Computed Tomography and MR Imaging of Thyroid Disease

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KEYWORDS

• CT • MR imaging • Thyroid • Cancer • Goiter • Thyroid nodules • Surgical implications

KEY POINTS

- Both CT and MR imaging are important imaging modalities that incidentally detect benign and malignant thyroid disease.
- Cross-sectional imaging is not typically the first-line imaging technique for thyroid nodule characteristics but is extremely beneficial for surgical staging.
- Staging of papillary thyroid cancer depends on a combination of imaging findings, histology, and the patient's age.
- Calcifications and/or cystic changes involving cervical lymph nodes are highly concerning for metastatic lymphadenopathy.

INTRODUCTION

Many benign and malignant disorders can occur in the thyroid. Some thyroid diseases can be subclinical; however, others present with structural (ie, thyroid goiter) or functional (ie, thyroiditis) abnormalities.[1,2] Thyroid cancer is the most common endocrine malignancy in the United States, affecting more than 400,000 people per year, with the incidence doubling between 2000 and 2009. This higher number of cases is likely due to increased usage of computed tomography (CT) and MR imaging. Incidental thyroid nodules are often found on neck/cervical spine imaging performed for a vast array of non–thyroid-related etiologies. Despite this overall increased incidence, patient mortality has not changed.[3] CT and MR imaging are especially important in the presurgical evaluation of thyroid diseases for extent of disease, involvement of the adjacent structures, and presence of distant disease.[4,5]

NORMAL ANATOMY AND IMAGING TECHNIQUE

The thyroid structure consists of 2 lobes, draped over the trachea and connected by the isthmus at midline.[6,7] The thyroid is hypervascular, part of the visceral space, and encapsulated by the middle layer of the deep cervical fascia. Typically, each lobe measures approximately 2.0 × 3.0 × 5.0 cm (transverse × anteroposterior × craniocaudal) with isthmus measuring up to 0.3 cm.[6,7] The superior border of the thyroid extends to level of the mid-thyroid cartilage and extends inferiorly to the fifth or sixth tracheal ring. The thyroid wraps around the trachea and into the tracheoesophageal grooves (TEG), containing the recurrent laryngeal nerve (RLN).[7] The common carotid arteries (CCA) and internal jugular veins (IJV) are posterolateral, and the strap muscles are anterior to the thyroid (**Fig. 1**).[6] The thyroid is hypervascular and supplied mainly by superior thyroid artery from the external carotid artery and the inferior thyroid artery from the thyrocervical trunk. In a small percentage of patients, a thyroid IMA arises directly from the aorta. The esophagus is posterior and separated from the thyroid by the TEG (**Fig. 2**A). The lymphatic drainage for the thyroid is variable, including the internal jugular chain, paratracheal, mediastinal, and retropharyngeal regions.[7]

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Imaging Technique and Protocol		
	Computed Tomography	**MR Imaging**
Field of view	Skull base to the carina	Skull base to the carina
Patient positioning	Patient's arm at the side with neck in neutral position to slightly extended to mimic operating room positioning[a,1]	Patient's arm at the side with neck in neutral position to slightly extended to mimic operating room positioning[a,1]
Imaging acquired	• Soft tissue windows in axial at 2.5-mm slice thickness with coronal and sagittal reconstructions. • Axial bone window at 1.25-mm slice thickness	• Anterior neck coil centered over the thyroid • Unenhanced T1-weighted in axial and sagittal planes • Axial fast spin-echo T2-weighted with fat saturation (FS)[b] • Axial and coronal T1-weighted post contrast with FS[b]

[a] This positioning is necessary for thyroid goiters, as incorrect positioning can result in the thyroid having a lower apparent neck position resulting in a sternotomy rather than a simple low collar incision.[1]
[b] FS is mandatory to allow the thyroid lesions to be more conspicuous.[7,8]

IMAGING CHARACTERISTICS

The imaging appearance of the thyroid varies with the modality.[6] Many different modalities are used to evaluate the thyroid, including ultrasonography, nuclear medicine scintigraphy, CT, and MR imaging.[1]

On nonenhanced (NE) CT, the thyroid is intrinsically hyperdense (80–100 Hounsfield units) when compared with the musculature due to elevated iodine content (see **Fig. 1**A).[7] The thyroid is able to concentrate 25 to 50 times more iodine than serum. The thyroid attenuation directly correlates with thyroid function; therefore, the more decreased the thyroid function the less hyperdense the thyroid.[8] On contrast-enhanced (CE) CT, the thyroid avidly enhances due to hypervascularity (see **Fig. 1**B).[7] The thyroid on MR imaging has homogeneous signal intensity, slightly greater than that of the strap musculature on T1-weighted and T2-weighted imaging (**Fig. 2**A, B). After the administration of gadolinium, the thyroid homogeneously enhances (**Fig. 2**C).[7]

THYROID PATHOLOGY

Benign

Imaging has significantly increased over recent years, resulting in an increased number of incidental findings, unrelated to the examination indication.[9] Many incidental findings are benign thyroid nodules, identified on ultrasonography (9%–33%), cross-sectional scans (16%–18%), and PET (1%–2%).[6,9] Incidence of these nodules increase with age, and they occur more frequently in women. Not all incidental nodules need ultrasonography follow-up, given the overall indolent behavior of most thyroid cancers (**Table 1**). In addition, these nodules only have a 1% to 2% risk of malignancy. If, however, a nodule has focal fludeoxyglucose uptake on PET, fine needle aspiration needs to be performed, as there is a 26% to

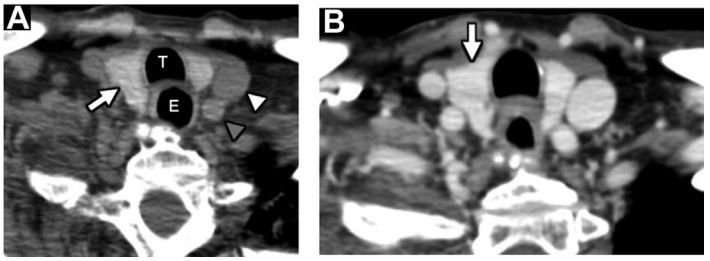

Fig. 1. Axial CT imaging of thyroid. (*A*) The thyroid is intrinsically hyperdense on unenhanced CT (*white arrow*). The common carotid artery (*gray arrowhead*) and internal jugular vein (*white arrowhead*) are posterolateral to the thyroid. Esophagus (E) is located posterior to the thyroid, whereas the trachea (T) is located anterior to the esophagus. (*B*) Contrast-enhanced CT shows avid enhancement of the thyroid (*white arrow*).

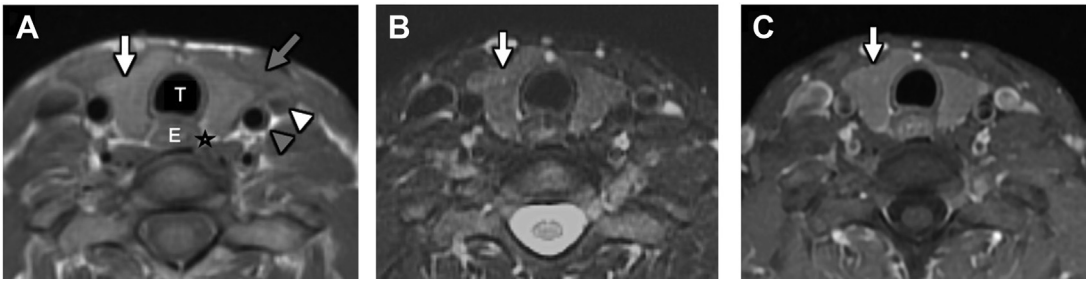

Fig. 2. MR imaging of thyroid. (*A*) T1-weighted axial MR image of thyroid (*white arrow*) is slightly hyperintense compared with adjacent strap muscles (*gray arrow*). Esophagus (E) is posterior to thyroid, and trachea (T) is anterior to the esophagus. Internal jugular vein (*white arrowhead*) is lateral to thyroid and common carotid artery (*gray arrowhead*). The tracheoesophageal groove (*star*) is the fat between the trachea, esophagus, and thyroid. (*B*) T2-weighted MR image shows that the thyroid (*white arrow*) is hyperintense to adjacent strap muscles (*gray arrow*). (*C*) T1-weighted, contrast-enhanced, fat-saturated axial MR image shows normal thyroid (*white arrow*) enhancement.

50% risk of primary thyroid malignancy.[1] Although thyroid nodules can be detected with CT and MR imaging, ultrasonography remains the best for nodule characterization.[6]

Incidental thyroid nodules

The goal of the evaluation for these incidental thyroid nodules is to determine malignancy risk, whereas most are benign. CT is often used in patients with head and neck cancer for operative planning, restaging, and follow-up; however, this is not necessarily true with thyroid cancer. Characterization of thyroid nodules on CT or MR imaging is largely nonspecific; however, these studies can help with large or retrosternal thyroid goiters (TGs), which are not adequately assessed on ultrasonography due to the trachea and sternum. CT also characterizes calcifications better than ultrasonography . Calcifications may be "egg-shell," rim-like, or curvilinear, and 22% of these types of calcifications are associated with malignancy.[10]

Table 1
Diagnostic criteria for managing incidental thyroid nodules on computed tomography or MR imaging[30]

Age, y	Nodule Size, cm	Recommendation
<35	<1	No additional imaging in low-risk patient
	≥1	Ultrasound advised
≥35	<1	No additional imaging in low-risk patient
	1–1.4	Additional imaging at providers discretion
	≥1.5	Ultrasound advised

From Hoang JK, Langer JE, Middleton WD, et al. Managing incidental thyroid nodules detected on imaging: white paper of the ACR Incidental Thyroid Findings Committee. J Am Coll Radiol 2015;**12**(2):143-50; with permission.

Thyroid goiter

TG occurs due to abnormal thyroid growth with or without substernal extension.[1] A simple TG occurs in the absence of autoimmune disease, thyroiditis, thyroid dysfunction, or thyroid malignancy.[11] Abnormal growth occurs over several years, most commonly in 50-year-old to 60-year-old women, and can be due to environmental and/or genetic factors. Functional (ie, hyperthyroidism) or structural abnormalities can cause a multitude of compressive symptoms (ie, dyspnea).[1] Multinodular TG is heterogeneous due to nodularity, hemorrhage, calcifications, cyst formation, and scarring (**Fig. 3**). There can be asymmetric hypertrophy of the thyroid with extension substernally or into the posterior mediastinum.[8] CT is important for presurgical evaluation, and there are specific details the surgeon needs to know: degree of substernal extension, displacement or compressed structures, symmetry of the vocal folds suggesting paralysis, and extrathyroidal extension suggesting superimposed malignancy. Imaging findings suggestive of malignancy include invasion of adjacent structures, rather than simple displacement or compression, and also the presence of cervical lymphadenopathy (**Fig. 4**).[1]

Thyroiditis

Thyroiditis is a benign inflammatory condition, often clinically apparent without need for imaging. However, Riedel's thyroiditis (RT) has fairly characteristic imaging findings. Although the etiology remains largely unknown, it is thought to be autoimmune. RT occurs due to a rare fibrotic condition

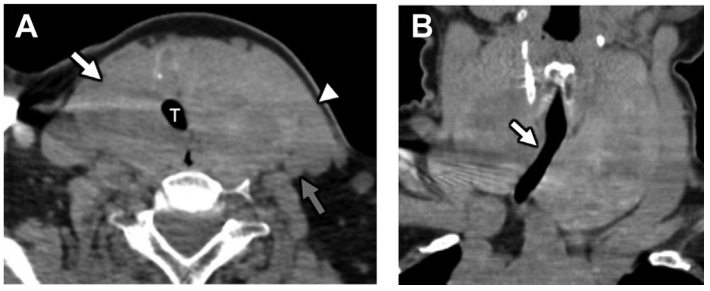

Fig. 3. Preoperative unenhanced CT for thyroid goiter. (*A*) Axial unenhanced CT at the level of the thyroid demonstrates massively enlarged, heterogeneous thyroid (*white arrow*) causing rightward tracheal (T) deviation with mild narrowing. Mass effect on the surrounding structures causes posterolateral displacement of the common carotid artery (*gray arrow*) and stretching/thinning of the strap muscles (*white arrowhead*). No findings of extrathyroidal extension or invasion of adjacent structures is seen. (*B*) Coronal unenhanced CT of the thyroid goiter demonstrates rightward tracheal deviation with mild narrowing (*white arrow*).

in which thyroid tissue is destroyed with infiltration of the adjacent soft tissues. This overgrowth of fibrosing connective tissue increases over time leading to a palpable, firm, painless enlarging thyroid mass with compressive symptoms (ie, dyspnea, dysphagia, hoarseness, aphonia). On clinical examination, the differential for RT includes malignancy, such as anaplastic thyroid cancer (ATC), lymphoma, and sarcoma. Definitive treatment of RT remains surgery to relieve the compressive symptoms.[12] RT can be suggested on MR imaging due to characteristic imaging features of fibrosis. The thyroid will be hypointense on T1/T2-weighted images (**Fig. 5**) with homogeneous enhancement. These imaging characteristics are in contradistinction to Hashimoto thyroiditis, thyroid carcinoma, and lymphoma, which are T2 hyperintense. RT also can be associated with mediastinal fibrosis, retroperitoneal fibrosis, and sclerosing cholangitis.[8]

Malignant

There are 4 predominant types of thyroid cancer: papillary (PTC), follicular (FTC), medullary (MTC), and ATC. Both PTC and FTC are considered well-differentiated thyroid cancers (DTC). DTCs have the best prognosis, with a 10-year survival rate greater than 95% for PTC and 85% for FTC. MTC has a 10-year survival rate of approximately 75%, whereas ATC is the most aggressive with a mean survival of 9 weeks and poor 5-year survival of 7%.[1] When a large thyroid mass is discovered, DTC remains the most likely diagnosis, as DTCs encompass more than 90% of all thyroid malignancies. However, lymphoma, ATC, MTC, and metastatic disease should still be considered.[13] DTC can occur at any age, but the mean age is 49 years with approximately 39% diagnosed before age 45. Although most DTCs are sporadic, family history and prior neck radiation are known risk factors. Young patients have the best prognosis due to the more indolent histologic subtypes and better treatment response. In fact, patients with DTC who are $\leq$55 years old can only be stage I or II despite advanced disease, reflecting the improved prognosis.[14,15] When a patient is >55 years old with DTC, the patient can be staged I-IVa/b depending on tumor extent (T), lymph node metastasis (N), and distant metastatic disease (M). When the tumor is limited to the thyroid gland, $\leq$4 cm in size, without positive lymph nodes or distant metastatic disease, the patient is stage I. For thyroid disease that is limited to the thyroid but greater than 4 cm or with gross extrathyroidal extension invading only the strap muscles, the stage is II. In addition, any T of DTC

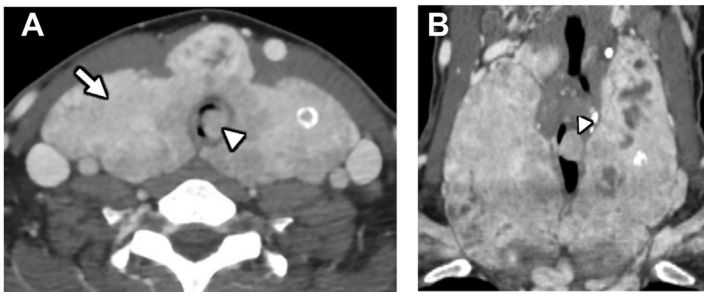

Fig. 4. A 32-year-old woman with known thyroid goiter, increasing size over the past 2 years with worsening dyspnea. (*A*) CECT axial image shows thyroid goiter (*white arrow*). Instead of simply compressing the trachea, a portion of the mass has invaded the trachea (white *arrowhead*), suggesting a more aggressive component. (*B*) CECT coronal image of the thyroid goiter demonstrates the site of tracheal invasion (*white arrowhead*). This portion of the mass was proven to be papillary thyroid cancer.

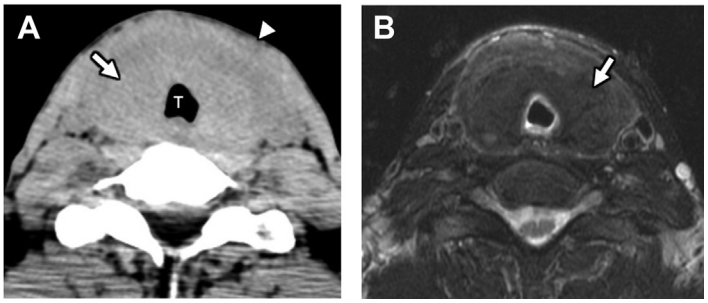

Fig. 5. A 42-year-old woman with a 5-month history of thyroid enlargement. At time of open biopsy, the thyroid was adherent to the strap muscles with preliminary pathology report being Riedel thyroiditis versus lymphoma. (*A*) Unenhanced CT axial image through thyroid demonstrates thyroidal enlargement with a smooth appearance (*white arrow*). No significant mass effect on the trachea (T) is seen. The strap muscles are stretched (*white arrowhead*). (*B*) T2-weighted, fat-saturated axial image shows diffusely T2-hypointense thyroid (*white arrow*) compared with Fig. 2B. Markedly decreased T2 signal suggests diagnosis of Riedel thyroiditis, which was later confirmed.

with lymph node metastasis is also stage II. For stage III, there can be any T or N of DTC with gross extrathyroidal extension and invasion of the subcutaneous soft tissues, larynx, trachea, esophagus, or RLN. Stage IVa can be any T or N with gross extrathyroidal extension invading the prevertebral fascia or with the presence of carotid artery or mediastinal vasculature encasement. Stage IVb occurs when there is any T or N stage with the presence of distant metastatic disease.[15]

Literature has shown that calcifications are more commonly found in thyroid malignancies over benign etiologies. For example, 26% to 79% of thyroid malignancies have calcifications, whereas benign etiologies have calcifications in only 8% to 39% of cases. CT is best for characterizing most calcifications versus ultrasonography , and these can be classified as macrocalcifications or microcalcifications. Microcalcifications have been found to have a higher association with thyroid malignancy; one study found that 70% of CT-detected microcalcifications were associated with malignancy, and 94% of these harbored PTC (Fig. 6D).[10]

Cervical lymphadenopathy from thyroid cancer can have calcification, hyperenhancement, internal proteinaceous components, hemorrhage, or may be cystic/necrotic.[1] Several studies have shown that the presence of lymphadenopathy in PTC leads to an increased risk of recurrence and an overall reduced survival. If there are calcifications within cervical lymph nodes, thyroid malignancy should be considered.[10]

DTCs rarely need CT or MR imaging for surveillance, and ultrasonography is less expensive and more accessible. In addition, iodinated contrast with CT is often contraindicated in thyroid cancer, as it could interfere and delay treatment with radioiodine due to false-negative radioiodine whole-body scans.[14] However, if it is determined that the addition of contrast will not delay treatment, CT neck with contrast and ultrasonography of the neck are usually appropriate in the presurgical evaluation of DTC according to the American College of Radiology (ACR) Appropriateness Criteria (AC). In preoperative evaluation, MR imaging of the neck with or without contrast or CT neck without contrast may be appropriate.[16] CT is helpful in characterizing thyroid nodal metastases to evaluate for cystic components, rounded shape, or calcifications. The primary role of CT is in the postoperative setting where the thyroglobulin continues to rise but ultrasonography remains negative. CT chest is often needed, as the lungs are the most common location for metastasis after the neck.[14]

Papillary

PTC is most common type, accounting for 84% to 91% of all thyroid malignancies. It most commonly affects female adolescents and young adults (2.5:1.0 women:men), and has the best prognosis with more than 95% 5-year survival rate.[17] PTC has only a 1% to 2% mortality rate at 20 years after diagnosis.[18] Of all of the thyroid malignancies, PTC has the highest rate of cervical lymph node involvement, with involvement in up to 50% of cases. These lymph nodes may be cystic/necrotic, hypervascular, calcified, or hemorrhagic (Fig. 6).[19] PTC can also rarely occur in a thyroglossal duct cyst (TDC) (Fig. 7). Therefore, any nodularity or calcification noted within a TDC should be concerning for superimposed thyroid cancer, which is most commonly PTC.[20,21]

PTC does not typically invade the surrounding structures; however, if there is adjacent soft tissue involvement, a more aggressive component is suggested. PTC most commonly spreads to the regional lymph nodes, and if there is invasion of the upper aerodigestive tract or distant metastasis, there is a poorer prognosis with increased risk for recurrence.[17]

Follicular

FTC is the second most common type, accounting for 5% of cases. They are well differentiated, low

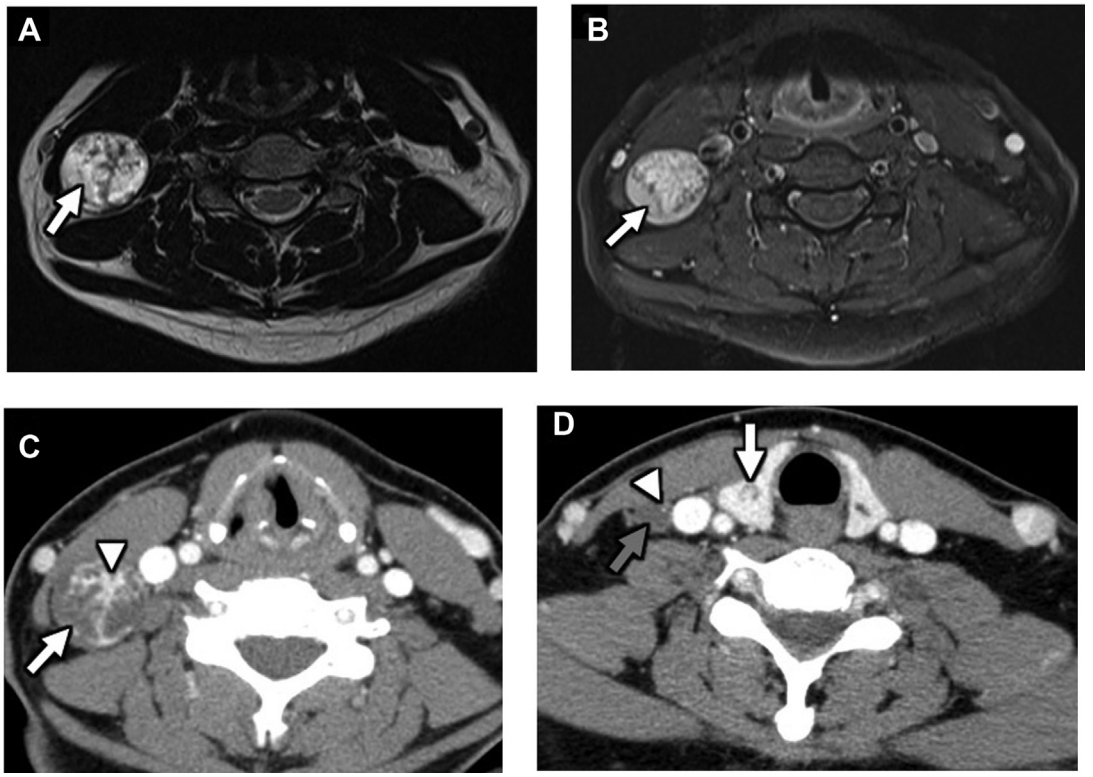

Fig. 6. A 43-year-old woman with optic neuritis. (*A*) T2-weighted axial MR image of the cervical spine was performed to look for demyelination; however, a partially cystic/necrotic right level III lymph node was discovered (*white arrow*). (*B*) T1-weighted, contrast-enhanced axial fat-saturated MR image shows same node avidly enhancing (*white arrow*). Given the young age, thyroid cancer was suggested and CECT was obtained. (*C*) CECT axial image through the level of the thyroid cartilage demonstrates a partially cystic/necrotic right level III lymph node (*white arrow*) with areas of enhancement/calcification (*white arrowhead*). (*D*) CECT axial image at the level of the thyroid. There is a largely cystic/necrotic right level IV lymph node (*gray arrow*) with a punctate calcification (*white arrowhead*). Pathology showed papillary thyroid cancer with the primary cancer being located in the right thyroid lobe (*white arrow*).

grade, and often found in the setting of iodine deficiency. FTC tends to be solitary and are slightly more aggressive than PTC. On pathologic evaluation, they have capsular and vascular invasion. Spread occurs via lymphatics, thus most commonly spreading to lung and bone. In the past decade, there have been many new studies showing that noninvasive encapsulated follicular variant PTC has virtually no risk of recurrence, metastasis, or death; however, the presence of more invasive components worsens prognosis. Although these tumors concentrate iodine less than PTC, radioiodine imaging may remain helpful.[22–24]

Medullary

MTC arises from the parafollicular C cells in the thyroid, accounting for 1% to 2% of all thyroid cancers. C cells secrete calcitonin, and the thyroid contains less than 0.01% to 0.1% of these cells. MTCs are typically sporadic, but approximately 25% are associated with hereditary causes such as multiple endocrine neoplasia - type 2A or 2B syndromes or other familial causes linked to the Ret Proto-Oncogene.[25]

At presentation, approximately 48% of the patients have localized disease, 35% have disease extending beyond the thyroid or regional lymphadenopathy, and 13% have metastatic disease to the lung, liver, or bone (**Fig. 8**).[25] MTC often requires a multitude of imaging to evaluate the full extent of disease to best direct management; initially, imaging of the neck is preferred.[16,25] However, if there are elevated tumor markers or symptoms that are concerning for disease recurrence in other parts of the body, these areas are individually imaged. In the asymptomatic patient, imaging is dependent on the calcitonin levels.[16] The current American Thyroid Association guidelines suggest imaging to exclude metastatic disease in

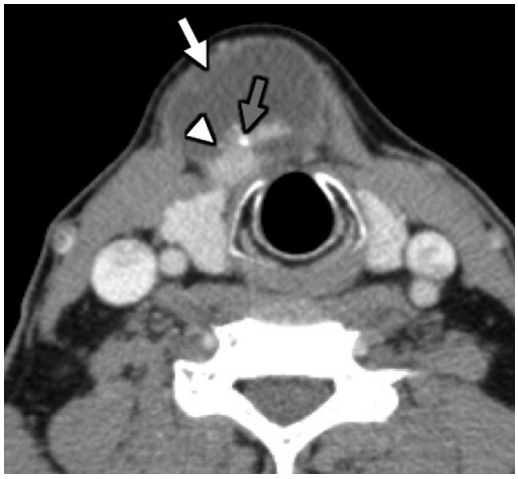

Fig. 7. A 35-year-old woman with an anterior neck mass. Unenhanced CT at the level of the thyroid demonstrates a TDC (*white arrow*) located at midline. Within the cyst, there is nodular, enhancing soft tissue (*white arrowhead*) with a punctate calcification (*gray arrow*). Pathology confirmed papillary thyroid cancer within a TDC.

pretreated patients with a calcitonin greater than 500 pg/mL (1836 pmol/L).[26] Postsurgical patients need imaging to exclude metastatic disease when serum calcitonin is >150 pg/mL (551 pmol/L).[27]

Most patients initially presenting with a palpable neck mass in the fifth or sixth decade of life have a sporadic case of MTC. These tumors are most likely located in the posterior thyroid resulting in compression or invasion of the adjacent structures leading to hoarseness, dysphagia, or respiratory impairment. Ultrasonography typically has nonspecific findings; therefore, CT and MR imaging are used for larger (>3 cm) nodules and to determine substernal extension or structural invasion. When the primary tumor is >1 cm, there is an increased risk for ipsilateral nodal involvement. Smaller thyroid malignancies may be first assessed with ultrasonography, with increased attention to the ipsilateral neck; however, there remains a 36% false-negative rate with these studies. CECT is often used to detect and characterize cervical and mediastinal lymphadenopathy, as well as to evaluate for pulmonary disease (see **Fig. 8**B–C). Although sclerotic or lytic lesions can be detected on CT, evaluation for bone marrow infiltration, spinal canal, and soft tissue is limited; therefore, further evaluation with MR imaging may be necessary.[25]

Surgery remains the only curative treatment in MTC, so detection of distant metastatic disease is critical. At the time of diagnosis, there is 35% to 50% nodal involvement and 10% to 15% distant disease.[25]

Anaplastic

ATC accounts for 1% to 2% of all thyroid malignancies; however, it accounts for more than 50% of all of the thyroid cancer deaths and continues to have the worst prognosis of all thyroid malignancies despite continued improvements in treatment. The mean survival rate remains at approximately 5 months, with the 1-year survival being 20%, and 2-year survival being 10%. ATC has been found to either occur de novo or via dedifferentiation of superimposed DTC. In contradistinction to all of the other thyroid malignancies, all cases of ATC are staged by the American Joint Committee on Cancer TNM stage as Stage IV due to its aggressiveness. Stage IVA is surgically resectable with tumor contained within the thyroid, stage IVB has extrathyroidal extension without distant disease, and stage IVC has distant metastatic disease. Surgical treatment is altered by presence of carotid encasement, vascular involvement, mediastinal extension, lymphadenopathy, distant disease, and invasion of the trachea, larynx, or esophagus.[13]

Typically, ATC presents with a rapidly enlarging neck mass in older patients, as the doubling rate can be as rapid as 1 week. There is a female predominance (1.5:1.0, women:men) with an overall characteristic of significant local invasion and soft tissue necrosis. Despite ultrasonography being the most common study for thyroid disease, these patients frequently undergo CECT due to the rapid neck enlargement. Typically, significant invasion of the adjacent structures occurs, involving the larynx, strap muscles, trachea, esophagus, and TEG. At diagnosis, approximately 40% have nodal spread, and 43% have distant disease. The most common sites of metastatic disease in decreasing order are lung, adrenals, liver, and brain. Death usually occurs from degree of pulmonary disease followed in frequency by airway compromise, hemorrhage, and cardiac arrest. Initial workup of these patients typically includes a high-quality CECT of the neck, whole-body PET-CT, brain MR imaging, and CT chest due to extent of distant disease at diagnosis.[13]

CECT for ATC characteristically shows a large necrotic thyroid mass with ill-defined margins, extrathyroidal extension, and invasion of the adjacent structures, versus DTCs, which are smaller and present with a solid, homogeneous, hypoattenuating nodule. Calcifications are commonly found in both PTC and AT; however, a higher incidence are found with ATC (62%) versus PTC (32%). Lymphoma and ATC can both present

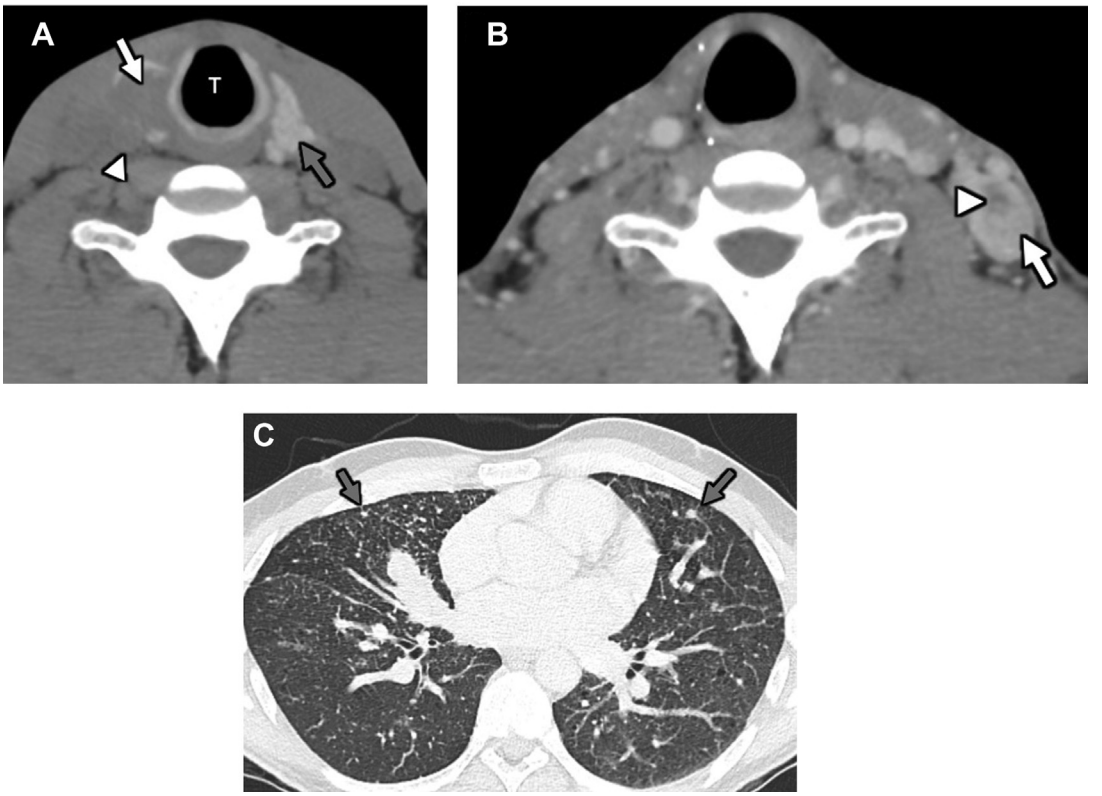

Fig. 8. A 33-year-old man with 2-year history of diarrhea and palpable anterior neck mass. Calcitonin level was 26,000. (*A*) Unenhanced CT axial image at level of thyroid shows ill-defined hypodense mass located in posterior right thyroid (*white arrow*). No definite invasion of the trachea (T) or significant mass effect on the right common carotid artery (*white arrowhead*) is seen. Left thyroid is normal and hyperdense due to the intrinsic iodine (*gray arrow*). (*B*) CECT axial image after total thyroidectomy demonstrates metastatic cervical lymphadenopathy. The enhancing node (*white arrow*) has small central area of necrosis (*white arrowhead*). (*C*) Axial CT of chest demonstrates military pattern of thyroid metastatic disease (*gray arrows*). Patient also had extensive necrotic mediastinal lymphadenopathy and disease in spine and liver.

with a rapidly enlarging neck mass, and distinction of the 2 is extremely important for treatment and diagnosis (flow cytometry is needed for lymphoma). Lymphoma also tends to typically have homogeneous enlargement, no calcifications, and no necrosis. Metastatic ATC also tends to be necrotic, whereas DTC typically is more homogeneously enhancing or solid, but occasionally also can be cystic.[13]

Lymphoma

Lymphoma is rare and accounts for 1.8% to 8.0% of all thyroid malignancies with a strong association with Hashimoto thyroiditis. The typical patient is an elderly woman with a rapidly enlarging thyroid with compressive symptoms. The presentation is very similar to AT; however, ATC is not associated with Hashimoto. On CT, lymphoma can demonstrate low-attenuation masses affecting either a large portion or the entire thyroid (**Fig. 9**). The 5-year survival rate for stage IE is 75% to 89%, with stage IIE falling to 25% to 40%. Lymphoma must be diagnosed early, and the prognosis is largely dependent on the initial stage. Although CT imaging characteristics with clinical symptoms are suggestive of the diagnosis, biopsy remains mandatory and should be targeted to the solid portion of the tumor.[28]

TREATMENT IMPLICATIONS

CT and MR imaging are not routinely used for preoperative evaluation of thyroid cancer because ultrasonography is typically sufficient.[1] However, the recently revised thyroid cancer guidelines and the ACR AC have included a strong recommendation for the preoperative utilization of CT.[5,16] CT and MR imaging are complementary and yield important information especially in the preoperative assessment of advanced and recurrent thyroid

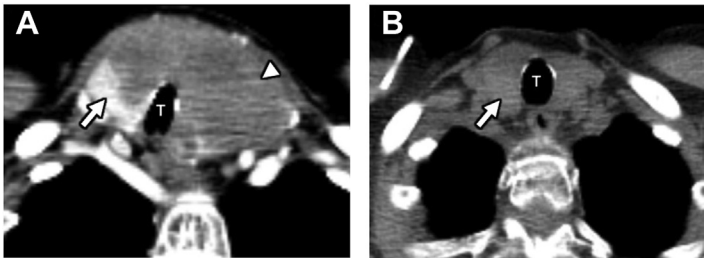

Fig. 9. A 68-year-old woman with long-standing history of Hashimoto thyroiditis with progressed swelling over past 5 days. (*A*) CECT axial image shows thyroidal enlargement with decreased enhancement of most of the thyroid (*white arrowhead*) with small noninvolved, normally enhancing thyroid tissue (*white arrow*). Minimal tracheal (T) narrowing and rightward deviation is present. (*B*) On unenhanced CT axial image after treatment, the thyroid is significantly decreased in size (*white arrow*) without residual tracheal (T) deviation.

carcinoma post-thyroidectomy. Cross-sectional imaging studies also aid in the evaluation of lymphadenopathy, especially in regions more difficult to assess with ultrasonography (ie, retropharyngeal region, mediastinum, low-level IV nodal station). The surgeon must know the extent of both thyroid and nodal disease. Invasion of the surrounding tissues can also be assessed on CT or MR imaging with attention to the paraspinal musculature, esophagus, trachea, larynx, and vasculature.[29]

The primary treatment in patients with thyroid cancer is total thyroidectomy followed by radioiodine, unless only microscopic disease is present.[7] In the past, NECT has been emphasized in thyroid cancer before radioiodine to not cause iodine overload before treatment; however, CECT has been found to be a good adjunct to ultrasonography when advanced disease is suspected, including invasive primary tumor and clinically apparent bulky lymphadenopathy.[4,5] Iodinated contrast is typically cleared from the residual thyroid tissue within 4 to 6 weeks, and thus should not have a significant negative impact on subsequent radioactive iodine analysis or treatment.[5] In the postoperative setting of thyroid cancer, the ACR AC states the utilization of thyroid ultrasonography is usually appropriate, whereas Iodine^{123}/Iodine^{131} whole-body scan, CT neck with contrast, and MR imaging neck with and without contrast may be appropriate.[16]

CT and MR imaging are necessary with a high clinical suspicion for local invasion, which may preclude curative intent or result in a more complicated surgery. The radiologist should focus on the thyroid and adjacent structures within the visceral space, including the trachea, esophagus, larynx, pharynx, and RLN. Imaging findings that raising concern for invasion include encasement of the trachea/esophagus greater than 180°, lumen deformity (see **Fig. 4**), focal mucosal irregularity, mucosal thickening, and effacement of the TEG fat with signs of vocal fold dysfunction.[1] T4a disease is diagnosed in the presence of invasion of any of these central structures.[7] After these more central structures are assessed, the vascular structures, strap muscles, and prevertebral space should be interrogated. If there is any deformation of the CCA, there is a much higher likelihood of arterial invasion. A less specific sign for arterial invasion, is $\geq$180° of soft tissue encasement of the CCA. The CCA is the most commonly invaded artery; however, the mediastinal vessels also need to be assessed (**Fig. 10**).[1] If there is more than 270° of encasement of the mediastinal or carotid arteries, the mass is likely to be unresectable. T4b disease occurs in the presence of vascular invasion.[7] Invasion of the strap muscles is suspected once the mass has extended beyond the external surface of these muscles. Prevertebral muscle involvement is more challenging because the mass can compress the muscle resulting in MR imaging signal changes without actual invasion. Last, metastatic disease should be assessed. PTC and MTC both more typically spread to the regional lymph nodes, whereas FTC more commonly spreads to the lung and bones. ATC is very locally aggressive, but it can also spread to lymph nodes and lung. Thyroid cancer nodal disease typically involves level VI first, followed by levels II-V. Despite these more common nodal levels, metastasis from thyroid cancer also can go to the retropharyngeal nodes (**Fig. 11**), retroesophageal nodes, and the superior mediastinal nodes.[1]

Thyroid malignancy can also result in occlusion or effacement of the IJV; however, this does not influence the surgically resectability or stage. The IJV is easily compressible and thus can be occluded or effaced without invasion. Also, the presence of venous occlusion is not a reliable finding to suggest invasion.[7]

DIFFERENTIAL DIAGNOSIS

- Rapidly enlarging thyroid: lymphoma, ATC
- Palpable, firm, enlarging thyroid: lymphoma, ATC, thyroid sarcoma, Riedel thyroiditis

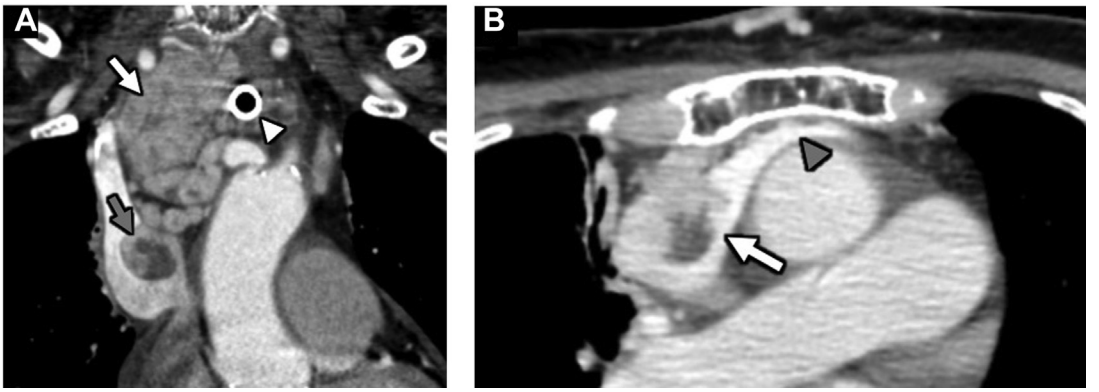

Fig. 10. A 74-year-old woman with papillary thyroid cancer and components of poorly differentiated thyroid cancer presenting with increasing shortness of breath. (*A*) CECT coronal image shows thyroidal enlargement enlarged thyroid (*white arrow*) with leftward tracheal deviation with endotracheal tube in place (*white arrowhead*). Inferior extension of thyroid into superior mediastinum is present with invasion of the superior vena cava (*gray arrow*). (*B*) CECT axial image at the level of the brachiocephalic vein (*gray arrowhead*) as it enters the superior vena cava shows the mass invades the adjacent vein (*white arrow*), rather than just compressing.

- Cystic lymphadenopathy: thyroid or human papillomavirus squamous cell carcinoma metastatic disease
- Calcifications in lymph nodes: thyroid carcinoma, granulomatous disease, treated lymphoma
- Cystic cervical lymph nodes in a young woman: consider thyroid carcinoma
- There can be ectopic thyroid tissue from the level of the foramen cecum to the thyroid bed, and this tissue can have same ailments as the normally positioned thyroid

PEARLS, PITFALLS, VARIANTS

- Presence of calcifications is nonspecific but can suggest malignancy
  - Punctate calcifications more likely to be due to PTC
- Retropharyngeal lymph node: think of nasopharyngeal, sinonasal, and thyroid carcinoma

WHAT THE REFERRING PHYSICIAN NEEDS TO KNOW

- Degree of substernal extension
- Deviation/compression of the adjacent structures ± suspected invasion
- Vocal fold asymmetry
- Cervical lymphadenopathy

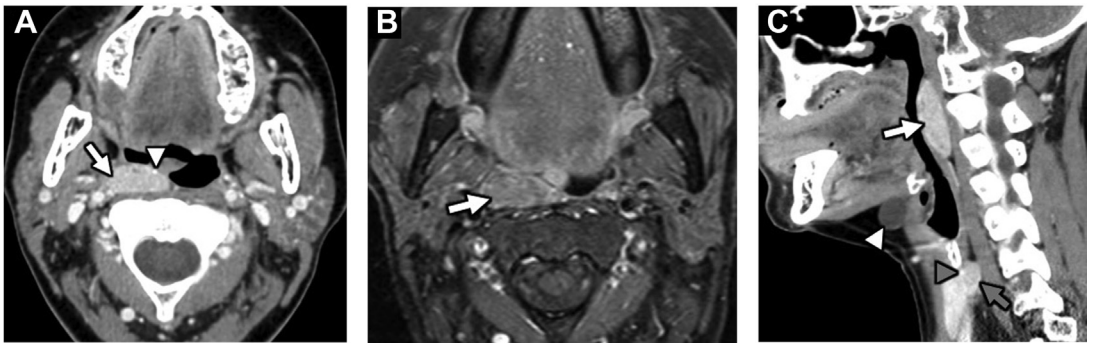

Fig. 11. A 39-year-old woman with an enlarging central neck mass for 1 year. (*A*) CECT axial image demonstrates an avidly enhancement right retropharyngeal lymph node (*white arrow*) with punctate calcification (*white arrowhead*). (*B*) T1-weighted contrast-enhanced, fat-saturated, axial MR image demonstrates enhancing retropharyngeal lymphadenopathy (*white arrow*). (*C*) CECT sagittal image shows the retropharyngeal lymph node (*white arrow*) positive for metastatic papillary thyroid cancer. Primary thyroid malignancy is in right thyroid (*gray arrow*) with a punctate calcification (*gray arrowhead*). Palpable central neck mass (*white arrowhead*) was a ruptured dermoid cyst.

- Suspicion of malignancy and whether biopsy is required

SUMMARY

Evaluation of thyroid disorders has continued to evolve; in the past, cross-sectional imaging was not used as it is currently. CT and MR imaging have become important in the preoperative assessment of benign etiologies such as thyroid goiter but are also important in the initial evaluation of thyroid malignancies and recurrent disease. It is important to discuss in the imaging report the substernal extent of the thyroid, extrathyroidal extension of disease, compression/displacement of the surrounding structures, and whether there is invasion of the adjacent structures as these findings can alter the surgical plan.

DISCLOSURE

The authors have nothing to disclose.

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