    - Somewhat less 16-25 w p.c.

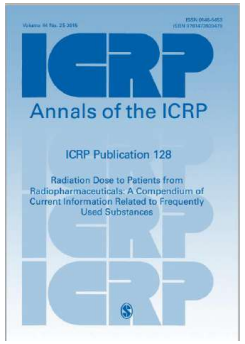
- Cancer (leukemia and solid tumours) – No threshold dose

Pregnancy and radiopharmaceuticals - Assessment of fetal dose

External dose from activity in the organs of the mother

Fetal dosimetry – "Organ dose"



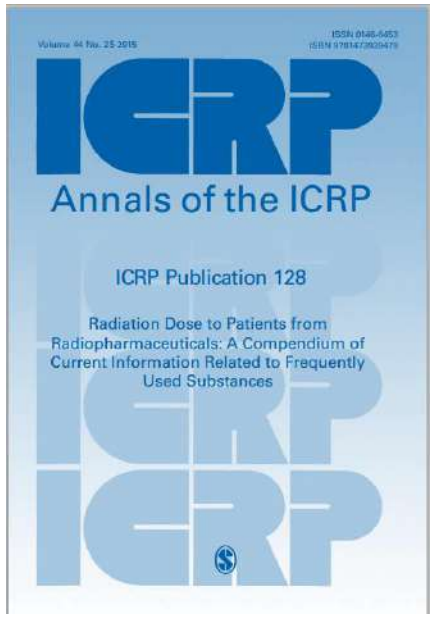


Dose to uterus of the mother

ICRP Publication 106 and 128
"Radiation Dose to Patients from Radiopharmaceuticals"

Dose to the embryo/fetus

- Russell JR *et al., Health Phys*, 1997:756-769
- Russell JR *et al*., *Health Phys*, 1997:747-755
- ICRP Publication 84
- Stabin MG, *J Nucl Med,* 2018:1005-1006
- Other publications in the "Fetal dose area"



ICRP, 2008. Ann. ICRP 38 (1-2)
ICRP, 2015. Ann. ICRP 44 (2S)

Dose to uterus of the mother

ICRP Publication 106 and 128
"Radiation Dose to Patients from Radiopharmaceuticals"

Table. Absorbed dose per unit A [mGy/MBq]

Radiation dose to patients from radiopharmaceuticals

Table C.31. Absorbed doses for ^{18}F-fluoro-2-deoxy-D-glucose.

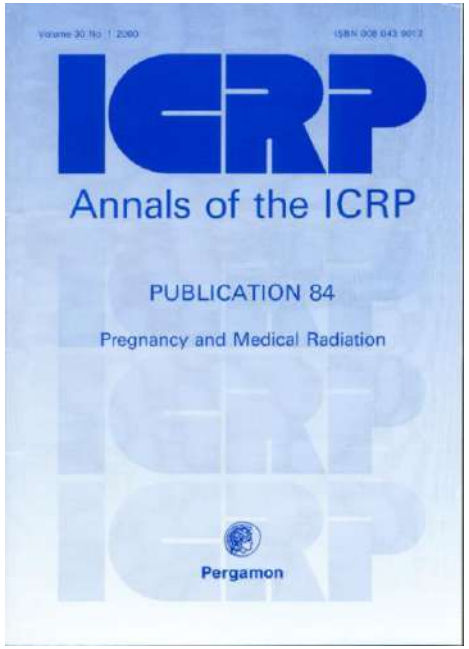
	Absorbed dose per unit activity administered (mGy MBq^{-1})				
Organ	Adult	15 years	10 years	5 years	1 year
Adrenals	1.2E−02	1.6E−02	2.4E−02	3.9E−02	7.1E−02
Bone surfaces	1.1E−02	1.4E−02	2.2E−02	3.4E−02	6.4E−02
Brain	3.8E−02	3.9E−02	4.1E−02	4.6E−02	6.3E−02
Breast	8.8E−03	1.1E−02	1.8E−02	2.9E−02	5.6E−02
Gallbladder wall	1.3E−02	1.6E−02	2.4E−02	3.7E−02	7.0E−02
Gastrointestinal tract					
Stomach wall	1.1E−02	1.4E−02	2.2E−02	3.5E−02	6.7E−02
Small intestine wall	1.2E−02	1.6E−02	2.5E−02	4.0E−02	7.3E−02
Colon wall	1.3E−02	1.6E−02	2.5E−02	3.9E−02	7.0E−02
(Upper large intestine wall	1.2E−02	1.5E−02	2.4E−02	3.8E−02	7.0E−02)
(Lower large intestine wall	1.4E−02	1.7E−02	2.7E−02	4.1E−02	7.0E−02)
Heart wall	6.7E−02	8.7E−02	1.3E−01	2.1E−01	3.8E−01
Kidneys	1.7E−02	2.1E−02	2.9E−02	4.5E−02	7.8E−02
Liver	2.1E−02	2.8E−02	4.2E−02	6.3E−02	1.2E−01
Lungs	2.0E−02	2.9E−02	4.1E−02	6.2E−02	1.2E−01
Muscles	1.0E−02	1.3E−02	2.0E−02	3.3E−02	6.2E−02
Oesophagus	1.2E−02	1.5E−02	2.2E−02	3.5E−02	6.6E−02
Ovaries	1.4E−02	1.8E−02	2.7E−02	4.3E−02	7.6E−02
Pancreas	1.3E−02	1.6E−02	2.6E−02	4.0E−02	7.6E−02
Red marrow	1.1E−02	1.4E−02	2.1E−02	3.2E−02	5.9E−02
Skin	7.8E−03	9.6E−03	1.5E−02	2.6E−02	5.0E−02
Spleen	1.1E−02	1.4E−02	2.1E−02	3.5E−02	6.6E−02
Testes	1.1E−02	1.4E−02	2.4E−02	3.7E−02	6.6E−02
Thymus	1.2E−02	1.5E−02	2.2E−02	3.5E−02	6.6E−02
Thyroid	1.0E−02	1.3E−02	2.1E−02	3.4E−02	6.5E−02
Urinary bladder wall	1.3E−01	1.6E−01	2.5E−01	3.4E−01	4.7E−01
Uterus	1.8E−02	2.2E−02	3.6E−02	5.4E−02	9.0E−02
Remaining organs	1.2E−02	1.5E−02	2.4E−02	3.8E−02	6.4E−02
Effective dose (mSv MBq^{-1})	1.9E−02	2.4E−02	3.7E−02	5.6E−02	9.5E−02

The physical half-life of ^{18}F is 1.83 h.

Pregnancy and radiopharmaceuticals - Assessment of fetal dose

Dose to the embryo/fetus

ICRP Publication 84



ICRP, 2000. Ann. ICRP 30 (1)

Table 2. Fetal whole body dose from common nuclear medicine examinations in early pregnancy and at term. (Dose includes maternal and fetal self dose contributions. Adapted from Russell, Stabin, Sparks et al., 1997, ICRP, 1988, and ICRP, 1998.)

Radiopharmaceutical	Procedure	Administered activity (MBq)	Early (mGy)	9 months (mGy)
^{99m}Tc	Bone scan (phosphate)	750	4.6–4.7	1.8
^{99m}Tc	Lung perfusion (MAA)	200	0.4–0.6	0.8
^{99m}Tc	Lung ventilation (aerosol)	40	0.1–0.3	0.1
^{99m}Tc	Thyroid scan (pertechnetate)	400	3.2–4.4	3.7
^{99m}Tc	Red blood cell	930	3.6–6.0	2.5
^{99m}Tc	Liver colloid	300	0.5–0.6	1.1
^{99m}Tc	Renal DTPA	750	5.9–9.0	3.5
^{67}Ga	Abscess/tumour	190	14–18	25
^{123}I	Thyroid uptake[1)]	30	0.4–0.6	0.3
^{131}I	Thyroid uptake[1)]	0.55	0.03–0.04	0.15
^{131}I	Metastases imaging[1)]	40	2.0–2.9	11.0

[1)] Fetal thyroid doses are much higher than fetal whole body dose, viz. 5–15 mGy/MBq for ^{123}I and 0.5–1.1 Gy/MBq for ^{131}I.

ICRP Publication 84
Pregnancy and Medical Radiation

Approximate whole body fetal dose (mGy) from common nuclear medicine procedures

Procedure	Activity (MBq)	Early pregnancy	9 months
Tc-99m			
Bone scan	750	4.7	1.8
Lung scan	240	0.9	0.9
Liver colloid scan	300	0.6	1.1
Thyroid scan	400	4.4	3.7
Renal DTPA	300	9.0	3.5
Red blood cell	930	6.0	2.5
I-123 thyroid uptake	30	0.6	0.3
I-131 thyroid uptake	0.55	0.04	0.15

Adapted data from publications by Russell JR *et al*, in Health physics

www.icrp.org

Pregnancy and radiopharmaceuticals - Assessment of fetal dose

Dose to the embryo/fetus

- **Russell JR *et al., Health Phys*,1997:756-769**
- **Russell JR *et al., Health Phys*,1997:747-755**

Mean absorbed dose to a target tissue, $\bar{D}_T$

$$\bar{D}_T = \sum \tilde{A} \cdot S_{T \leftarrow S}$$ **[mGy]**

$\tilde{A}$ – Cumulated activity [MBq·h]

$S_{T \leftarrow S}$ – S-value [mGy/MBq·h]

Target tissue = fetus

Source tissues = activity in the organs of the mother

S-values (or SAFs) are based on mathematical phantoms describing a pregnant female in early pregnancy, first trimester, second trimester and third trimester

SAF: Specific Absorbed Fraction

Pregnancy and radiopharmaceuticals - Assessment of fetal dose

- **Dose to the embryo/fetus**

Russell JR *et al.*, *Health Phys*,1997:756-769

"Radiation absorbed dose to the embryo/fetus from radiopharmaceuticals"

Dose coefficients

Table 3a. Absorbed Dose Estimates to the Embryo/Fetus Per Unit Activity of Radiopharmaceutical Administered to the Mother (maternal contributions only).

Radiopharmaceutical	Early mGy/MBq	3 Month mGy/MBq	6 Month mGy/MBq	9 Month mGy/MBq
^{111}In DTPA	6.5×10^{-2}	4.8×10^{-2}	2.0×10^{-2}	1.8×10^{-2}
^{111}In Pentetreotide	8.2×10^{-2}	6.0×10^{-2}	3.5×10^{-2}	3.1×10^{-2}
^{111}In Platelets	1.7×10^{-1}	1.1×10^{-1}	9.9×10^{-2}	8.9×10^{-2}
^{111}In Red Blood Cells	2.2×10^{-1}	1.3×10^{-1}	1.1×10^{-1}	8.6×10^{-2}
^{111}In White Blood Cells	1.3×10^{-1}	9.6×10^{-2}	9.6×10^{-2}	9.4×10^{-2}
^{99m}Tc Albumin Microspheres	4.1×10^{-3}	3.0×10^{-3}	2.5×10^{-3}	2.1×10^{-3}
^{99m}Tc Disofenin	1.7×10^{-2}	1.5×10^{-2}	1.2×10^{-2}	6.7×10^{-3}
^{99m}Tc HEDP	7.2×10^{-3}	5.2×10^{-3}	2.7×10^{-3}	2.4×10^{-3}
^{99m}Tc HMPAO	8.7×10^{-3}	6.7×10^{-3}	4.8×10^{-3}	3.6×10^{-3}
^{99m}Tc Human Serum Albumin	5.1×10^{-3}	3.0×10^{-3}	2.6×10^{-3}	2.2×10^{-3}
^{99m}Tc MAG3	1.8×10^{-2}	1.4×10^{-2}	5.5×10^{-3}	5.2×10^{-3}
^{99m}Tc MIBI-rest	1.5×10^{-2}	1.2×10^{-2}	8.4×10^{-3}	5.4×10^{-3}
^{99m}Tc MIBI-stress	1.2×10^{-2}	9.5×10^{-3}	6.9×10^{-3}	4.4×10^{-3}
^{99m}Tc RBC-Heat Treated	1.7×10^{-3}	1.6×10^{-3}	2.1×10^{-3}	2.2×10^{-3}

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Pregnancy and radiopharmaceuticals - Assessment of fetal dose

- **Dose to the embryo/fetus**

Russell JR *et al.*, *Health Phys*,1997:756-769

"Radiation absorbed dose to the embryo/fetus from radiopharmaceuticals"

Fetal doses

Table 4a. Fetal Dose Estimates from Various Nuclear Medicine Procedures (maternal contributions only).

Radiopharmaceutical	Activity Admin. MBq (mCi)	Early, mGy (rad)	3 Month, mGy (rad)	6 Month, mGy (rad)	9 Month, mGy (rad)
^{57}Co Vitamin B-12, Normal-Flushing	0.04 (0.001)	4.0×10^{-2} (4.0×10^{-3})	2.7×10^{-2} (2.7×10^{-3})	3.4×10^{-2} (3.4×10^{-3})	3.5×10^{-2} (3.5×10^{-3})
^{57}Co Vitamin B-12, Normal-No Flushing	0.04 (0.001)	6.0×10^{-2} (6.0×10^{-3})	4.0×10^{-2} (4.0×10^{-3})	4.8×10^{-2} (4.8×10^{-3})	5.2×10^{-2} (5.2×10^{-3})
^{57}Co Vitamin B-12, PA-Flushing	0.04 (0.001)	8.4×10^{-3} (8.4×10^{-4})	6.8×10^{-3} (6.8×10^{-4})	6.8×10^{-3} (6.8×10^{-4})	6.0×10^{-3} (6.0×10^{-4})
^{57}Co Vitamin B-12, PA-No Flushing	0.04 (0.001)	1.1×10^{-2} (1.1×10^{-3})	8.4×10^{-3} (8.4×10^{-4})	8.8×10^{-3} (8.8×10^{-4})	8.0×10^{-3} (8.0×10^{-4})
^{58}Co Vitamin B-12, Normal-Flushing	0.03 (0.0008)	7.5×10^{-2} (7.5×10^{-3})	5.7×10^{-2} (5.7×10^{-3})	6.3×10^{-2} (6.3×10^{-3})	6.3×10^{-2} (6.3×10^{-3})
^{58}Co Vitamin B-12, Normal-No Flushing	0.03 (0.0008)	1.1×10^{-1} (1.1×10^{-2})	8.4×10^{-2} (8.4×10^{-3})	9.3×10^{-2} (9.3×10^{-3})	9.3×10^{-2} (9.3×10^{-3})
^{58}Co Vitamin B-12, PA-Flushing	0.03 (0.0008)	2.5×10^{-2} (2.5×10^{-3})	2.2×10^{-2} (2.2×10^{-3})	1.9×10^{-2} (1.9×10^{-3})	1.4×10^{-2} (1.4×10^{-3})
^{58}Co Vitamin B-12, PA-No Flushing	0.03 (0.0008)	2.9×10^{-2} (2.9×10^{-3})	2.6×10^{-2} (2.6×10^{-3})	2.3×10^{-2} (2.3×10^{-3})	1.8×10^{-2} (1.8×10^{-3})
^{18}F FDG	370 (10)	1.0×10^{1} (1.0×10^{0})	6.3×10^{0} (6.3×10^{-1})	3.5×10^{0} (3.5×10^{-1})	3.0×10^{0} (3.0×10^{-1})
^{197}Hg Chlormerodrin	4 (0.1)	4.4×10^{-2} (4.4×10^{-3})	3.0×10^{-2} (3.0×10^{-3})	2.7×10^{-2} (2.7×10^{-3})	2.8×10^{-2} (2.8×10^{-3})
^{123}I Hippuran	75 (2)	2.3×10^{0} (2.3×10^{-1})	1.8×10^{0} (1.8×10^{-1})	6.3×10^{-1} (6.3×10^{-2})	5.9×10^{-1} (5.9×10^{-2})
^{123}I IMP	200 (5.5)	3.8×10^{0} (3.8×10^{-1})	2.2×10^{0} (2.2×10^{-1})	1.4×10^{0} (1.4×10^{-1})	1.2×10^{0} (1.2×10^{-1})
^{123}I MIBG phaeochromocytoma	350 (9.5)	6.3×10^{0} (6.3×10^{-1})	4.2×10^{0} (4.2×10^{-1})	2.4×10^{0} (2.4×10^{-1})	2.2×10^{0} (2.2×10^{-1})

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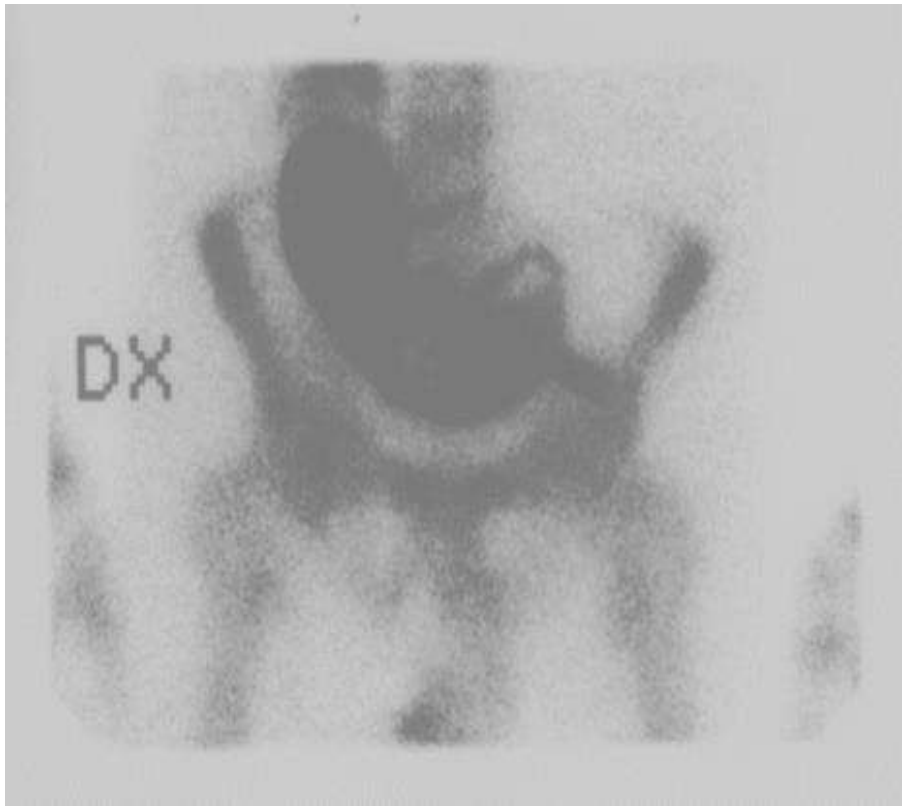
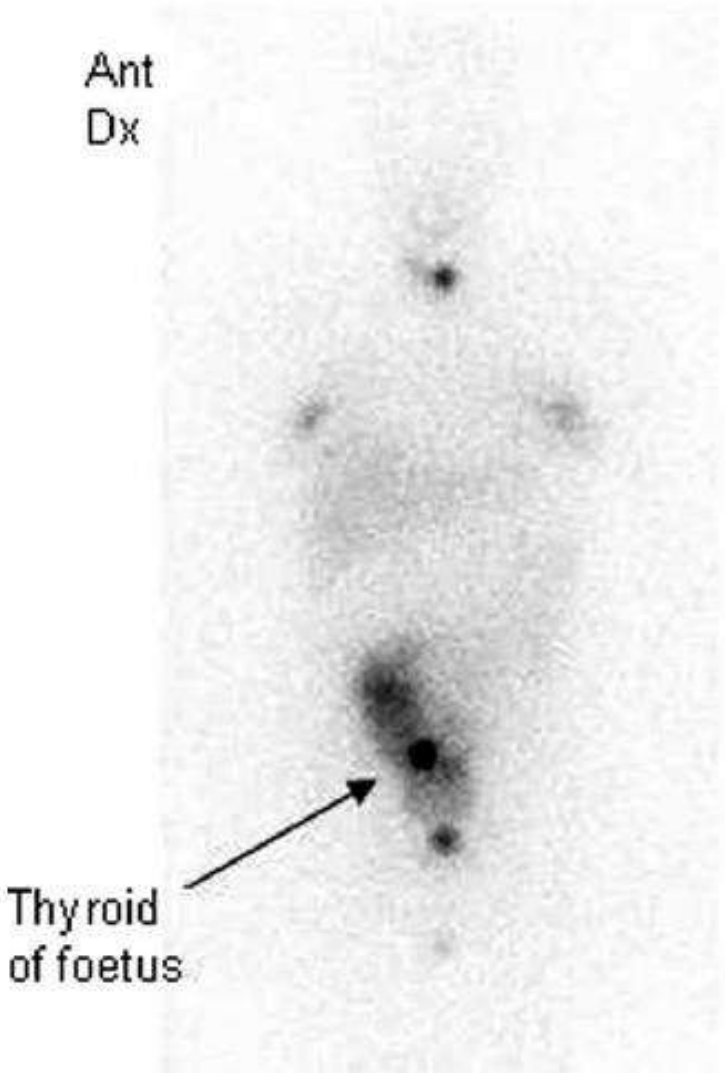
Pregnancy and radiopharmaceuticals - Assessment of fetal dose

Some radiopharmaceuticals may cross the placenta and concentrate in fetal tissue i.e. **internal exposure** of the fetus



^{99m}Tc-pertechnetate adm. to the mother



Berg G et al., Acta Oncol. 47, 145-149, 2008

^{131}I-NaI adm. to the mother

Pregnancy and radiopharmaceuticals - Assessment of fetal dose

Dose to the embryo/fetus

Russell JR et al, *Health Phys* 1997:747-755

"Placental transfer of radiopharmaceuticals and dosimetry in pregnancy "

Russell JR et al., *Health Phys*,1997:756-769

"Radiation absorbed dose to the embryo/fetus from radiopharmaceuticals"

Table 3b. Absorbed Dose Estimates to the Embryo/Fetus Per Unit Activity of Radiopharmaceutical Administered to the Mother (maternal and fetal self dose contributions).

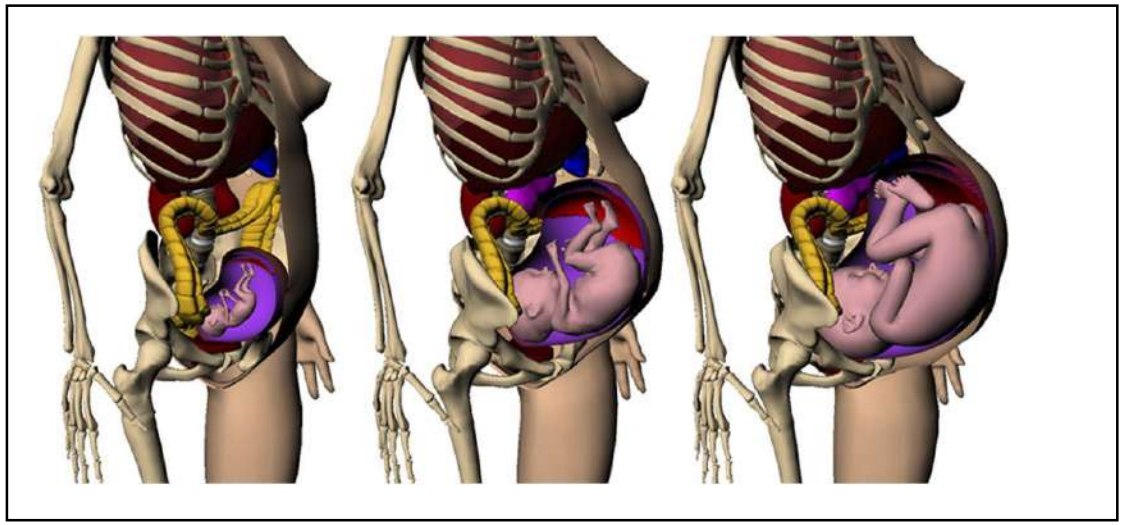
Radiopharmaceutical	Early mGy/MBq	3 Month mGy/MBq	6 Month mGy/MBq	9 Month mGy/MBq
^{67}Ga Citrate	9.3×10^{-2}	2.0×10^{-1}	1.8×10^{-1}	1.3×10^{-1}
^{123}I Sodium Iodide	2.0×10^{-2}	1.4×10^{-2}	1.1×10^{-2}	9.8×10^{-3}
^{131}I Sodium Iodide	7.2×10^{-2}	6.8×10^{-2}	2.3×10^{-1}	2.7×10^{-1}
^{99m}Tc DMSA	5.1×10^{-3}	4.7×10^{-3}	4.0×10^{-3}	3.4×10^{-3}
^{99m}Tc DTPA	1.2×10^{-2}	8.7×10^{-3}	4.1×10^{-3}	4.7×10^{-3}
^{99m}Tc DTPA Aerosol	5.8×10^{-3}	4.3×10^{-3}	2.3×10^{-3}	3.0×10^{-3}
^{99m}Tc Glucoheptonate	1.2×10^{-2}	1.1×10^{-2}	5.3×10^{-3}	4.6×10^{-3}
^{99m}Tc HDP	5.2×10^{-3}	5.4×10^{-3}	3.0×10^{-3}	2.5×10^{-3}
^{99m}Tc MAA	2.8×10^{-3}	4.0×10^{-3}	5.0×10^{-3}	4.0×10^{-3}
^{99m}Tc MDP	6.1×10^{-3}	5.4×10^{-3}	2.7×10^{-3}	2.4×10^{-3}
^{99m}Tc Pertechnetate	1.1×10^{-2}	2.2×10^{-2}	1.4×10^{-2}	9.3×10^{-3}
^{99m}Tc PYP	6.0×10^{-3}	6.6×10^{-3}	3.6×10^{-3}	2.9×10^{-3}
^{99m}Tc RBC-in vitro	6.8×10^{-3}	4.7×10^{-3}	3.4×10^{-3}	2.8×10^{-3}
^{99m}Tc RBC-in vivo	6.4×10^{-3}	4.3×10^{-3}	3.3×10^{-3}	2.7×10^{-3}
^{99m}Tc Sulfur Colloid-normal	1.8×10^{-3}	2.1×10^{-3}	3.2×10^{-3}	3.7×10^{-3}
^{99m}Tc Sulfur Colloid-Liver Disease	3.2×10^{-3}	2.5×10^{-3}	2.8×10^{-3}	2.8×10^{-3}

Pregnancy and radiopharmaceuticals - Assessment of fetal dose

Dose to the embryo/fetus

Stabin MG. *J Nucl Med* 2018:1005-1006

An example of a pregnant female computational phantom



Rensselaer Polytechnic Institute pregnant female models for 3 mo (left), 6 mo (middle), and 9 mo (right) of gestation.

This was originally published in JNM. Michael G Stabin. New-Generation Fetal Dose Estimates for Radiopharmaceuticals. J Nucl Med. 2018;59:1005-1006.

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Radiopharmaceutical	Estimated fetal dose (mGy/MBq*)			
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^{13}N-ammonia	2.3×10^{-3}	1.9×10^{-3}	2.0×10^{-3}	1.8×10^{-3}
^{18}F-FDG	2.6×10^{-2}	1.9×10^{-2}	1.4×10^{-2}	6.9×10^{-3}
^{18}F-fluoride	3.1×10^{-2}	2.2×10^{-2}	8.6×10^{-3}	6.7×10^{-3}
^{32}P-phosphate	8.7×10^{-1}	1.7×10^{0}	2.3×10^{0}	2.3×10^{0}
^{67}Ga-citrate	9.4×10^{-2}	7.1×10^{-1}	1.1×10^{-1}	3.2×10^{-2}
^{123}I-hippuran	4.9×10^{-2}	3.3×10^{-2}	9.2×10^{-3}	6.6×10^{-3}
^{123}I-IMP	2.2×10^{-2}	1.6×10^{-2}	1.1×10^{-2}	8.9×10^{-3}
^{123}I-mIBG	2.2×10^{-2}	1.6×10^{-2}	8.2×10^{-3}	6.8×10^{-3}
^{123}I-NaI	2.3×10^{-2}	1.6×10^{-2}	9.3×10^{-3}	6.3×10^{-3}
^{125}I-HSA	2.4×10^{-1}	1.6×10^{-1}	1.2×10^{-1}	1.0×10^{-1}
^{125}I-mIBG	3.2×10^{-2}	2.0×10^{-2}	1.0×10^{-2}	9.1×10^{-3}
^{131}I-hippuran	9.8×10^{-2}	6.8×10^{-2}	2.0×10^{-2}	1.4×10^{-2}
^{131}I-mIBG	1.2×10^{-1}	9.6×10^{-2}	7.3×10^{-2}	6.6×10^{-2}
^{131}I-NaI	7.6×10^{-2}	1.6×10^{-1}	2.9×10^{-1}	2.2×10^{-1}
^{111}In-DTPA	9.4×10^{-2}	6.5×10^{-2}	2.1×10^{-2}	1.6×10^{-2}
^{111}In-pentetreotide	1.1×10^{-1}	7.8×10^{-2}	3.7×10^{-2}	3.0×10^{-2}
^{111}In-platelets	1.7×10^{-1}	1.3×10^{-1}	1.1×10^{-1}	9.8×10^{-2}
^{111}In-RBCs	2.2×10^{-1}	1.6×10^{-1}	1.4×10^{-1}	1.2×10^{-1}
^{111}In-WBCs	1.2×10^{-1}	9.3×10^{-2}	8.6×10^{-2}	8.0×10^{-2}
^{81m}Kr-gas	1.2×10^{-7}	1.4×10^{-7}	1.9×10^{-7}	2.0×10^{-7}
^{177}Lu-DOTATATE (*1*)	1.9×10^{-2}	1.9×10^{-2}	2.0×10^{-2}	1.9×10^{-2}
^{82}Rb-chloride	9.5×10^{-4}	3.5×10^{-4}	6.3×10^{-4}	6.3×10^{-4}
^{153}Sm-EDTMP (*2*)	2.0×10^{-2}	3.6×10^{-2}	1.8×10^{-2}	1.3×10^{-2}
^{89}Sr-chloride (*3*)	8.4×10^{-1}	2.1×10^{0}	2.3×10^{0}	2.3×10^{0}
^{99m}Tc-disofenin	1.9×10^{-2}	1.3×10^{-2}	7.8×10^{-3}	6.4×10^{-3}
^{99m}Tc-DMSA	5.9×10^{-3}	8.8×10^{-3}	3.4×10^{-3}	2.2×10^{-3}
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^{99m}Tc-DTPA aerosol	7.6×10^{-3}	5.1×10^{-2}	1.9×10^{-3}	2.1×10^{-3}
^{99m}Tc-glucoheptonate	1.6×10^{-2}	1.4×10^{-2}	4.8×10^{-3}	3.7×10^{-3}
^{99m}Tc-HMPAO	1.0×10^{-2}	7.2×10^{-3}	4.3×10^{-3}	3.6×10^{-3}
^{99m}Tc-MAA	3.2×10^{-3}	1.2×10^{-2}	2.6×10^{-3}	1.7×10^{-3}
^{99m}Tc-MAG3	2.6×10^{-2}	1.8×10^{-2}	5.7×10^{-3}	4.1×10^{-3}
^{99m}Tc-MDP	8.1×10^{-3}	9.1×10^{-3}	2.6×10^{-3}	2.1×10^{-3}
^{99m}Tc-MIBI rest	1.7×10^{-2}	1.2×10^{-2}	6.9×10^{-3}	5.6×10^{-3}
^{99m}Tc-MIBI stress	1.4×10^{-2}	9.5×10^{-3}	6.0×10^{-3}	4.8×10^{-3}
^{99m}Tc-pertechnetate	1.4×10^{-2}	6.2×10^{-2}	1.1×10^{-2}	5.8×10^{-3}

**Shaded rows indicate consideration of placental crossover in the fetal dose estimates

Cont´d

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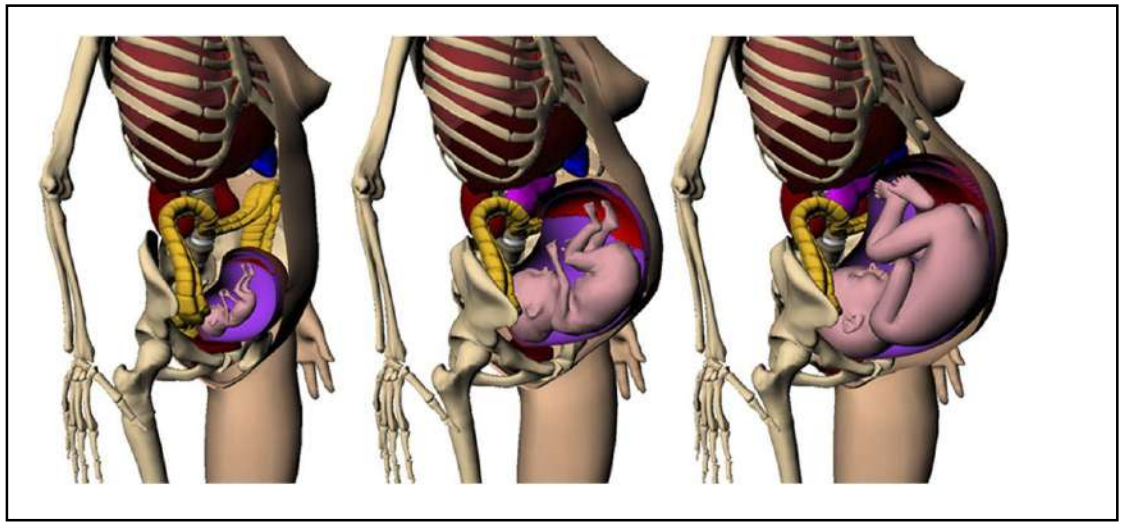

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^{99m}Tc-X: 1-10 mGy
^{18}F-FDG: 10 mGy
^{111}In-pentetreotide: 20 mGy

Sigrid Leide-Svegborn 2021

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**Shaded rows indicate consideration of placental crossover in the fetal dose estimates

Cont´d

Warning!
Radioactive iodine. In particular radionuclide therapy!

- Radioiodine administered to a pregnant patient: after 8-10 weeks post-conception, the fetal thyroid concentrates iodide which crosses the placenta

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- Radioiodine administered to a pregnant patient: after 8-10 weeks post-conception, the fetal thyroid concentrates iodide which crosses the placenta

Examples:

Administration:

a) 30 MBq $^{123}I^-$ to the mother
b) 0.4 MBq $^{131}I^-$ to the mother
c) 500 MBq $^{131}I^-$ to the mother

Mean dose to the fetus:

a) 0.7 mGy
b) 0.1 mGy
c) 145 mGy

Warning!
Radioactive iodine. In particular radionuclide therapy!

- Radioiodine administered to a pregnant patient: after 8-10 weeks post-conception, the fetal thyroid concentrates iodide which crosses the placenta

Examples:

Administration:	***Mean dose to the fetus:***	***Dose to the fetal thyroid:***
a) 30 MBq $^{123}I^-$ to the mother	a) 0.7 mGy	a) 300 mGy
b) 0.4 MBq $^{131}I^-$ to the mother	b) 0.1 mGy	b) 300 mGy
c) 500 MBq $^{131}I^-$ to the mother	c) 145 mGy	c) 600 Gy (!)

- High fetal thyroid doses from radioiodide can result in permanent hypothyroidism

Treatment of thyroid cancer

3700 MBq at 18 weeks.
Fetus: Whole body dose: 700 mGy
Fetal thyroid dose: 300 (260-2 000) Gy
Fetus did not survive.

Berg G *et al*., *Acta Oncol.* 2008: 145-149

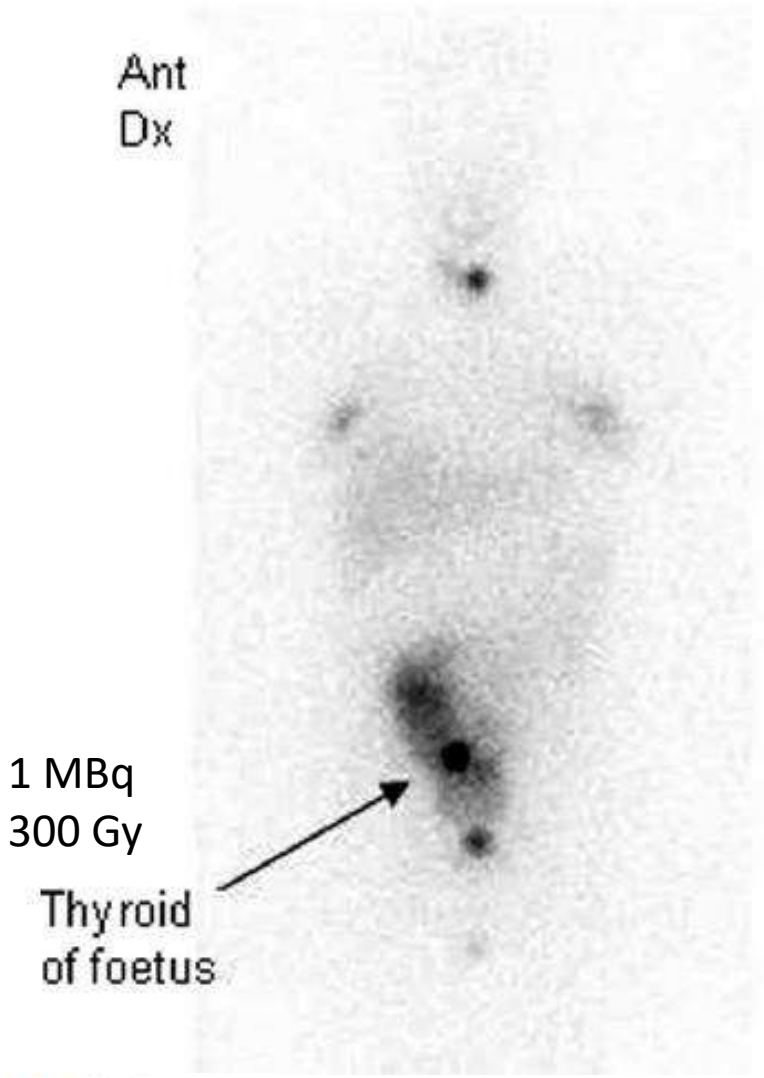

Figure 1. Gamma camera examination 6 days after administration of 3 700 MBq 131-I in Case 2. Note small uptake in the thyroid bed, uptake in mammary glands, and uptake in the fetal thyroid and fetal body/amniotic fluid.

Pregnancy and radiopharmaceuticals

Keep the perspective!

- Most diagnostic procedures are done with short-lived radionuclides (such as ^{99m}Tc or ^{18}F) that do not cause large fetal doses
- Prenatal doses from most properly performed diagnostic procedures present no measurably increased risk of prenatal death, malformation or mental impairment, however..
- Encourage the mother to drink more than usual and to frequent urine voiding, this will reduce the fetal dose and risk of childhood cancer
- Some radionuclides do cross the placenta and can pose fetal risks
- Radioiodine (such as ^{131}I) may cause significant fetal thyroid harm. Give the mother stable iodine if pregnancy is discovered early after the administration.

Thank you for your attention!

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