Thyroid

5

Barry Shulkin and Thomas Neil Pascual

5.1 Thyroid Scintigraphy in Congenital Hypothyroidism

Clinical Indications [1–4]

- To determine the etiology of CHT.
- To differentiate between permanent and transient forms of CHT.

Pre-Exam Information

- This is an urgent scan and should be booked within 3–4 days from birth.
- A thyroid function blood test may be performed following the positive screening result. If this confirms the diagnosis of hypothyroidism, the newborn is started on thyroxine.
- Is the infant receiving hormonal replacement therapy? If so, for how many days?
- Whether there has been maternal thyroid disease during pregnancy and/or antithyroid drug therapy.
- History of exposure of the newborn to iodine-containing antiseptics used in maternal (C-section) or newborn surgery or contrast media in radiologic procedures.

Study Protocol for Thyroid Scintigraphy in Neonates [5, 6]

Patient Preparation

- A cannula is placed for tracer injection and blood tests if required.
- No fasting is required for intravenous (IV) radiotracer administration.
- Oral ^{123}I administration requires 2 h of fasting before the scan to ensure rapid and complete absorption.

Radiopharmaceutical, Activity, and Mode of Delivery.

Radiopharmaceutical:

- [^{99m}Tc]Pertechnetate (Pertechnetate): is the preferred radiopharmaceutical in children because of its quick localization within thyroid tissue.
- [^{123}I]Na Iodine (^{123}I) is theoretically the most physiologic radiopharmaceutical and yields better images even with low uptake.

B. Shulkin (✉)
Department of Diagnostic Imaging, St. Jude Children's Research Hospital, Memphis, TN, USA
e-mail: Barry.Shulkin@stjude.org

T. N. Pascual
Department of Science and Technology, Manila, Philippines

Z. Bar-Sever et al. (eds.), *A Practical Guide for Pediatric Nuclear Medicine*,
https://doi.org/10.1007/978-3-662-67631-8_5

Activity:

- Pertechnetate: the injected activity in a neonate is about 10 MBq (0.35 mCi).
- ^{123}I administered IV: the recommended activity is 3 MBq (0.08 mCi) but some centers use only 1.2 MBq (0.03 mCi).
- ^{123}I administered orally (following 2 hours fast): 0.2 MBq/Kg (0.005 mCi/Kg) with a minimum dose of 3 MBq (0.08 mCi).

  Refer to the EANM pediatric dosage card and to the North American consensus guidelines on radiopharmaceutical administration in children in the respective EANM and SNMMI and image gently web sites.

  Reference to national regulation guidelines, if available, should be considered.

Delivery:

- IV tracers are administered through a cannula, which should be adequately flushed with normal saline before and after the injection.

Acquisition Protocol.
Pertechnetate:

- Time of imaging: 15–20 min post-injection.
- Pinhole collimator is recommended when available.

  If a pinhole collimator is not available use general purpose, high or ultra-high resolution collimator.
- Position: supine with the neck extended. A folded towel under the neck helps achieve the desired extension.
  - The infant is secured to the camera bed, with the arms by the side of the body.
- Projections: standard anterior, right and left anterior oblique (RAO, LAO). A lateral view of the neck indicated in cases of ectopy, is obtained with the infant lying on his side.
- ^{57}Co markers positioned on the suprasternal notch and optionally on the chin to improve spatial orientation.
- Acquisition parameters:
  - Duration: 5–10 min/view.
    Alternatively: 250 Kcounts; for images with markers 50 Kcounts.
    Pinhole: 100–200 Kcounts.
    Zoom of 1.5–2 (typical), matrix 128 × 128 or 256 × 256.

^{123}I

- Time of imaging 2–6 h if early imaging is desired. Otherwise 24 h after ingestion is standard.
- All other parameters are the same as for Pertechnetate (*see above*).

Study Interpretation

- Normal scan:
  - Symmetrical tracer uptake in both thyroid lobes, resembling a butterfly shape.
  - The gland is positioned at the base of the neck, the normal thyroid bed.
  - Faint uptake is seen in the salivary glands and the gastric mucosa.
- Lack of tracer uptake in the thyroid gland can be due to:
  - Agenesis.
  - Maternal antithyroid antibodies in the newborn's blood (preventing tracer uptake).
- Ectopic focal uptake:
  - In the upper neck midline, the region of the oropharynx, suggests a "lingual thyroid."
  - One or, occasionally, two foci in the lower neck, above the normal thyroid bed, located along the thyroglossal duct.
- Faint, ill-defined uptake in thyroid bed can be due to:
  - Maternal antibodies.

  - Exposure of the newborn to iodine.
  - A hypoplastic gland.
  - Treatment with replacement thyroid hormones for more than 7 days.
- Visualization of a single lobe is due to hemiagenesis.
- Intense uptake in both lobes of a normally positioned thyroid gland suggests dyshormonogenesis.

Perchlorate Discharge Test [7]

- Iodide is an essential substrate of thyroid hormones. It is normally trapped in thyroid cells and undergoes organification and incorporation into tyrosine residues in thyroglobulin (Tg). Organification defects in thyroid hormone synthesis cause accumulation of free iodide in the thyroid cells.
- Perchlorate is a drug that shares the same uptake mechanism as iodide and is also trapped in thyroid cells. This results in the discharge of excess non-organified iodide from the cells.

Perchlorate Test Protocol

- Following administration of ^{123}I a region of interest (ROI) is placed over the thyroid gland and a background ROI over the right lung.
- 90 mg of Perchlorate is administered orally.
- A repeat anterior view of the thyroid is obtained after 60 minutes and processed with the same ROI.
- A positive study indicating an organification defect requires a greater than 10% decay-corrected reduction in the net thyroid counts at 60 min after Perchlorate administration.

Correlative Imaging

- US of the neck may show the presence of the thyroid in the neck and can be used to screen for a possible mass at the base of the tongue. This assessment can however be difficult due to small size of infants and thus limited access to the neck area. When a normally situated gland is visualized, an ectopic gland can be excluded.
- Neck US can help determine the presence or absence of the thyroid that is not visualized on scintigraphy as well as to confirm the morphology and location of the gland.
- If struma ovarii is suspected US or other cross-sectional imaging of the pelvis may be warranted.

Red Flags

- It is best to perform the thyroid scan before the initiation of hormonal replacement therapy, but scheduling limitations should not postpone treatment.
- Some centers prefer to position the child directly on the collimator surface, lying in the prone position with the head gently cradled in the hands of a parent/caregiver or staff.
- In practice, the use of ^{123}I is not necessary unless a perchlorate discharge test is planned.
- Some centers use a reduced dose of ^{123}I administered IV by more than 50% of the recommended activity, 1.2 MBq (0.03 mCi) instead of 3 MBq (0.08 mCi) with satisfactory image quality while also achieving a significant decrease in the effective exposure dose.

Take Home Messages

- ^{123}I is not widely available, being expensive and having a higher radiation burden than Pertechnetate.
- Thyroid scans for CHT are urgent studies and should be given priority in scheduling.
- Study results can still be informative after a few days of therapy.

- Positioning the child directly on the collimator surface in the prone position decreases the distance between the thyroid gland and the collimator, improving spatial resolution and shorter acquisition time.
- Pinhole collimators provide optical magnification and enhance the spatial resolution that may improve diagnostic accuracy. This is especially important given the small thyroid gland size in the newborn.
- In cases of dyshormonogenesis, when using ^{123}I, a perchlorate discharge test can substantiate the diagnosis. Perchlorate will not discharge iodide from normal thyroid glands.
- The normal uptake of Pertechnetate is 0.4–4% of the injected activity.
- Faint, ill-defined uptake in the thyroid bed is less specific than the other patterns of thyroid visualization and can be due to a number of causes, as described above.
- Maternal antithyroid antibodies in the newborn's blood can severely impede tracer uptake by the gland due to transient hypothyroidism, a condition that subsides within a few weeks after the disappearance of the antibodies from the blood. Neck US can help distinguish between this option and agenesis of the gland.
- The best study interpretation is obtained when combining scintigraphy and results of neck US.

Representative Case Examples

Case 5.1. Non-visualization of Thyroid Gland (Fig. 5.1)

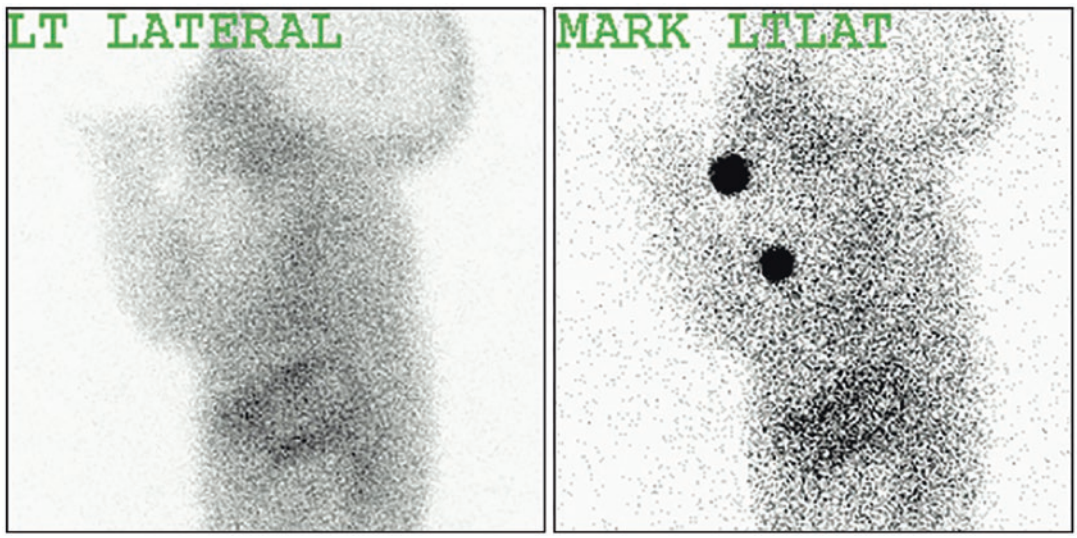

Fig. 5.1 History: Neonate with congenital hypothyroidism. Study report: In the left lateral view (right, with, and left, without markers), there is no evidence of functioning thyroid tissue in the neck or elsewhere. Impression: The findings are compatible with thyroid agenesis or a severely dysplastic thyroid

Case 5.2. Sublingual Thyroid (Fig. 5.2)

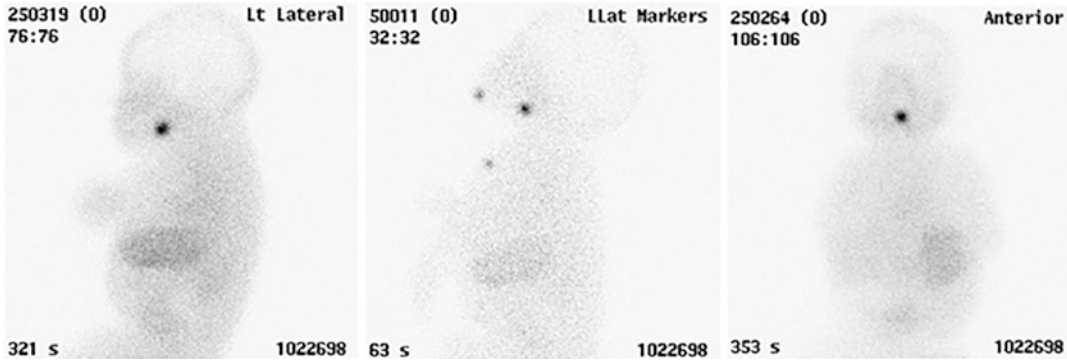

Fig. 5.2 History: Neonate with congenital hypothyroidism. Study report: On left lateral views (left without markers, center with markers) there is a focal area of Pertechnetate uptake in the sublingual position. In the anterior view (right) the focus appears round-shaped and not in the typical butterfly shape of the normal thyroid gland. Impression: The findings are compatible with a sublingual thyroid. This child is likely to need thyroxine for life

Case 5.3. Ectopic Thyroid Tissue (Fig. 5.3)

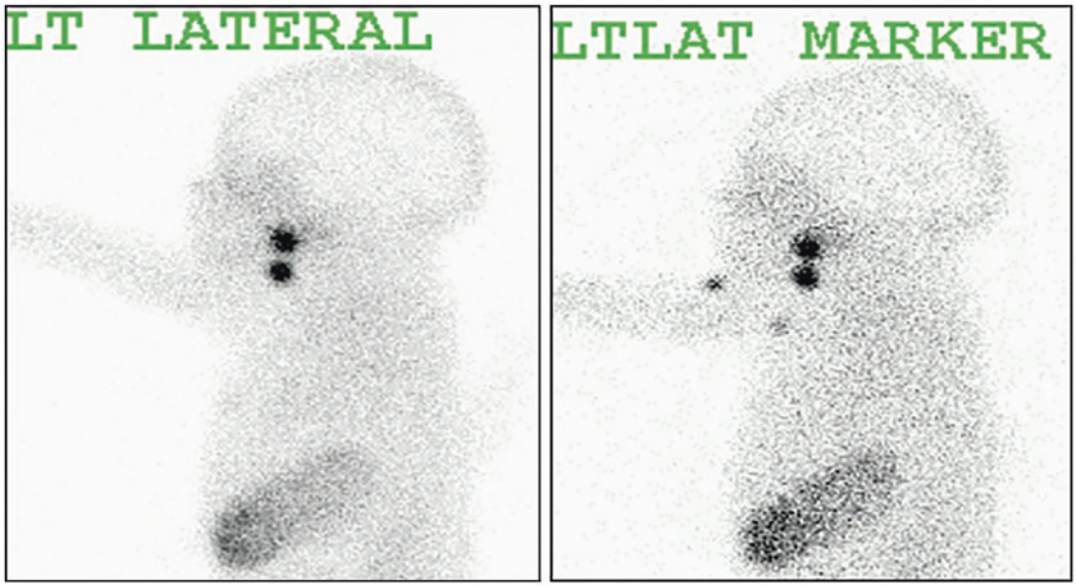

Fig. 5.3 History: Neonate with congenital hypothyroidism. Study report: Following administration of Pertechnetate, on the left lateral view (left, without markers) there are two foci of tracer uptake behind the tongue. No tracer uptake is seen in the physiologic thyroid location in the neck (right, with markers). Impression: The findings are compatible with foci of functioning ectopic sublingual thyroid tissue. This child is likely to need thyroxine for life

Case 5.4. Dyshormonogenesis (Fig. 5.4)

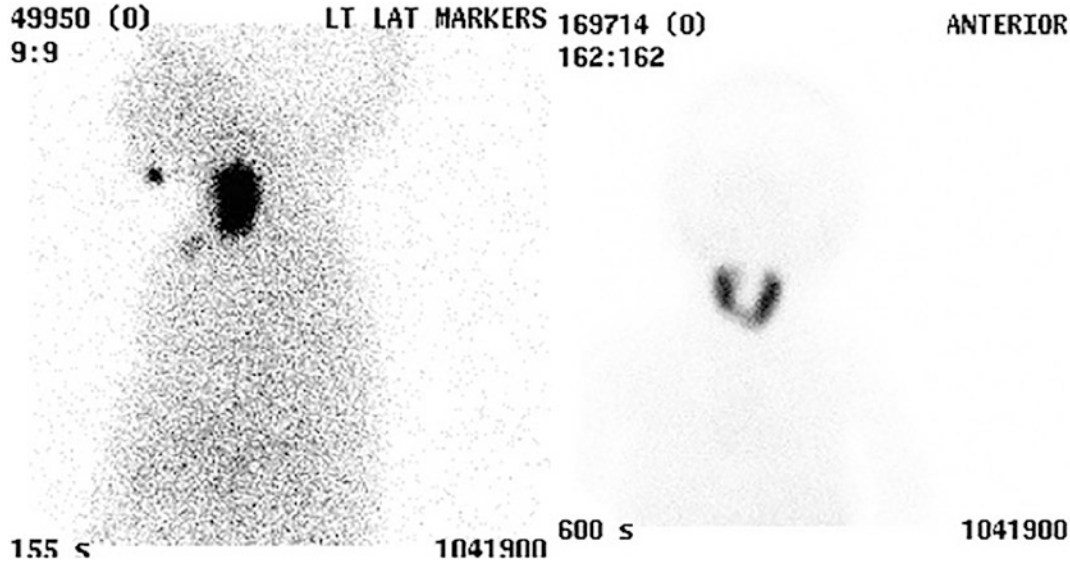

Fig. 5.4 History: Neonate with congenital hypothyroidism. Study report: There is high Pertechnetate uptake of 13.6% (normal range: 0.45–4%) in a normally located thyroid gland (left-lateral, right-anterior view) showing the usual butterfly shape. Impression: The findings are compatible with dyshormonogenesis

5.2 Thyroid Scintigraphy in Acquired Benign Thyroid Disease

Clinical Indications [8]

- Determining the cause of abnormal thyroid function, both in hyper- and hypothyroidism.
- Evaluation of goiter.
- Evaluation of thyroid nodules.
- Determining the presence of functioning thyroid tissue in a suspected thyroglossal cyst.
- Suspected thyroiditis.
- In combination with radioiodine uptake (RAIU) measurement to calculate the dose for radioactive iodine (RAI) therapy.

Pre-Exam Information

- Recent values of thyroid function tests (thyroid hormones, TSH, antithyroid antibodies).
- History of thyroid disease in the family.
- Medications taken by the child with emphasis on thyroid hormones, antithyroid drugs [e.g., methimazole (mercaptizol®), propylthiouracil (PTU)], and iodine-containing medications (e.g., amiodarone)].
- History and date of exposure to iodine in IV contrast media and iodine-containing antiseptics (e.g., surgical preparation with betadine).
- History of previous thyroid surgery and RAI therapy.
- History of iodine-rich diets or intake of vitamins or nutritional support products.

Study Protocol for Thyroid Scintigraphy

Patient Preparation

- When possible, it is advised to withhold a thyroid scan until the effects of interfering factors diminish:
  - Discontinue iodine-containing drugs, diet, and supplements.
    Iodine-rich foods and supplements (e.g., seaweed, kelp, and sushi): 1 week.
    Lugol's solution, Saturated Solution of Potassium Iodide (SSKI), KI tablets, vitamin/minerals: 1–3 weeks.
    Cough medications and skin cleansers containing iodine: 2–4 weeks.
    IV iodinated contrast: 4–6 weeks.
    Amiodarone: 3–6 months.
  - Discontinue drugs that interfere with RAI uptake.
    Methimazole, PTU: 3 days.
    Lithium carbonate: 1 year (rarely used in children).
- In cases of oral RAI administration: fast for 1–2 hours prior to and 30 minutes after the administration to ensure adequate absorption.

Radiopharmaceutical, Activity, and Mode of Delivery.

Radiopharmaceuticals:

- [^{99m}Tc]Pertechnetate (Pertechnetate): readily available.
- [^{123}I]Na Iodine (^{123}I): theoretically the best tracer.
- [^{131}I]Na Iodine (^{131}I): as a rule, it should not be used for the evaluation of benign thyroid diseases, especially in children.

Activity and mode of delivery:

- Pertechnetate: 1.1 MBq/Kg (0.03 mCi/Kg), minimum 7 MBq (0.19 mCi), maximum 93 MBq (2.5 mCi).
- ^{123}I:
  - Administered orally: 3.7–7.4 MBq (0.1–0.2 mCi) after a fast of 1 h.
  - Administered IV: 0.28 MBq/kg (0.0075 mCi/kg) minimum 1 MBq (0.027 mCi), maximum 11 MBq (0.3 mCi).
- ^{131}I: 0.15–0.37 MBq (0.004–0.01 mCi).
  - Administered orally for RAIU measurements after a fast of 1–2 h.

Refer to the EANM pediatric dosage card and to the North American consensus guidelines on radiopharmaceutical administration in children in the respective EANM and SNMMI and image gently web sites.

Reference to national regulation guidelines, if available, should be considered.

Acquisition Protocol

- Collimator: general purpose, high- or ultrahigh resolution.
  Pinhole collimator is recommended when available.
- Position: supine, a folded towel under the neck to achieve desired extension.
- The child should be secured to the camera bed. Arms are down by the side of the body.
- Time of imaging:
  - Pertechnetate: 20 min after administration.
  - ^{123}I: 2–6 hours after oral and 1 hour after IV administration.
- Static scans: anterior, RAO, LAO, and anterior "bird's eye" non-zoomed view.
- Duration of acquisition:
  - Pertechnetate: 100–200 Kcounts/view.
  - ^{123}I: 50–100 Kcounts/view or 5–20 min.
- Matrix 128 x 128 or 256 x 256.
- ^{57}Co markers should be placed on the suprasternal notch, the chin, and any palpable thyroid nodule to improve spatial orientation.

RAIU Test

- Provides quantitative assessment of RAIU values as a diagnostic add-on to thyroid scan findings.
- It is required for dose calculation when RAI therapy is planned.
- Can be performed with either ^{123}I or ^{131}I.
- Typically RAIU is measured with a probe detector.
- A second dose with the same activity as the one administered to the patient is used as a standard.
- RAIU calculation: ratio between background-corrected counts in the thyroid and counts in the standard.
- Time of measurement: typically at 24 h. Earlier measurements at 4–6 h can be performed as well.
- Normal values: 3–16% at 4 h and 8–25% at 24 h.

Study Interpretation (for Thyroid Scan and RAIU) [9–14]

- The maximal length of each thyroid lobe should be measured serving as a tool to assess the size of the gland.

Suspected hyperthyroidism

- Graves' disease: demonstrates diffuse thyroid enlargement, increased, homogenous tracer activity, high RAIU.
- "Toxic" autonomous nodule: intense focal uptake and faint, suppressed activity in the remainder of the gland.
- Multinodular goiter: appears as several foci of increased or decreased tracer activity in the thyroid. Some may have mild autonomous activity without suppression of uptake in the adjacent normal gland tissues.
- Thyroid inflammation such as subacute or Hashimoto thyroiditis: various degrees of reduced tracer uptake in the gland and reduced RAIU.

Hypothyroidism

- Autoimmune hypothyroidism or secondary to prior thyroid ablation: reduced tracer uptake and low RAIU.
- Chronic thyroiditis (e.g., Hashimoto): may appear as patchy tracer activity in some cases.
- Ectopic autonomous thyroid tissue (rare cases, e.g., struma ovarii): reduced tracer activity in the thyroid due to TSH suppression.

Correlative Imaging [15–17]

- Thyroid US should be correlated for assessment of gland appearance, presence of nodules, calcification, and vascularity.

Red Flags [18, 19]

- Discontinuation of medications in preparation for a thyroid scan should be decided in collaboration with the referring physician.
- ^{131}I should not be used, in particular, in children, because of the high radiation burden and inferior imaging properties related to its high-energy gamma emission of 364 kEv and beta particle emission which adds to radiation burden and limits the amount that may be prescribed, and its relatively long physical half-life of approximately 8 days.
- When imaging with a pinhole collimator the thyroid should fit within the central two-thirds of the FOV to prevent distortion of the gland anatomy.
- Some scintigraphic and RAIU findings are characteristic of specific entities causing thyroid dysfunction, while others are non-specific.
- Small amounts of tracer are excreted in the saliva and accumulate in the oropharynx and esophagus, mimicking uptake in ectopic thyroid tissue or in a pyramidal lobe. Asking the patient to swallow a few sips of water before imaging will eliminate activity in the mouth and esophagus and help prevent misinterpretations.
- Normal RAIU value may depend on the prevalence of iodine in the diet and can vary among different geographical locations.
- Normal RAIU in the presence of very low TSH levels can still indicate Graves' disease.
- Thyroid inflammation may cause transient hyperthyroidism due to the uncontrolled release of thyroid hormones from damaged thyroid tissue.
- Inappropriate intake of thyroid hormones (thyrotoxicosis factitia) can also cause hyperthyroidism with reduced tracer uptake.
- Reduced uptake in euthyroid patients can be due to an iodine-rich diet, to iodine-containing medications/supplements, to IV administered contrast agents, to antithyroid drugs and hormonal replacement therapy.
- Certain processing software can calculate the percent tracer uptake in the gland from the injected dose. This requires measuring the full and empty syringe counts, and placing thyroid and background regions of interest. The percent uptake from injected dose can aid visual assessment of the intensity of tracer uptake but has not been formally validated and cannot routinely replace RAIU with a dedicated probe.

Take Home Message

- Accurate pre-exam information is essential for the correct interpretation of thyroid scans.
- When available, findings on thyroid scans should always be interpreted in conjunction with thyroid function tests, pertinent clinical findings, and neck US results.
- The presence of a focal increased or decreased tracer uptake seen in the thyroid on a scan and suspected to represent a nodule should be verified by manual palpation and US of the neck.
- An anterior "bird's eye" non-zoomed view provides a larger FOV that includes the head, neck, and chest, demonstrates the position of the thyroid relative to other structures and allows detection of an intrathoracic extension of the thyroid tissue such as a retrosternal goiter.
- Thyroid nodules are found in approximately 5–7% of children and young adults. They require further evaluation with US-guided fine needle aspiration (FNA) regardless of their appearance on scintigraphy to exclude malignancy.
- Pertechnetate is preferred in children because of the lower radiation burden than ^{123}I which is the most physiologic tracer but limited in availability and expensive.
- RAIU measurements and thyroid scan can be performed with an oral dose of ^{123}I.
- When early RAIU measurements show very low or no uptake, there is no need to recall the

patient for a 24-hour measurement the next day.
- A significant drop between the early and late measurements is characteristic of high iodine turnover in the thyroid.
- In practice, the use of ^{123}I is not a necessity unless a perchlorate discharge test is planned or when used orally for a combined thyroid scan and RAIU measurement.
- When available, ^{123}I is highly preferable to ^{131}I due to the lower radiation exposure and improved image quality.
- The study report should include:
  – Medical history, thyroid function tests, medications, dietary supplements, other factors that could affect the scan and RAIU results.
  – Size and structure of the gland, homogeneity and intensity of tracer activity, uptake in ectopic locations (e.g., pyramidal lobe and thyroglossal cyst).
  – Presence and type of thyroid nodules (hot, cold, warm) their location and correlation with manual palpation findings and US results.

Representative Case Examples

Case 5.5. Graves' Disease (Fig. 5.5)

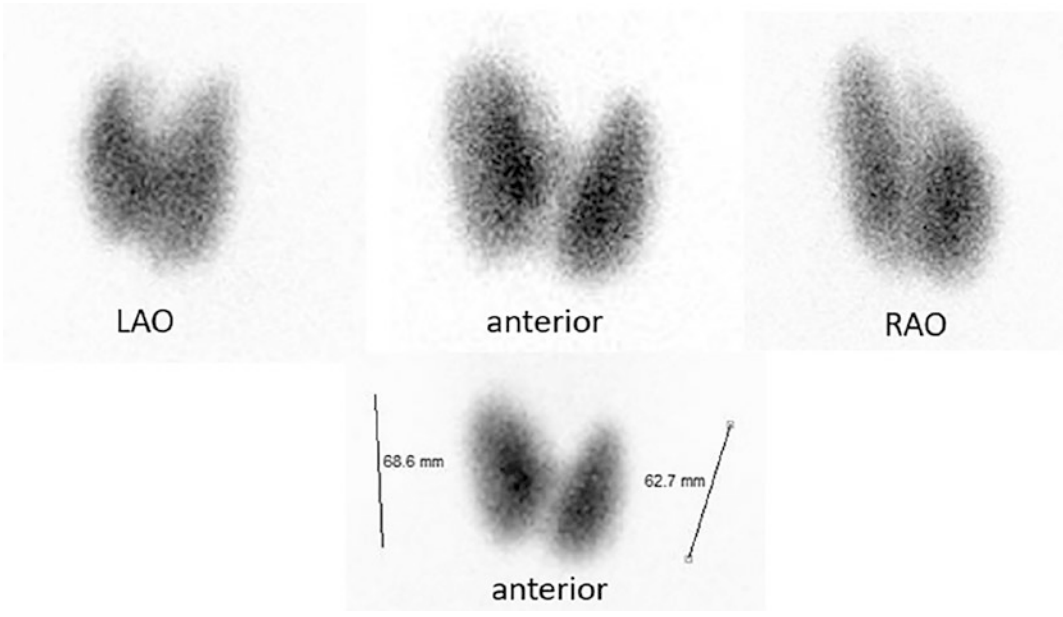

Fig. 5.5 History: A 13-year-old girl presented with heat intolerance, excessive perspiration, tachycardia, palpitations, increased appetite, and weight loss. Thyroid function tests showed a barely measurable plasma TSH of 0.008 mIU/L (normal range 0.51–4.0 mIU/L), highly elevated levels of FT4 70 pmol/L (normal range 10.7–18 pmol/L) and T3 > 30 pmol/L (normal levels 3.5–6.5 pmol/L). Physical examination revealed a large goiter. A Pertechnetate thyroid scan was requested to determine the cause of her overt hyperthyroidism. Study report: Anterior, LAO and RAO pinhole views (top row) and anterior parallel-hole collimator "bird's eye" view with size measurements (bottom row) show a markedly enlarged thyroid gland, right lobe larger than left, with intense, homogenous tracer activity. The percent tracer uptake from the injected dose of Pertechnetate is markedly elevated, 30%. Impression: The findings are consistent with Graves' disease. The girl was treated with beta adrenergic antagonists and methimazole with gradual clinical and biochemical improvement

Case 5.6. Autonomous Adenoma (Fig. 5.6)

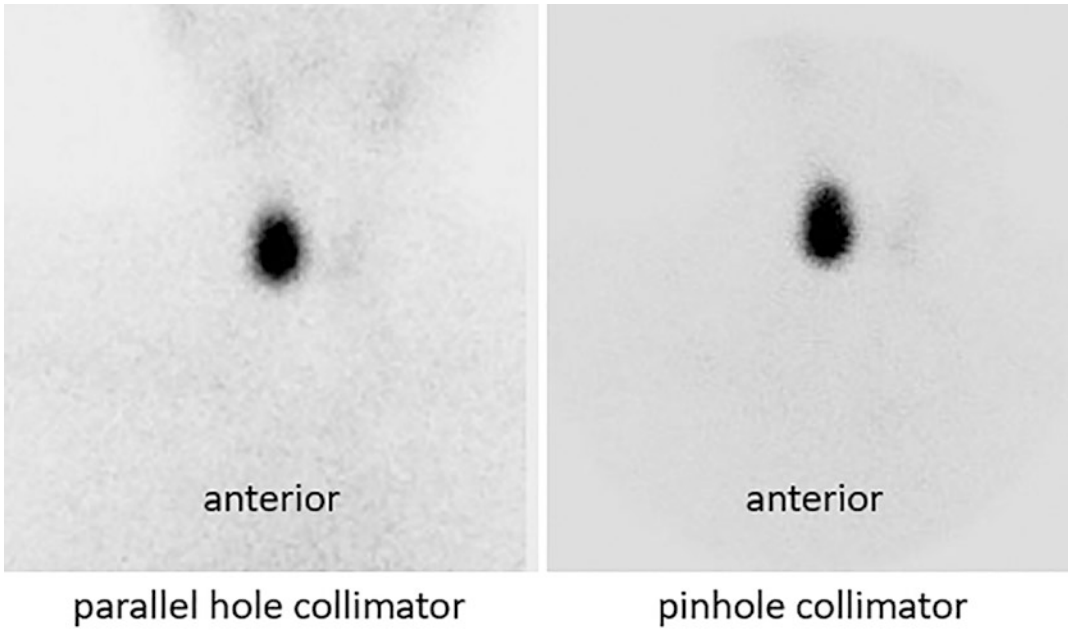

Fig. 5.6 History: A 16-year-old girl complained of fatigue, weakness and headaches for several months. Her lab results showed low TSH levels, normal FT4 and mildly elevated T3. Physical examination revealed a nodule in the right thyroid lobe. Neck US demonstrated a 2.7 × 1.5 cm solid nodule in the lower pole of the right thyroid lobe. Study report: A Pertechnetate thyroid scan, anterior view with a parallel-hole collimator (left) and anterior pinhole image (right) show intense tracer uptake in the lower part of the right thyroid lobe, at the location of the known nodule. The remainder of the right lobe and the entire left lobe show only very faint tracer activity. Impression: The findings are consistent with an autonomous thyroid adenoma suppressing tracer uptake in the normal gland. FNA showed colloid, groups of follicular cells and scattered follicular and microfollicular structures with minor atypia. The patient underwent surgical resection of her right thyroid lobe

5.3 Thyroid Cancer Imaging

Clinical Indications [20–25]

- Post-thyroidectomy: using either ^{123}I or ^{131}I, depending on availability, diagnostic whole-body scan and 24-hour neck RAIU performed at 6–12 weeks post-surgery and Tg measurements. While the American Thyroid Association (ATA) guidelines suggest this for intermediate- and high-risk groups, many pediatric centers perform it in all risk groups [24]:
  - To determine the presence and extent of residual functioning thyroid tissue.
  - To determine the need and dose of RAI for ablation of remnant thyroid tissue.
  - To determine the need and dose of RAI for treatment of metastatic or recurrent disease.
- After RAI therapy: Using either ^{123}I or ^{131}I, depending on availability:
  - Surveillance.
  - To detect the presence and location of residual cancer, recurrence and/or metastases.
- FDG can be used in cases with suspected recurrence because of rising Tg and negative RAI imaging (for doses, acquisition protocol, and study interpretation, see Chap. 12).

Pre-Exam Information [26, 27]

- Discontinue iodine-containing drugs and diet:
  - Iodine-rich foods and supplements (e.g., seaweed, kelp, and sushi): 1 week.
  - Lugol's solution, SSKI, KI tablets, vitamin/minerals: 1–3 weeks.
  - Cough medications and skin cleansers containing iodine: 2–4 weeks.
  - IV iodinated contrast: 4–6 weeks.
  - Amiodarone: 3–6 months.
- Discontinue drugs that interfere with RAI uptake.
  - Lithium carbonate: 1 year (rarely used in children).
- Confirm adequate TSH levels: 30 mIU/L or higher (measured 1–3 days before RAI administration).

Study Protocol for Imaging Pediatric Thyroid Cancer [25, 27, 28]

Patient Preparation.

Methods to reach these TSH levels:

- Thyroid hormone withdrawal:
  - Levothyroxine (l-T4) deprivation for 4 weeks.
  - Alternative: change to triiodothyronine (T3) for 4 weeks, followed by T3 discontinuation for 2 weeks before RAI scintigraphy.
- Recombinant human TSH (rhTSH) stimulation.
  - No need to stop thyroid hormone treatment.
  - Day 1 and 2: intramuscular injection of 0.9 mg rhTSH.
  - Day 3: administration of RAI.
  - Day 4: imaging with ^{123}I.

On the day of the examination:

- Fast for 2 hours prior to tracer administration and continue for 1-h post-administration.
- Instruct the patient to drink water prior to imaging to clear physiologic activity remaining after RAI has been swallowed.

Radiopharmaceutical, Activity, and Mode of Delivery

Radiopharmaceuticals:

- [^{123}I]Na Iodine (^{123}I) oral solution/capsule
- [^{131}I]Na Iodine (^{131}I) oral solution capsule
- [^{18}F]-Fluorodeoxyglucose (FDG).

Activity:

- [^{123}I]Na Iodine in adults: 37–74 MBq (1–2 mCi).
- [^{131}I]Na Iodine in adults: 37–148 MBq (1–4 mCi).
- [^{18}F]FDG: 3.7–5.2 MBq/kg (0.1–0.14 mCi/kg) minimum 26 MBq (0.7 mCi).

There is no consensus regarding weight-based administration of these tracers in children.

Reference to national regulation guidelines, if available, should be considered.

Acquisition Protocol

Diagnostic scan:

^{123}I

- Collimator: low energy or medium energy.
- Time of imaging: 6–24 h after RAI administration.
- 15–20% window centered on 159 keV photopeak.

^{131}I

- Collimator: high energy.
- 15–20% window centered on the 364-keV photopeak.
- Time of imaging: 24–72 h after RAI administration.
- The use of radioactive markers in the neck allows the differentiation between uptake in remnant thyroid tissue, salivary glands, or lymph node metastases.

Post-therapy scan.

^{131}I

- Time of imaging: 4–7 days post RAI therapy.

Acquisition parameters:

- Patient positioning: supine with neck in slight extension.
- Whole-body (vertex to mid-thigh) 8–10 cm/min, matrix 256 x 1024.
- Spot images (head, neck, chest, abdomen): 10 min/view, matrix 256 x 256 can replace or be added to whole-body imaging.
- SPECT or SPECT/CT with non-contrast CT, when available, can increase the accuracy and diagnostic confidence of the test.
  - FOV: skull base-to-upper abdomen to evaluate for cervical, upper mediastinal, and pulmonary metastatic disease.
  - 20 sec/step, 64 projections, matrix 128 × 128; iterative reconstruction.

Study Interpretation [29]

- Physiologic activity is seen in the stomach, large intestines, and bladder and of low intensity in the liver and salivary glands.
- False positives can occur due to pooling of excreted activity in sites including saliva in mouth or esophagus, uptake in salivary glands, thymus, ectopic thyroid, and inflammatory foci.
- False negatives can be caused by inadequate patient preparation.
- Star artifacts can be seen as marked streaks going in multiple directions from an area with intense tracer activity.

Correlative Imaging

- Correlation with US of the neck for assessment of remnant thyroid tissue as well as for diagnosis and localization of enlarged regional lymph nodes prior to FNA.
- Correlation with chest CT (without iodinated contrast if ^{131}I therapy is considered) to evaluate for pulmonary metastases.

Red Flags

- Some centers use lower ^{131}I doses, 37–74 MBq (1–2 mCi), for diagnostic scans in order to reduce the risk of stunning if treatment is considered.
- Adjustment of brightness and contrast on the display monitor of the workstation is standard for appropriate interpretation of whole-body studies.
- Star artifacts can appear in areas with intense tracer activity. They occur because of penetration of photons through the collimator septae, due to a very large flux of photons and/or due to penetration of high-energy photons.
- External contamination can be due to spilled tracer activity onto clothes, skin, or collimator.
- Up to 7% of patients with thyroid cancer have remnant thyroid tissue, and 25% have metastases seen only on the ^{131}I scan performed 3 days post-therapy.
- Additional RAI-avid foci will be detected only on the seventh day of study in approximately 10% of remnant thyroid tissue foci and in 30% of metastatic lesions.

Take Home Messages

- Performing two post-therapy scans can be difficult. The decision for a repeat scan should be made after the initial scan, in cases it is negative, and the patient's Tg is "positive," or if there is clinical or other imaging evidence of metastases. The delayed scan should attempt to identify the site of the elevated Tg or to define whether the structural abnormality is RAI-avid.
- For ^{123}I there is better lesion detectability on images at 24 hours since in early studies, performed after 6 h, there is still high blood pool and background activity.
- For ^{131}I there is better lesion detectability on diagnostic images performed at 48–72 h. In 24-h studies, images may not have clearly defined activity, and repeat acquisition may be needed to improve the target-to-background ratio.
- Static spot images are, as a rule, superior to computer integrated whole-body acquisitions obtained from moving detectors since they are often obtained following a longer acquisition time, thus resulting in better image quality. They also have the advantage of repeating only a shorter time acquisition if the child moves.
- Focal increased activity in the thyroid bed can be related to remnant thyroid tissue, to small tracer amounts excreted onto the floor of the mouth or esophagus, or malignant lesions such as metastatic lymph nodes. SPECT/CT can help distinguish between these options [30].

Representative Case Examples

Case 5.7. Post-Therapy ^{131}I Study (Fig. 5.7)

Case 5.8. Papillary Thyroid Cancer, Lung Metastasis (Fig. 5.8)

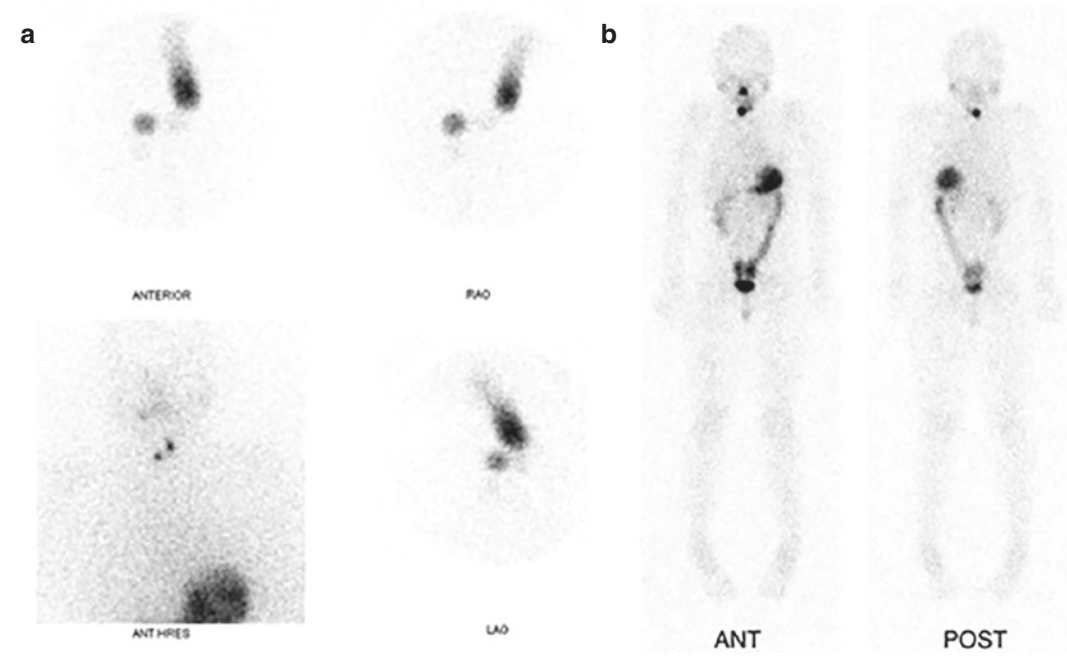

Fig. 5.7 History: A 9-year-old girl had a right thyroid lobe resection followed by complete thyroidectomy for follicular thyroid cancer. Study report: on the post-surgery ^{123}I thyroid scan (**a**) there are RAI-avid foci with 3% residual tracer uptake in the neck, more in the left lobe of the thyroid. Repeat surgery was performed only on the left side neck because of a significant amount of scar tissue on the right side. The patient then received a 1110 MBq (30 mCi) ablative dose of ^{131}I and was referred for a post-therapy whole-body scan (**b**). This study shows a focus of increased tracer uptake in the right neck, corresponding to the known remnant thyroid tissue in the right lobe. No additional lesions are seen. Note also physiologic RAI activity in the GIT, mainly the stomach and bowel, and the urinary bladder, and salivary glands. Impression: No evidence of metastatic thyroid cancer

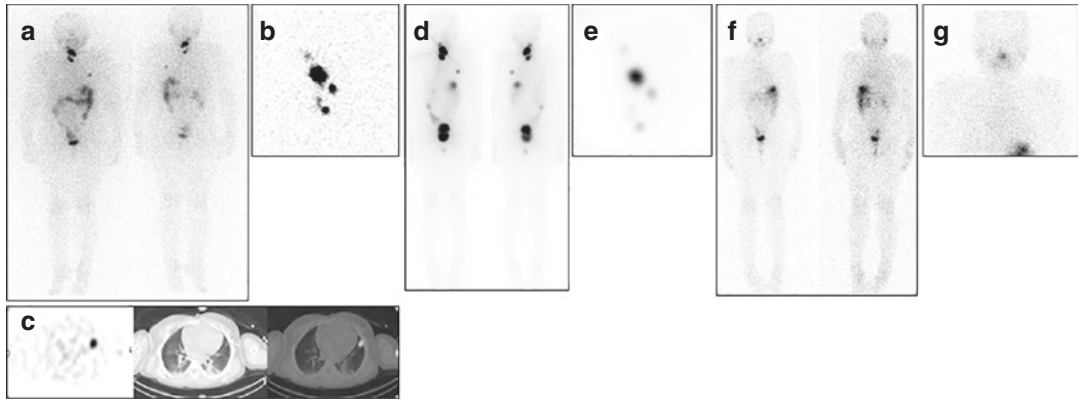

Fig. 5.8 History: A 6-year-old girl presented with a right-sided neck mass and underwent thyroidectomy. A 4-cm papillary carcinoma with extrathyroidal extension and lymph node involvement was found. Study report: The ^{123}I post-thyroidectomy scan (**a**, whole-body anterior and posterior views, **b**, pinhole images of the neck) revealed several foci of remnant thyroid tissue in the neck as well as a focal area of tracer uptake in a left lung nodule as demonstrated on SPECT/CT (**c**), consistent with a RAI-avid left lung metastasis. The patient received a therapeutic dose of 3663 MBq (99 mCi) ^{131}I . Post-therapy ^{131}I whole-body (**d**) and pinhole images of the neck (**e**) show the same findings seen on the pretreatment scan. Note also the large amount of physiological RAI excreted into the urinary bladder. A surveillance ^{123}I follow-up study including a whole-body (**f**) and pinhole neck scan (**g**) performed 1 year after RAI treatment shows resolution of the previously seen foci of increased RAI activity in the neck and in the left lung metastasis. There are no new areas of abnormal RAI uptake. Impression: No evidence of thyroid cancer

Case 5.9. Dedifferentiated Non-RAI-Avid, FDG-Avid Thyroid Cancer (Fig. 5.9)

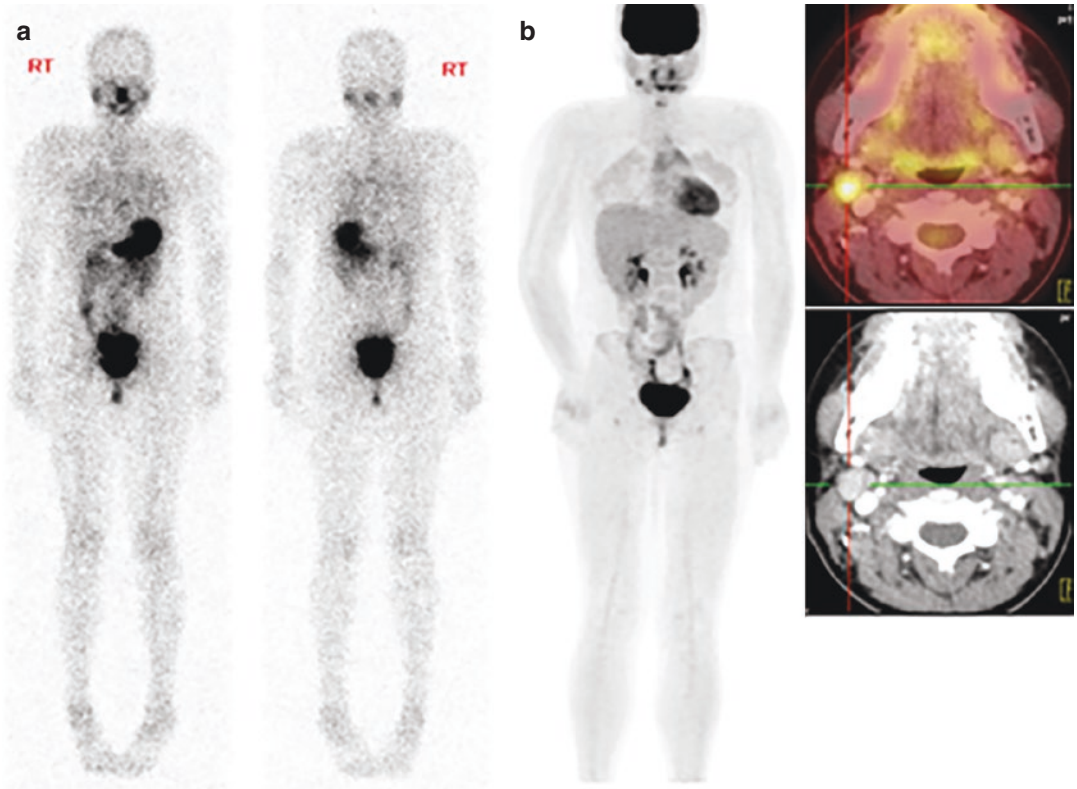

Fig. 5.9 History: A 14-year-old girl presented with a right thyroid nodule. US-guided FNA diagnosed papillary thyroid cancer. The patient underwent thyroidectomy and lymph node dissection. Right cervical lymph node metastases were found. Study report: A ^{123}I whole-body scan performed after surgery was negative (**a**). The patient received RAI treatment with 3440 MBq (93 mCi) ^{131}I. No sites of disease were found on a post-therapy scan (not shown). Six months later, the patient presented with rising Tg levels and suspicious cervical nodes on US. Because of known non-RAI-avid disease, the patient was referred to FDG-PET/CT (**b**) which shows a focal area of tracer uptake in the right upper cervical region. Impression: The findings are consistent with right cervical lymph node metastasis, further confirmed following lymph node dissection

References

1. American Academy of, P, et al. Update of newborn screening and therapy for congenital hypothyroidism. Pediatrics. 2006;117(6):2290–303.
2. Grant FD, Treves ST. Thyroid. In: Treves ST, editor. Pediatric nuclear medicine and molecular imaging. New York, NY: Springer New York; 2014. p. 99–129.
3. Leger J, et al. European Society for Paediatric Endocrinology consensus guidelines on screening, diagnosis, and management of congenital hypothyroidism. J Clin Endocrinol Metab. 2014;99(2):363–84.
4. van Trotsenburg P, et al. Congenital Hypothyroidism: a 2020-2021 Consensus Guidelines Update-An ENDO-European Reference Network Initiative Endorsed by the European Society for Pediatric Endocrinology and the European Society for Endocrinology. Thyroid. 2021;31(3):387–419.
5. Clerc J, et al. Scintigraphic imaging of paediatric thyroid dysfunction. Horm Res. 2008;70(1):1–13.
6. Worth C, et al. Thyroid scintigraphy differentiates subtypes of congenital hypothyroidism. Arch Dis Child. 2021;106(1):77–9.
7. Meller J, et al. Diagnostic value of 123iodine scintigraphy and perchlorate discharge test in the diagnosis of congenital hypothyroidism. Exp Clin Endocrinol Diabetes. 1997;105(Suppl 4):24–7.
8. Volkan-Salancı B, Kıratlı P. Nuclear medicine in thyroid diseases in pediatric and adolescent patients. Mol Imaging Radionucl Ther. 2015;24(2):47–59.
9. Williams JL, Paul DL, Bisset G 3rd. Thyroid disease in children: part 1: state-of-the-art imaging in pediatric hypothyroidism. Pediatr Radiol. 2013;43(10):1244–53.
10. Williams JL, Paul D, Bisset G 3rd. Thyroid disease in children: part 2 : state-of-the-art imaging in pediatric hyperthyroidism. Pediatr Radiol. 2013;43(10):1254–64.
11. Gupta A, et al. A standardized assessment of thyroid nodules in children confirms higher cancer prevalence than in adults. J Clin Endocrinol Metab. 2013;98(8):3238–45.
12. Corrias A, Mussa A. Thyroid nodules in pediatrics: which ones can be left alone, which ones must be investigated, when and how. J Clin Res Pediatr Endocrinol. 2013;5(Suppl 1):57–69.
13. Giovanella L, et al. EANM practice guideline/SNMMI procedure standard for RAIU and thyroid scintigraphy. Eur J Nucl Med Mol Imaging. 2019;46(12):2514–25.
14. Iakovou I, Giannoula E, Sachpekidis C. Imaging and imaging-based management of pediatric thyroid nodules. J Clin Med. 2020;9:2.
15. Silva CT, Navarro OM. Pearls and pitfalls in pediatric thyroid imaging. Semin Ultrasound CT MR. 2020;41(5):421–32.
16. Tritou I, et al. Pediatric thyroid ultrasound: a radiologist's checklist. Pediatr Radiol. 2020;50(4):563–74.
17. Fornwalt B, et al. Pediatric thyroid nodules: ultrasound characteristics as indicators of malignancy. OTO Open. 2022;6(1):2473974x211073702.
18. Mariani G, et al. The role of nuclear medicine in the clinical management of benign thyroid disorders, part 1: hyperthyroidism. J Nucl Med. 2021;62(3):304–12.
19. Mariani G, et al. The role of nuclear medicine in the clinical management of benign thyroid disorders, part 2: nodular goiter, hypothyroidism, and subacute thyroiditis. J Nucl Med. 2021;62(7):886–95.
20. Grigsby PW, et al. Childhood and adolescent thyroid carcinoma. Cancer. 2002;95(4):724–9.
21. Newman KD, et al. Differentiated thyroid cancer: determinants of disease progression in patients <21 years of age at diagnosis: a report from the surgical discipline Committee of the Children's cancer group. Ann Surg. 1998;227(4):533–41.
22. Luster M, et al. Thyroid cancer in childhood: management strategy, including dosimetry and long-term results. Hormones (Athens). 2007;6(4):269–78.
23. Franzius C, et al. Procedure guideline for radioiodine therapy and 131iodine whole-body scintigraphy in paediatric patients with differentiated thyroid cancer. Nuklearmedizin. 2007;46(5):224–31.
24. Francis GL, et al. Management guidelines for children with thyroid nodules and differentiated thyroid cancer. Thyroid. 2015;25(7):716–59.
25. Lebbink CA, et al. New national recommendations for the treatment of pediatric differentiated thyroid carcinoma in The Netherlands. Eur J Endocrinol. 2020;183(4):P11–8.
26. Kuijt WJ, Huang SA. Children with differentiated thyroid cancer achieve adequate hyperthyrotropinemia within 14 days of levothyroxine withdrawal. J Clin Endocrinol Metab. 2005;90(11):6123–5.
27. Luster M, et al. Recombinant thyrotropin use in children and adolescents with differentiated thyroid cancer: a multicenter retrospective study. J Clin Endocrinol Metab. 2009;94(10):3948–53.
28. Bartel Chair TB, et al. SNMMI procedure standard for scintigraphy for differentiated thyroid cancer. J Nucl Med Technol. 2020;48(3):202–9.
29. Mostafa M, et al. Variants and pitfalls on radioiodine scans in pediatric patients with differentiated thyroid carcinoma. Pediatr Radiol. 2016;46(11):1579–89.
30. Nadel HR. SPECT/CT in pediatric patient management. Eur J Nucl Med Mol Imaging. 2014;41(Suppl 1):S104-14.

The opinions expressed in this chapter are those of the author(s) and do not necessarily reflect the views of the IAEA: International Atomic Energy Agency, its Board of Directors, or the countries they represent.