REVIEW ARTICLE

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Role of CT and MRI in the Preoperative Evaluation of Thyroid Nodules and Differentiated Thyroid Cancer

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In the preoperative evaluation of the patients with thyroid nodules and differentiated thyroid cancer, we aimed to review the basics for the acquisition and interpretation of CT (computed tomography) and MRI (magnetic resonance imaging) and to describe imaging checklists that radiologists should know about. Familiarity with CT and MRI checklists in the preoperative evaluation of thyroid cancer may help surgeons in treatment planning and patient management.

Key Words: Thyroid cancer, Computed tomography, Magnetic resonance imaging

Introduction

High-resolution ultrasonography is the current imaging modality of choice for evaluating the thyroid nodule because it has better sensitivity and specificity in differentiating between benign and malignant nodules. According to the 2009 Revised American Thyroid Association management guideline, routine use of alternative imaging modalities such as CT (computed tomography) and MRI (magnetic resonance imaging) is not recommended.[1] However, CT and MRI may be preferable in some clinical settings because they provide additional anatomical information about the surrounding cervical structures including the thyroid gland.[2-4] It is especially helpful to use CT or MRI when ultrasonographic evaluation is uninformative, as in a case of retrotracheal or mediastinal invasion of thyroid cancer or extensive lymph node metastasis.

The purposes of this study are to review the basic imaging techniques of CT and MRI and to describe imaging checklists that radiologists should know about during the preoperative interpretation of CT and MRI in the patients with thyroid nodules and differentiated thyroid cancer.

Imaging Techniques of CT and MRI

CT is usually performed in the supine position with mild neck extension, according to the general acquisition method of neck CT after intravenous contrast administration. Placing the patient's arms by the side can minimize exaggeration of the substernal goiter excursion on the acquired image.[5] Axial images are acquired vertical to the hard palate from the skull base to the superior mediastinum with a reconstructed slice thickness of approximately 3 mm. It is recommended that a total of 100 ml of an iodinated contrast agent be injected intravenously at the rate 1.5～3 ml/s using an automated injector, and scan delay time is 40～60 sec after contrast administration. However, some authors suggest that earlier image acquisition in the arterial or early equilibrium phase can distinguish, with more sensitivity, metastatic lymph

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nodes of thyroid cancer from the reactive ones, because most thyroid malignancies and their metastatic lymph nodes are hypervascular.[6] Additionally, precontrast CT is helpful in detecting calcification of the thyroid nodule and differentiating tumor recurrence from remnant thyroid tissue, however routine acquisition of precontrast images is not usually recommended.

Multi-detector row computed tomography (MDCT), now commonly used, provides better image quality with rapid image acquisition and various multiplanar reformation techniques. Sagittal or coronal reformatted images might be especially helpful for evaluating lymph node enlargement in the central compartment and substernal extension of a goiter (Fig. 1).

Fig. 1. A 74-year-old man with thyroid cancer. Lymph node enlargement in the central compartment (arrow) is well depicted on contrast-enhanced CT with coronal reformatted images.

MRI is generally performed by positioning the patient in the same way as for CT and coils appropriate to neck imaging, T1-, T2-weighted, and gadolinium-enhanced images with 5-mm section thickness are usually acquired.

MRI is more useful than CT, especially in evaluating tumor invasion in the trachea, esophagus, and surrounding muscles because of better soft tissue contrast.[2] Recently, it has been reported that the apparent diffusion coefficient (ADC) is also helpful in differentiating benign and malignant thyroid nodules.[7]

Imaging Characteristics of Thyroid Gland

In CT, the normal thyroid gland shows higher attenuation in comparison with adjacent cervical structures with an 80∼100 Hounsfield unit (HU) because it contains an approximately 100-fold higher concentration of iodine than serum (Fig. 2). Therefore, CT attenuation of the thyroid gland prior to contrast administration reflects the function of the thyroid gland.[8] An iodine contrast agent may impair iodine uptake by the thyroid for up to 4 weeks, thus caution should be taken for patients anticipating postoperative radioactive iodine treatment for the CT examination and treatment schedules.[9]

On MRI, in comparison with adjacent muscles, the thyroid gland showed iso- or slight hyperintensity on T1-weighted images, hyperintensity on T2-weighted images, and homogeneous contrast enhancement (Fig. 3). It is the benefit of gadolinium contrast agent

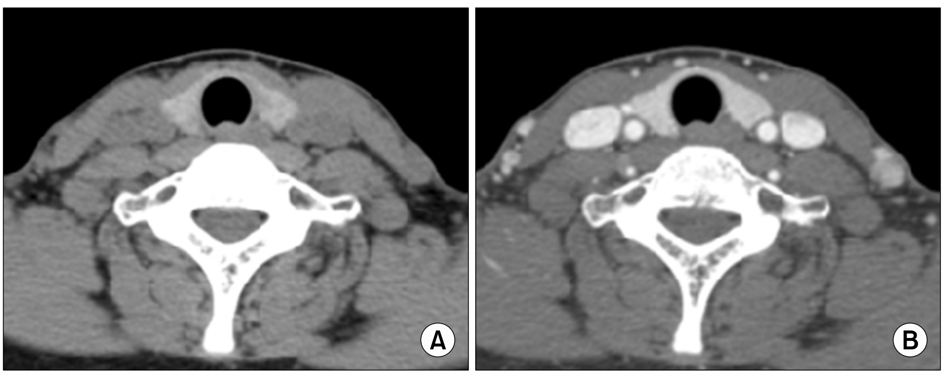

Fig. 2. A 49-year-old woman with normal thyroid function. (A and B) Normal thyroid gland shows higher attenuation compared to the adjacent structures on nonenhanced CT (A) and homogeneous contrast enhancement on contrast-enhanced CT (B).

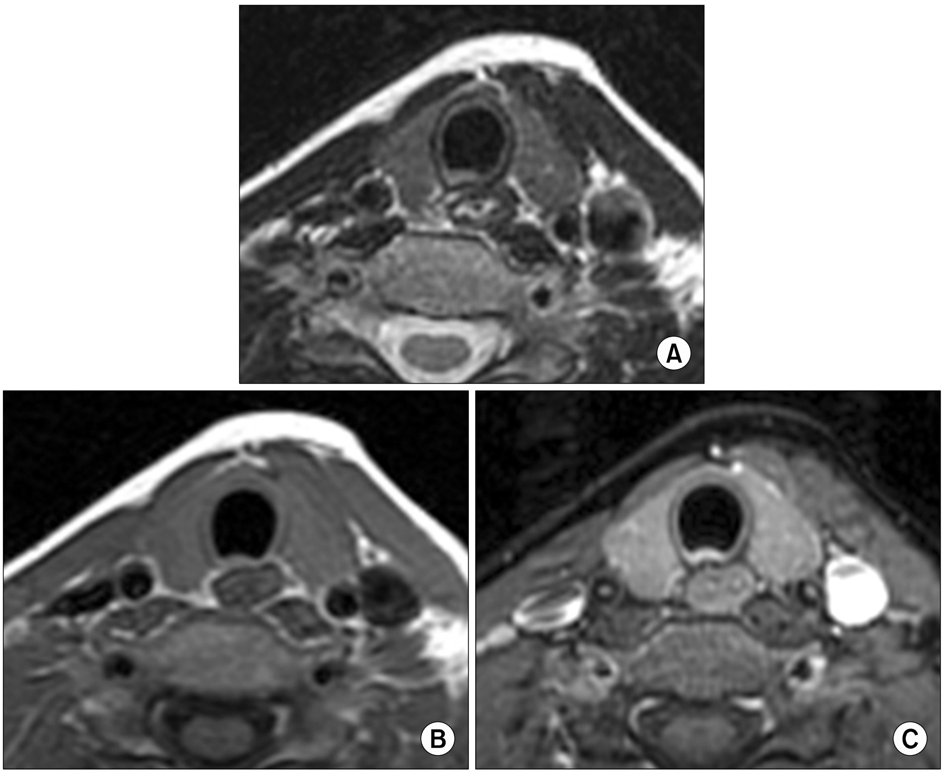

Fig. 3. A 45-year-old woman with normal thyroid function. (A–C) In comparison to adjacent muscles, the thyroid gland shows high signal intensity on T2-weighted MR images (A), iso- to hyperintensity on T1-weighted MR images (B), and homogeneous contrast enhancement (C).

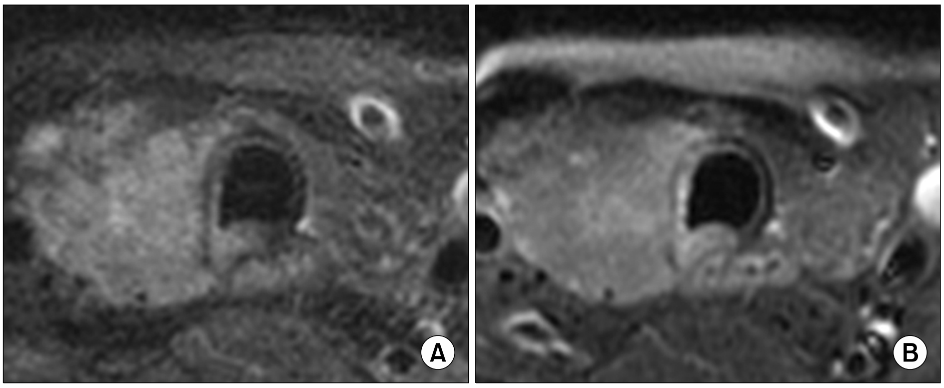

Fig. 4. A 56-year-old woman with thyroid cancer. (A and B) Focal enhanced soft-tissue signal in the right lateral wall of tracheal cartilage on axial fast spin-echo T2- weighted MR images (A) and contrast-enhanced T1-weighted MR images (B) suggest tracheal invasion of thyroid cancer.

that does not impair iodine uptake.

Imaging Checklists in Preoperative Evaluation

Assessment of adjacent tissue invasion and preoperative staging

The preoperative staging is essential in order to select the appropriate surgical extent and to predict patient's prognosis.[1,10] Staging for thyroid cancer is now based on the recently issued seventh edition of the AJCC/UICC (American Joint Committee on Cancer/International Union Against Cancer) TNM classification system in 2009.[11]

MRI is used to assess adjacent organ invasion of thyroid cancer (i.e. the trachea, esophagus, carotid artery, muscles) and for preoperative staging. When an intraluminal mass, soft-tissue signal in tracheal cartilage, or tumor circumference $>180^\circ$ around the trachea are observed on MRI, tracheal invasion may be suspected (Fig. 4).[12] A circumferential mass $>180^\circ$ or focal T2 signal abnormality on the esophageal wall suggests the presence of esophageal invasion (Fig.

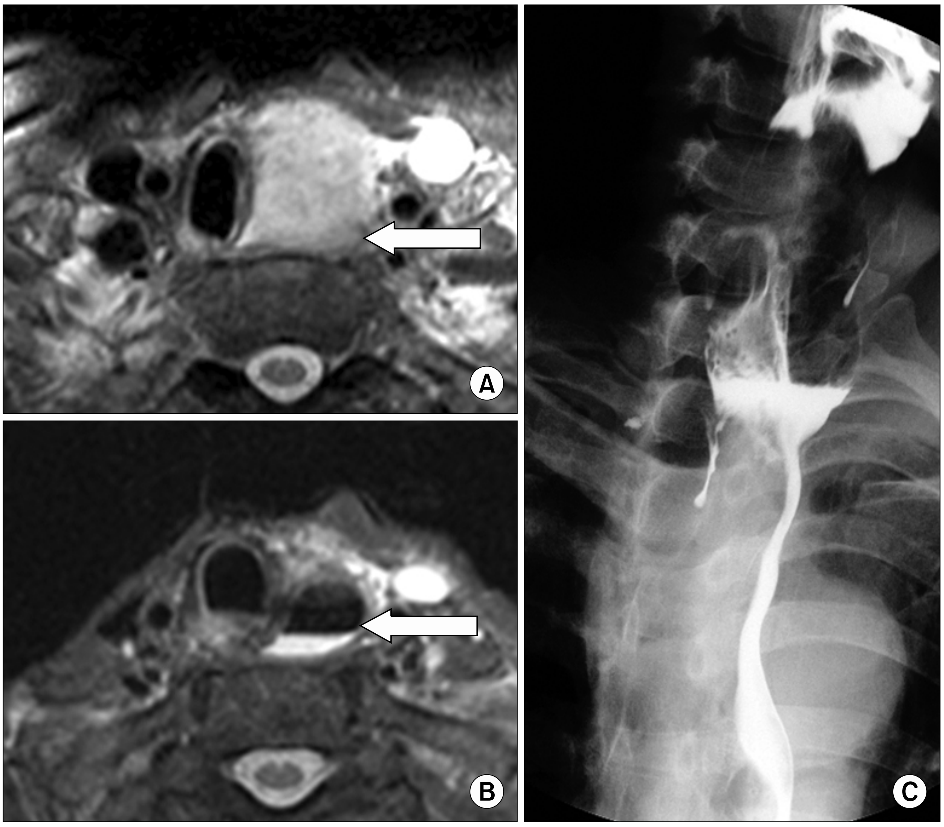

Fig. 5. A 62-year-old man with thyroid cancer. (A and B) Axial fast spin-echo T2-weighted MR image with fat saturation shows esophageal invasion by thyroid cancer (A, arrow) and dilatation of proximal esophageal lumen (B, arrow). (C) Barium swallow study also demonstrates esophageal invasion.

Fig. 6. A 67-year-old man with thyroid cancer. (A and B) Axial contrast-enhanced CT shows effacement of normal fatty tissue in the tracheoesophageal groove by the thyroid cancer (A, arrow) and paralysis of the right true vocal cord (B).

5).[13] In addition, the effacement of normal fatty tissue in the tracheoesophageal groove may be a predictive factor of recurrent laryngeal nerve invasion (Fig. 6),[14] and signal alteration of muscles or the presence of contrast enhancement in muscle suggests muscle invasion of tumor.[15,16]

CT also can depict intraluminal mass or tumor extension into tracheoesophageal groove, but MRI is superior, especially in the evaluation of tumor invasion into the adjacent soft tissue organ.

Assessment of lymph node metastasis

The spread pattern and prognosis of lymph node metastasis of thyroid cancer are completely different from other head and neck cancers and their N staging follows a different classification method. The first drainage route of thyroid cancer is level VI, such as the paralaryngeal, paratracheal, and prelaryngeal areas. CT has slightly higher sensitivity and specificity than ultrasonography in the detection of lymph node metastasis in the central and lateral compartments of the neck.[6,17,18] Particularly, CT and MRI are useful for assessing the lymph node metastasis in the retropharyngeal space and the mediastinum that could not be assessed by ultrasonography (Fig. 7).

To differentiate metastatic lymph nodes from benign lymph nodes, diverse imaging methods have been suggested but definite diagnostic imaging criteria have not yet been established. The criteria of a pathological lymph node on CT and MRI are based on size in other head and neck cancers and if the minimum or maximum diameter of a lymph node is longer than 10 mm, it is considered a pathologic lymph node.[19] It has been also known that cystic or necrotic change, calcification, dense cortical enhancement without hilar vessel enhancement, and focal area of high attenuation on precontrast CT are findings suggestive of lymph node metastasis of thyroid cancer on CT.[6,17,20,21] Lymph nodes showing cystic changes, even when small in size, are an especially distinct sign of papillary thyroid carcinoma metastasis (Fig. 8).

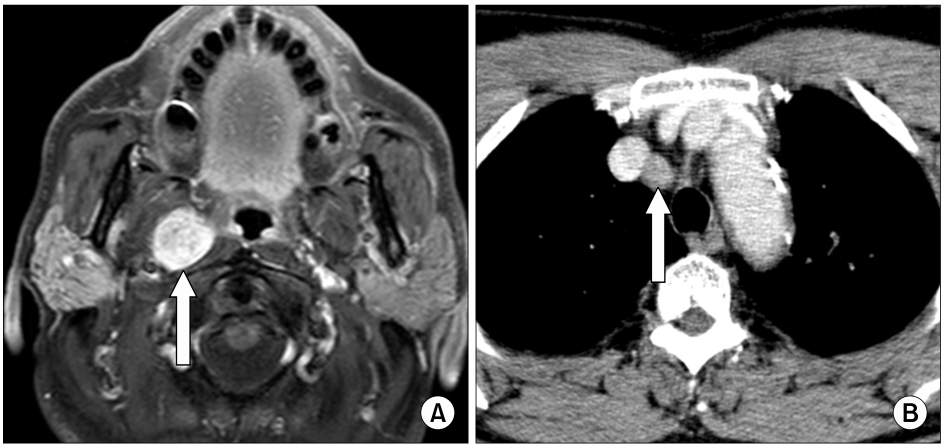

Fig. 7. A 65-year-old woman with thyroid cancer. (A) Axial fast spin-echo T2-weighted MR image with fat saturation shows lymph node metastasis of thyroid cancer in retropharyngeal space (arrow). (B) Axial contrast-enhanced CT shows lymph node metastasis of thyroid cancer in the mediastinum (arrow).

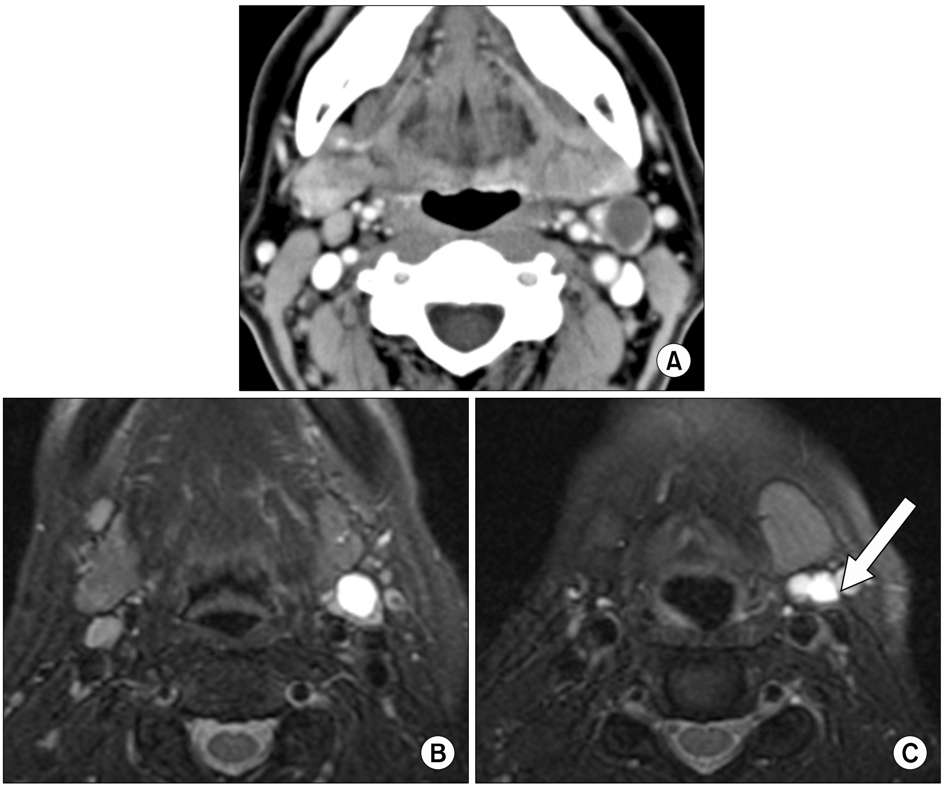

Fig. 8. A 57-year-old woman with thyroid cancer. (A and B) Axial contrast-enhanced CT (A) and axial T2-weighted fast spin-echo MR image with fat saturation (B) show cystic lymph node metastasis of papillary thyroid cancer. (C) Fluid-fluid level (arrow) is seen within the lymph node on axial T2-weighted fat-saturated fast spin-echo MR image.

Evaluation of mediastinal extension

For cases of substernal goiter, CT and MRI accurately evaluate the size and extent of the enlarged thyroid gland prior to surgery and depict its relationship to the blood vessels in the mediastinum (Fig. 9). Sternotomy or thoracotomy could not be avoidable when the patient had an intrathoracic goiter.[22)]

Detection of ectopic or accessory thyroid tissue

Ectopic thyroid tissue can be found at any location along the migration path from the foramen cecum to the mediastinum. The lingual thyroid is most common, accounting for 90% of reported cases, and other rare sites of ectopic thyroid gland include the mediastinum, esophagus, lung, heart, aorta, breast, and abdomen. The most common site of ectopic thyroid tissue in neck is the submandibular region, and other rare locations such as carotid bifurcation have been reported.[23)]

Ecpotic thyroid tissue can exist with or without a coexisting normally located thyroid gland and it is the only functional thyroid tissue in 70∼80% of cases, which radiologists should know. CT can be helpful in the simultaneous detection of ectopic thyroid tissue and a normally functioning thyroid gland (Fig. 10).

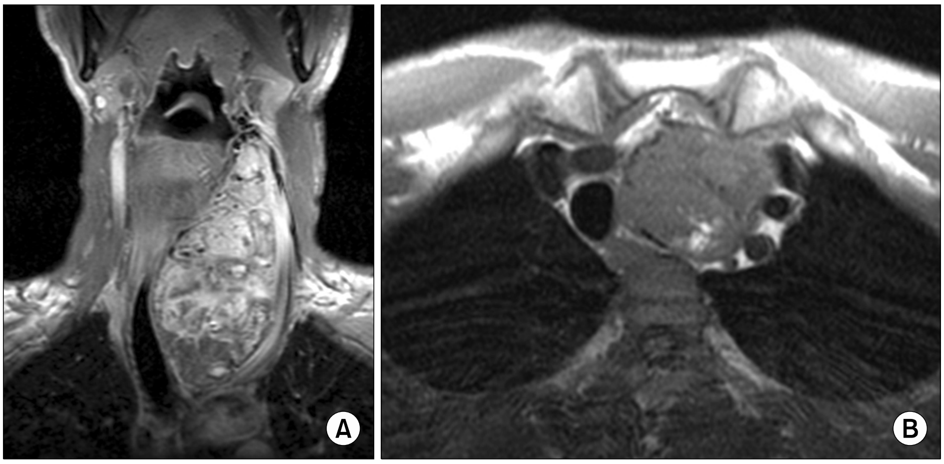

Fig. 9. A 39-year-old man with a substernal goiter. (A) Coronal contrast-enhanced T1-weighted MR image demonstrates substernal extension of a goiter. (B) Axial T1-weighted MR image depicts the relationship of the goiter to the major neck vessels in the mediastinum.

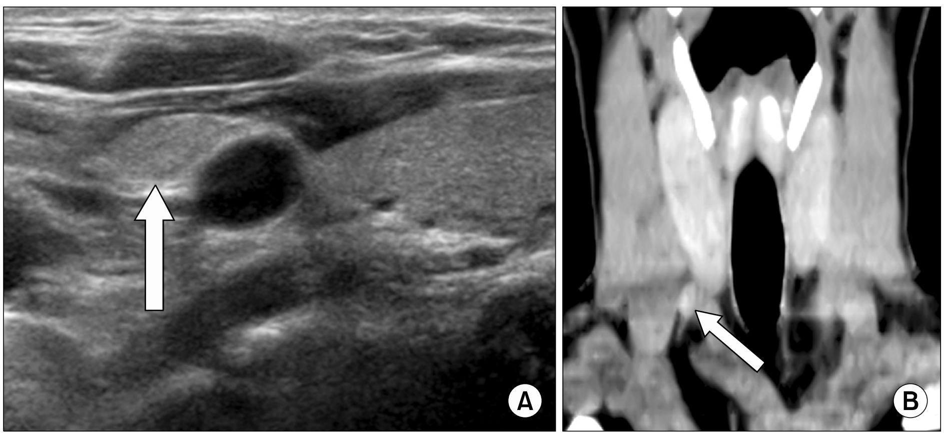

Fig. 10. A 41-year-old woman with a lateral neck mass incidentally found during a check-up. (A) Sonogram demonstrates an echogenic mass (arrow) in the right lower neck, anterolateral to the common carotid artery, which shows similar echotexture to that of the thyroid gland. (B) Coronal nonenhanced CT shows small ectopic thyroid tissue (arrow) in the right lower lateral neck and coexisting normally located thyroid gland, which show higher attenuation in comparison with adejacent cervical structures. Fine needle aspiration biopsy reveals a thyroid tissue.

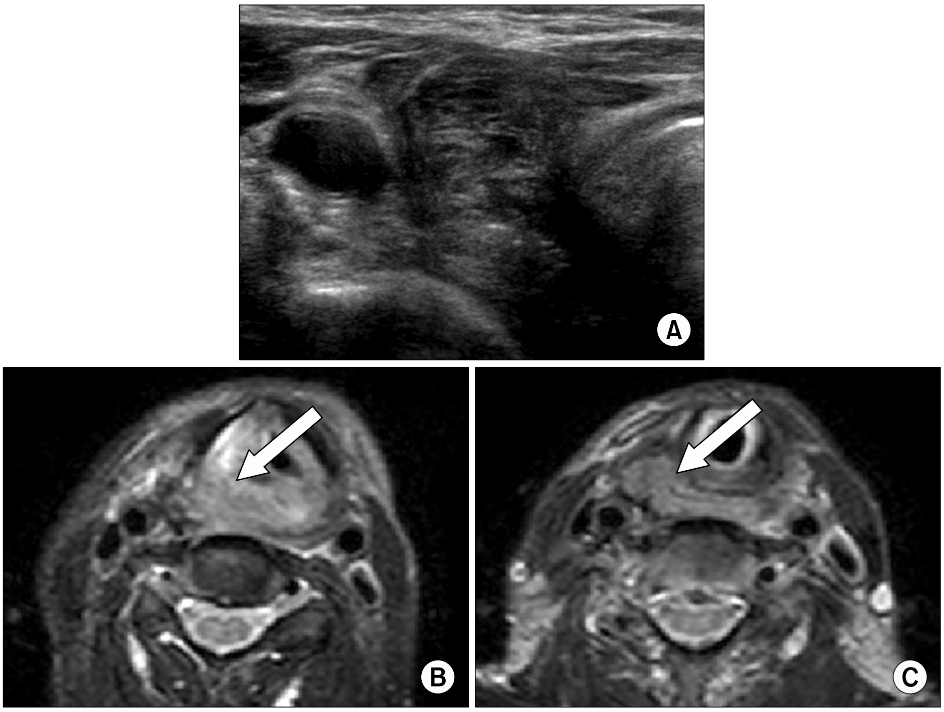

Fig. 11. A 63-year-old woman with hypopharyngeal cancer revealed on MRI. (A) Sonogram of thyroid gland shows an hypoechoic mass in the right thyroid lobe. (B and C) Axial T2-weighted fast spin-echo MR images show hypopharyngeal cancer arising from the right pyriform sinus (B, arrow) and thyroid invasion by the tumor (C, arrow).

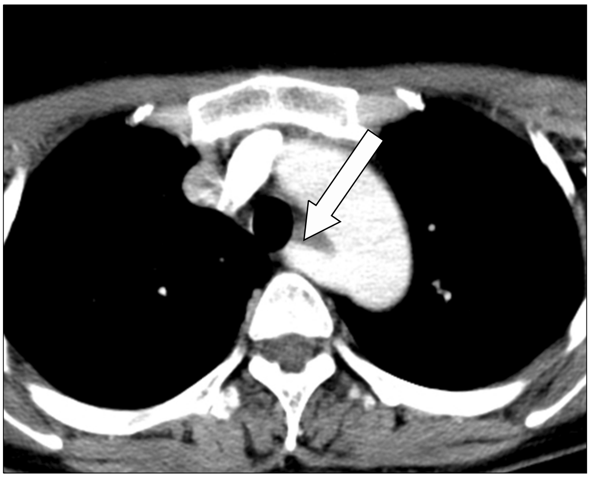

Fig. 12. A 40-year-old woman with thyroid cancer. The right aberrant subclavian artery (arrow) is incidentally seen on axial contrast-enhanced CT, suggesting the presence of a right non-recurrent inferior laryngeal nerve.

Differentiation from other neck masses

The trachea, hypopharynx, esophagus, parathyroid glands, lymph nodes, and other cervical structures are located near the thyroid gland. Many lesions originating from the anterior neck could mimic thyroid nodules.[24] Ultrasonography has limitations in evaluating deep cervical structures, and CT or MRI is required to accurately assess the anatomic origins of neck masses and determine the character and extent of the lesion (Fig. 11).

Identification of anatomical variations

When an aberrant right subclavian artery exists, the recurrent laryngeal nerve does not follow the normal traveling pathway and branches directly from the vagus nerve instead of taking a recurrent course and traveling below the subclavian artery. Thus, it is referred to as the "non-recurrent inferior laryngeal nerve." It is a developmental anatomical variation, and this rare entity should be considered when identifying the recurrent laryngeal nerve during thyroid gland surgery (Fig. 12). The incidence has been reported to be 0.52~0.7% and it appears only on the right side.[25,26]

Conclusion

CT and MRI are alternative imaging modalities in the evaluation of thyroid cancer because of their lower sensitivity and specificity in the detection and characterization of thyroid nodule than ultrasonography. However, in order to select the appropriate surgical procedure in the patients with thyroid cancer, accurate preoperative evaluation of disease extent and recognition of anatomic variations which surgeons need to know by CT or MRI are essential. Therefore, the imaging checklists in the preoperative interpretation of CT and MRI should be made known to the radiologists.

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