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REVIEW

Imaging of thyroid carcinoma with CT and MRI: approaches to common scenarios

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Abstract

Computed tomography (CT) and magnetic resonance imaging (MRI) can play an important role in preoperative and post-treatment assessment of thyroid malignancy. The radiologist should be aware of the pathological behavior of thyroid carcinoma, and the characteristic imaging appearance of the primary tumor and metastases. This review describes the approach to imaging thyroid cancer on CT and MRI for four common scenarios: detection of the incidental thyroid nodule, evaluation of thyroid metastases, presurgical imaging for invasive disease, and evaluation for recurrence in the post-treatment neck.

Keywords: *Thyroid cancer; computed tomography; magnetic resonance imaging; incidental thyroid nodule.*

Introduction

Although sonography is the primary imaging test for a palpable thyroid nodule or known thyroid malignancy[1], thyroid abnormalities are frequently first discovered on other cross-sectional modalities of computed tomography (CT) and magnetic resonance imaging (MRI). A thyroid lesion may be seen as an incidental finding, or CT and MRI may be first used for evaluation of an unknown neck mass.

This review describes four common scenarios in which CT and MR imaging of thyroid carcinoma may arise: detection of the incidental thyroid nodule (ITN), evaluation of thyroid nodal metastases, presurgical imaging for invasive disease, and evaluation for recurrence in the post-treatment neck.

Histological types and risk factors

The incidence of thyroid cancer is estimated at 37,000 per year in the United States and has more than doubled over the last 30 years[2]. This has been largely attributed to an increased work-up of incidentally detected thyroid nodules on imaging. Most primary thyroid carcinomas are papillary (88%), follicular (8%), medullary (1%) or anaplastic (1%)[3]. These four histopathologies are the focus of this article. Other primary cancers of the thyroid such as squamous cell carcinoma (SCCa), sarcoma and lymphoma are extremely rare (combined less than 1%).

Papillary and follicular carcinomas (including Hurthle cell variant of follicular) are known as differentiated thyroid carcinomas (DTC). Both have an excellent prognosis with 10-year survival rates of greater than 95% and 85%, respectively[4,5]. In particular, small papillary cancers have indolent behavior. Epidemiological studies show the absence of a survival improvement despite increased diagnosis of small thyroid cancers, and a Japanese study showed no deaths over 10 years in non-aggressive small thyroid carcinomas that did not receive treatment[5,6].

Medullary thyroid carcinoma (MTC) arises from neuroendocrine C cells in the thyroid gland that produce

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calcitonin. The survival rate (75% at 10 years) is still favorable[4]. Anaplastic carcinoma is an aggressive undifferentiated tumor typically occurring in the elderly with a 5-year survival rate of 7%[7].

Risk factors are different for each histological type. Papillary carcinoma is associated with ionizing radiation exposure, particularly childhood head and neck irradiation, or total body irradiation for bone marrow transplantation[2]. Family history of thyroid carcinoma with or without a thyroid carcinoma syndrome is also an important risk factor for DTC and for MTC. A quarter of cases of MTC are associated with familial medullary thyroid carcinoma (FMTC), which is due to inherited mutations in the protooncogene RET[8]. The combination of FMTC and tumors of other endocrine glands is called multiple endocrine neoplasia (MEN). Other familial syndromes associated with MTC include Cowden syndrome, familial polyposis, Carney complex and Werner syndrome. In developing countries, follicular carcinoma and anaplastic carcinoma have been associated with a diet low in iodine.

Imaging protocol

Communication with the clinician is important before performing a contrast CT scan in a patient with known thyroid malignancy. In many cases, a noncontrast study is preferred because the free iodide load of contrast medium injections interferes with iodide uptake in the thyroid for at least 6–8 weeks[9,10]. For patients with DTC, this compromises the use of diagnostic thyroid scintigraphy and radioiodine ablation for 2–6 months depending on the institution[10]. MRI contrast (gadolinium) does not interfere with iodine uptake.

CT imaging at our institutions involves multidetector acquisition from the skull base to the tracheal bifurcation with or without contrast. Multiplanar 2-mm axial, coronal and sagittal images are provided for interpretation. Our MRI protocol has a similar coverage from the skull base to the tracheal bifurcation and includes the following sequences: axial and coronal T1-weighted and fat-saturated T2-weighted images, followed by post-contrast axial and coronal T1-weighted images.

Imaging with CT and MRI

ITN on CT and MRI

With increased use of CT and MRI, ITNs or so-called thyroid incidentalomas are becoming a growing problem. ITNs are common and present in up to 1 in 6 CT studies of the neck[11–13]. The decision to report the nodule is difficult because in the absence of frank local invasion or fluorodeoxyglucose (FDG)-positron emission tomography (PET) focal uptake, there are no findings on CT and routine MRI to reliably identify the malignant lesions[14–16]. Studies have shown value in adding diffusion-weighted imaging to neck MRI because benign nodules have a higher apparent diffusion coefficient value, but the preferred modality for work-up is still ultrasonography[17,18].

Arguments against work-up of small ITNs with ultrasonography are that the malignancy rate in the incidental nodule is low, ranging from 0 to 9%[12,13,19–22], and, as discussed, the prognosis of malignancy is excellent with many patients dying with, rather than of, thyroid carcinoma[23]. Despite these favorable factors, radiologists still worry about missing malignancy. Many struggle with the balance of being cost-effective about recommending further imaging and the fear of missing a potential tumor[12].

Without guidelines for reporting ITNs on CT and MRI, previous authors have suggested extrapolating from sonographic criteria for fine-needle aspiration biopsy and using a size cut-off of 10 mm or 15 mm to triage nodules detected on CT or MRI for work-up[2,24]. The most common method for selecting a CT-detected ITN for ultrasonography is to use a 10-mm size cut-off[25]. The disadvantage of this method is that a large number of benign nodules would qualify for work-up: up to 78% of incidentally detected nodules on CT would require sonography[13]. Hoang et al.[16] recently proposed a strategy for reporting ITNs seen on cross-sectional imaging based on prioritizing subsets of patients who are more likely to have malignant nodules. Their 3-tiered system selects nodules for work-up based on nodule size but also imaging features of advanced malignant disease and young patient age. A modified version of this reporting system (Table 1) was recently applied to a single institution's cohort of 133 CT-detected incidental nodules and the National Cancer Institute's SEER database of thyroid carcinoma. Compared with using a 10-mm size cut-off alone, the 3-tiered risk stratification method, with a 15-mm nodule size cut-off, identified almost half the number of ITNs for work-up, but captured the same proportion of cancers; there was no difference in the high-mortality cancers missed[11].

Evaluating for nodal metastases

Papillary carcinoma and MTC are the most common thyroid cancers to metastasize to lymph nodes, whereas nodal metastases are uncommon in follicular carcinoma. Nodal masses may be the first presentation for papillary carcinoma and MTC, and CT or MRI may be performed to search for an unknown primary. In this setting, any thyroid nodule should be regarded as suspicious and warrant further evaluation with ultrasonography. The radiologist should also be aware that some thyroid primaries may not be seen on CT and MRI as they may be small, diffuse or multifocal (Figs. 1 and 2)[26].

In a patient presenting with adenopathy, the findings from a nodal mass that suggest a primary thyroid origin include cystic components (Figs. 1–3), calcification (Figs. 2 and 4), intense enhancement, or proteinaceous or hemorrhagic content appearing as hyperdensity on CT

Table 1 **The 3-tiered system of risk categories for thyroid nodules detected by CT, MRI or PET**

Category	Characteristic of incidental nodules	Suggested work-up recommendations
Risk category 1: highly suspicious for malignancy	PET avid thyroid nodule Associated lymphadenopathy Extrathyroid spread with or without signs of vocal cord palsy on side of nodule Lung metastases	Recommend fine-needle aspiration
Risk category 2: indeterminate with risk factors	High-risk history[a] Demographics: female <20 years or male <35 years	Recommend ultrasonography for further characterization
	Demographics: female 20–35 years	Comment that ultrasonography for characterization can be considered given the young age
Risk category 3: indeterminate without risk factors	>1.5 cm or substantial interval growth	Describe in the impression
	≤1.5 cm	Describe in body of report only

[a]High-risk history: history of thyroid cancer in one or more first-degree relatives; history of external beam radiation as a child; exposure to ionizing radiation in childhood or adolescence; previous hemithyroidectomy with discovery of thyroid cancer, MEN2/FMTC-associated RET protooncogene mutation, calcitonin >100 pg/ml. MEN, multiple endocrine neoplasia; FMTC, familial medullary thyroid cancer.

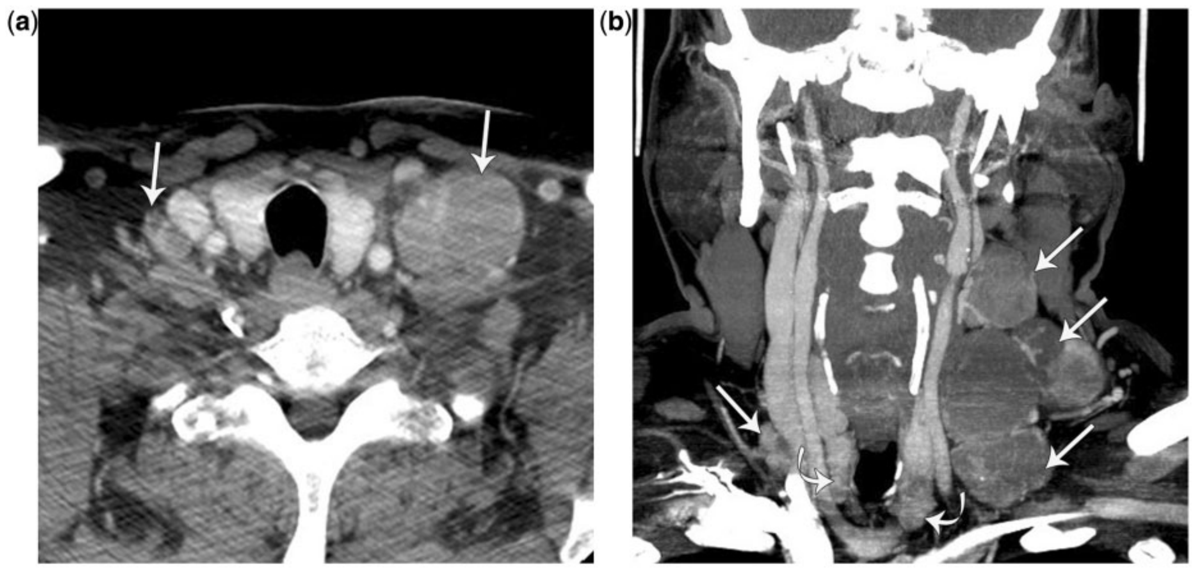

Figure 1 **A 58-year-old man with papillary thyroid carcinoma presenting with large cystic nodal metastases and occult primary on imaging. (a) Axial enhanced CT image shows bilateral neck cystic masses, larger on the left (arrows). The thyroid had normal appearance on CT without focal lesions. The gland was also normal on sonography (not shown). (b) Coronal reformatted enhanced CT image shows multiple complex solid cystic masses in lateral nodal groups, levels II, III and IV on the left and level IV on the right (arrows). There are similar smaller cystic masses inferior to both lobes of the thyroid gland in keeping with level VI nodes (curved arrows). Fine-needle aspiration of one of the nodes revealed psammoma bodies and stained positive for thyroglobulin, which was diagnostic of papillary carcinoma. The surgical specimen from total thyroidectomy found multifocal papillary carcinomas of various sizes from 0.1 cm to 1.4 cm in the isthmus and both lobes.**

and T1 hyperintensity on MRI[27]. It is important that cystic neck masses in young adults are not dismissed as congenital cysts, but considered SCCa or thyroid carcinoma until proven otherwise (Fig. 3).

In patients with diagnosed thyroid malignancy, nodal staging is optimal if the radiologist is cognizant of the common sites of nodal metastases. Previous studies are useful resources for the location of the nodal groups[27,28]. Thyroid nodal metastases commonly occur in the central compartment (level VI) and the lateral nodal groups (levels II–IV) (Figs. 1–5)[29]. The highest lymph node in the central compartment is the Delphian node or prelaryngeal lymph node (Fig. 5) and involvement of this group in papillary thyroid cancer is predictive of advanced nodal disease in that patients are nine times more likely to have lateral nodal involvement[30]. Other nodal sites that should not be neglected are the lower paratracheal nodes in the superior mediastinum (level VII), and the retropharyngeal (Fig. 6) and retroesophageal groups[31].

Figure 2 **A 61-year-old man with papillary thyroid carcinoma in both thyroid lobes and bilateral nodal metastases of varying morphological appearance and size. Coronal enhanced CT image shows the primary tumor as a large heterogeneous mass in the inferior left thyroid lobe with areas of coarse and eggshell calcifications (arrowheads). There is a large heterogeneous left level III nodal metastasis (asterisk). The inferior right lobe of the thyroid has a subtle low attenuation region (black arrow), which was also malignant on the total thyroidectomy specimen. There are small cystic nodal metastases in the right level VI and level II nodal groups (curved arrows) of different morphology from the large left neck mass.**

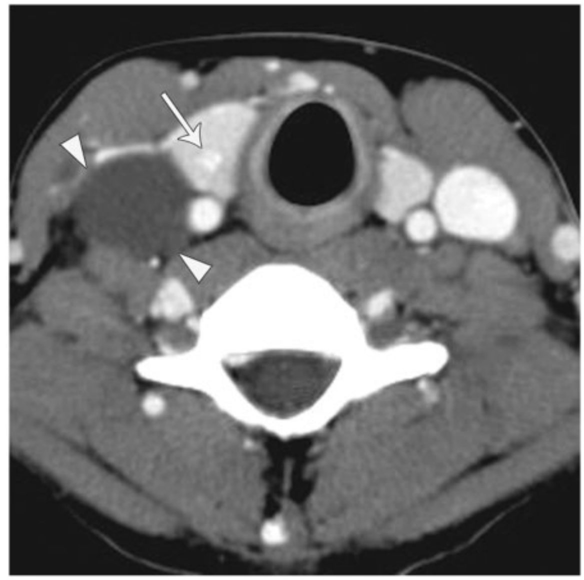

Figure 3 **A 19-year-old woman with papillary thyroid carcinoma presenting with cystic nodal metastases. Axial enhanced CT image shows a radiographically simple cyst (arrowheads) that actually represents a right level IV nodal metastasis. The right internal jugular vein is compressed anterior to the cyst indicating this lesion lies in the carotid space. There is a 1 cm solid primary tumor in the right lobe of the thyroid with fine calcifications (arrow). The differential for a cystic neck mass in a young patient and particularly in a female is a cystic nodal metastasis from thyroid carcinoma, SCCa and a congenital cyst such as a branchial cleft cyst.**

The American Joint Committee on Cancer (AJCC)/Union for International Cancer Control (UICC) TNM staging system classifies nodal stage by site: N1a is level VI nodal disease (including pretracheal, paratracheal, and Delphian nodes), and N1b is involvement of unilateral or bilateral lateral cervical nodes, or superior mediastinal nodes[7]. The presence of superior mediastinal nodes may preclude surgery for curative intent so CT or MRI may be indicated if there are predictors of mediastinal disease such as lateral nodes or primary tumor greater than 1.5 cm[32].

It is important to remember that assessment of abnormal nodal morphology is better than using size criteria for metastatic disease because up to 61% of nodal metastases may be less than 10 mm in diameter[33]. Other special characteristics about thyroid nodal metastases are that discontinuous nodal metastases (skip metastases) occur in up to 21% of cases of MTC[34]. Whereas nodal metastases are much less common with follicular thyroid carcinoma, local invasion and distant metastases to the bone and lung are more common (Fig. 7).

Assessing invasion for preoperative planning

With the exception of most cases of anaplastic carcinoma, the treatment of thyroid carcinoma involves total or near total thyroidectomy, central nodal resection, and possible radioiodine ablation[2]. The management of small tumors less than 10 mm may be limited to lobectomy, but if the small tumors are multifocal, treatment still involves total thyroidectomy and radioiodine ablation. CT and MRI cannot diagnose multifocal tumor and cannot reliably determine the histology of thyroid cancer. Preoperative work-up with imaging starts with ultrasonography to detect multifocal disease and lymphadenopathy. CT and MRI are performed if local invasion is suspected.

The implication of locally invasive carcinoma may be more extensive surgery (e.g., laryngectomy), involvement of other specialty surgeons (e.g., thoracic or reconstructive plastic surgery), or a decision not to operate. Local invasion is also a key component of the AJCC/UICC tumor (T) staging (Table 2)[7]. This staging system focuses on four groups of structures: the airway and nerves centrally (including trachea, esophagus, larynx

Figure 4 **A 57-year-old man with MTC and coarsely calcified nodal metastases. Coronal reformatted unenhanced CT image shows a large coarsely calcified left level VI nodal mass. This is immediately inferior to the left lobe of the thyroid and was mistaken for a benign calcified hyperplastic thyroid nodule on initial ultrasonography before the CT. Several truly benign thyroid nodules were also found on ultrasonography leading to an incorrect diagnosis of multinodular goiter. CT showed other left level IIa and III nodal masses with coarse calcification, also representing MTC metastases (arrowheads).**

Figure 5 **A 24-year-old woman with metastatic papillary carcinoma including a Delphian nodal metastasis. She presented with a right neck mass. Axial enhanced CT image shows a large mass in the right lobe of the thyroid. There are heterogeneously enhancing right level IV nodal masses (arrows) and an enlarged Delphian node (arrowhead).**

and pharynx, and recurrent laryngeal nerve (RLN)), the carotid arteries laterally, the prevertebral space posteriorly, and the mediastinum inferiorly.

MRI and CT have similar accuracy for predicting local invasion of the esophagus, trachea/larynx and RLN[35–38]. The sensitivity, specificity and accuracy of MRI and CT from several retrospective studies are summarized on Table 3. The main sign for tracheal and esophageal invasion on both MRI and CT is a mass contacting 180° or more of the circumference of these organs. Other findings suggesting tracheal invasion are deformity of the lumen, focal mucosal irregularity or thickening, and intraluminal mass (Figs. 8 and 9)[36,38]. The esophageal wall is more difficult to evaluate than the trachea because it is usually not distended with air. On MRI, the most suspicious finding for esophageal invasion is a focal T2 signal in the outer layer of the esophageal wall. On CT, the radiologist should look for loss of the normal esophageal wall and lumen[38,39]. Invasion of the RLN can be predicted on MRI and CT by effaced fatty tissue in the tracheoesophageal groove where the nerve courses (Fig. 10)[35]. Other imaging features of RLN invasion are signs of vocal cord dysfunction (Fig. 10) and 25% or more of the circumference of the primary tumor abutting the capsule at the posterior portion of the thyroid (sign of posterior extracapsular invasion)[38].

Vascular and prevertebral space invasion are designated T4b disease (Table 2)[7]. In general, these findings preclude the patient from curative surgery. Seo et al.[38] found contact of thyroid tumor with 180° or more of the circumference of the vessel to be a highly specific sign for common carotid artery and internal jugular vein invasion on CT (Figs. 7 and 8). However, in another study of head and neck tumors, this finding had low accuracy of 50% for arterial invasion due to a high rate of false-negative cases[40]. The investigators found that more accurate CT findings for arterial involvement were arterial compression/deformation or fat/fascial plane deletion (accuracy 84%) (Fig. 8)[40]. Increasing the criterion of circumferential encasement to 270° also increases the specificity; this sign on MRI had 100% sensitivity and 88% specificity[41]. On MRI, prevertebral musculature invasion can be excluded if there is preservation of the retropharyngeal fat, but determining invasion with findings of muscle T2 hyperintensity, enhancement, or contour abnormality is less accurate (accuracy <60%)[42].

Cross-sectional imaging has a secondary role in detecting anomalous anatomy that can make surgery more complicated or predispose structures to injury. An example is the non-recurrent inferior laryngeal nerve (NRILN), a variant of the inferior laryngeal nerve. Rather than looping under the right subclavian artery (SCA), the NRILN branches from the vagus and directly enters the larynx. The radiologist can suggest the possibility of a right NRILN when there is an aberrant right SCA[43].

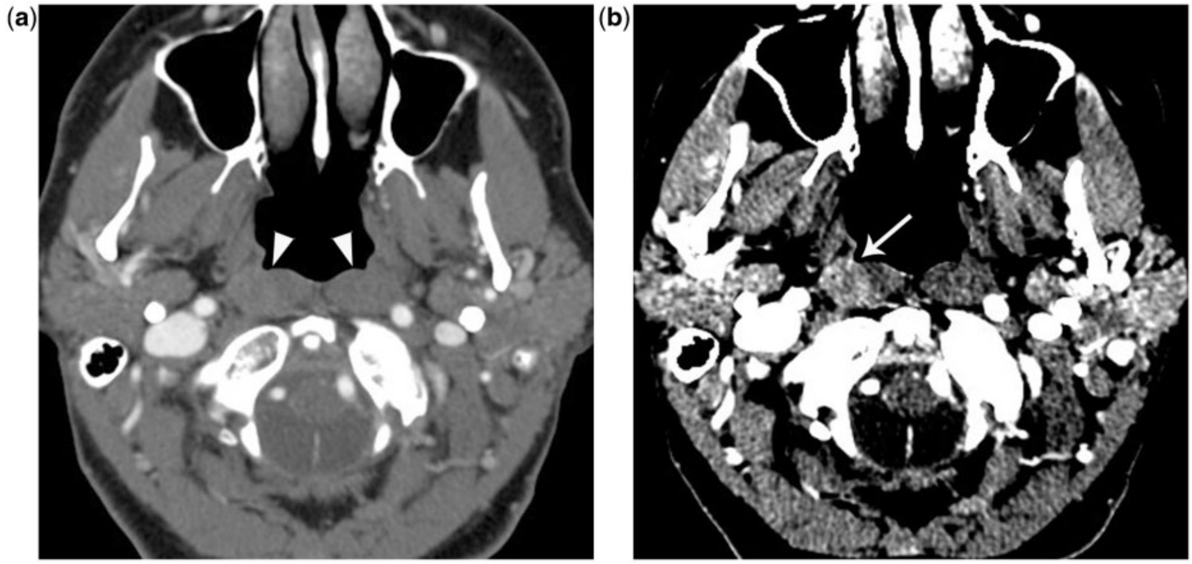

Figure 6 **A 52-year-old woman with papillary carcinoma and a retropharyngeal metastasis. She had a history of fibromyalgia and presented with 1 year of right-sided neck pain. On clinical examination, she was found to have right neck adenopathy and an enlarged right thyroid lobe, subsequently proven to contain papillary thyroid carcinoma. A contrast-enhanced CT scan was performed before thyroid carcinoma was suspected. (a) Axial enhanced CT image shows subtle asymmetry of the prevertebral muscles (arrows). (b) The same axial enhanced CT image with narrowed window width shows a metastatic right retropharyngeal node (arrow) to be much more conspicuous. This case highlights the subtlety of retropharyngeal nodes on CT, which may be even more problematic when contrast is not given.**

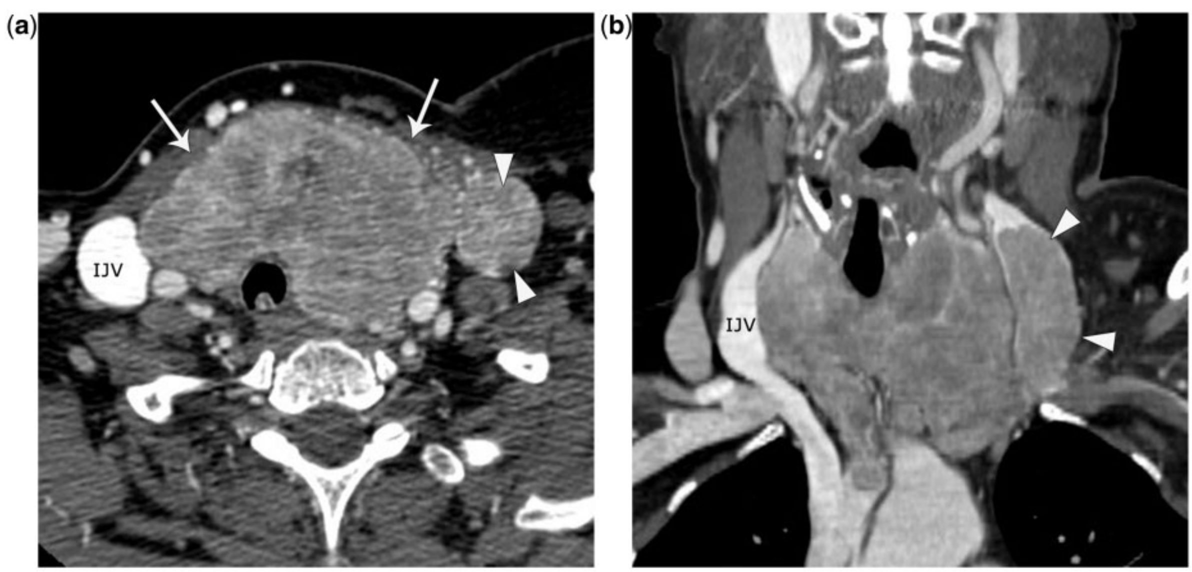

Figure 7 **A 51-year-old woman with follicular carcinoma with venous invasion. She presented with an enlarging neck mass. (a) Axial enhanced CT image demonstrates a heterogeneously enlarged thyroid gland (arrows), displacing the trachea to the right. This was biopsied and determined to be follicular carcinoma. There was no evidence of neck adenopathy, and what resembles a node in the left neck (arrowheads) represents intravenous extension of tumor in the left internal jugular vein (IJV). (b) Coronal reformatted enhanced CT image better delineates extension of tumor in the left IJV (arrowheads).**

Evaluating for recurrence in the post-treatment neck

Serum thyroglobulin level is used as a marker for recurrent or residual DTC. When increased, a neck ultrasonogram and ^{131}I or ^{123}I whole-body imaging are typically obtained. The latter may be negative in 50–80% of patients and represents progression with dedifferentiated thyroid cancer[44,45]. In such cases, MRI or PET/CT have a role in localizing the tumor for surgery. The outcome may still be curative provided there is complete resection of tumor tissue[46]. If the metastatic disease is too extensive, the treatment regimen may be changed to a palliative approach.

MRI can be readily performed for assessment of thyroid recurrence, even if it is not dedifferentiated, because it does not use iodinated contrast. MRI also has the ability to detect nodal disease with high protein content from colloid, thyroglobulin, and blood products (Fig. 11)[31]. If lateral and central neck dissections have been performed, it becomes even more important to carefully evaluate the retropharyngeal nodal groups[31].

PET/CT typically has limited sensitivity for detection of DTC but as the tumor dedifferentiates its tendency to take up FDG increases. The intensity of FDG uptake is correlated with progressive dedifferentiation and a more aggressive tumor, but does not always mean a worse prognosis[46]. PET/CT has 81–82% sensitivity and 64–89% specificity for detection of recurrent tumor in the setting of increased serum thyroglobulin level and negative whole-body iodine scan (Fig. 12)[45–47]. A pitfall of PET is that most thyroid nodal metastases are typically small and may be missed by the resolution of PET/CT. Aside from regional metastases, PET/CT can also detect unrecognized distant metastases in the lungs and bones.

Serum calcitonin and carcinoembryonic antigen (CEA) are markers used for detection of otherwise subclinical MTC recurrence. For MTC, FDG-PET uptake can be helpful if positive, but FDG uptake is variable

Table 2 **AJCC TNM staging for thyroid cancer: T staging of DTC and MTC**

T stage	Size in greatest dimension	Presence of invasion
T1	≤2 cm	No extracapsular invasion
T2	>2 cm, ≤4 cm	No extracapsular invasion
T3	>4 cm	OR minimal extrathyroid extension (e.g., extension to sternothyroid muscle or perithyroid soft tissues)
T4a	Any size	Beyond the thyroid capsule to invade subcutaneous soft tissues, larynx, trachea, esophagus, or recurrent laryngeal nerve
T4b	Any size	Prevertebral fascia or encases carotid artery or mediastinal vessels

Patients with DTC <45 years of age can only be staged as stage I or II; stage II has metastatic disease (M1).
For patients with DTC ≥45 years and MTC at any age, M1 determines stage IVc.
All anaplastic carcinomas are T4a, confined to thyroid, or T4b, invasion beyond the capsule. Therefore, all are Stage IV.

Table 3 **Sensitivity, specificity and accuracy of CT and MRI for extrathyroid invasion**

	CT (%)	CT criteria[38]	MRI (%)	MRI criteria
Trachea				
Sensitivity	59	One of:	100	One of:
Specificity	91	≥180° circumferential contact	84	≥180° circumferential contact
Accuracy	83	Lumen deformity	90	Soft tissue signal in cartilage
		Mucosal abnormality		Intraluminal mass[36]
Esophagus				
Sensitivity	29	≥180° circumferential contact OR	82	Outer layer invasion[37]
Specificity	96	Abnormal wall or lumen	94	
Accuracy	91		91	
Recurrent laryngeal nerve				
Sensitivity	78	2 of the following:	94	Effaced fatty tissue in tracheoesophageal groove on at least one axial image[35]
Specificity	90	Effaced fatty tissue in	82	
Accuracy	86	tracheoesophageal groove	88	
		>25% of tumor abutting posterior portion of thyroid		
		Signs of ipsilateral vocal cord palsy		
Carotid artery				
Sensitivity	75		100	≥270° circumferential encasement[41]
Specificity	99	≥180° circumferential contact	88	
Accuracy	99		91	
Internal jugular vein				
Sensitivity	33			
Specificity	99	≥180° circumferential contact		
Accuracy	97			

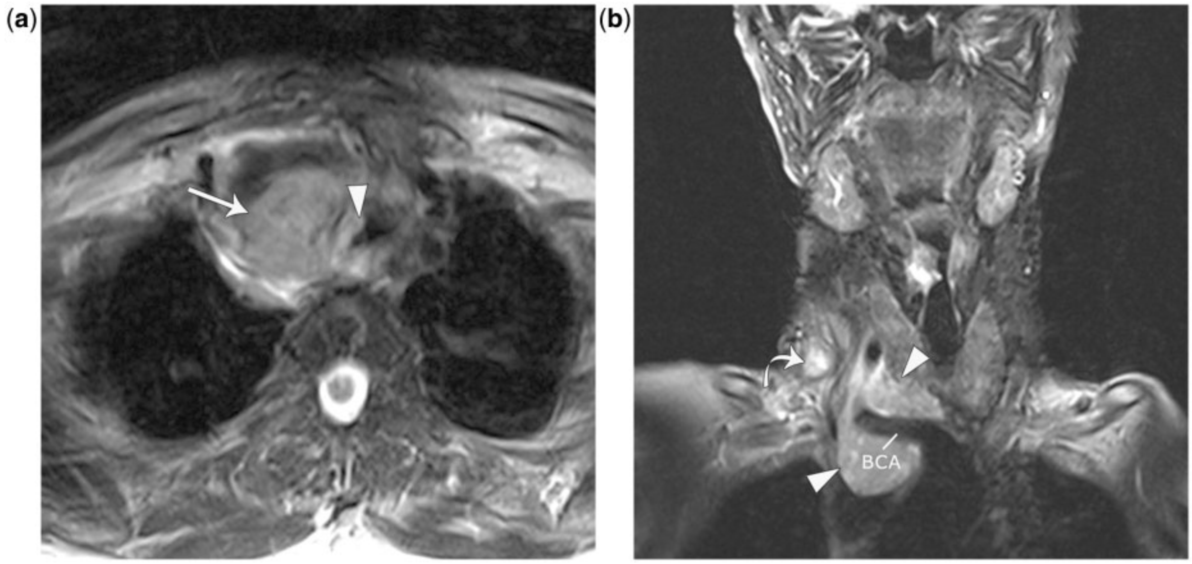

Figure 8 **A 68-year-old woman with papillary thyroid carcinoma with nodal metastatic disease invading the trachea. (a) Axial T2-weighted image shows a T2 hyperintense mass in the right paratracheal region (arrow) with soft tissue signal in the right tracheal cartilage and an intraluminal mass (arrowhead). (b) Coronal T2-weighted image shows the mass encasing the right brachiocephalic artery (BCA) with loss of the fat plane. There is also a right level IV nodal metastasis (curved arrow). She was treated with radioactive iodine and tracheal stenting. Four months later she presented with massive hemoptysis. CT images at presentation showed progression of disease.**

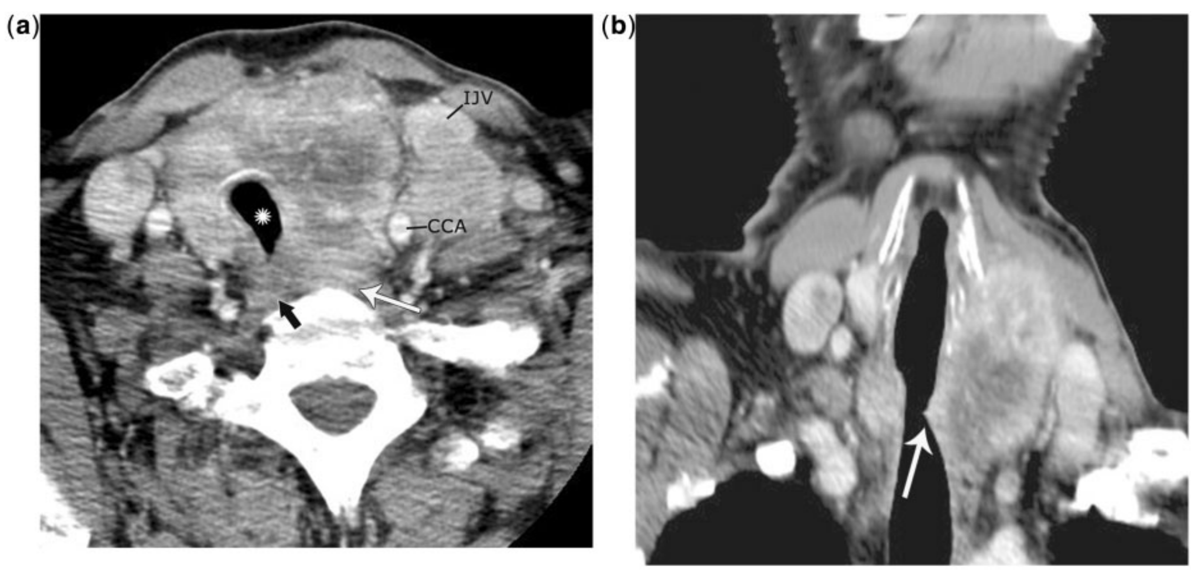

Figure 9 **A 65-year-old man with locally invasive and metastatic MTC with tracheal invasion. He presented with a neck mass and had increased calcitonin levels. (a) Axial enhanced CT image shows a large left thyroid lobe mass that mildly narrows the trachea (asterisk), and abuts the esophagus (black arrow) with loss of the fat plane. The mass contacts the vertebral body (arrow), which was concerning for prevertebral space invasion. There is also a large left level IV nodal metastasis that displaces and indents the internal jugular vein (IJV) anteriorly and the common carotid artery (CCA) medially. (b) Coronal reformatted enhanced CT image shows tenting on the inner margin of the left trachea (arrow) suggesting intraluminal tumor extension. At surgery, there was frank invasion of the left trachea and prevertebral space, which precluded curative resection.**

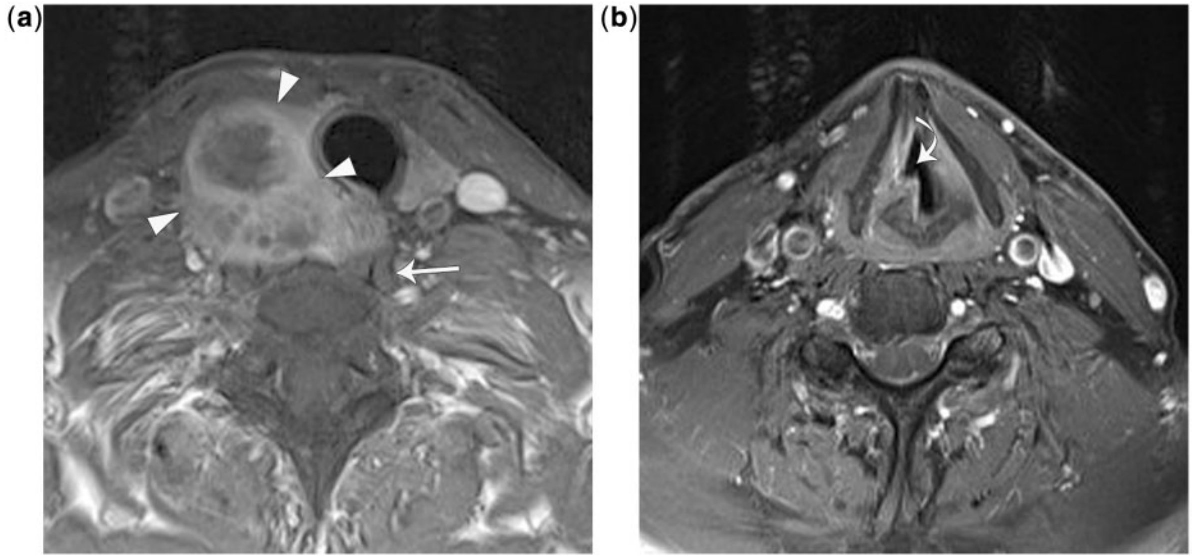

Figure 10 **A 61-year-old man with anaplastic thyroid carcinoma with invasion of the recurrent laryngeal nerve. He presented with hoarseness. (a) Axial enhanced T1-weighted MRI shows a heterogeneous enhancing mass (arrowheads) in the right lobe of the thyroid. There is loss of the fat plane in the tracheoesophageal groove. The mass abuts the trachea but the mass is $<180^\circ$ around the trachea. There is posterior displacement of the esophagus (arrow), but there is no circumferential mass. (b) Axial enhanced T1-weighted MRI at the level of the true vocal cords shows a dilated right laryngeal ventricle (curved arrow) and anteromedial positioning of the right arytenoid cartilage suggesting vocal cord paralysis. At surgery there was invasion of the right recurrent laryngeal nerve, and perichondrium of the cricoid and 1st to 3rd tracheal rings without deep tracheal invasion. Biopsies of the esophagus were negative. The patient had a total thyroidectomy, followed by chemoradiotherapy. One and two years later he had resection of a right adrenal metastasis and two lung metastases, respectively.**

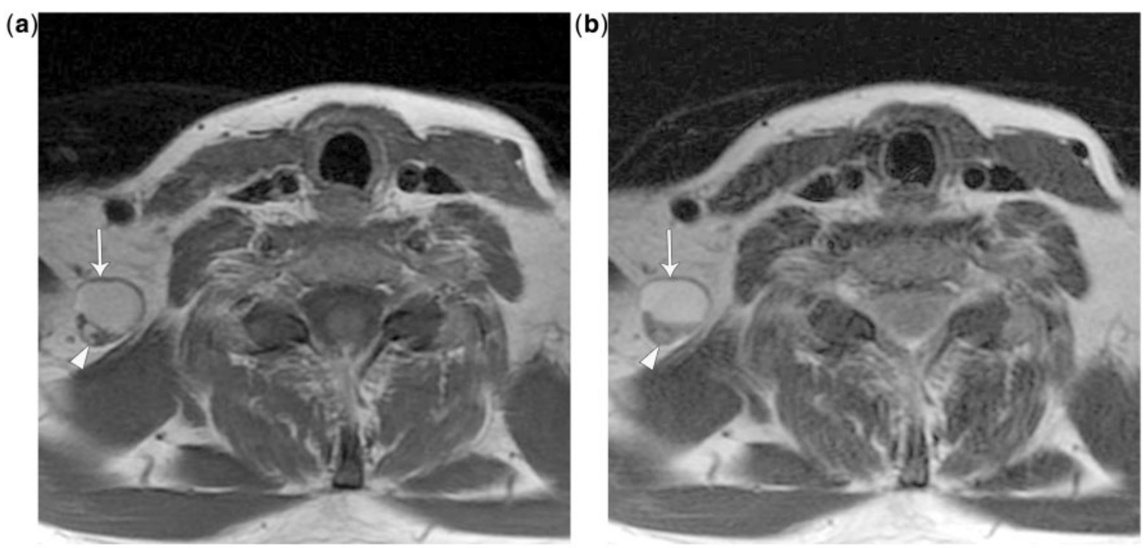

Figure 11 **A 41-year-old woman with treated papillary carcinoma and a cystic nodal recurrence. She was initially treated with thyroidectomy and a central neck dissection followed by ablative ^{131}I therapy. Serum thyroglobulin levels were not increased on follow-up, but a palpable low neck mass was evident. (a) Axial T1-weighted MRI demonstrates a rounded hyperintense lesion (arrow) with a posterior solid nodule (arrowhead) anterior to the right trapezius muscle corresponding to level Vb. The lesion has similar signal intensity to adjacent fat. (b) Axial T2-weighted MRI shows the lesion to be T2 hyperintense (arrow) except for the solid posterior nodule (arrowhead). This was resected and found to be a predominantly cystic papillary thyroid nodal recurrence. The T1 and T2 hyperintense signal likely represents high protein content in the cyst from colloid, thyroglobulin or blood products. Intrinsically hyperintense nodal metastases can be difficult to appreciate on T1 and non-fat-saturated T2 and post-contrast sequences, especially when they are small nodal metastases. Cystic metastases may also be negative on ^{131}I and PET imaging.**

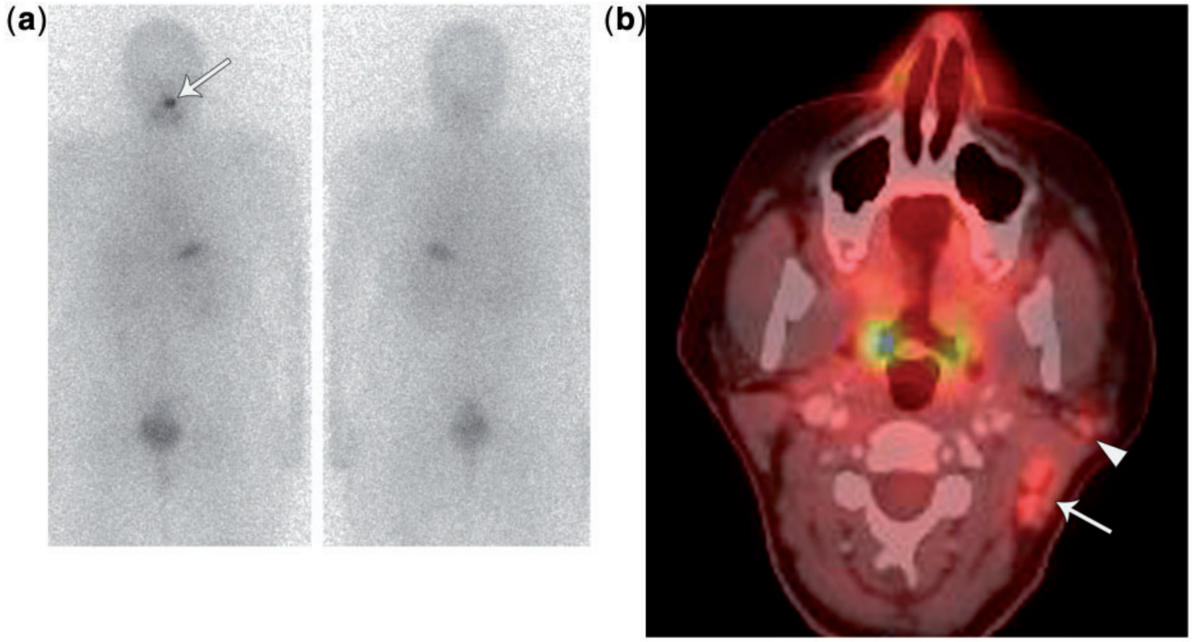

Figure 12 **A 24-year-old woman with recurrent metastatic papillary thyroid carcinoma. She was previously treated with total thyroidectomy and selective central compartment neck dissection followed by radioactive iodine therapy. Metastasis was suspected due to an increasing serum thyroglobulin level. (a) Anterior and posterior whole-body images from an ^{131}I scan show normal salivary pooling in the neck (arrow). There was no abnormal uptake. (b) Axial fused PET/CT shows low-level FDG uptake in subcentimeter left level IIb (arrow) and left parotid nodes (arrowhead). Surgical resection was performed, which confirmed the diagnosis of recurrent papillary thyroid carcinoma in the left lateral nodal groups.**

for MTC and even large metastases can be FDG negative[48]. Therefore, lack of uptake should not be interpreted as absence of disease in MTC. In a study comparing FDG-PET with CT and MRI, the cross-sectional modalities detected a higher percentage of pulmonary and hepatic metastases, but FDG-PET was superior in detecting nodal metastases[49]. Hence, the combination of CT with PET increases sensitivity and specificity compared with PET alone.

Conclusion

The radiologist should be aware of the scenarios in which thyroid malignancy can be imaged with CT and MRI and how to approach a thyroid nodule and nodal disease with these modalities. There are clinical and cross-sectional imaging findings that make an ITN more suspicious for malignancy. For known malignancy, CT and MRI are helpful for detecting extrathyroid invasion. Knowledge of the behavior and appearance of nodal metastases on CT and MRI is crucial for preoperative assessment and for evaluation of recurrent tumor.

Conflict of interest

C.M. Glastonbury is an investor in and consultant for Amirsys.

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