Molecular Imaging in the Head and Neck
Diagnosis and Therapy

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KEYWORDS

• Head and neck • Nuclear medicine • PET • SPECT • Radionuclide therapy • Dosimetry

KEY POINTS

- I-131 sodium iodide continues to be invaluable for remnant ablation and adjuvant therapy of well-differentiated thyroid cancer.
- Recent studies of patients after I-131 radioablative therapy have shown a small increased rate of solid cancer mortality and development of secondary cancers; further studies are needed.
- Tc99m-sestamibi remains a workhorse for workup of hyperparathyroidism, with F-18 fluorocholine PET/computed tomography scans showing promise in detection of parathyroid adenomas and multigland disease.
- Ga-68 DOTATATE is highly sensitive and specific for staging of somatostatin receptor-positive neuroendocrine tumors of the head and neck, having supplanted In-111 Octreoscan and playing a complementary role to I-123 meta-iodo-benzyl-guanidine.

INTRODUCTION

From the first production of radioactive iodine in 1936 by Enrico Fermi to the subsequent application of ^{130}I-sodium iodide (later ^{131}I) to treat hyperthyroid patients in 1946 by Drs Saul Hertz and others, molecular imaging and therapy of the head and neck was born.[1]

THYROID-BENIGN DISEASE

The thyroid gland descends during development from the foramen cecum at the base of the tongue to its location anterior to the trachea and inferior to the thyroid cartilage, weighs approximately 25 g, and measures 4 to 5 cm tall and 1 to 2 cm wide. Ectopic thyroid can occur anywhere along this descent, including at the base of tongue (lingual thyroid), hyoid bone (thyroglossal duct cyst), superior to either lobe or isthmus (pyramidal lobe), or in the mediastinum (substernal goiter).[2] Symptoms of the hyperthyroid patient can be due to Graves disease (caused by autoantibodies to the thyroid-stimulating hormone [TSH] receptor), toxic multinodular goiter (caused by hyperplasia of follicular cells which become autonomous of TSH, and TSH receptor mutations),[3] toxic adenoma, or thyroiditis.[4] Unusual causes of thyrotoxicosis, including struma ovarii, lithium, and the Jod–Basdow effect (from iodinated contrast), and of hypothyroidism (lingual thyroid) have been previously reviewed.[5] Nuclear techniques can differentiate between these entities and provide definitive treatment.

Imaging of the thyroid is performed with a thyroid uptake and scan, either with I-123 sodium iodide, or I-131 sodium iodide for the uptake and Tc99m-pertechnetate for the scan (**Table 1**). On a thyroid scan in a patient with Graves' disease, the thyroid gland seems to be homogeneous with convex contours, with a 24-hour iodine uptake of typically 60% to 80%. A mildly elevated or high-normal 24-hour uptake can sometimes be observed with rapid turnover Graves' disease,

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Table 1
-Technical details of molecular imaging of the thyroid and parathyroid glands

Imaging Protocol	Notes
Thyroid uptake and scan - pediatric/mediastinal mass characterization Off PTU or methimazole >3 d	400 μCi I-123 sodium iodide via capsule or oral solution; pediatric 5.7 μC/kg; Uptake and scan: 4 h post images: anterior /anterior 10 cm/RAO, LAO, 5 min Uptake: 24 h Pinhole collimator, 159 keV 20% window Captus uptake probe
Thyroid uptake and scan - routine Off PTU or methimazole >3 d	5–12 μCi sodium iodide I-131 capsule by mouth Adult dose: 6 mCi Tc-99m pertechnetate IV Returns 24 h after post I-131 for uptake measurement and then scan 20 min after injection Give crackers and water after injection Views: anterior, anterior −10 cm, RAO, LAO, 5 min/view Pinhole collimator, 140 keV, 20% window
Total body iodine scan No CT contrast within 4 wks Preparation options: 1) Discontinue levothyroxine for 4 wks 2) At 4 wks, switch from levothyroxine to liothyronine, then cease liothyronine at 2 wks prior to scan 3) Thyrogen™	Adult dose: 2 mCi sodium I-123 oral solution Pediatric dose: 28.6 μCi/kg Patients on Thyrogen™: dosed at least 4 h after second Thyrogen™ shot Uptake w/Captus probe Images: whole body - anterior and post 8 cm/min; neck statics, neck statics w/sternal notch marker
Parathyroid scan	Adult dose: 25 mCi Tc99m-sestamibi Pediatric dose: 0.28 mCi/kg Images: immediate, anterior (10 min) Images: 2 h, anterior (10 min)
Parathyroid SPECT/CT	2 h SPECT/CT 128 × 128 matrix, 1.5 zoom, dual head 30 sec/stop, step and shoot with body contour If unable to tolerate SPECT/CT, may acquire RAO and LAO views

Abbreviations: LAO, left anterior oblique; PTU, propylthiouracil; RAO, right anterior oblique.

when a 4-hour uptake (typically only obtained with I-123) would have been elevated. Although patients are often first treated medically with methimazole, radioablative therapy is ultimately pursued owing to the unfavorable side effect profile of thionamides. Radioablation for Graves' disease with ^{131}I-sodium iodide typically uses a calculated method, with the dose proportional to the weight of the gland (in grams) and a constant (100–200 μCi/g), and inversely related to the uptake fraction; typically 10–15 mCi is the resulting dose. This method is selected to avoid radiation thyroiditis and ensure ablation success, but studies have shown that the risk of thyroid storm is very low and does not correlate with untreated hyperthyroidism before radioiodine ablation[1]; an empiric, fixed-dose method is similarly efficacious.[6] Side effects include sialadenitis with possible xerostomia, sore throat, neck discomfort, and dysgeusia. Graves' ophthalmopathy can be worsened by I-131 therapy, which is thought to result from deposition of antigen–antibody complexes. Compared with methimazole, radioiodine was associated with a lower recurrence but a higher incidence of ophthalmopathy in a large meta-analysis.[7,8]

Toxic multinodular goiter exhibits patchy uptake on scintigraphy, with a 24-hour radioiodine uptake of 30% to 60%. Although photopenic regions may represent degenerating adenomas or suppressed normal thyroid tissue, the "cold nodule" carries a 10% risk of malignancy and warrants ultrasound examination and potential biopsy.[9] Thyroid malignancy is more common in patients with underlying thyroid disease and prior head and neck radiation. In cases of large nontoxic multinodular goiter

when the patient is not a surgical candidate, recombinant human thyroid stimulating hormone (rhTSH: Thyrogen™, Genzyme Corporation, Cambridge, MA) can be used.[10] In a hyperthyroid patient with a solitary tracer-avid focus and absent uptake elsewhere in the gland, this entity is likely a toxic adenoma. Toxic adenomas larger than 4 cm are usually surgically excised, but smaller nodules may be ablated successfully with 20 to 30 mCi I-131 sodium iodide (more activity is needed owing to suppressed gland and lower uptake). Toxic multinodular goiter is treated with a similar dose. After radioablative therapy, the failure rate is 10%, with underestimation of a large gland size representing the most common reason. A recent retrospective cohort study of 18,805 patients by Kitahara and colleagues[11] showed a modest association between greater absorbed organ doses of radioactive iodine and increased risk of death from solid cancers, including breast cancer (5%–10% increase per 100-mGy dose).

Scintigraphic evaluation is occasionally performed for workup of neonatal hypothyroidism, which is usually secondary to thyroid dysgenesis or aplasia, or organification defect. For the latter, a perchlorate washout test may be performed using Tc99m pertechnetate and I-123; in this procedure, trapping of iodide is demonstrated on a Tc99m pertechnetate scan; however, a relative washout of more than 10% is observed on I-123 scans after administration of perchlorate, an inhibitor of iodide trapping (i.e., a sodium–iodine symporter), thereby confirming lack of organification.[12] Additional use of I-123 sodium iodide scanning includes verification of the thyroid origin of indeterminate mediastinal masses.

THYROID-MALIGNANT DISEASE

Thyroid cancer has increased in incidence, likely owing to increased detection, with more than 60,000 new cases in 2013, and is now the fifth most common cancer in women.[13] Follicular epithelial-derived cancers (papillary, follicular, some poorly differentiated) concentrate iodine, enabling adjuvant treatment with I-131 sodium iodide, and express thyroglobulin, which may be used as a marker for tumor recurrence after ablation of remnant tissue after thyroidectomy. Follicular cancer is more aggressive and more likely to present with distant metastases than papillary histology (**Fig. 1**). Hurthle cell carcinoma and anaplastic thyroid cancer are typically not iodine avid. Staging is either based on disease-specific mortality (American Joint Committee on Cancer) or the risk of recurrence (American Thyroid Association [ATA]). In the American Joint Committee on Cancer system, stages I to IV are based on T-, N-, and M parameters, with age less than 55 years being a positive factor and extrathyroidal extension, age greater than 55 years, and distant metastases being negative prognostic factors. In the 2009 ATA guidelines, high-risk patients may have distant metastases, gross extrathyroidal extension, or incomplete resection; intermediate-risk patients have nodal metastasis, advanced age, and adverse histology (e.g. tall cell); and low-risk patients have tumors confined to the thyroid, favorable histology, and no nodal or distant metastatic disease. After the issuance of the 2015 ATA guidelines, microscopic nodal metastases were placed into the low-risk category along with other changes.[14] The 5-year survival of patients with localized tumor is 100%, nodal metastasis is 97%, and distant metastasis is 57%.

Factors associated with higher recurrence or mortality include advanced age, extrathyroidal extension, multiple and enlarged nodal metastases in the lateral neck, and distant metastatic disease (to the lungs or bones), and I-131 treatment is unquestionably the standard of practice for such patients. Its benefit in low-risk patients has not consistently been shown and radioablative therapy is now tending to be reserved for intermediate- or high-risk patients. Moreover, a recent large study demonstrated a slightly increased risk of salivary gland malignancies and leukemia with radioiodine therapy, which is dose dependent and inversely correlated with age.[14–16]

Total body iodine scanning plays an integral role in the patient's initial staging evaluation (see **Table 1**). After thyroidectomy, the patient is typically prepared by thyroid hormone withdrawal for 4 weeks, or Thyrogen™ 0.9 mg IM × 2 days (plus 1 week of a low-iodine diet) to achieve TSH stimulation, then administered 2 mCi I-123 sodium iodide, followed by a total body scan and uptake the following day.

Diagnostic I-131 sodium iodide total body scan is less preferred, owing to concern of "stunning" the thyroid cancer cells and making them more resistant to subsequent radioiodine therapy. The total body scan may reveal unanticipated distant metastatic disease, prominent residual thyroid tissue that may warrant further surgery, or a burden of pulmonary metastases that may require dosimetry. A pretherapy scan is advocated by Van Nostrand and colleagues[17] who, in a study of 355 scans, found that 53% of the patients had findings on preradioablation whole body scan that might have altered the management. Alternatively, the nuclear radiologist can treat empirically based on clinicopathologic data, and obtain a post-therapy scan 5 to 7 days later to complete the diagnostic

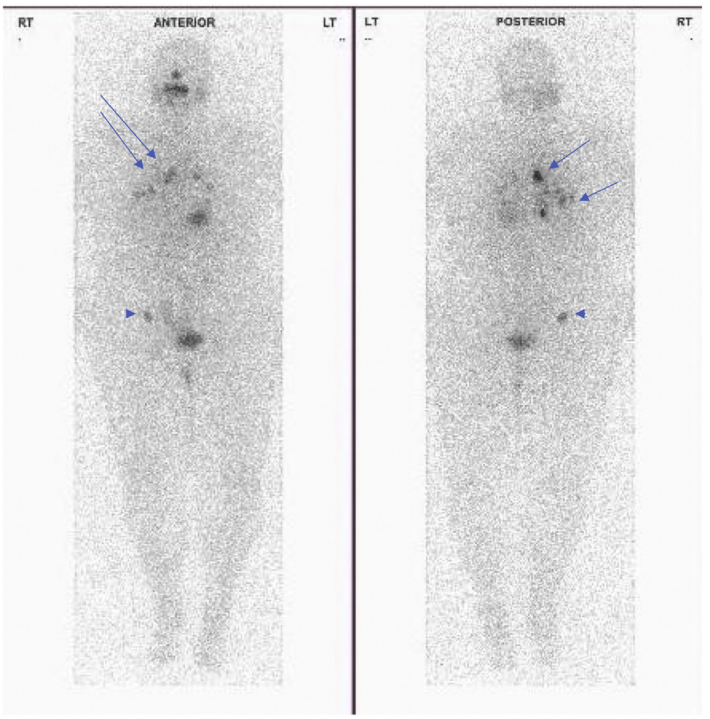


Fig. 1. A 67-year-old woman with follicular thyroid carcinoma metastatic to lungs (*arrows*) and right ilium (*arrowhead*) on I-123 total body scan.

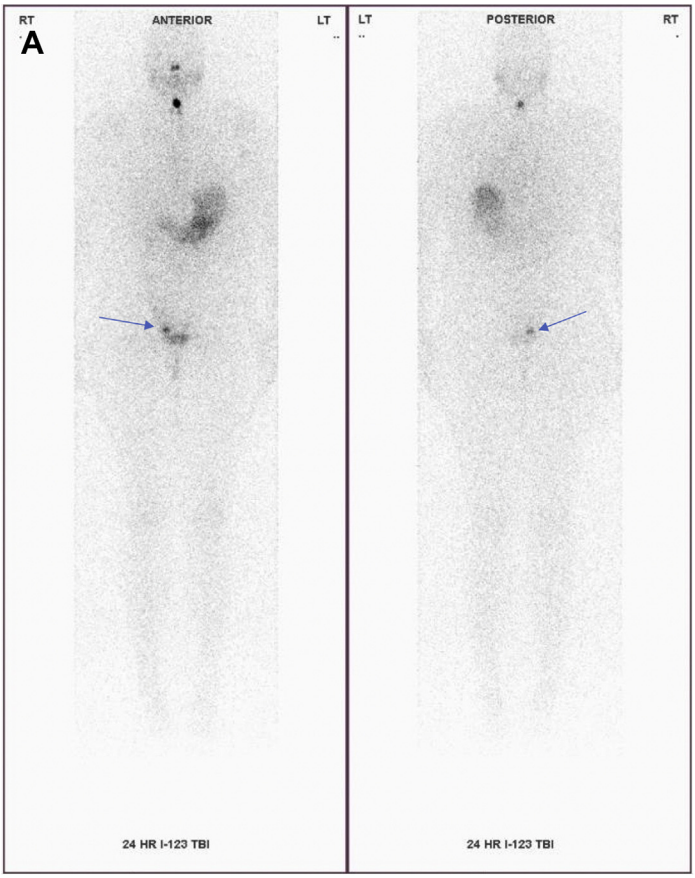
evaluation; in the event of unanticipated metastatic disease, additional I-131 could still be given at a later time. Chen and colleagues[18] also reported that I-123 preablation whole body scan was able to provide additional critical information in 25% of the patients, requiring significant changes in the I-131 therapy strategy. I-123 single photon emission computed tomography/computed tomography (SPECT/CT) scan can change management, most often on post-therapy scan, with a less clear benefit for the pretherapy scan.[19] A SPECT scan is helpful for evaluating unexpected distant sites of iodine uptake (**Fig. 2**).

Thyrogen™ is approved by the US Food and Drug Administration for remnant ablation, but is increasingly used off-label in patients with metastatic disease owing to increased convenience and patient comfort relative to thyroid hormone withdrawal. It has been demonstrated that renal clearance is lower with thyroid hormone withdrawal, suggesting that dose to tumor would be higher than with Thyrogen™.[20] This finding is supported by studies of 124 I-PET/CT, which have showed a lower radiation dose to metastases with recombinant human TSH stimulation compared with thyroid hormone withdrawal[21] and decreased detection of metastases compared with thyroid hormone withdrawal.[1,22]

Other methods of treatment for thyroid cancer include thyroid hormone suppression, radiation, tyrosine kinase inhibition, and restoration of iodine avidity in iodine-negative cancers via the mitogen-activated protein kinase pathway (under investigation).[23] I-124 PET/CT imaging has been used to quantitate difference in sodium-iodine symporter expression before and after such redifferentiation therapy in patients with radioiodine-refractory metastatic thyroid cancer.[24]

State-of-the-art radioiodine therapy offers the opportunity to provide personalized dosimetry. In patients with renal impairment or diffuse pulmonary metastases (**Fig. 3**), a pre-dosing and post-dosing I-123 total body scan can be used to compute the effective renal clearance half-time, and using a modified Benua–Leeper approach, calculate maximum tolerated doses of I-131 sodium iodide to avoid bone marrow and lung toxicity, respectively.[25] Sgouros and colleagues[26] have suggested that the 80 mCi at 48-hour Benua threshold for lung toxicity may overestimate the risk of pulmonary complications. Lesion-specific dosimetry is possible using OLINDA software, but its use is not widespread.[27]

Although the selection of I-131 dose for thyroid cancer treatment is controversial, and ranges from 30 to 200 mCi, there are certain consistent themes, such as 100 to 200 mCi for therapy of



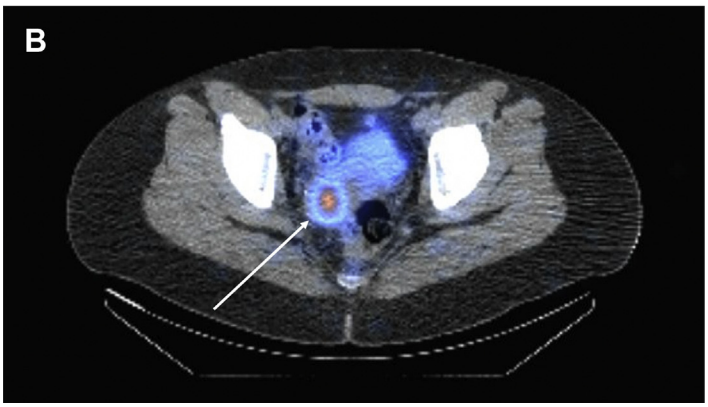


Fig. 2. A 27-year-old woman with thyroid cancer status post thyroidectomy. (*A*) I-123 total body scan shows remnant thyroid activity and unexpected focal activity in the right pelvis (*arrow*). (*B*) On SPECT/CT scanning, this activity localized to the right uterus (*arrow*). Given a normal follow-up pelvic ultrasound examination, this result was favored to represent physiologic uterine activity.

distant metastatic disease and 30 mCi for remnant ablation. The recommendations of the ATA and Society of Nuclear Medicine and Molecular Imaging are summarized by Ylli and colleagues.[28] Similar to hyperthyroid therapy, side effects of I-131 therapy for thyroid cancer include sialadenitis, lacrimal gland dysfunction, and xerostomia, the risk of which can likely be mitigated by lemon juice at 24 hours after therapy.

A PET/CT scan fludeoxyglucose (FDG) is useful in the detection of iodine-negative thyroid carcinoma that has become dedifferentiated and for initial staging and follow-up of invasive and metastatic Hurthle cell and anaplastic thyroid carcinoma. Medullary thyroid cancer can be evaluated by a FDG PET/CT scan after surgery, if the patient has persistently elevated calcitonin.[29] Incidental thyroid uptake on FDG PET scans is

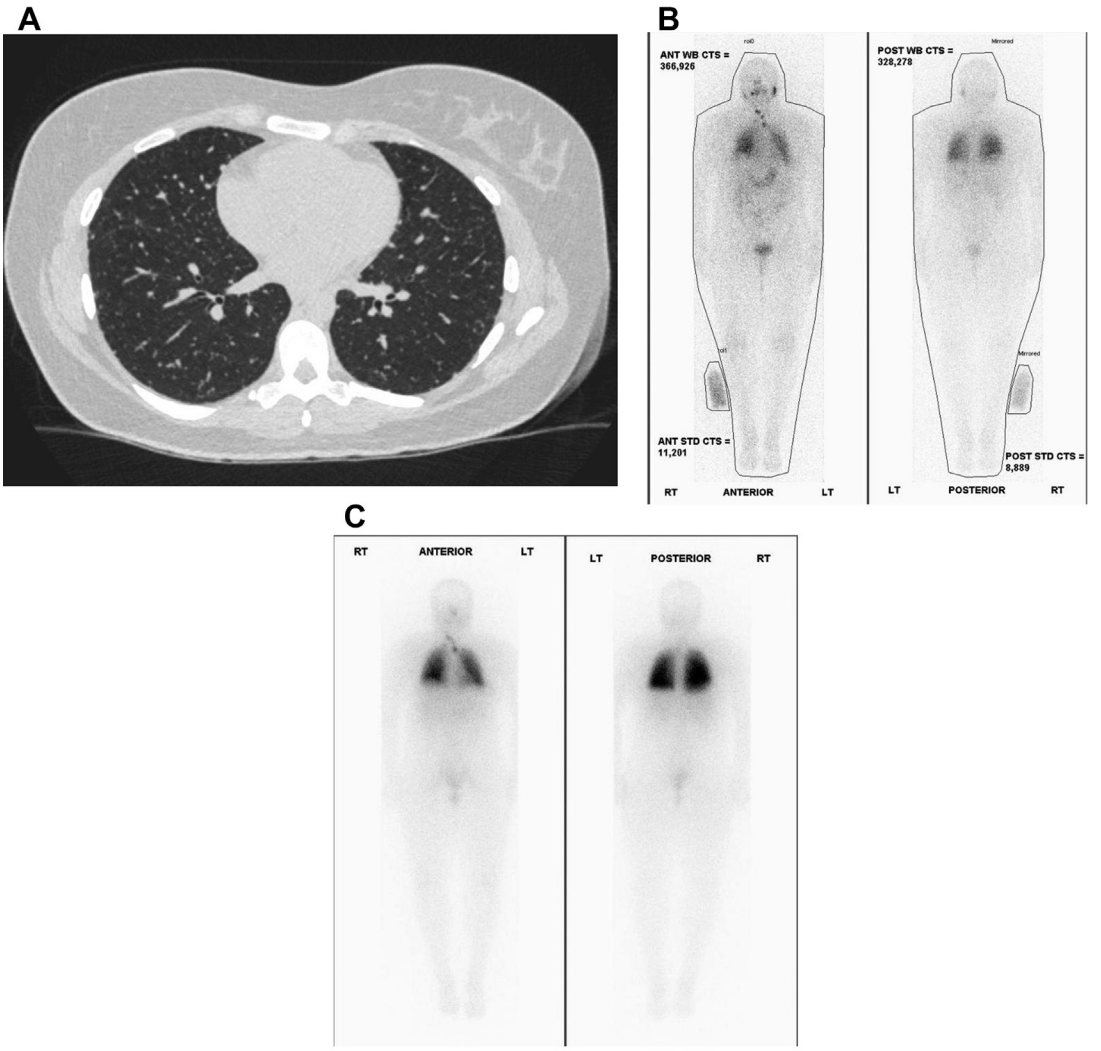


Fig. 3. A 21-year-old woman with metastatic thyroid cancer to the lungs, treated with 100 mCi I-131 6 months previously at an outside hospital. (*A*) A CT scan demonstrates persistence of innumerable small pulmonary nodules. (*B*) On I-123 total body scan performed before repeat I-131 therapy, the pulmonary metastases were diffusely iodine avid; a scan was performed using regions of interest about the whole body and I-123 standard bottle, as part of dosimetry to avoid pulmonary toxicity. (*C*) Total body iodine scan performed 7 days after dosimetrically determined therapy with 125 mC I-131, showing intense uptake in pulmonary metastases.

usually benign, such as follicular adenoma or Hurthle cell lesions; however, Nayan and colleagues[30] showed that 20% are primary thyroid cancers; 15% of those are papillary, and further evaluation is warranted with ultrasound examination.

PARATHYROID DISEASE

Patients with hyperparathyroidism present with hypercalcemia. The underlying cause is a solitary parathyroid adenoma in 85%, multigland hyperplasia (or double adenoma) in 15%, and carcinoma in 1% of instances. Complete resection of the hyperfunctioning tissue is necessary to resolve the patient's symptoms. The parathyroid glands can range from 2 to 6 in number (usually 4) and are located adjacent to the upper and lower thyroid poles. Ectopic glands can occur in the thymus, carotid sheath, and mediastinum; they can also be retroesophageal or intrathyroid in location. Preoperative scintigraphy can obviate the need for bilateral neck exploration.[31,32]

Tc99m sestamibi (2-methoxy-isobutyl-isonitrile) is delivered to the hypervascular parathyroid adenoma, passively diffuses into the cell, and is believed to bind electrostatically to the mitochondrial membrane. Adenomas have a high

proportion of the mitochondria-rich oxyphil cells, which results in retention on dual phase parathyroid scan with SPECT scanning. Other protocols include dual isotope Tc99m sestamibi/Tc99m pertechnetate and Tc99m sestamibi/I-123-iodide, both with subtraction; in the latter, I-123 is given first with imaging at 4 hours, followed by Tc99m-sestamibi imaging (see **Table 1**). Subtraction imaging can be affected by patient motion. The characteristic appearance of parathyroid adenoma is a focal tracer-avid area on immediate image, which remains avid on delays, whereas the thyroid activity washes out. False negatives can occur with a rapid washout adenoma, small adenoma less than 500 mg, parathyroid hyperplasia (which contain more chief cells than oxyphil cells and are usually smaller than adenomas), and expression of P-glycoprotein/multidrug resistance protein.[33] False positives include thyroid adenoma or multinodular goiter, nodal or thyroid metastatic disease (i.e., breast or lung cancer), chronic lymphocytic thyroiditis, or Hurthle cell lesions. A 4-dimensional CT scan may be helpful for imaging after discordant ultrasound examination and scintigraphy, persistent or recurrent hyperparathyroidism, or multiglandular disease.[34–38] In a large meta-analysis of 1236 patients, the detection rate of sestamibi was 88%.[39] An advantage of SPECT scanning is the ability to differentiate ectopic superior glands in the tracheoesophageal groove (the most common site of missed ectopic adenoma) from inferior glands.[40] It is also highly sensitive for recurrent or persistent disease after surgery for primary hyperparathyroidism or 4-gland parathyroidectomy and autotransplantation.[41,42] Using an intraoperative gamma probe, a count ratio of 1.5 times the background thyroid is suggestive of an adenoma; an ex vivo count of more than 20% greater than thyroid background and/or intraoperative parathyroid hormone assay is confirmatory.[43–45]

After several investigators imaging prostate cancer with C-11 and F-18-choline PET/CT scans incidentally noted uptake in a parathyroid adenoma, this was more systematically investigated. Lezaic and colleagues[46] compared F-18 fluorocholine-PET/CT scans and conventional parathyroid scintigraphic imaging consisting of Tc99m-sestamibi SPECT/CT scans, Tc99m-sestamibi dual-phase imaging, and Tc99m-sestamibi/pertechnetate subtraction imaging in 24 patients and compared against histology, postoperative serum calcium, and intact parathyroid hormone values. The sensitivity and specificity of F-18 fluorocholine-PET/CT scans were 92% and 100%, respectively, in contrast with 49% and 100%, 46% and 100%, and 44% and 100% for Tc99m-sestamibi SPECT/CT scans, Tc99m-sestamibi dual-phase imaging, and Tc99m-sestamibi/pertechnetate subtraction imaging, respectively. The performance of (18)F-fluorocholine PET/CT scans was found to be superior in patients with multiple lesions or hyperplasia. Michaud and colleagues[47,48] found that in 12

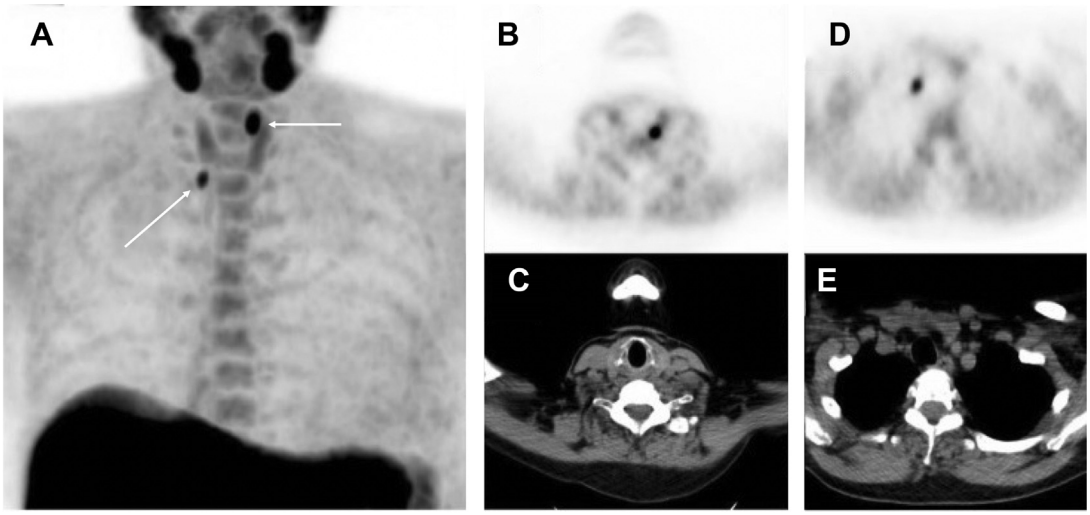


Fig. 4. Patient with hypercalcemia and hyperparathyroidism underwent F-18-fluorocholine PET/CT scan showing a double parathyroid adenoma. (*A*) On a coronal PET image, 2 foci of intense choline uptake are noted in the neck (*arrows*), with physiologic uptake in the salivary glands, thyroid gland, liver, spleen, and marrow. Axial PET (*B*) and CT (*C*) images show foci of uptake posterior and superior to the left thyroid lobe measuring 7 × 5 mm and maximum standardized uptake value of 8.7. Axial PET (*D*) and CT (*E*) images show uptake inferior to the right thyroid lobe measuring 6 × 4 mm and maximum standardized uptake value of 5.6. (*Courtesy of* Dr. Wouter Broos.)

patients with discordant ultrasound examinations and sestamibi scintigraphy results, F-18 fluorocholine detected hyperfunctioning parathyroid tissue in 11 of 12 patients, and 7 adenomas and 10 hyperplasias, with surgical pathology correlation (Fig. 4).

Secondary hyperparathyroidism is a complication of end-stage renal disease, where diffuse hyperplasia in response to hypophosphatemia and other factors gives way to asymmetric nodular growth; patients are then treated with subtotal parathyroidectomy or total parathyroidectomy with autotransplantation. Scintigraphy can identify supernumerary or ectopic glands, which may change the operative approach. The sensitivity of Tc99m-sestamibi in this situation is reported to be significantly higher using a Tc99m-sestamibi/I-123 subtraction protocol (75%) compared with 56% to 63% for dual phase Tc99m-sestamibi and 52% to 63% for Tc99m-sestamib/pertechnetate subtraction protocols.[49]

SALIVARY GLANDS

The most common primary tumors of the salivary glands are the Warthin tumor and pleomorphic adenoma, which appear as enhancing, circumscribed FDG-avid nodules on PET/CT scans and most commonly occupy the parotid gland (Fig. 5). Tumors in the submandibular and sublingual glands are less common, and in the minor salivary glands in the oral cavity, tongue, and larynx even rarer, although they are more likely to be malignant; adenoid cystic and mucoepidermoid carcinoma, and adenocarcinoma are examples. Adenoid cystic and mucoepidermoid carcinomas have a propensity for perineural invasion.[50,51]

NEUROENDOCRINE TUMORS OF THE HEAD AND NECK

The major neuroendocrine tumors in the head and neck are paragangliomas. These slow-growing hypervascular tumors may involve the carotid bifurcation (carotid body), jugular bulb (glomus jugulare), or cochlear promontory (glomus tympanicum) and are associated with germline or sporadic succinate dehydrogenase mutations. These tumors express somatostatin receptors (SSTRs), decarboxylate amino acid precursors, and in 30% of cases have an active catecholamine pathway. Given these physiologic characteristics, they can be imaged with the radiopharmaceuticals I-123 meta-iodo-benzyl-guanidine (MIBG)—a norepinephrine analog, and the SSTR-targeting agents In-111 DTPA-octreotide (Octreoscan) and Ga-68 DOTATATE (targeting SSTR type 2 and approved by the US Food and Drug Administration in 2016).[52]

SSTR imaging is superior to I-123/I-131 MIBG for paranganglioma in the head and neck. In a study of 29 patients with head and neck paragangliomas, Koopmans and colleagues[53] found a sensitivity of 93% versus 44% and 89% versus 42% for Octreoscan versus MIBG on a per-patient and per-lesion basis, respectively. Data are limited for Ga-68 DOTATATE PET/CT in head and neck paragangliomas, but it does visualize them and has been shown to be superior to CT scans, MR imaging, F-18 DOPA PET/CT scans, and F-18 FDG PET/CT scans (38/38 lesions for

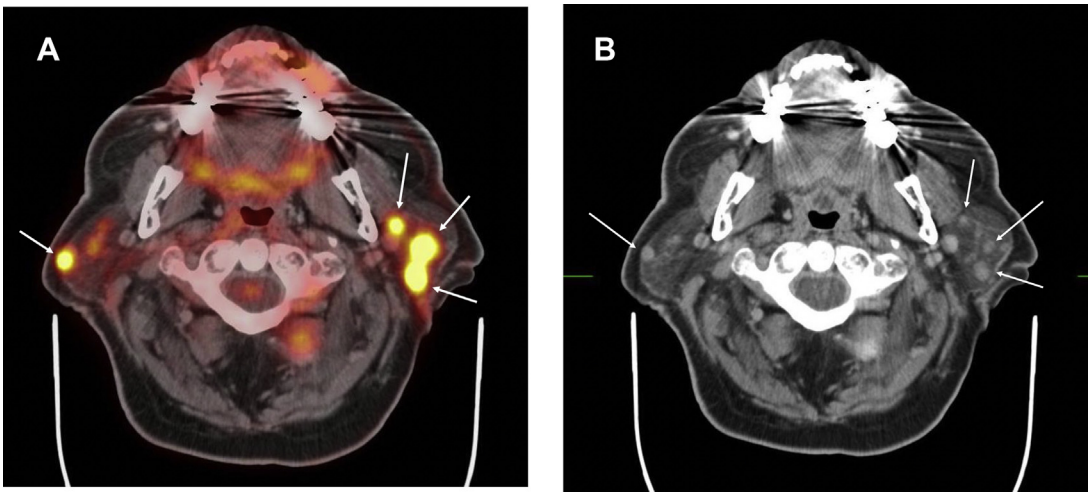


Fig. 5. A 77-year-old man with metastatic melanoma and stable hypermetabolic parotid nodules compatible with Warthin tumors. (*A*) FDG PET/CT fusion imaging showing multiple hypermetabolic parotid nodules (*arrows*). (*B*) CT imaging showing multiple parotid soft tissue nodules (*arrows*).

DOTATATE, 37/38 for DOPA, 27/38 for FDG, and 23/38 for CT/MR imaging).[54,55]

Patients who are germline mutation carriers of succinate dehydrogenase (SDHx) are at risk for later development of paraganglioma and pheochromocytoma. Kong and colleagues[56] retrospectively reviewed 20 SDHx carriers with these tumors who underwent Ga-68 DOTATATE PET/CT scans, and found the modality to have a sensitivity and specificity of 100% and 100%, compared with 85% and 50% for MR imaging/CT scans on a per-patient basis, and 100% and 75% compared with 80% and 25% on a per-lesion basis, as well as resulting in a management change in 40% of patients.

Lu-177 DOTATATE therapy showed strong efficacy in patients with gastroenteropancreatic carcinoid in the NETTER-1 trial, and was approved in 2018 by the US Food and Drug Administration. Several small series have reported on the use of this therapy for head and neck paragangliomas, after confirming expression of SSTR by Ga-68 DOTA PET. Estevao and colleagues reviewed 14 patients treated with 3 cycles of Lu-177 DOTATATE. Ten of the 14 patients showed decreased uptake after treatment; 90% of patients with jugulotympanic paragangliomas had symptomatic improvement or stabilization, and patients with carotid body paragangliomas had a worse response to the treatment.[57,58]

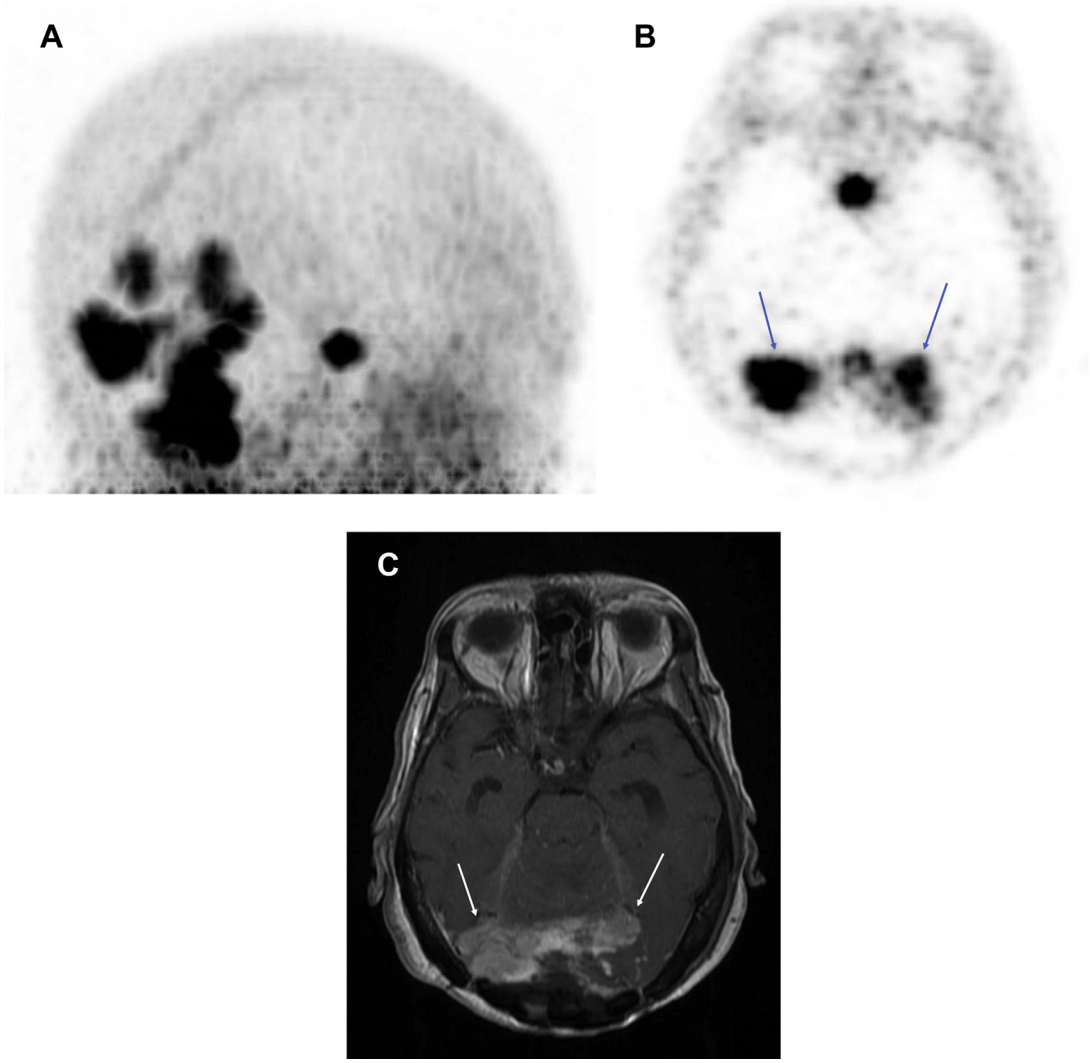


Fig. 6. An 80-year-old woman with grade II occipital meningioma complained of worsening vision despite surgery and radiotherapy. (*A*) Three-dimensional and (*B*) axial Ga-68 DOTATATE PET (*arrows*) and (*C*) post-contrast MRI (*arrows*) showed tracer-avid enhancing dural-based masses, consistent with somatostatin receptor-positive meningioma. Based on these findings, she started octreotide therapy and improved clinically.

Meningiomas are the most common intracranial tumor and usually are treated with surgery and radiotherapy if high grade. Although meningiomas are not commonly thought of as neuroendocrine tumors, they highly express SSTR type 2 and may be imaged with somatostatin scintigraphy. Compared with standard MR imaging, SSTR PET scans may add valuable additional diagnostic information in these patients, particularly in the differential diagnosis of newly diagnosed brain lesions suspicious for meningiomas, delineation of meningioma extent for resection or radiotherapy planning, and the differentiation of tumor progression from a post-treatment change.

Ivanidze and colleagues[59] reported on 20 patients with biopsy-confirmed meningioma who had undergone surgery or radiation. Ga-68 DOTATATE PET/MR imaging was able to identify 49 meningiomas and differentiate them from post-treatment change based on a higher maximum standardized uptake value (17 vs 1.7; $P<.0001$) (**Fig. 6**).

SUMMARY

I-131 ablative therapy remains a critical tool in the treatment of benign and malignant thyroid disease, and there is a trend to decreasing dose for certain subsets of patients, although recent data have shown an increased rate of secondary cancers with this therapy. This risk needs to be weighed against the benefit of treating potentially fatal hyperthyroid symptoms and adequately addressing thyroid cancer, which may become iodine negative and refractory if not treated fully. Parathyroid scintigraphy remains a valuable adjunct to a multimodality preoperative workup, with superior performance promised by radiolabeled choline tracers. SSTR-targeted diagnostic imaging and therapy (i.e., "Theranostics") is an exciting recent development. With a much higher binding affinity to SSTR type 2 than In-111 Octreoscan, Ga-68 DOTATATE PET/CT scans have a high sensitivity and specificity. Along with Lu-177 DOTATATE, its beta-emitting cousin, a new era in diagnosis and therapy of neuroendocrine tumors in the head and neck has arrived.

DISCLOSURE

None.

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