Thyroid scintigraphy plays an important role in the evaluation of the thyroid gland owing to the functional and anatomic information it provides. Ultrasound-guided fine-needle aspiration (FNA), as well as the increased availability of sensitive serum assays for thyrotropin (thyroid-stimulating hormone, TSH) and thyroglobulin (Tg), play an important role in the routine evaluation of thyroid disease. However, measurement of radioactive iodine uptake remains the only direct test of thyroid function and, when complemented by studies that permit anatomic correlation, scintigraphy is a powerful tool in the investigation of both benign and malignant thyroid disorders. This chapter focuses on the role of radioiodine in the diagnosis and therapy of hyperthyroidism and in the treatment and surveillance of children with differentiated thyroid cancer (DTC). The rarity of these diseases in children has precluded the generation of consensus guidelines, but approaches for the evaluation of thyroid nodules and for the preparation of patients prior to iodine-131 (131I) therapy are suggested.

Method

Radiopharmaceuticals

This chapter focuses on the three radiopharmaceuticals routinely employed in clinical thyroid practice: 131I, 123I, and technetium-99m (99mTc)O₄. Several noniodine radiopharmaceuticals have been used for thyroid scintigraphy, including thallium-201 (201Tl), technetium-99m-methoxyisobutylisotitirle (99mTc-sestamibi), 99mTc-tetrafosmin, and fluorine-18-fluorodeoxyglucose (18F-FDG). The utility of these radionuclides in the imaging of differentiated thyroid cancer patients who have measurable serum Tg but negative radiiodine scans is an area of active investigation. However, their clinical application is controversial and their role in pediatrics has yet to be established.

Iodine-131 (131I)

Radioactive isotopes of iodine are physiologically indistinguishable from the naturally occurring iodine-127 (127I). Iodine-131 (131I) (physical half-life 8.1 days; gamma emission 364 keV) has been used in thyroid scintigraphy for decades. Its advantages include wide availability and relatively low cost. Its major disadvantage is its high radiation absorbed dose due to its long physical half-life and beta-particle emission. These features make 131I inappropriate for routine scintigraphy in pediatric patients but useful for the therapeutic ablation of benign or malignant thyroid follicular cells.

Iodine-123 (123I)

For pediatric thyroid scintigraphy, 123I (physical half-life 0.55 days; gamma emission 159 keV) is the ideal isotope. Due to its short half-life and the absence of beta radiation, compared to 131I, 123I delivers only 1% of radiation to the thyroid per millicurie administered. The energy of its
main gamma ray is ideal for detection by gamma cameras, and so it is routinely used for thyroid uptake and scans. Recent data suggest that it is also superior to $^{131}$I for diagnostic whole-body scans in patients with differentiated thyroid cancer. Disadvantages include more limited availability and high expense. A tracer quantity of inorganic radioiodine ($^{123}$I or $^{131}$I) is administered orally and then rapidly equilibrates with the endogenous $^{127}$I in the extracellular fluid. Plasma levels of radioiodine fall exponentially with more than 90% of the administered dose removed by the thyroid and kidneys at the end of 24 hours. However, the thyroid iodine concentration increases to a plateau [radioactive iodine uptake (RAIU) at plateau = $C_t/(C_t + C_k)$] defined by the relative clearance of iodide by the thyroid ($C_t$) and the kidneys ($C_k$).

Technetium-$^{99m}$Tc Pertechnetate ($^{99m}$Tc-NaO$_4^-$)

$^{99m}$Tc-pertechnetate (Tc-NaO$_4$) (physical half-life 6 hours; gamma emission 140keV) is a monovalent anion that, like iodine, is actively transported by the sodium-iodine symporter (NaIS) and can therefore be used to measure thyroid uptake. Unlike iodine, it undergoes negligible organic binding and rapidly diffuses out of the thyroid as its plasma concentration falls. $^{99m}$Tc-pertechnetate is administered by intravenous injection with scintigraphy performed within 30 minutes of administration during peak thyroid activity. Advantages include its wide availability, low cost, low radiation exposure, and the short interval required for scintigraphy. Also, as $^{99m}$Tc-pertechnetate only measures uptake, scans can be performed during antithyroid treatment with thionamides. Disadvantages include its relatively low thyroid uptake (4.0% 20 minutes after administration), its susceptibility to background artifact from salivary and vascular activity, and its low sensitivity in the detection of hypofunctioning thyroid nodules. Salivary and vascular activity can obscure uptake in the lateral neck and thorax; therefore, $^{99m}$Tc-pertechnetate is not appropriate for the assessment of substernal/intrathoracic goiters or metastatic DTC. For scintigraphy that is performed to evaluate possible thyroid ectopy, patients should be instructed to drink water before imaging to reduce background activity from saliva; early images (5 minutes after administration) before salivary uptake is high are helpful. Approximately 5% to 10% of thyroid tumors that are hypofunctioning on radioiodine scintigraphy appear to be functioning with $^{99m}$Tc-pertechnetate, presumably because these nodules can trap but not organify iodine. This can lead to the false conclusion that a thyroid nodule is functioning and therefore benign. Accordingly $^{99m}$Tc-pertechnetate scintigraphy is not appropriate to evaluate the malignant potential of thyroid nodules.

Thyroid Scintigraphy

Thyroid follicular cells concentrate iodine under the regulation of thyrotropin (TSH) via the NaIS. Thyroid scintigraphy should be interpreted in the context of anatomic and biochemical data. This information should be obtained prior to scintigraphy to evaluate thyroid dysfunction or a palpable thyroid mass. Before scintigraphy, full thyroid function tests [TSH, thyroxine ($T_4$), THBR] should be obtained and the physician should palpate the thyroid gland to document thyroid size and the location of any discrete mass. The normal thyroid gland is bilobed and connected by an isthmus that overlies the second through fourth tracheal cartilages. The main lobes of the thyroid are usually equal in size, but the right lobe is frequently a little larger and tends to enlarge to a greater degree that the left in patients with diffuse thyromegaly. Assessment of goiter should take into account the normal thyroid size for age. Several pediatric norms have been published. The equation of $T = 1.48 + 0.054A$, where $T$ is the weight of the thyroid in grams and $A$ is the age in months, describes the average thyroid weight from birth to 20 years. In North America, the normal adult thyroid weighs approximately 14 to 20g (average weight 14.4 g for females 20 to 69 years of age; 16.4 g for males 20 to 29 years of age; 18.5 g for males 30 to 69 years of age). If a thyroid ultrasound has been obtained prior to scintigraphy, the mass of the gland in grams can