Nuclear Medicine Companion

A Case-Based Practical Reference for Daily Use

Abdelhamid H. Elgazzar
Ismet Sarikaya

Springer

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ISBN 978-3-319-76155-8 ISBN 978-3-319-76156-5 (eBook)
https://doi.org/10.1007/978-3-319-76156-5

Library of Congress Control Number: 2018945185

Printed on acid-free paper

This Springer imprint is published by the registered company Springer International Publishing AG part of Springer Nature.
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

To our patients who suffer in a world which needs to wake up humanitarianly

Abdelhamid Elgazzar

To my precious ones: My mother Fatma and my nephew Alex Cem

Ismet Sarikaya

Preface

Nuclear medicine has shown significant advancement and is continuing to change with new technology, new procedures, and new clinical applications. A book with illustrative cases along with necessary information about the technique and interpretation is thought to add to the practice of this specialty. The global vision made us include the most recent technology as well as the established basic studies for the students and trainees as well as practicing physicians with different setups and resources for best utilization to serve patients.

In this volume, a simple presentation of the basic understanding of the principles of the techniques along with their clinical uses and significance is emphasized. This book is divided into system chapters ending with a chapter on miscellaneous conditions. Each chapter starts with simple presentation on the techniques, their indications, and presentation of normal patterns. Cases on most relevant pathologies are then presented with a brief on the related clinical and scintigraphic aspects.

The book includes chapters on endocrine, pulmonary, cardiovascular, skeletal, renal, digestive, hepatobiliary, central nervous system, inflammation, oncology, and miscellaneous conditions.

The objective of this volume is therefore to provide a brief, simple, up-to-date, clear, and informative case-based text to help readers as a practical reference which ultimately assists them in learning, practice, and patient care.

We hope that this work will help students, trainees, and practicing physicians particularly in imaging specialties to facilitate their task in serving patients.

Safat, Kuwait

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Ismet Sarikaya

Acknowledgment

Our thanks and appreciation go to Drs. Khattab Khaled, Salwa Shams, Medhat Osman, Abedelmonem Omar, Saud Enezi, Charito Love, Ali Sarykaya, and Isabel Roca and Mr. Amgad Elsayad, Mrs. Heba Essam, Mrs. Reham Alhajji, Mrs. Akla AlMutairi, and Mr. LS Spencer for their help and support.

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Endocrine System

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1.1 Endocrine System Imaging Studies and Normal Patterns

1.1.1 Thyroid Scan and Uptake

Indication Thyroid scan and uptake evaluate the functional (hyper, hypo, or normal function) and structural (enlargement, nodules, ectopy) status of the thyroid gland. These are used to differentiate Graves' disease from toxic nodular goiter, thyroiditis, and factitious hyperthyroidism, determine the functional status of the thyroid nodule(s), locate ectopic thyroid tissues, evaluate babies with congenital hypothyroidism, and determine if a neck mass contains thyroid tissue.

Procedure Thyroid hormone supplements, antithyroid medications, iodine-containing foods and medications, and iodine procedures should be avoided for a certain time as they interfere with radioactive iodine uptake by the thyroid gland. Many patients stop taking thyroid hormones 3–4 weeks and antithyroid medications 3–5 days before the test, but this should be consulted with the referring physician before stopping these medications. Patients should not have radiological studies involving iodine contrast in the last 4–8 weeks. Iodine-containing solutions, vitamins, and medications should not be taken 1–2 weeks before the study.

Thyroid scintigraphy is commonly performed with Tc-99m pertechnetate. In routine studies, either Tc-99m pertechnetate thyroid scintigraphy

A. H. Elgazzar, I. Sarikaya, *Nuclear Medicine Companion*,
https://doi.org/10.1007/978-3-319-76156-5_1

and Iodine-131 (I-131) thyroid uptake or Iodine-123 (I-123) uptake and scan are performed. Although I-123 is the ideal agent for thyroid uptake and scan, it is less commonly used due to its high cost and less availability. I-131 is no longer used for thyroid imaging due to its high radiation dose to the thyroid but routinely used for thyroid uptake and detection of metastases and recurrences of differentiated thyroid cancer.

If Tc-99m pertechnetate is used, thyroid images are obtained 15–20 min after the intravenous injection of 185 MBq (5 mCi) for adults. Patient drinks some water to clear esophageal activity and optionally lemon to clear salivary gland activity. The patient is placed in supine position with pillow under shoulders and chin up (Water's position). Anterior and anterior oblique views are obtained using a pinhole collimator equipped with 5 mm insert. Anterior image with markers at the suprasternal notch and thyroid cartilage including the salivary glands is acquired for 100 kct. Anterior and left and right anterior oblique images with the gland in the center and occupying two thirds of field of view (FOV) are acquired for 150–200 kct or 5 min. Another image with a marker at the palpable nodule may be obtained. Images are acquired using 256 × 256 matrix with 20% energy window centered at 140 keV. If the images show midline radioactivity which may be due to radioactive saliva in the esophagus, the patient is asked to drink water, and the imaging is repeated.

If I-123 is used, the adult activity is 3.7–11.1 MBq (100–300 μCi). The images are obtained 24 h after oral administration of activity, and thyroid uptake measurements are performed at 4–6 h and 24 h.

I-131 activity for thyroid uptake study is 0.37 MBq (10 μCi). Thyroid uptake is measured at 24 h after oral administration of I-131. I-131 is not recommended in children.

In uptake studies, a thyroid uptake probe is directed at the region of the thyroid bed in the extended neck, and 1 min neck, thigh, standard, and background counts each are measured from a 20–30 cm distance.

Radioactive iodine uptake (RAIU) is measured using the following formula:

$$\text{RAIU}\,(\%) = \frac{\text{Neck counts} - \text{Thigh counts}}{\text{Standard counts} - \text{Bkg counts}} \times 100$$

Case 1.1 Normal Thyroid Scan (Fig. 1.1)
Normal Findings In a normal thyroid scan, there is homogeneous distribution of radiotracer in the thyroid gland which appears like a butterfly. Uptake in the salivary glands and soft tissues is noted if Tc-99m pertechnetate is used. Salivary gland uptake is not seen on I-123 images.

Normal RAIU is 6–18% at 4 h and 10–35% at 24 h with range differing according to patient population and technique used [1].

Companion Points The thyroid gland develops from the foramen cecum of the tongue, to which it is connected by the thyroglossal duct. It descends during fetal life to reach the anterior neck by about the 7th week [2]. The normal adult

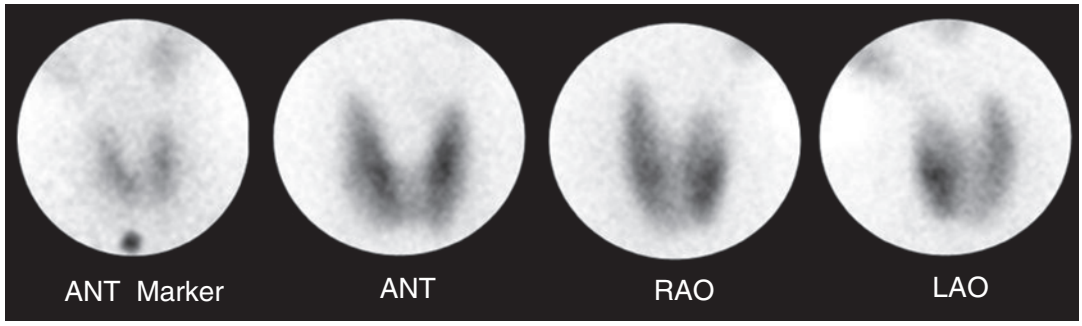

Fig. 1.1 Tc-99m pertechnetate pinhole thyroid scan in anterior (with marker), anterior, right and left anterior oblique views

thyroid gland weighs 14–18 g. Synthesis of thyroid hormones takes place in the thyroglobulin (Tg), a glycoprotein, which is produced in the thyroid cells and extruded into the colloid. Iodine combines with thyrosine in Tg to form monoiodothyrosine and diiodothyrosine. Subsequently, the iodothyrosines are coupled with the formation of thyroxine (T4) and triiodothyronine (T3). The coupling reaction is mediated by peroxidase. Thyrotropin-releasing hormone (TRH) originating from the hypothalamus stimulates the secretion and synthesis of thyroid-stimulating hormone (TSH, thyrotropin), by the anterior pituitary. TSH increases the transport of iodide, synthesis of hormone, and release of T3, T4, and Tg.

There are many anatomic variations of the thyroid gland which include shape and size of the lobes and isthmus, presence of pyramidal lobes, and presence of levator glandulae thyroideae [3]. The left lobe is usually smaller than the right. Pyramidal lobe is present in about half of the thyroid glands and more prevalent on the left side of the median plane. Isthmus may be incomplete. Levator glandulae thyroideae is a fibromuscular band which is usually on the left side connecting the pyramidal lobe and the hyoid bone.

Developmental abnormalities of the thyroid gland include agenesis, dysgenesis (hemiagenesis or ectopy), and abnormalities due to persistence of the thyroglossal duct [4, 5].

Tc-99m pertechnetate has a short half-life of 6 h and main gamma energy of 140 keV. It is readily available and cheaper than I-123. It is only trapped by the thyroid gland but not organified and therefore only reflects the iodine uptake.

I-123 is expensive and not readily available. It has a half-life of 13 h, and its main gamma energy is 159 keV. It is both trapped and organified by the thyroid gland like nonradioactive iodine. It is taken up by thyroid follicular cells via sodium-iodine symporter, organified and incorporated into thyroid hormones.

Thyroid images should be interpreted in association with clinical and laboratory data (thyroid function tests) as well as the result of thyroid uptake especially in cases of hyperthyroidism due to Graves' disease since near normal image appearance can be present in this condition.

1.1.2 Radioactive Iodine Whole Body Scan

Indication Whole body scan with radioactive iodine (I-131 or I-123) is used to determine the presence and extent of residual functioning thyroid tissue after total thyroidectomy and after I-131 ablation and detect functioning differentiated thyroid cancer residues, recurrences, or metastases.

Procedure The physician should obtain and record a pertinent, standard history and examination findings as well as results of laboratory tests (Tg, anti-Tg, and TSH). A measurement of serum TSH prior to the study is used to ensure maximum stimulation of any functional thyroid tissue. TSH should be >30 μLU/mL.

The study is performed 4–8 weeks post near total thyroidectomy. The patient must be off thyroid hormones, 4 weeks for T4 and 2 weeks for T3. Alternately the patient will have intramuscular Thyrogen injections (0.9 mg) for 2 days prior to dosing [6]. Thyrogen helps to increase the sensitivity of testing while allowing patients to avoid the potentially debilitating symptoms associated with thyroid hormone withdrawal. If the patient had intravenous iodinated contrast agents (intravenous pyelogram, computed tomography (CT) with contrast, or angiogram), the study should be delayed for 4 weeks. For intrathecal contrast (myelogram), this duration is 8 weeks; however, the adverse effect on the study may last as long as a year.

The patient should be fasting overnight or at least 3 h before oral administration of the radioactive iodine and for 3 h afterward. Low iodine diet is preferred starting 10 days before the test and continued throughout the period of imaging and for 1–2 days after treatment. The following foods and ingredients should be avoided: iodized salt, sea salt, seafood and sea products, dairy products, egg yolks or whole eggs, red dye #3 (erythrosine or E127), soybeans, foods containing high salt, iodine-containing vitamins and food supplements, and iodine-containing medications (e.g., iodinated contrast, amiodarone, and betadine). A pertinent menstrual history and pregnancy test as well as nursing and lactation history should be obtained.