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Current Indications for Nuclear Thyroid Imaging Clinic and Policlinic for Nuclear Medicine University of Wurzburg

The first thyroid scan has been acquired appr. 50 years ago with Iodine-131. Thyroid scintigraphy however became clinically relevant only after the introduction of Technetium-99m as a radiotracer in the early sixties. Today approximately 1.500.000 thyroid scans are performed yearly in Germany with Technetium-99m (a little bit less than 50% of all Nuclear Medicine examinations in Germany) (8). Recently the American Society of Nuclear Medicine (10-12) and the German Nuclear Medicine Society (2-5) published guidelines or procedure guidelines respectively for diagnosis of thyroid diseases.

Radiopharmaceuticals

It is well-known since many years that the thyroid takes up Iodine actively out of the blood stream. This mechanism has been defined vaguely as “Iodine-trap”. The process has been clarified by studies from Nancy Carrasco’s group since 1996: A glycoprotein consisting of 618 amino acids, which is located in the plasma-membrane of the thyreocyte catalyzes the active transport of Iodide into the cell (6). This protein has been named “Sodium (=Natrium) Iodide-Symporter” (NIS), since it has been revealed, that one Iodide-anion is transported simultaneously with 2-Sodium-kations into the cell (fig. 1). It has been anticipated that Perchlorate should be transported in a similar way; however, Perchlorate is a potent inhibitor of NIS acting not as a substrate but as a blocker. Until today it has not been clarified definitively, whether Tc-99m-Pertechnetate acts – in a similar way – as an inhibitor of Iodide uptake or maybe a substrate for the NIS as other monovalent anions (e.g. Thiocyanate). The NIS is up-regulated by TSH, whereas moderate doses of Iodide lead to a down-regulation of NIS (6).

Figure 2 shows typical retention curves of I-131-sodiumiodide and Tc-99-Pertechnetate. It is shown that Pertechnetate is taken up much less by the thyroid as compared to Iodide: the uptake shows a nadir already after 20 minutes; the maximum uptake ranging between 2% (sufficient iodine supply) and 5% (iodine deficiency). On the contrary, the retention curve of Radioiodide increases up to a nadir after 24 hours after application; the maximum uptake ranging between 30% (sufficient iodine supply) and 50% (iodine deficiency). The different kinetics of Pertechnetate and Iodide depend not only on the NIS, but preferentially on the pendrin-regulated Iodide channel located in the apical cell-membrane (fig. 1), which transports Iodide out of the cell into the follicular lumen.

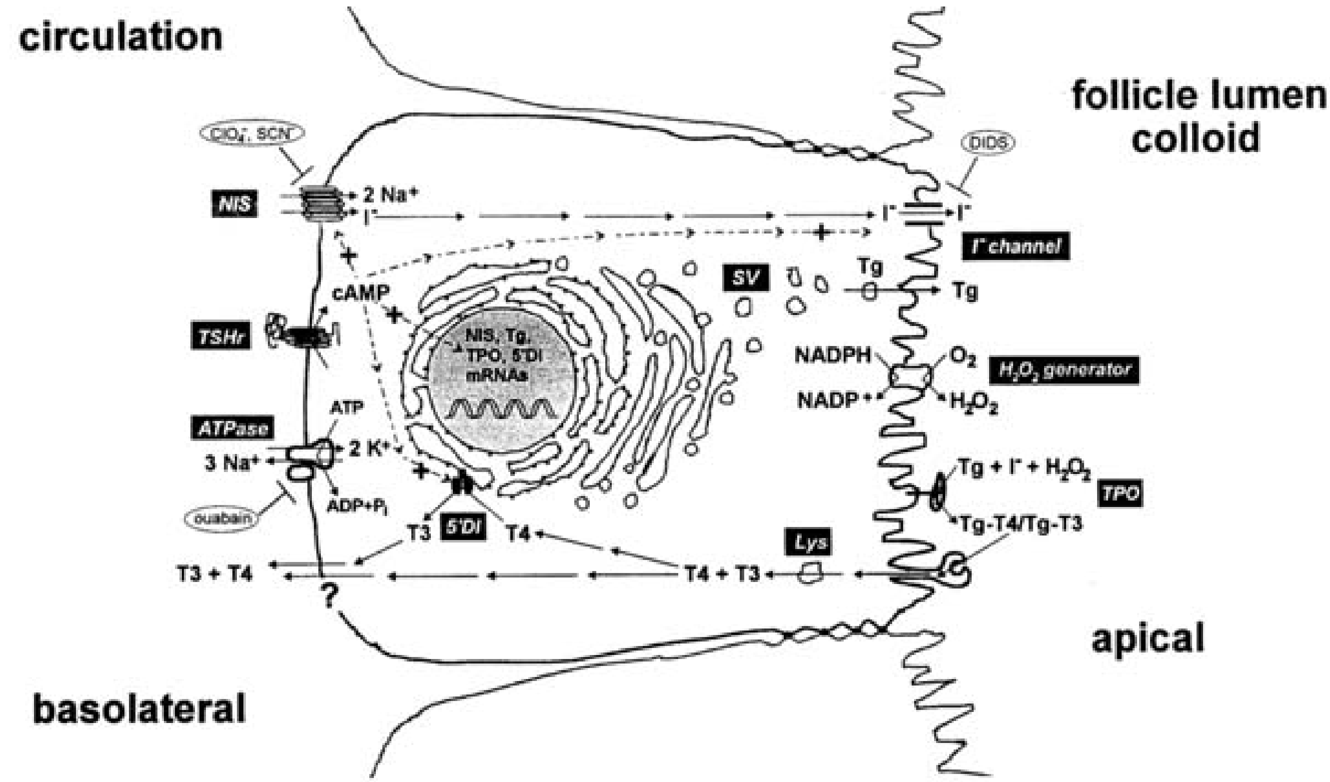

Fig. 1: The role of the sodiumiodide symporter (NIS) and the iodide channel for biosynthesis of thyroid hormones (9).

According to the kinetic curves shown in figure 2, Radioiodine should be used for scintigraphy of thyroid glands with low uptake or possible attenuation of the gamma-radiation by overlying tissue (e.g. thoracical goiters) (fig. 2). Since radiation exposure is much lower with the short-lived pure gamma-emitter I-123 (T ? 13,2 h), it should be preferred instead of I-131, which emits additional beta-radiation and has a considerably longer halftime (8 d).

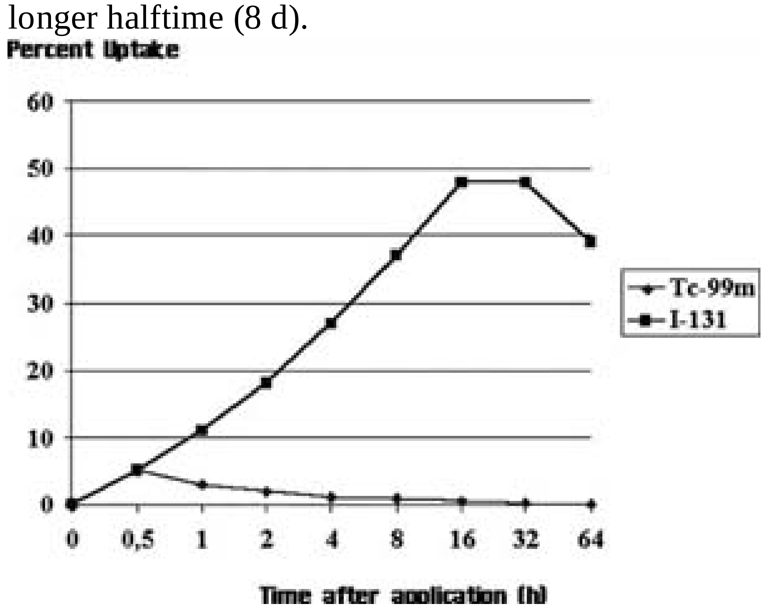

Fig. 2: Comparison of the thyroid uptake of Tc-99m-pertechnetate and I-131-iodide.

Quantitative thyroid scintigraphy

The objective of qualitative thyroid scintigraphy is the analysis of functional topography of the thyroid (2). Tc-99m-Thyroid-Uptake (TcTU) and Radioiodide Thyroid Uptake

(RITU) correlate well with Iodide Clearance, so that TcTU and RITU are used as clearance-equivalents. A high Iodide-Clearance means, that the thyroid clears a high plasma volume from Iodide. This may be the case in Iodine deficiency or hyperthyroidism. A low Iodide-Clearance reveals that only a small plasma volume is cleared because of sufficient iodine supply or lacking TSH-stimulus. A very low Iodide-Clearance is seen in the case of Iodide-excess (2).

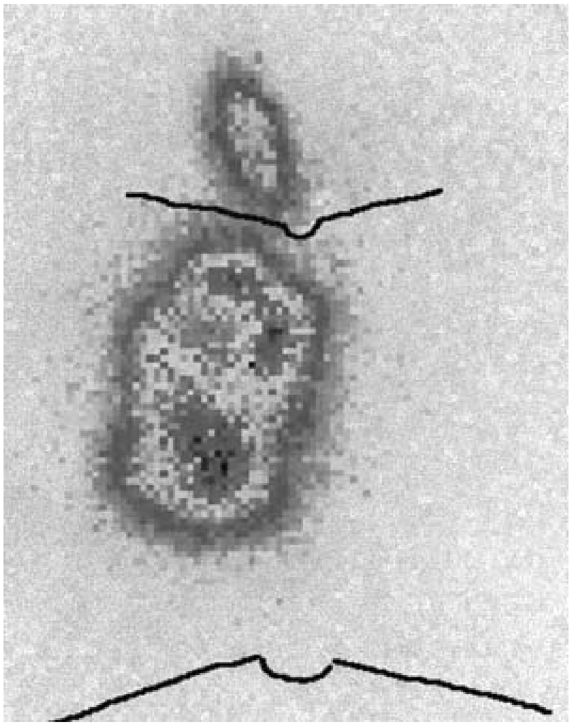

Fig. 3: Gammacamera-scan of the thorax with I-123-sodiumiodide in a patient after subtotal resection of the thyroid with a thyroid remnant and a large intrathoracical part of the goiter.

The uptake is influenced by thyroid hormone medication or anti-thyroid drugs. In case of normal TSH, the administration of TSH-suppressive doses of thyroid hormones is necessary for suppression-scintigraphy. If a thyroid scan is indicated without thyroid hormone medication, liothyronine has to be withdrawn at least 10 days and levothyroxine at least 4 weeks before the scan. Iodide-containing drugs (e.g. X-ray contrast media, antiseptica etc.) have to be avoided at least 4 weeks before thyroid scintigraphy. Moderate, physiological doses of Iodide (up to 200 µg daily) don't disturb scintigraphy (2).

The interpretation of the results of quantitative thyroid scintigraphy is possible only, if the Nuclear Medicine physician has informations about clinical findings and the following issues (2):

1. thyroid specific medication
2. exposure to Iodide containing drugs or X-ray contrast media
3. consumption of food containing large amounts of Iodide (e.g. sea-weed, kelp)
4. in-vitro-tests of thyroid function (especially basal TSH)
5. relevant sonographic findings
6. findings of previous thyroid scans
7. recently administered radiopharmaceuticals

Thyroid scintigraphy is contraindicated during pregnancy.

Today, usually between 20 and 80 MBq of Tc-99m-Pertechnetate or 5-20 MBq I-123-Sodiumiodide are injected intravenously. Scanning should be performed with a small field of view Gamma camera, which guarantees a spatial resolution of at least 2 mm/pixel. This Gamma camera has to be connected to a computer which allows digital storage of scans and analysis by ROI-technique with a dedicated and approved software. The background corrected thyroid uptake should be determined 5-25 min. after Tc-99m-Pertechnetate or 2-4 hours after I-123-Sodiumiodide. Recently, precise procedure guidelines have been published referred to data analysis and documentation of findings (1, 2).
For suppression scintigraphy, different regiments are used:

1. 60-100 µg liothyronine daily over 8-10 days
2. 150-200 µg levothyroxine daily over 14 days
3. 2 µg levothyroxine per kg of bodyweight daily for 4-6 weeks.

At the time of scintigraphy, the suppression of TSH has to be documented by a laboratory test. The application of thyroid hormones in case of already endogenously suppressed TSH (< 0,1 mU/l) is contraindicated (5).
For interpretation of thyroid scans, the knowledge of patient’s history, thyroid findings by palpation and/or ultrasonography is mandatory. The pattern and intensity of uptake as well as the localisation and size of focal lesions with increased or decreased uptake have to be described. It is strongly recommended to correlate scintigraphic and sonographic findings with respect to size, margin and localisation.
A thyroid gland of normal size has a basal TcTU between 0.5 and 2% in case of sufficient Iodine supply. With respect to the extent of Iodine deficiency, TcTU may increase up to 8% in patients with normal thyroid function. A low basal TcTU may be encountered after Iodine excess and acute thyroiditis. TcTU should be measured after suppression to differentiate between Iodine deficiency and hyperthyroidism. The normal range for TcTU under TSH-suppression is 0.5-2.0%. In cases of relevant functional autonomy, the TcTU under suppression is higher than 2% (8). It has to be mentioned however, that in case of small lesions with functional autonomy, which may be localised scintigraphically clearly, TcTU under suppression may be in the normal range. That is why interpretation of TcTU always has to include a qualitative description of the scintigraphic findings (fig. 4).

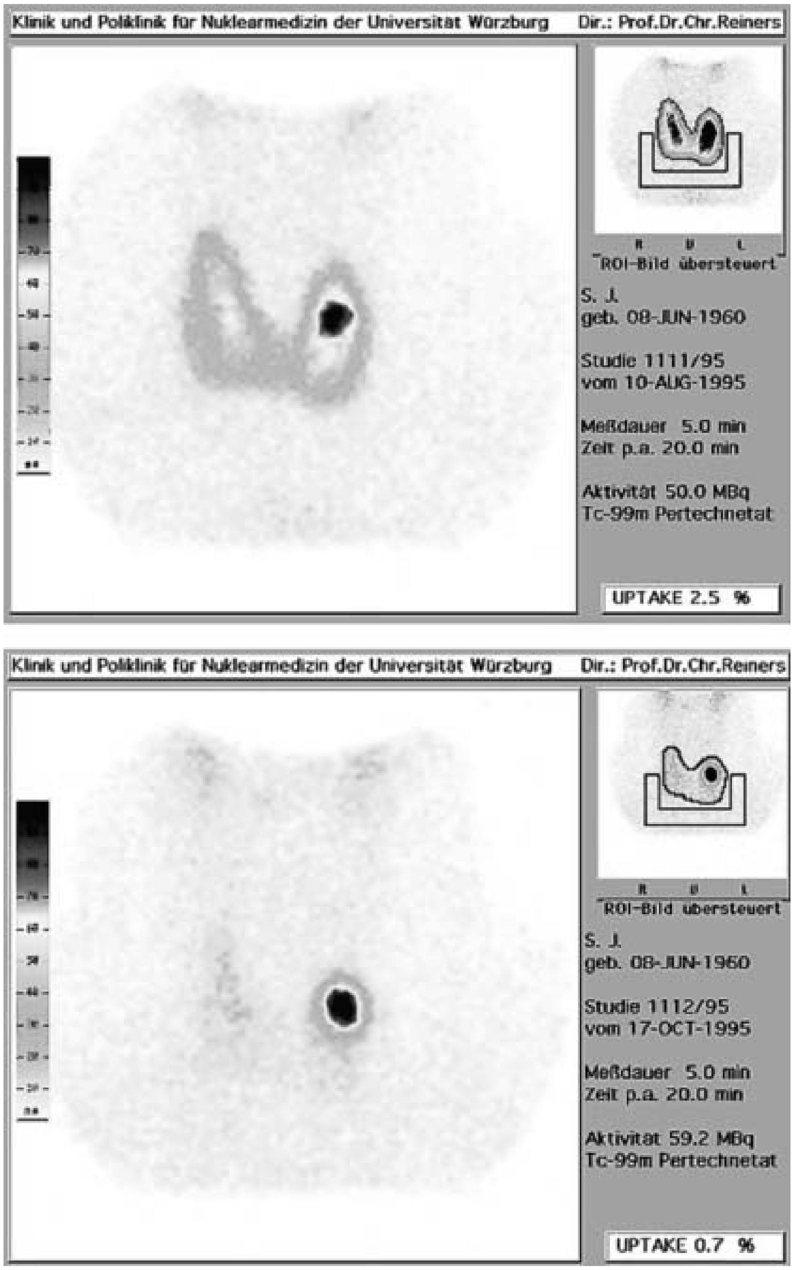

Fig. 4: Basal thyroid scan with Tc-99m-pertechnetate (top) and suppression scan after 6 µg of liothyronin for 8 days (bottom) in a patient with small unifocal functional autonomy: functional autonomy can be detected clearly visually but TcTU under suppression is with 0.7% normal.

Indications:

According to the guidelines of the American (10) and German (2, 5) Society of Nuclear Medicine, scintigraphy with Tc-99m-Pertechnetate is indicated (5, 10) in case of

1. palpable and/or sonographically determined focal lesions (diameter ? 1 cm).
2. suspected focal or diffuse functional autonomy in case of manifest of latent hyperthyroidism
3. to differentiate thyroiditis and factitious hyperthyroidism from Graves' disease
4. to document the success of radioiodine therapy
5. for follow-up of functional autonomy which is not treated by surgery or radioiodine.

Thyroid scintigraphy with I-123-Sodiumiodide is indicated (2, 5) in case of

1. ectopic thyroid tissue

2. connatal hypothyroidism
3. defects of Iodine organification (Perchlorate-discharge-test).

Radiation exposure

The exposure of the thyroid (tab. 1) using Tc-99m-Pertechnetate with a typical activity of 50 MBq leads to a thyroid dose of 1 mGy and an effective dose of 0.5 mSv. Using approximately 10 MBq of I-123, the dose to the thyroid of 60 mGy and the effective dose of 3 mSv is considerably higher. If I-131 with an activity of 3 MBq is used for dosimetry before I-131-therapy; a typical activity of 3 MBq is followed by a high exposure of the thyroid of 1.8 Gy and a very high effective dose of approximately 100 mSv.

Tab. 1: Thyroid dose and effective dose as a measure or whole-body exposure in nuclear thyroid imaging (7)

Radiation exposure in nuclear thyroid imaging				
Nuclide	*Kind of radiation*	*Half-time*	*Thyroid dose (mGy/MBq)*	*Effective dose (mGy/MBq)*
I-131	γ, β	8 d	620	33
I-123	EC	13,2 h	6,0	0,3
Tc-99m	γ	6 h	0,02	0,01

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Legends