A Step-by-step Guide: How to Calculate Fetus Dose?
Manage Unsuspected Pregnancy during Radionuclide Therapy

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Talk Outline

01 **Introduction**

- Why is important?
- RAI in Thyroid Disease
- Radiation Effects to fetus

02 **RAI after Pregnancy*****

- How to estimate radiation dose?
- What information is needed?
- Fetal Hypothyroidism

03 **Pregnancy after RAI**

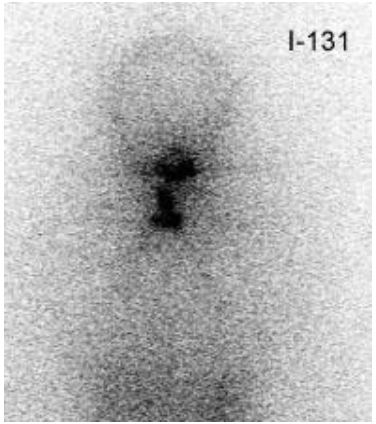
- Fetus Absorbed Dose
- Recommendations

04 **Breast Feeding during RAI**

05 **Summary**

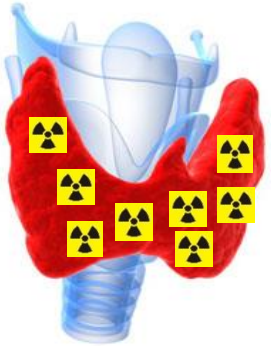
Radiodione (RAI) in Thyroid Diesease

- Radioactive iodine (^{131}I) is widely used in the diagnosis and treatment of hyperthyroidism and thyroid cancer (since 1940s)



Dose Selection?

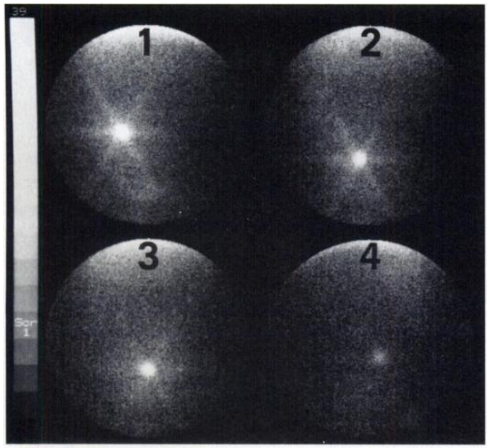
RAI	Activity
Diagnostic	1 – 2 mCi
Benign Thyroid Disease	5 – 30 mCi
Thyroid Malignant (ATA) • Low-Risk • Intermedia- High-Risks and Metastasis	 No RAI 30 mCi 150 – 200 mCi



RAI in Pregnancy

- Administration of radiopharmaceuticals for therapeutic are generally contraindicated in pregnancy
  - **Compulsory pregnancy test prior Tx**

- If a pregnant woman is exposed to a radioactive substance, it may be absorbed into the bloodstream and **pass through the placenta** to the fetus (total ablation of fetal thyroid)



- In general, radiation effects are due to either cell killing or unrepaired DNA damage

Medical Exposure to Pregnant/Lactating Patient

Effects on the Embryo/Fetus

1. Pregnancy loss (abortion ,stillbirths)
2. Congenital malformations (anatomical defects)
3. Neurobehavioral abnormalities (mental retardation)
4. Fetal growth retardation (reversible and irreversible)
5. Cancer

Deterministic

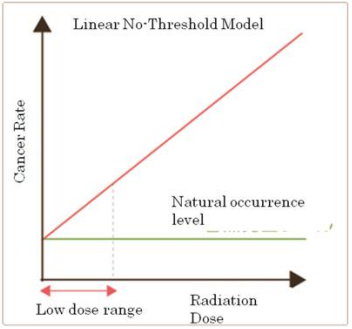
Stochastic

Effect and Risk of In-Utero Exposure

Gestation stage (days or weeks after conception)	Pre-implantation 0–9 days	Organogenesis 2–8 weeks	Fetal stages 100 - 300 mGy 8–15 weeks	16–25 weeks	26 weeks-	Threshold doses for effects (mGy)	Spontaneous frequency (%)
Prenatal death	+++	+	–	–	–	100	30–60
Malformation	–	+++	–	–	–	100 (100 mGy)	6
Growth restriction	–	+	+	+	+	250	5–10
Mental retardation	–	–	+++	+	–	100–300	0.5
Hypothyroidism	–	–	+	+	+	100	0.03–0.05
Cancer (Stochastic)		+	+	+	+	0.06 % per 10 mGy	0.2–0.3
Hereditary effects (Stochastic)		–	–	–	–	1000–1500	10

Effect of RAI on Fetus

- **Absorbed Dose**
- **Stage of Gestation**



European Journal of Obstetrics & Gynecology and Reproductive Biology 259 (2021) 53–59

ACR/CDC Statement

- **United States Nuclear Regulation Commission (USNRC)** and **ACR (American College of Radiology)** also recommend total fetus radiation **dose below 50 mGy is considered safe** and does **not cause any harm**
- According to the Centers for Disease Control (CDC), radiation dose between **50 mGy - 100 mGy** is regarded as **inconclusive regarding impact on the fetus**.

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

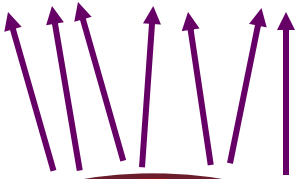
CDC
CENTERS FOR DISEASE CONTROL AND PREVENTION

ACR®
AMERICAN COLLEGE OF RADIOLOGY

https://www.ncbi.nlm.nih.gov/books/NBK551690/

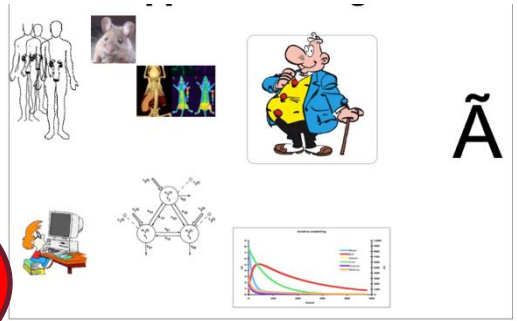
Fetal Dose Calculation

Target (fetus)



Source(S)
(uterus, kidney, bladder)

$$D(r_k) = \sum_h \tilde{A}_h \times S(r_k \longleftarrow r_h)$$



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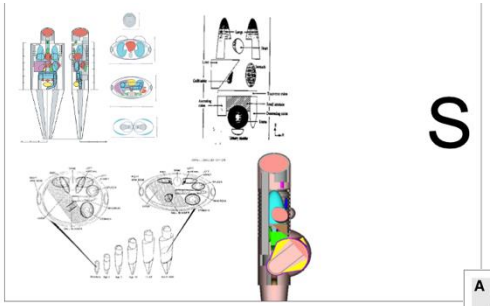

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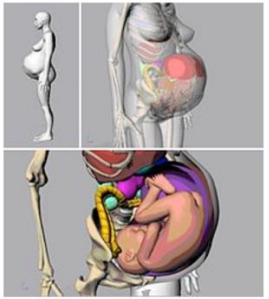
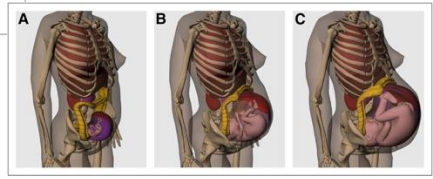


Pregnant female
Guo et al. (2010)
RPD 138(1):20-28



Poppulation (Pregnant) Kinetics

Standard (Pregnant) Phantom

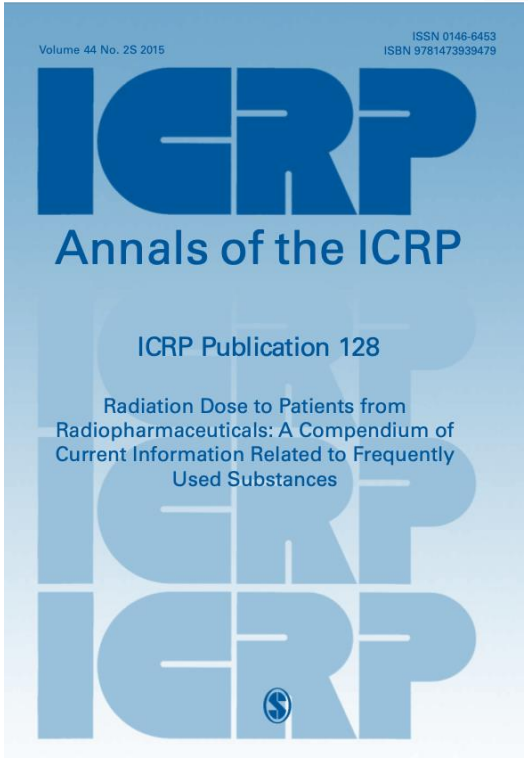
No Official
ICRP Publication

ICRP 128 – Fetus Dose (Paragraph 68 - 69)

7. DOSE TO EMBRYO AND FETUS

(68) The absorbed dose to the uterus, which is included in the dose tabulations, may be used as a substitute for the absorbed dose to the embryo if the subject is in the first 2–3 months of pregnancy. Similarly, the absorbed dose to the fetus from radioactive substances without placental transfer is expected to be in the same range as the dose to the uterus. For radioactive substances with placental transfer, the absorbed dose to organs and tissues of the mother may, as a first approximation, be taken as representative of the absorbed dose to the corresponding organs and tissues of the fetus.

(69) More detailed radiation dose estimates for the fetus from administration of a number of radiopharmaceuticals to women at various stages of pregnancy are given by Russell et al. (1997). Their data illustrate that the majority of studies will probably involve fetal doses <10 mGy. Only studies using ^{131}I-iodide, ^{201}Tl-chloride, and ^{67}Ga-citrate appear to result in fetal doses >10 mGy, according to present knowledge. Therapeutic administrations are routinely contra-indicated in the case of pregnancy or breast feeding as this may result in very high fetal doses. In addition, beyond 10–13 weeks of gestation, the fetal thyroid may receive extremely high doses in cases of therapy using ^{131}I-iodide (Watson et al., 1989; Berg et al., 1998). For substances in their ionic form, a comprehensive compilation of doses to the embryo and fetus is found in *Publication 88* (ICRP, 2001).



Fetal Dose Calculation

Dose Coefficient (mGy/MBq)

Gestation Week

Fetal Dose (mGy)

Original paper

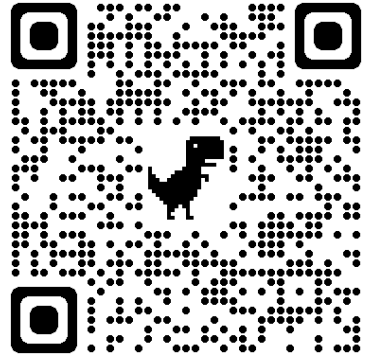
Radiation dose and risks to fetus from nuclear medicine procedures

Michael G. Stabin *

Vanderbilt University, Nashville, TN, USA

Table 4
Absorbed Dose Estimates to the Embryo/Fetus Per Unit Activity of Radiopharmaceutical Administered to the Mother (shading indicates maternal and fetal self dose contributions) (From Russell et al. [4]).

Radiopharmaceutical	Early mGy/MBq	3 Months mGy/MBq	6 Months mGy/MBq	9 Months mGy/MBq
^{57}Co Vitamin B-1, Normal-Flushing	1.0×10^{0}	6.8×10^{-1}	8.4×10^{-1}	8.8×10^{-1}
^{57}Co Vitamin B-12, Normal-No Flushing	1.5×10^{0}	1.0×10^{0}	1.2×10^{0}	1.3×10^{0}
^{57}Co Vitamin B-12, PA- Flushing	2.1×10^{-1}	1.7×10^{-1}	1.7×10^{-1}	1.5×10^{-1}
^{57}Co Vitamin B-12, PA-No Flushing	2.8×10^{-1}	2.1×10^{-1}	2.2×10^{-1}	2.0×10^{-1}
^{58}Co Vitamin B-12, Normal Flushing	2.5×10^{0}	1.9×10^{0}	2.1×10^{0}	2.1×10^{0}
^{58}Co Vitamin B-12, Normal-No Flushing	3.7×10^{0}	2.8×10^{0}	3.1×10^{0}	3.1×10^{0}
^{58}Co Vitamin B-12, PA-Flushing	8.3×10^{-1}	7.4×10^{-1}	6.4×10^{-1}	4.8×10^{-1}
^{58}Co Vitamin B-12, PA-No Flushing	9.8×10^{-1}	8.5×10^{-1}	7.6×10^{-1}	6.0×10^{-1}
^{60}Co Vitamin B-12, Normal Flushing	3.7×10^{1}	2.8×10^{1}	3.1×10^{1}	3.2×10^{1}
^{60}Co Vitamin B-12, Normal-No Flushing	5.5×10^{1}	4.2×10^{1}	4.7×10^{1}	4.7×10^{1}
^{60}Co Vitamin B-12, PA-Flushing	5.9×10^{0}	4.7×10^{0}	4.8×10^{0}	4.5×10^{0}
^{60}Co Vitamin B-12, PA-No Flushing	8.3×10^{0}	6.5×10^{0}	6.8×10^{0}	6.5×10^{0}
^{18}F FDG	2.2×10^{-2}	2.2×10^{-2}	1.7×10^{-2}	1.7×10^{-2}
^{18}F Sodium Fluoride	2.2×10^{-2}	1.7×10^{-2}	7.5×10^{-3}	6.8×10^{-3}
^{67}Ga Citrate	9.3×10^{-2}	2.0×10^{-1}	1.8×10^{-1}	1.3×10^{-1}
^{123}I Hippuran	3.1×10^{-2}	2.4×10^{-2}	8.4×10^{-3}	7.9×10^{-3}
^{123}I IMP	1.9×10^{-2}	1.1×10^{-2}	7.1×10^{-3}	5.9×10^{-3}
^{123}I MIBG	1.8×10^{-2}	1.2×10^{-2}	6.8×10^{-3}	6.2×10^{-3}
^{123}I Sodium Iodide	2.0×10^{-2}	1.4×10^{-2}	1.1×10^{-2}	9.8×10^{-3}
^{124}I Sodium Iodide	1.4×10^{-1}	1.0×10^{-1}	5.9×10^{-2}	4.6×10^{-2}
^{125}I HSA	2.5×10^{-1}	7.8×10^{-2}	3.8×10^{-2}	2.6×10^{-2}
^{125}I IMP	3.2×10^{-2}	1.3×10^{-2}	4.8×10^{-3}	3.6×10^{-3}
^{125}I MIBG	2.6×10^{-2}	1.1×10^{-2}	4.1×10^{-3}	3.4×10^{-3}
^{125}I Sodium Iodide	1.8×10^{-2}	9.5×10^{-3}	3.5×10^{-3}	2.3×10^{-3}
^{126}I Sodium Iodide	7.8×10^{-2}	5.1×10^{-2}	3.2×10^{-2}	2.6×10^{-2}
^{129}I Sodium Iodide	1.8×10^{-1}	1.3×10^{-1}	7.6×10^{-2}	5.7×10^{-2}
^{131}I Hippuran	6.4×10^{-2}	5.0×10^{-2}	1.9×10^{-2}	1.8×10^{-2}
^{131}I HSA	5.2×10^{-1}	1.8×10^{-1}	1.6×10^{-1}	1.3×10^{-1}
^{131}I MAA	6.7×10^{-2}	4.2×10^{-2}	4.0×10^{-2}	4.2×10^{-2}
^{131}I MIBG	1.1×10^{-1}	5.4×10^{-2}	5.8×10^{-2}	5.5×10^{-2}
^{131}I Sodium Iodide	7.2×10^{-2}	6.8×10^{-2}	2.3×10^{-1}	2.7×10^{-1}
^{131}I Perchlorate	2.2×10^{-1}	2.2×10^{-1}	1.6×10^{-1}	9.0×10^{-2}
^{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 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 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 MAA	2.8×10^{-3}	4.0×10^{-3}	5.0×10^{-3}	4.0×10^{-3}
^{99m}Tc MAG3	1.8×10^{-2}	1.4×10^{-2}	5.5×10^{-3}	5.2×10^{-3}
^{99m}Tc MDP	6.1×10^{-3}	5.4×10^{-3}	2.7×10^{-3}	2.4×10^{-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 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-Heat Treated	1.7×10^{-3}	1.6×10^{-3}	2.1×10^{-3}	2.2×10^{-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}
^{99m}Tc Teboroxime	8.9×10^{-3}	7.1×10^{-3}	5.8×10^{-3}	3.7×10^{-3}
^{99m}Tc Tetrofosmin	9.6×10^{-3}	7.0×10^{-3}	5.4×10^{-3}	3.6×10^{-3}



Physica Medica 43 (2017) 190–198

Iodine-131 after Conception

(1)

Not Pregnant

false negative

I-131 after conception

1. Activity
2. Gestation Age
3. Fetal thyroid dose

Dose Coefficient (mGy/MBq) × Activity in Fetal Dose (mGy)

Radionuclide	mGy/MBq			
	Early	3 month	6 month	9 month
Iodine-131	7.2×10^{-2}	6.8×10^{-2}	2.3×10^{-2}	2.7×10^{-2}

Fetal Dose	MBq (mCi)	MBq (mCi)	MBq (mCi)	MBq (mCi)
50 mGy	694.44	735.29	217.39	185.19
	(18.77)	(19.87)	(5.88)	(5.01)

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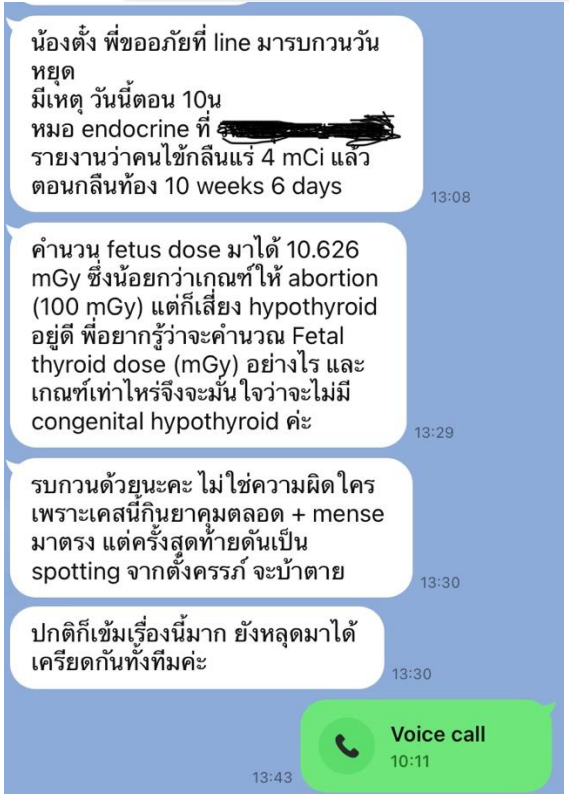
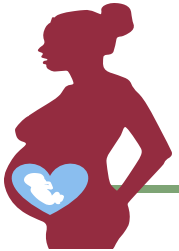
Case Example I



- Case from private hospital
- Hyperthyroid Patient, Contraception was confirmed by patient (birth control pill)
- Administered ^{131}I activity 4 mCi
- After ^{131}I, u/s was confirmed that on the treatment date GA around 10 - 11 Weeks
- Fetal Dose Calculation?

How to calculate dose?



No pregnancy test

GA 10-11 weeks

I-131 after conception

Radionuclide	mGy/MBq			
	Early	3 month	6 month	9 month
Iodine-131	7.2×10^{-2}	6.8×10^{-2}	2.3×10^{-2}	2.7×10^{-2}

- Fetal absorbed dose 10.06 mGy (use Stabin 2017, 3 month pregnant 6.8E-2 mGy/MBq)

Original paper

Radiation dose and risks to fetus from nuclear medicine procedures

Michael G. Stabin*

Vanderbilt University, Nashville, TN, USA

- Below 50 mGy (ACR).....What else we need to concern?

Radiation Absorbed Dose for Fetal Thyroid

- The thyroid gland is the first endocrine organ to function during fetal life
- Thyroid organogenesis is largely completed by 10–12 weeks of gestation
- After the 10th week of gestation, the fetal thyroid gland starts trapping and concentrating iodine and synthesizing thyroid hormones

Dose to Fetal Thyroid per MBq of ^{131}I administered to the mother

Doses to the fetal thyroid (mGy to the fetal thyroid per MBq administered to the mother) [13].

Gestational Age (mo)	I-123	I-124	I-125	I-131
3	2.7	24	290	230
4	2.6	27	240	260
5	6.4	76	280	580
6	6.4	100	210	550
7	4.1	96	160	390
8	4.0	110	150	350
9	2.9	99	120	270

Watson EE. 1992. Radiation absorbed dose to the human fetal thyroid

Watson Iodine Kinetic Model and Dose Estimation

Absorbed Dose to Fetal Thyroid per MBq of ^{131}I administered to the mother

Estimated doses delivered to the whole body of the embryo/fetus and the fetal thyroid gland by radioactive iodine (^{131}I) administered to the mother during various periods of pregnancy.

Gestational age	Estimated whole-body dose to the embryo/fetus (mGy/MBq)	Estimated fetal thyroid dose (mGy/MBq)
Early period	0.072	–
3 months	0.068	230
4 months	–	260
5 months	–	580
6 months	0.23	550
7 months	–	390
8 months	–	350
9 months	0.27	270

The estimated embryo/fetal absorbed doses are based on the methodology of Russell et al. [33], and fetal thyroid doses are based on the methodology of Watson [32]. Estimated doses delivered to the embryo/fetus or fetal thyroid are expressed in mGy per MBq administered to the mother.

Watson EE. 1992. Radiation absorbed dose to the human fetal thyroid

For ^{131}I

- Watson et al (1992) developed and summarised kinetic model for fetal dose in case of iodine administration to pregnant patient **(No more recent data)**
- Start uptake at Week 10th and Peak at 2nd Trimester
- Radioactive iodine can result in total ablation

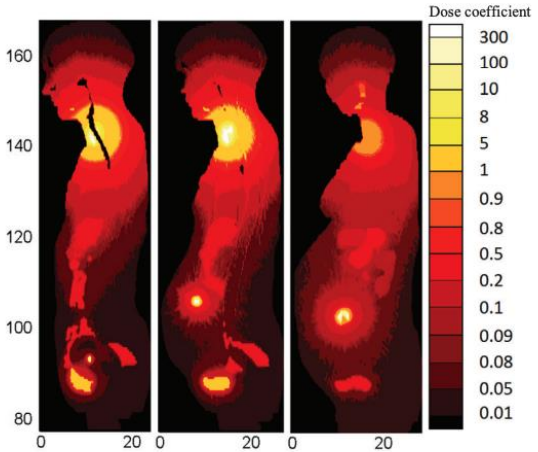


Figure 5. Distributions of dose coefficients (mGy MBq^{-1}) for thyroid scan with ^{131}I in a sagittal view of 3, 6 and 9 month pregnant female phantoms.

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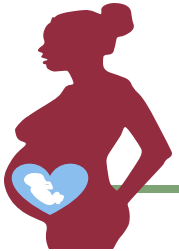
How to calculate dose? – Case I



No pregnancy test

I-131 after conception

GA 10-11 weeks

- Fetal absorbed dose 10.06 mGy (use Stabin 2017, 3 month pregnant 6.8E-2 mGy/MBq)
- Fetal thyroid 34.04 Gy (use Watson et al 1992, fetal thyroid 230 mGy/MBq)

Original paper

Radiation dose and risks to fetus from nuclear medicine procedures

Michael G. Stabin *

Vanderbilt University, Nashville, TN, USA

Congenital Hypothyroidism Due To Maternal Radioactive Iodine Exposure During Pregnancy

Selim Kurtoğlu[1,2], Mustafa Ali Akın[1], Ghaniya Daar[3], Leyla Akın[2], Şeyma Memur[1], Levent Korkmaz[1], Osman Baştuğ[1], Selcan Yılmaz[1]

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[3]Nevşehir Government Hospital, Department of Pediatrics, Nevşehir, Turkey

Congenital hypothyroidism may occur at 30 Gy due to total ablation (fetal thyroid start uptake iodide at 10th -12th week of gestation

J Clin Res Pediatr En docrinol 2012;4(2):111-113

Fetal and Neonatal Hypothyroidism

- **A few reports** describing congenital hypothyroidism following maternal ^{131}I therapy have been published

- If the embryo/fetus was received RAI at 8 – 10 weeks **(before fetal thyroid organogenesis)** and the exposure discovered within 12 h of ^{131}I administration
- Giving the mother 60–130 mg of stable potassium iodide (KI) will partially block the fetal thyroid and reduce the thyroid dose

How to evaluate fetal thyroid function?

- **Fetal blood samples** are obtained by cordocentesis (invasive procedure can cause complications)
- การเจาะเลือดสายสะดือทารกในครรภ์ (cordocentesis) หมายถึง การดูดเก็บตัวอย่างเลือดทารกในครรภ์จากสายสะดือโดยใช้เข็มเจาะผ่านทางหน้าท้องมารดา

Summary of known outcomes for fetuses and neonates born of mothers who were inadvertently exposed to radioactive iodine (^{131}I) therapy during pregnancy.

Reference publication and year	Age of mother (years)	Maternal disease	Pregnancy test	^{131}I dose (MBq)	Gestational age at ^{131}I therapy	Estimated fetal ^{131}I dose (mGy)	Estimated fetal thyroid dose of ^{131}I (×1000 mGy)	Pregnancy outcome	Thyroid disease of the infant	Age at thyroid therapy	Other complications in the infant
Berg et al., 1998 [13]	43	Hyper	No	500	20 weeks	115	290	FD	Hypo	14 days	No
Berg et al., 2008 [14]	28	TC	No	3700	20 weeks	851	2035	MA	Hypo	–	Fetal hypothyroidism
Basbug et al., 2010 [15]	33	TC	No	185	16 weeks	12.6	48.1	PD	Hypo	–	Died soon after birth
Tran et al., 2010 [16]	UK	Hyper	No	732.6	8–10 days	52.8	NA	FD	Hyper	–	–
Kurtoğlu et al., 2012 [17]	UK	Hyper	No	740	12 weeks	50.3	170.2	FD	Hypo	15 days	UK
Sadakata et al., 2014 [18]	43	TC	No	1850	5.5 weeks	133.2	NA	FD	No	–	No
Radacic-Aumiler et al., 20 [19]	22	Hyper	No	1369	3 weeks	2.7	NA	FD	No	–	No
Demir et a 2019 [20]					weeks						
	UK	Hyper	No	481	3 weeks	34.6	NA	FD	No	–	No
	UK	Hyper	No	3700	2.5 weeks	266.4	NA	MA	UK	–	UK
	UK	TC	No	5555	13 weeks	377.8	1278	MA	UK	–	UK

Radioactivity doses of 550 MBq after 10th week are likely to result in ablation of the fetal thyroid gland, causing hypothyroidism

Fetal absorbed doses delivered by ^{131}I administered to the mother were estimated using the methodology of Russell et al. [33], and fetal thyroid doses delivered by ^{131}I administered to the mother were estimated using the methodology of Watson [32]. UK, unknown; Hyper, hyperthyroidism; TC, thyroid cancer; NA, not analyzed; Hypo, hypothyroidism; FD, full-term delivery; PD, preterm delivery; MA, medical abortion; DD, developmental delay; MR, mental retardation; SGA, small for gestational age.

Case Example II

27 มี.ค. 2024 09:27

สวัสดีค่ะอาจารย์ตั๋ง ขออนุญาต consult คำนวณเคส กลืนแร่ Hyper : 30 mci ผ่านมา3เดือน เวียนหัว อาเจียน ตรวจครรภ์ พบว่าตั้งครรภ์มา 12 สัปดาห์แล้วค่ะ

- Case from Cancer Hospital
- Hyperthyroid Patient 30 mCi on 2nd Jan 2024
- Serum HCG negative (On the Tx day)
- After ^{131}I, u/s was confirmed that on the treatment date GA around 2-3 days
- What should we do?

How to calculate dose?

Serum HCG negative

I-131 after conception

2nd Jan 2024

Mar 2024

Radionuclide	mGy/MBq			
	Early	3 month	6 month	9 month
Iodine-131	7.2×10^{-2}	6.8×10^{-2}	2.3×10^{-2}	2.7×10^{-2}

Original paper

Radiation dose and risks to fetus from nuclear medicine procedures

Michael G. Stabin *

Vanderbilt University, Nashville, TN, USA

- Fetal absorbed dose 79.92 mGy (use Stabin 2017, 3 month pregnant 7.2E-2 mGy/MBq)
- Fetal Dose > 50 mGy
- Little is known about the effects of irradiation during the very early stages of pregnancy, from conception to implantation of the conceptus (the first 9–10 days)
- This effect is generally an "all-or-none" response: either embryo death or no detectable effects at all.

ACR Guideline for RAI in Pregnancy

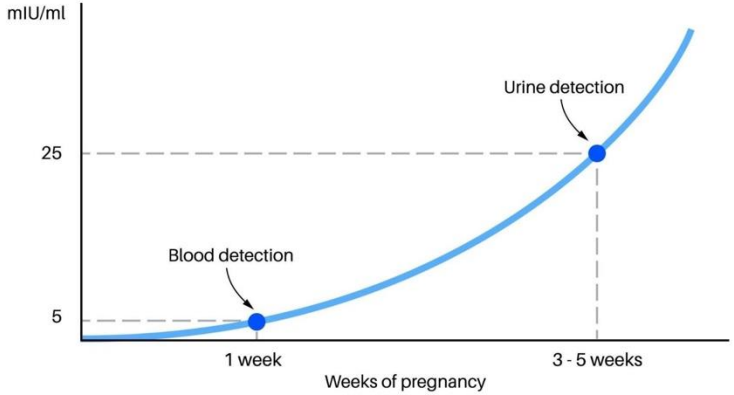
ACR Practice Parameter for the Performance of Therapy With Unsealed Radiopharmaceutical Sources

Daniel E. Spratt, MD, Bassem I. Zaki, MD,† Benjamin L. Franc, MD, MS, CPE,‡ Alan C. Hartford, MD, PhD, FACR,† and Joseph R. Osborne, MD, PhD§*

A patient **should not be pregnant** at the time of radiopharmaceutical administration

Pregnancy should be excluded prior to RP administration by one of the following:

- Negative human chorionic gonadotropin (hCG) test – serum or urine
- Documented hysterectomy
- Postmenopausal state (absence of menstrual bleeding for 2 years), or pre-menstrual age (<10 years or younger)
- A 2-week contraception (using condom) should be recommended to female patients before RAI



- Serum HCG may falsely negative 7-8 days after contraception
- Urine HCG may falsely negative ~ 3 - 5 weeks

https://www.narayanahealth.org/ml/blog/pregnancy-test-when-to-take-types-accuracy

Talk Outline

01 **Introduction**

- Why is important?
- RAI in Thyroid Disease
- Radiation Effects to fetus

02 **RAI after Pregnancy*****

- How to estimate radiation dose?
- What information is needed?
- Fetal Hypothyroidism

03 **Pregnancy after RAI**

- Fetus Absorbed Dose
- Recommendations

04 **Breast Feeding during RAI**

05 **Summary**

Pregnancy after RAI

(1)

false negative

I-131 after conception

(2)

Not Pregnant

Pregnant

Pregnancy after RAI

Birth Control for 6 months for female after RAI → If pregnant

Pregnancy after RAI

Original paper

Radiation dose and risks to fetus from nuclear medicine procedures

Michael G. Stabin *

Vanderbilt University, Nashville, TN, USA

Table 6
Fetal dose estimates for hyperthyroid and euthyroid patients, in the case in which conception occurs after administration of $Na^{131}I$. Absorbed Dose to Fetus in Cases of Hyperthyroidism (mGy/MBq).

Maximum	Time in Weeks After Administration That Conception Occurs							
% Uptake	1	2	3	4	5	6	7	8
5%	4.1E−04	1.9E−04	8.7E−05	4.0E−05	1.9E−05	8.7E−06	4.0E−06	1.9E−06
10%	8.3E−04	3.8E−04	1.7E−04	8.0E−05	3.7E−05	1.7E−05	7.8E−06	3.6E−06
15%	1.3E−03	5.8E−04	2.6E−04	1.2E−04	5.5E−05	2.5E−05	1.1E−05	5.2E−06
20%	1.7E−03	7.8E−04	3.5E−04	1.6E−04	7.2E−05	3.3E−05	1.5E−05	6.7E−06
25%	2.2E−03	9.8E−04	4.4E−04	2.0E−04	8.8E−05	4.0E−05	1.8E−05	8.0E−06
30%	2.7E−03	1.2E−03	5.3E−04	2.3E−04	1.0E−04	4.6E−05	2.0E−05	9.1E−06
35%	3.2E−03	1.4E−03	6.1E−04	2.7E−04	1.2E−04	5.2E−05	2.3E−05	1.0E−05
40%	3.7E−03	1.6E−03	7.0E−04	3.0E−04	1.3E−04	5.7E−05	2.4E−05	1.1E−05
45%	4.3E−03	1.8E−03	7.8E−04	3.3E−04	1.4E−04	6.0E−05	2.6E−05	1.1E−05
50%	4.8E−03	2.0E−03	8.5E−04	3.6E−04	1.5E−04	6.3E−05	2.6E−05	1.1E−05
55%	5.4E−03	2.2E−03	9.2E−04	3.8E−04	1.6E−04	6.4E−05	2.7E−05	1.1E−05
60%	6.0E−03	2.4E−03	9.8E−04	4.0E−04	1.6E−04	6.4E−05	2.6E−05	1.0E−05
65%	6.7E−03	2.6E−03	1.0E−03	4.0E−04	1.6E−04	6.2E−05	2.5E−05	9.7E−06
70%	7.3E−03	2.8E−03	1.1E−03	4.1E−04	1.5E−04	5.9E−05	2.2E−05	8.6E−06
75%	7.9E−03	2.9E−03	1.1E−03	4.0E−04	1.5E−04	5.4E−05	2.0E−05	7.2E−06
80%	8.5E−03	3.0E−03	1.1E−03	3.7E−04	1.3E−04	4.6E−05	1.6E−05	5.7E−06
85%	9.1E−03	3.0E−03	1.0E−03	3.4E−04	1.1E−04	3.8E−05	1.3E−05	4.2E−06
90%	9.6E−03	3.0E−03	9.2E−04	2.9E−04	8.9E−05	2.8E−05	8.6E−06	2.7E−06
95%	9.8E−03	2.8E−03	7.9E−04	2.2E−04	6.3E−05	1.8E−05	5.1E−06	1.4E−06
100%	9.8E−03	2.4E−03	6.1E−04	1.5E−04	3.8E−05	9.3E−06	2.3E−06	5.8E−07

Absorbed Dose to Fetus in Euthyroid Cases (mGy/MBq)

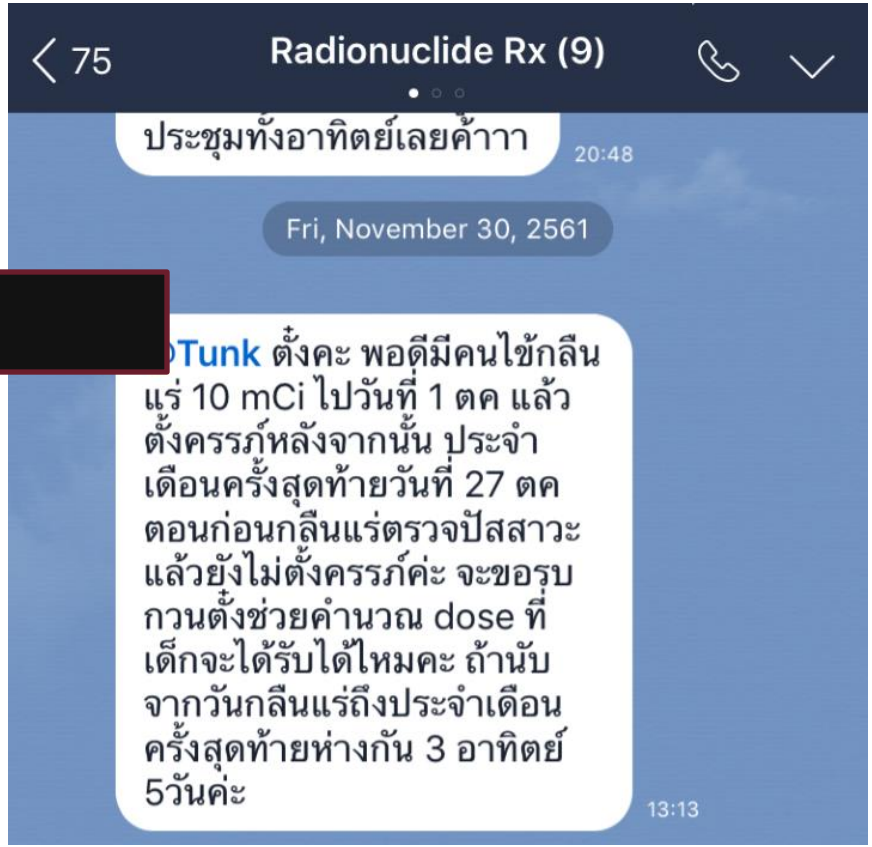
Maximum	Time in Weeks After Administration That Conception Occurs							
% Uptake	1	2	3	4	5	6	7	8
5%	3.1E−04	1.5E−04	7.7E−05	3.8E−05	1.9E−05	9.5E−06	4.7E−06	2.4E−06
15%	8.8E−04	4.4E−04	2.2E−04	1.1E−04	5.6E−05	2.8E−05	1.4E−05	7.2E−06
25%	1.4E−03	7.1E−04	3.6E−04	1.8E−04	9.2E−05	4.7E−05	2.4E−05	1.2E−05

Pregnancy after RAI

1. Hyperthyroid - Euthyroid
2. Maximum uptake
3. Activity
4. Time in weeks after administration that conception occurs

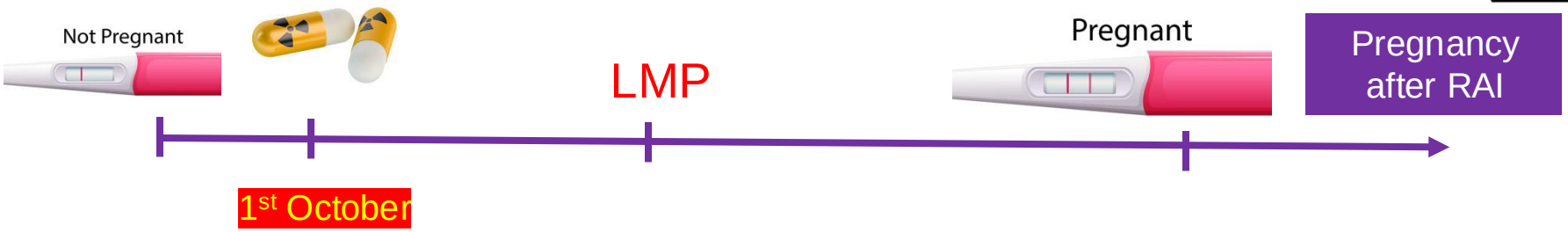
Physica Medica 43 (2017) 190–198

Case Example III



- Hyperthyroid patient received ^{131}I 10 mCi on 1st October
- LMP – 27th October
- Known pregnant on 30th November (urine test)

How to calculate dose?



- Worse case scenario - Conception might occur 26 days after administration (use 3 weeks for calculation)
- Review chart – 67% uptake (use 70% uptake for calculation)
- From table, 1.1E-3 mGy/MBq and 10 mCi (370 MBq)
- Fetal absorbed dose 0.41 mGy

Case Example IV

- Hyperthyroid Patient plan for radioiodine
- 10th Jan 2023 - LMP, Urine HCG –ve
- 17th Jan 2023 - ^{131}I 15 mCi
- 21st Feb 2023 – Urine HCG +ve

Pregnancy after RAI

1. Hyperthyroid - Euthyroid
2. Maximum uptake
3. Activity
4. Time in weeks after administration that conception occurs

Thyroid uptake ^{99m}Tc Dec 2022 – 14.7%

$^{99m}TcU_{20min}$, if TRAb < 10 IU/ml, looks as follows:

$$^{131}IU_{24h} = 17.72 \times \ln(99mTcU_{20min}) + 30.485$$

whereas if TRAb > 10 IU/ml:

$$^{131}IU_{24h} = 18.03 \times \ln(99mTcU_{20min}) + 38.726$$

Endocrine (2016) 54:751–756
DOI 10.1007/s12020-016-1074-7

ORIGINAL ARTICLE

Calculation of therapeutic activity of radioiodine in Graves' disease by means of Marinelli's formula, using technetium (^{99m}Tc) scintigraphy

Piotr Szumowski[1] · Małgorzata Mojsak[1] · Saeid Abdelrazek[1] · Monika Sykała[1] · Anna Amelian-Fiłonowicz[1] · Dorota Jurgilewicz[1] · Janusz Myśliwiec[1]

Endocrine (2016) 54:751–756

$^{131}IU_{24h}$ = 78.1%

How to Calculate?

Original paper

Radiation dose and risks to fetus from nuclear medicine procedures

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Maximum	Time in Weeks After Administration That Conception Occurs			
% Uptake	1	2	3	4
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15%	1.3E−03	5.8E−04	2.6E−04	1.2E−04
20%	1.7E−03	7.8E−04	3.5E−04	1.6E−04
25%	2.2E−03	9.8E−04	4.4E−04	2.0E−04
30%	2.7E−03	1.2E−03	5.3E−04	2.3E−04
35%	3.2E−03	1.4E−03	6.1E−04	2.7E−04
40%	3.7E−03	1.6E−03	7.0E−04	3.0E−04
45%	4.3E−03	1.8E−03	7.8E−04	3.3E−04
50%	4.8E−03	2.0E−03	8.5E−04	3.6E−04
55%	5.4E−03	2.2E−03	9.2E−04	3.8E−04
60%	6.0E−03	2.4E−03	9.8E−04	4.0E−04
65%	6.7E−03	2.6E−03	1.0E−03	4.0E−04
70%	7.3E−03	2.8E−03	1.1E−03	4.1E−04
75%	7.9E−03	2.9E−03	1.1E−03	4.0E−04
80%	8.5E−03	3.0E−03	1.1E−03	3.7E−04
85%	9.1E−03	3.0E−03	1.0E−03	3.4E−04
90%	9.6E−03	3.0E−03	9.2E−04	2.9E−04
95%	9.8E−03	2.8E−03	7.9E−04	2.2E−04
100%	9.8E−03	2.4E−03	6.1E−04	1.5E−04

- UPT might positve 10 -14 days after conception
  - 17th Jan 2023 - ^{131}I 15 mCi
  - 21st Feb 2023 – UPT +ve

4 wk

- Calculate 2 – 4 weeks after administration

2 weeks after conception (error from urine test)

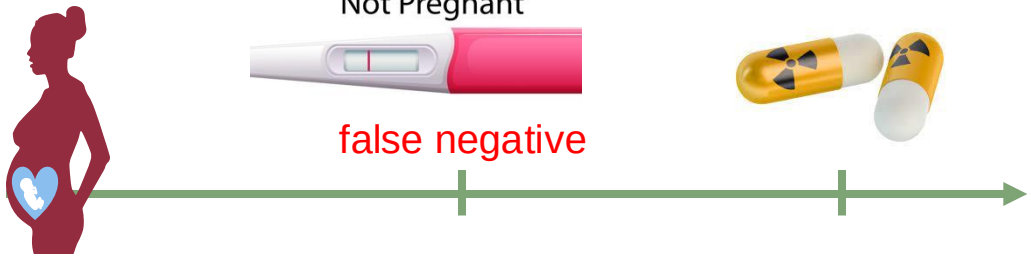
- 15 mCi * 37 MBq/mCi * 3.0E-3 mGy/MBq = 1.67 mGy

4 weeks after conception

- 15 mCi * 37 MBq/mCi * 3.73E-3 mGy/MBq = 2.07 mGy

Recommendation for Pregnancy after RAI

(1)



I-131 after conception

(2)

Pregnancy after RAI

ACR (2016)

Fetus dose calculation→Pregnant within 2 months (8 weeks) after RAI → Inform Gynecologist and Family, Record Fetus Dose in Medical Record

Breast Feeding

- During pregnancy, there is a substantial increase in the mammary epithelial population to prepare for lactation
- In this situation, the mammary epithelial tissues can receive a significant radiation dose.
- The mammary gland binds and concentrates **the ^{131}I and transfers it to the breast milk.**

RAI Treatment
4000 MBq
^{131}I in Thyroid
Carcinoma

Ingested Breast Milk

+

External Radiation from Close Contact

Infant Dose

J Nuc-Med 1994; 35:1797-1801

Academy of Breastfeeding Medicine 2019

TABLE 1. COMMON NUCLEAR MEDICINE IMAGING AGENTS AND RECOMMENDATIONS FOR BREASTFEEDING

Imaging agent	*Breastfeeding interruption*
Noncontrast radiographs	No
Nonvascular administration of iodinated contrast	No
CT with iodinated intravenous contrast	No
MRI with gadolinium-based intravenous contrast	No
Nuclear medicine imaging	
PET	No
Bone scan	No
Thyroid imaging	
I-131	Cessation for this infant
I-123	Recommendations vary, up to 3 weeks
Technetium-99m pertechnetate	Up to 24 hours, depending on dose
Renal imaging	
Tc-99m DTPA	No[a]
Tc-99m MAG3	No[a]
Tc-99m DMSA	No[a]
Tc-99m glucoheptonate	No[a]
Cardiac imaging	
Tc-99m Sestamibi	No[a]
Tc-99m Tetrofosmin	No[a]
MUGA	
Tc-99m RBCs in vitro	No[a]
Tc-99m RBCs in vivo	Up to 12 hours, depending on dose
VQ scan	
Tc-99m MAA	12 hours
Breast imaging	
Screening or diagnostic mammography	No
Ultrasound	No
MRI with gadolinium-based intravenous contrast	No

[a]The International Atomic Energy Administration recommends withholding breastfeeding for 4 hours or one feeding to account for any external radiation and free Tc99m pertechnetate in the product.

CT, computed tomography; MRI, magnetic resonance imaging; MUGA, multigated acquisition scan; Tc-99m MAA, technetium-99m macroaggregated albumin; PET, positron emission tomography; Tc-99m MAG3, technetium-99m mertiatide; Tc-99m DMSA, technetium-99m succimer; VQ, ventilation-perfusion.

^{131}I – Stop breastfeeding

ICRP Publication 94 (2004) - A guideline recommends that patients should avoid breastfeeding for 6–12 months after radiotherapy

BREASTFEEDING MEDICINE Volume 14, Number 5, 2019

Summary and Take-Home Messages

- Radiation-induced effects on the embryo/fetus are highly dependent on the stage of pregnancy, the dose absorbed by the embryo/fetus

- How to estimate radiation dose? (> 50 mGy should be worried)
  - ✓ Dose Coefficient Table from Publications (Stabin 2017)

Original paper

Radiation dose and risks to fetus from nuclear medicine procedures

Michael G. Stabin *

Vanderbilt University, Nashville, TN, USA

  - ✓ What information are needed?

Type of RP, Activity, Gestation Age

RAI after Pregnancy

Pregnancy after RAI

} Until 8 weeks

- **Congenital Hypothyroidism** – if RAI after the 10th Week of Gestation

Thanks