Thyroid Uptake Test With I-123 Sodium Iodide

1. OVERVIEW AND INDICATIONS

(adapted from Society of Nuclear Medicine Procedure Guideline for Thyroid Uptake Measurement, Version 3.0; reprinted from http://snmmi.files.cms-plus.com/docs/Thyroid%20Uptake%20Measure%20v3%200.pdf, © SNMMI Inc.)

a) Thyroid uptake determination is the measurement of the fraction of an administered amount of radioactive iodine that accumulates in the thyroid at selected times following ingestion.

b) Hyperthyroidism refers to an excess of circulating thyroid hormones. The thyroid uptake test is valuable for determining the activity of I-131 sodium iodide to be administered to patients for therapy of hyperthyroidism due to Graves' disease and toxic nodular goiter. The uptake measurement should be performed as close in time as possible to the treatment.

c) Thyroid uptake determination is differentiation of subacute or painless thyroiditis and factitious hyperthyroidism from Graves' disease and other forms of hyperthyroidism; for confirmation of the diagnosis of hyperthyroidism due to Graves' disease.

d) Thyroid uptake determination is of limited value in diagnosing hypothyroidism.

2. RADIOPHARMACEUTICALS UTILIZED

a) **I-123 sodium iodide**. The iodide has a charge of 1- and is sold as the sodium iodide salt (NaI). This radiopharmaceutical is used far more frequently than the I-131 sodium iodide

b) **I-131 sodium iodide**. The iodide has a charge of 1- and is sold as the sodium iodide salt (NaI). This radiopharmaceutical is used for specialized uptake studies, e.g., in a patient with a substernal thyroid.

3. CHARACTERISTICS OF THE RADIONUCLIDES

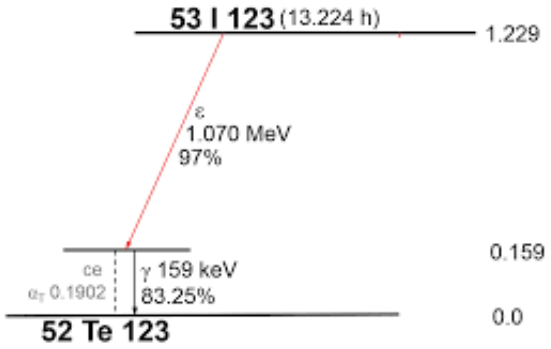
I-123

a) Iodine-123 decays by electron capture with a physical half-life of 13.2 hours. Photons used for detection and imaging of I-123 have an energy of 159 KeV.

b) The specific gamma ray constant for I-123 is 1.6 R/hr-mCi at 1 cm.

c) The first half-value thickness of lead (Pb) for I-123 is 0.005 cm and the first tenth value layer is 0.54 cm of Pb.

d) Decay Scheme



Adapted from www.nucleonica.com

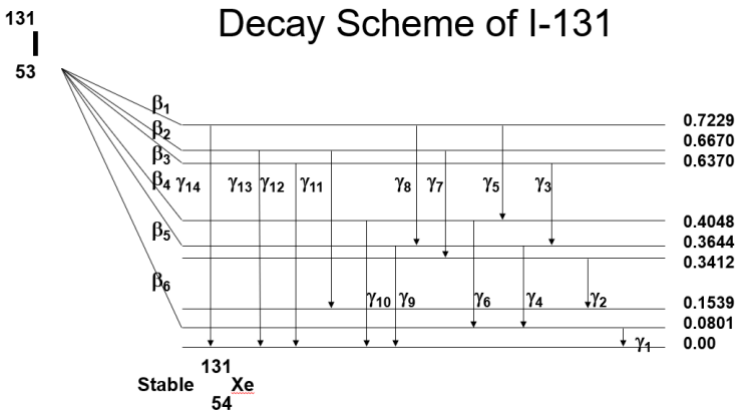
I-131

a) Iodine I-131 decays by beta emission and associated gamma emission with a physical half-life of 8.04 days. Photons used for detection and imaging of I-131 have an energy of 364.4 KeV.

b) The specific gamma-ray constant for iodine I-131 is 2.2 R/hr-millicurie at 1cm.

c) The first half-value thickness of lead (Pb) for iodine I-131 is 3 mm and the first tenth value layer is 11 mm of Pb.

d) Decay Scheme



Adapted from www.nucmedtutorials.com

4. DRUG AVAILABILITY

a) Both radiopharmaceuticals are readily available from any central Radiopharmacy.

5. MOLECULAR STRUCTURES

a) Sodium iodide is an ionic compound containing Na^{1+} and I^{1-} ions. It really doesn't have a molecular structure, although there is a crystal lattice structure that has been well-characterized.

6. DRUG PREPARATION

a) None required- each dose is precalibrated by the central pharmacy for a specific patient.

7. QUALITY CONTROL PROCEDURES

a) None required- requisite quality control procedures are performed by the central pharmacy prior to shipping doses of any of these radiopharmaceuticals.

8. RADIOCHEMICAL REACTIONS RELATED TO DRUG PREPARATION.

a) None required

9. CLINICAL PHARMACOLOGY

a) **Sodium iodide (I-123 or I-131)**

i. Iodide is readily absorbed from the upper gastrointestinal tract. Following absorption, the iodide is distributed primarily within the extracellular fluid of the body. It is trapped and organically bound by the thyroid and concentrated by the stomach, choroid plexus and salivary glands. It is excreted by the kidneys. The fraction of the administered dose which is accumulated in the thyroid gland may be a measure of thyroid function in the absence of unusually high or low iodine intake or administration of certain drugs which influence iodine accumulation by the thyroid gland. Accordingly, the patient should be questioned carefully regarding previous medications and/or procedures involving radiographic media.

ii. Normal subjects can accumulate approximately 8 to 35% of the administered iodine dose in the thyroid gland, however, the normal and abnormal ranges are established by individual physician's criteria. The mapping (imaging) of sodium iodide I-123 distribution in the thyroid gland may provide useful information concerning thyroid anatomy and definition of normal and/or abnormal functioning of tissue within the gland.

iii. Trapped iodide is oxidized to iodine and organically incorporated so rapidly that the iodide trap of the thyroid contains less than 0.2% free iodide in comparison to the organically bound iodine. This process results in further concentration of iodine in the thyroid gland to about 500 times that in the blood. The iodinated organic compounds chiefly consist of thyroxine (T_4) and triiodothyronine (T_3), which are bound by thyroglobulin in the follicular colloid. T_4 and T_3 are released by enzymatic proteolysis of thyroglobulin into the blood where they are specifically bound and transported by plasma thyroid binding proteins. These reactions are primarily under the control of anterior pituitary gland release of thyroid stimulating hormone (TSH) and hypothalamic thyroid release factor (TRF).

iv. Iodide is excreted by the kidneys. The normal range of urinary excretion is 37-75% of the administered dose; varies with the renal function of the patient.

9. MECHANISM OF LOCALIZATION OF RADIOPHARMACEUTICAL:

a) The mechanism of localization is referred to as **Active Transport**. This is defined as utilization of a normally active, energy-dependent metabolic pathway in the body to transport a radiopharmaceutical across a cell membrane and into the cell. In the case of the radioiodides, the iodide is first trapped, then undergoes intermediate syntheses involving a thyroglobulin intermediate, and is first organified into T_1 then stepwise into T_2 then T_3 and finally T_4. Each of these iodination steps is energy dependent, of primary importance in meeting the requirements of a normally active, energy-dependent metabolic pathway.

10. NORMAL DISTRIBUTION OF DRUG

(target organ = organs receiving highest radiation dose);
adapted from www.radiopaedia.org/articles/iodine-123

a) thyroid gland (target organ)
b) nasopharynx
c) salivary glands
d) stomach (target organ)
e) colon

f) bladder (target organ)
g) lactating breasts

11. NORMAL RANGE OF THYROID UPTAKE OF IODIDE: AVERAGE VALUES

a) < 8% = hypothyroid; 8-35% = euthyroid; >35% = hyperthyroid.
b) **The euthyroid range varies from 8-10 on the low end to 30-35 on the high end.**

12. TYPICAL ADMINISTERED DOSE FOR UPTAKE STUDIES

a) The recommended adult dose of I-123 sodium iodide for thyroid uptake is 200 μCi (7.4 MBq) , administered orally, and for thyroid scintigraphy is 200 to 400 μCi (7.4 to 14.8 MBq).
b) Use of I-131 is strongly discouraged for routine use because of its much greater radiation dose to the thyroid. If it is required, however, the dose should not exceed 100 μCi.

13. PATIENT PREPARATION FOR THYROID UPTAKE WITH I-123 NaI

a) It is very important to carefully interview the patient prior to administration of the I-123 sodium iodide as there are so many potential interferences in the uptake procedure that could invalidate the results. Included are the following:

i. Is the patient pregnant or lactating?
ii. Is the patient taking any herbal supplements, as they may also affect the test results?
iii. Has the patient received iodine-containing contrast (e.g. for CT or angiography)?
iv. Is the patient consuming substances that contain iodine, including kelp, seaweed, seafood, cough syrups, multivitamins or heart medications can interfere with both uptake and scan?
v. Is the patient taking any of the medications on the "Interfering Medications List"? Medications that interfere with thyroid uptake of radioiodine could delay the procedure for up to 4 weeks.
vi. It might be necessary to perform blood tests to measure the level of thyroid hormones in the patient's blood.
vii. Jewelry and other metallic accessories in the region of the thyroid should be removed prior to the exam because they may interfere with the procedure.

b) Patients should be fasted for 4 hours prior to and for 1-2 hours after receiving the capsule.

14. DRUG ADMINISTRATION PROCEDURE

a) I-123 NaI and I-131 NaI

   i. Capsule is taken orally with a cup of water. Patient must remain NPO for at least 1 hour.

15. COUNTING PROTOCOLS

(adapted from Society of Nuclear Medicine Procedure Guideline for Thyroid Uptake Measurement, Version 3.0, approved September 5, 2006; reprinted from http://snmmi.files.cms-plus.com/docs/Thyroid%20Uptake%20Measure%20v3%200.pdf , © SNMMI Inc.)

a) A sodium iodide (NaI) crystal uptake probe with suitable lead shielding and a flat field collimator should be used. This is usually integrated with a multiple channel analyzer and recording computer.

b) The measurement of thyroid uptake is usually performed 18–24 hr after administration of the radioiodine. In some circumstances, it may be performed between 2 and 6 hr after radioiodine ingestion, as well. The uptake is usually measured with 25– 30 cm between the face of the crystal and the anterior neck or phantom. Neck counts, lower thigh counts (body background), counts of a calibrated standard in a neck phantom and room background counts are preferably obtained at each counting session. Alternatively, the radioiodine dose can be counted in the neck phantom before oral administration, and the counts obtained can be corrected for decay at each patient counting session. The ORINS, IAEA or a comparable neck phantom is recommended.

c) Thyroid uptake can alternatively be measured using a scintillation camera, LEAP collimator and appropriate regions of interest. Validation of gamma camera techniques by comparison with a reliable standard is recommended.

15. ADVERSE REACTIONS ASSOCIATED WITH RADIOPHARMACEUTICALS USED FOR THYROID IMAGING

a) Although very rare, reactions associated with the administration of I-123 sodium iodide for diagnostic use include, in decreasing order of frequency, nausea, vomiting, chest pain, tachycardia, itching skin, rash and hives.

b) Adverse reactions that have been reported with doses of sodium iodide I-131 used in the treatment of benign disease include sialadenitis, chest pain, tachycardia, iododerma, itching skin, rash, hives, hypothyroidism, hyperthyroidism, thyrotoxic crisis, hypoparathyroidism, and local swelling.

MEDICATIONS AND FOODS THAT AFFECT THYROID UPTAKE TEST

The following chart indicates which drugs and foods may interfere with thyroid uptake and may affect image quality**. Source:** **www.drugs.com/pro/sodium-iodide-i-123.html**

Medication	**Recommended duration of withdrawal**
Adrenocorticosteroids	1 week
Bromides	1 week
Butazolidine	1 week
Mercurials	1 week
Methimazole (Tapazole)	1 week
Nitrates	1 week
Perchlorate	1 week
Propylthiouracil	1 week
Salicylates (large doses)	1 week
Sulfonamides	1 week
Thiocyanate	1 week
Tri-iodothyronine (Cytomel)	2 to 3 weeks
Thyroid extract (Synthroid)	4 weeks
Iodine solution (Lugol's, SSKI)	weeks
Iodine containing foods: iodized salt, dairy products, egg yolks, seafood, turkey, and liver	2 weeks
Iodine-containing antiseptics	weeks
Kelp	4 weeks
Some cough medicines	4 weeks
Some Vitamin preparations	4 weeks
Intravenous contrast agents	1 to 2 months
Oil-based iodinated contrast	3 to 6 months
Amiodarone	3 to 6 months

16. CONTRAINDICATIONS

a) To date there are no known contraindications to the use of I-123 Sodium Iodide or Tc-99m pertechnetate except for pregnancy or breastfeeding.

17. INTERNAL RADIATION DOSIMETRY

i. **I-123 and I-131 sodium iodide**: The estimated absorbed radiation doses to several organs of an average patient (70 kg) from oral administration of 400 μCi of I-123 are shown in the table below for thyroid uptakes of 5, 15, and 25%. For comparison at these three values of thyroid uptake, the estimated radiation doses from a dose of 100 μCi I-131, also used as thyroid imaging agent, are also included.

Absorbed Radiation Dose Estimates as a Function of Maximum Thyroid Uptake for Sodium Iodide I-123 at Time of Calibration and Expiry Compared to Sodium Iodide I-131*

		Estimated Radiation Absorbed Doses		
		I-123 mGy/14.8 MBq (rads/400 µCi)		I-131 mGy/3.7 MBq (rads/100 µCi)
Target Organ	Maximum Thyroid Uptake (%)	TOC	TOE	
Bladder†	5	1.7 (0.17)	1.7 (0.17)	2.9 (0.29)
	15	1.6 (0.16)	1.6 (0.16)	2.7 (0.27)
	25	1.4 (0.14)	1.5 (0.15)	2.4 (0.24)
Stomach Wall	5	0.96 (0.096)	0.98 (0.098)	1.7 (0.17)
	15	0.89 (0.089)	0.91 (0.091)	1.5 (0.15)
	25	0.82 (0.082)	0.85 (0.085)	1.4 (0.14)
Small Intestine	5	0.70 (0.070)	0.71 (0.071)	1.2 (0.12)
	15	0.65 (0.065)	0.67 (0.067)	1.1 (0.11)
	25	0.60 (0.060)	0.62 (0.062)	0.99 (0.099)
Liver	5	0.089 (0.0089)	0.13 (0.013)	0.16 (0.016)
	15	0.10 (0.010)	0.18 (0.018)	0.28 (0.028)
	25	0.11 (0.011)	0.24 (0.024)	0.41 (0.041)
Ovaries	5	0.18 (0.018)	0.19 (0.019)	0.18 (0.018)
	15	0.17 (0.017)	0.18 (0.018)	0.18 (0.018)
	25	0.16 (0.016)	0.18 (0.018)	0.17 (0.017)
Skeleton	5	0.11 (0.011)	0.16 (0.016)	0.12 (0.012)
	15	0.12 (0.012)	0.18 (0.018)	0.18 (0.018)
	25	0.14 (0.014)	0.21 (0.021)	0.24 (0.024)
Red Marrow	5	0.12 (0.012)	0.16 (0.016)	0.15 (0.015)
	15	0.12 (0.012)	0.18 (0.018)	0.21 (0.021)
	25	0.13 (0.013)	0.19 (0.019)	0.27 (0.027)
Testes	5	0.076 (0.0076)	0.089 (0.0089)	0.12 (0.012)
	15	0.072 (0.0072)	0.087 (0.0087)	0.12 (0.012)
	25	0.068 (0.0068)	0.085 (0.0085)	0.12 (0.012)
Thyroid	5	25 (2.5)	75 (7.5)	260 (26)
	15	77 (7.7)	230 (23)	780 (78)
	25	130 (13)	410 (41)	1300 (130)
Total Body	5	0.11 (0.011)	0.16 (0.016)	0.24 (0.024)
	15	0.14 (0.014)	0.25 (0.025)	0.47 (0.047)
	25	0.17 (0.017)	0.35 (0.035)	0.70 (0.070)

* Concentration at Time of Calibration: 97% I-123, 2.9% I-125, 0.1% Te-121
Concentration at Time of Expiry: 87.2% I-123, 12.4% I-125, 0.4% Te-121
Metabolic model in MIRD Dose Estimate Report 5 followed for I-123 and I-125
Metabolic model in ICRP 30 followed for Te-121

† Bladder voiding interval 4.8 hours.

19. RADIOACTIVE IODINE UPTAKE TEST (RAIU) CALCULATIONS

a) The question answered by the % uptake value is, what percent of the I-123 NaI in the capsule accumulates in the thyroid gland at 24 hr post administration of the dose?

b) **The formula used for calculation is**

$$\% \text{ Uptake} = \frac{\text{(Net Counts/Min in Thyroid) X 100\%}}{\text{Decay-Corrected Net Counts/Min in Capsule}}$$

c) **Radioactive Iodine Uptake Test: Sample Problem**

A capsule of I-123 NaI was counted at T_0. Patient then swallowed capsule and returned at 24 hr for counting.

($T_{1/2}$ = 13.3 hr; 24 hr decay factor: 0.2863)

Patient background: 1,000 counts/5 min
Capsule background: 1,000 counts/5 min
Thyroid counts At T_{24}: 50,000 counts/2 min
Capsule counts At T_0: 300,000 counts/2 min

What is % RAIU?

If patient and capsule are counted at the same time, then decay correction can be ignored.

d) Solution to problem

$$\% \text{ UPTAKE} = \frac{\text{(Net Counts/Min in Thyroid) X 100\%}}{\text{Decay-Corrected Net Counts/Min in Capsule}}$$

$$\% \text{ UPTAKE} = \frac{\text{(25,000-200) X 100\%}}{\text{(150,000-200) X 0.2863}}$$

$$\% \text{ UPTAKE} = 58.7\%$$

DIAGNOSIS: Hyperthyroid

20. MISCELLANEOUS INFORMATION

a) 30-35 years ago, the upper end of the normal range of thyroid uptake was 35-40%. Now it is 30-35%. The main cause for this decrease is the ubiquitous presence of iodized salt in many foods that we eat, as well as increased consumption of seafood, especially ocean fish, and sushi which contains seaweed, a significant source of iodine.

b) Inderal (propranolol) and most other beta-blockers do not interfere with thyroid uptake tests. They are frequently prescribed for hyperthyroid patients to keep their pulse rates at acceptable levels.