Oral Cavity, Larynx, and Pharynx

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Imaging of the oral cavity, the larynx, and the pharynx must be coordinated with the clinical exam [1, 2]. The information acquired at imaging usually emphasizes the deeper tissues as the superficial assessment is done by direct visualization. The description of the anatomy is key to description of any lesion.

Anatomy

Oral Cavity

The oral cavity extends from the lips and oral fissure to the oropharyngeal isthmus. It is bounded anteriorly and laterally by the lips and cheeks. The roof of the oral cavity consists of the hard and soft palate, and its floor is formed by the muscular oral floor and the structures it supports.

The tongue occupies almost all of the oral cavity when the mouth is closed, its upper surface lying against the palate. The musculature of the tongue consists of intrinsic muscles as well as extrinsic muscles that are inserted into the tongue. The posterior limit of the oral cavity is made up of the anterior tonsillar pillars and the circumvallate papillae along the dorsum of the tongue.

The floor of the mouth is inferior to the tongue. Immediately inferior to the mucosal is the sublingual gland in the sublingual pace. The mylohyoid muscle supports the floor of the mouth with the geniohyoid/genioglossal muscle complex vertically segmenting the soft tissues above the mylohyoid.

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Pharynx

The pharynx consists of the nasopharynx, the oropharynx, and the hypopharynx.

Nasopharynx

The nasopharynx is the upper portion of the pharynx. The sphenoid bone forms the roof of the nasopharynx, while the floor and junction with the oropharynx are at the level of the soft palate. These anatomic relationships are best seen on sagittal and coronal sections. The pharyngeal recess (fossa of Rosenmüller) is a pouch-like recess in the lateral wall of the nasopharynx directed toward the parapharyngeal space and lying directly adjacent to the torus tubarius and the eustachian tube orifice. Many nasopharyngeal malignancies have their origin in the fossa.

Oropharynx

The oropharynx extends from the soft palate/uvula to the margin of the epiglottis. The palatine tonsils are located along the lateral walls of the oropharynx. The anterior and posterior pillars converge superiorly at a sharp angle to form the supratonsillar fossa. Portions of the tongue base and valleculae belong to the oropharynx. The principal superficial structures are the paired palatine tonsils.

Hypopharynx

The hypopharynx extends from the oropharynx to the supraglottic portion of the larynx. It is bounded superiorly by the free margin of the epiglottis and the lateral pharyngoepiglottic folds that form the valleculae. The left and right piriform sinuses and post-cricoid region represent the lower part of the hypopharynx.

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Larynx

The larynx opens from the anterior wall of the hypopharynx and extends to the trachea.

Important Mucosal Landmarks

Several key anatomic structures are important to the radiological assessment of the larynx. Perhaps the most important relationship in the larynx is that of the false vocal fold, true vocal fold, and ventricle complex. The ventricle is a crucial reference point. Much imaging of tumors is aimed at defining the location of a lesion relative to this key landmark. Another important landmark is the upper margin cricoid cartilage. This cartilage is the only complete ring of the cartilage framework and thus is key to the integrity of the airway.

The true vocal folds (cords) play a major role in speech. The cords stretch across the lower larynx and are in the horizontal or axial plane. The small crease just above the true vocal fold is called the ventricle. Immediately above the ventricle and again parallel to both the ventricle and true fold are the false vocal folds. The mucosa curves out laterally from the false vocal folds to the upper edges of the larynx at the aryepiglottic folds.

These structures are the basis for anatomic localization within the larynx. The glottic larynx refers to the true vocal folds. The glottis has been defined as extending from the ventricle to a plane approximately 1 centimeter below the ventricle. Here, the glottis merges with the subglottis (the lower part of the larynx). The subglottis extends from the lower margin of the glottis to the inferior margin of the cricoid cartilage. Everything above the ventricle of the larynx is part of the supraglottis.

Another important anatomic term is the anterior commissure. This is the point where the true folds converge anteriorly and the vocal ligaments insert into the thyroid cartilage.

Cartilage Framework

The cartilages make up the framework of the larynx and give it structure (Fig. 1). The cricoid cartilage is the foundation of the larynx. The arytenoid cartilages perch upon the posterior edge of the cricoid at the cricoarytenoid joint. Above the cricoid is the thyroid cartilage. This shield-like cartilage provides protection to the inner workings of the larynx. The epiglottis is a fibrocartilage extending behind the thyroid cartilage in the supraglottic larynx.

In axial imaging the cartilages can help orient us to the mucosal levels in the larynx (Fig. 2). The cricoid is at the level of the glottis and subglottis. The upper posterior edge of the cricoid cartilage is actually at the level of the true folds and ventricle. The lower edge of the cricoid cartilage represents the lower boundary of the larynx and, therefore, the lower edge of the subglottis.

The arytenoid cartilage spans the ventricle. The upper arytenoid is at the level of the false fold, whereas the vocal process defines the position of the vocal ligament and, therefore, the true fold. The epiglottis is totally within the supraglottic larynx.

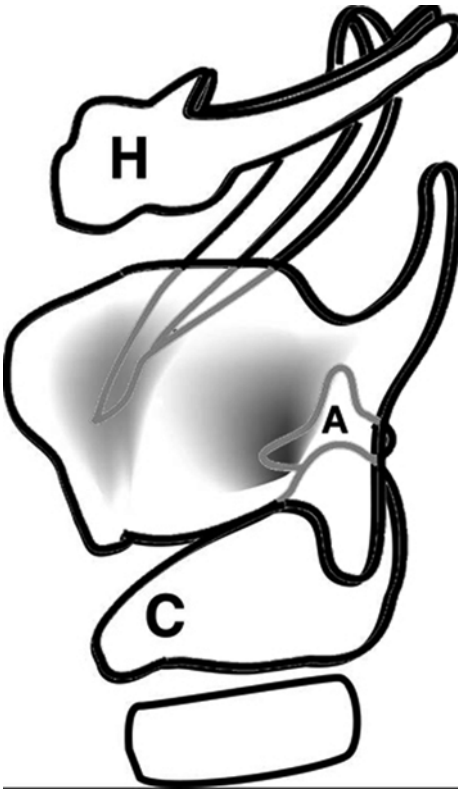

Fig. 1 Line diagram showing the relationships of larynx cartilages. The thyroid cartilage attaches to the signet-ring-shaped cricoid cartilage (*C*). The arytenoid cartilages (*A*) perch on the posterior aspect of the cricoid cartilage. The epiglottis is protected by the hyoid bone (*H*) and the thyroid cartilage

Deep Soft Tissues

Muscles There are many muscles within the larynx. The key muscle for the radiologist is the thyroarytenoid muscle. This forms the bulk of the true fold or cord and extends from the arytenoid to the anterior part of the thyroid cartilage at the anterior commissure. The radiologist should be familiar with this muscle because identifying this muscle identifies the level of the true vocal fold.

Paraglottic Space The paraglottic space refers to the major part of the soft tissue between the mucosa and the cartilaginous framework of the larynx. At the supraglottic or false fold level, the space predominantly contains fat, whereas at the level of the true fold, the paraglottic region is filled by the thyroarytenoid muscle (Fig. 2). Again, this concept is helpful in orienting one to the level within the larynx. The level of the ventricle is identified as the transition between the fat and muscle. At the level of the subglottis, the paraglottic space essentially disappears.

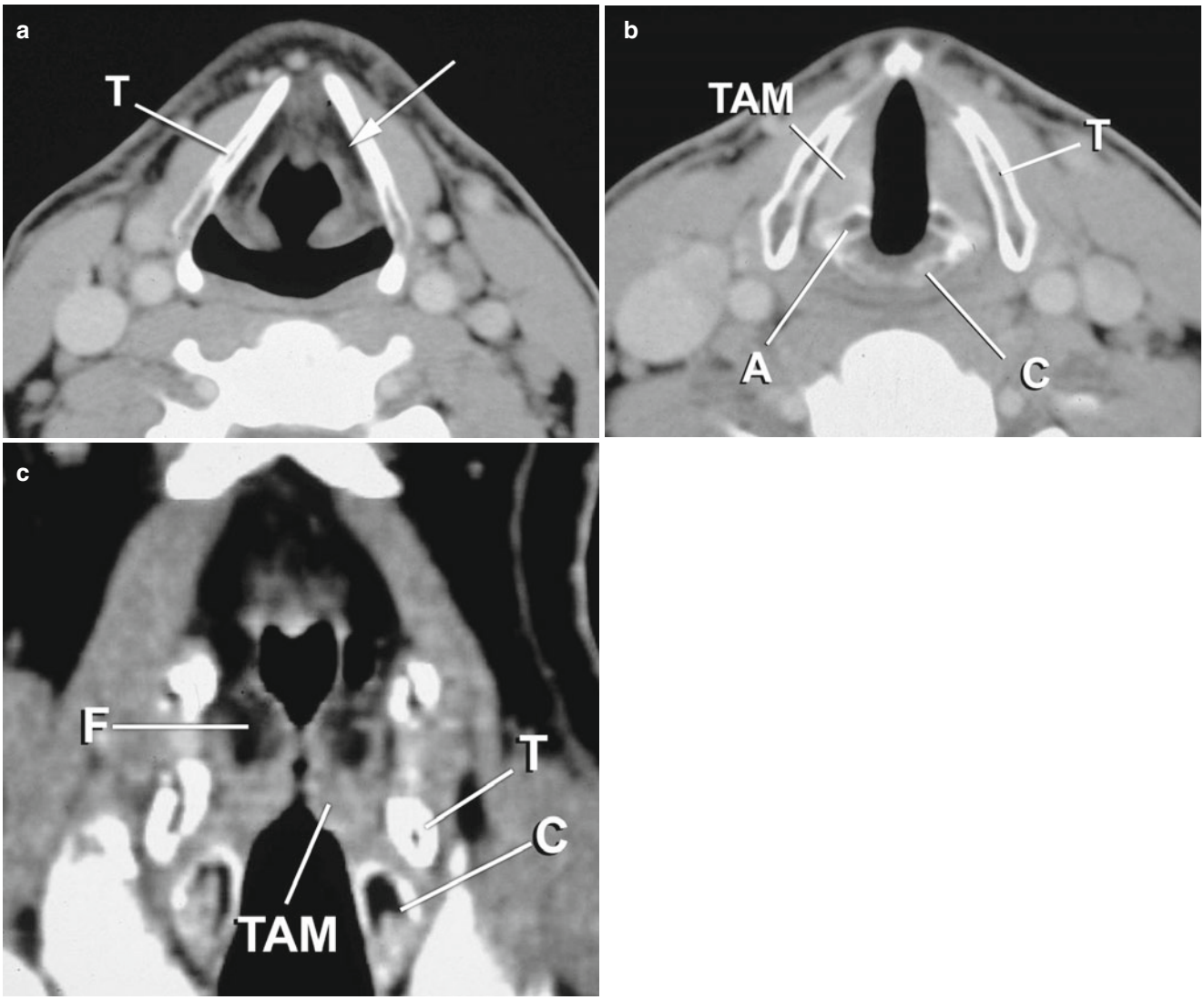

Fig. 2 Normal CT. (**a**) Axial image through the supraglottis. Notice the fat (*arrow*) in the paraglottic space of the lateral larynx. (*T*) Thyroid cartilage. (**b**) Axial image through the level of the true cord. The thyroarytenoid muscle (*TAM*) makes up the bulk of the true cord. Other structures seen at this level include the thyroid cartilage (*T*), the upper edge of the posterior cricoid cartilage (*C*), and the arytenoid cartilage (*A*). The vocal ligament attaches to the anterior margin or vocal process of the arytenoid cartilage. (**c**) Coronal image through larynx. The thyroarytenoid muscle (*TAM*) makes up the bulk of the true cord or fold. Note the fat (*F*) in the paraglottic space of the supraglottis. The ventricle is not seen but can be predicted to be at the level of the transition of fat to muscle. (*C*) Cricoid cartilage; (*T*) thyroid cartilage

The pre-epiglottic space is the fat-filled region anterior to the epiglottis in the supraglottic larynx.

Pathology and Imaging

Nasopharynx

Five percent of all malignant tumors of the head and neck originate in the nasopharynx, and more than 90 % of these are carcinomas. The most common nasopharyngeal malignancies in adults are squamous cell carcinoma and lymphoepithelial neoplasms. Lymphomas and rhabdomyosarcomas are more common in children and tend to undergo early, extensive lymphogenous spread.

Benign nasopharyngeal tumors are rare. However, cystic lesions within the mucosa of the nasopharynx (e.g., retention cyst, Tornwaldt cyst) are quite common. Detection and the evaluation of the infiltration pattern are the main goal of imaging. MR imaging is the method of choice for the evaluation of the nasopharynx [3].

Oropharynx and Oral Cavity

Most tumors of the oropharynx and the oral cavity are detected during clinical examination. However, the infiltration pattern (e.g., tongue base, perineural spread, infiltration of the pterygopalatine fossa, and contiguous tissues) is

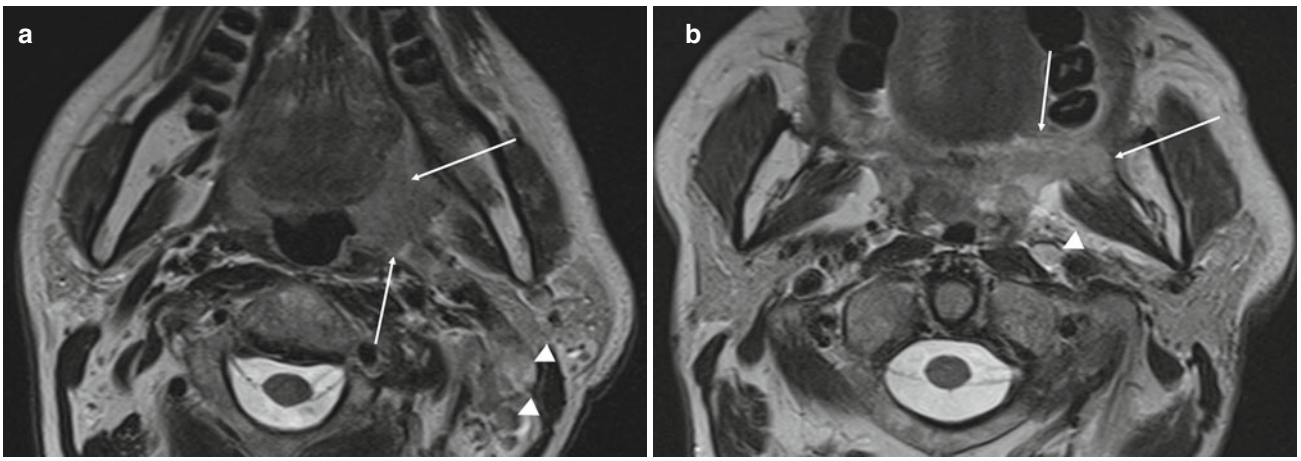

Fig. 3 Carcinoma of the tonsil. (**a**) Level of the tonsil. The tumor (*arrows*) infiltrates of the constrictor muscles and the parapharyngeal space. Metastatic lymph node, level 2 (*arrowhead*). (**b**) Level of the retromolar trigone shows tumor (*arrows*). There is infiltration of the masticator space. Metastatic retropharyngeal node – *arrowhead*

critical and has significant influence in the management of the patient (Fig. 3). In addition the increase in human papillomavirus (HPV)-associated head and neck squamous cell carcinoma plays an important role [4, 5]. MR imaging is usually preferred for the evaluation of the oropharynx and the oral cavity as it is less affected by dental artifacts and is providing a better evaluation of the infiltration pattern [6–8].

The floor of the mouth is immediately inferior to the tongue. Squamous cell carcinoma can invade the deeper soft tissues and can invade the inner cortex of the mandible. Imaging plays a role in defining the extension of cancers and also plays a role in evaluation of submucosal masses in the floor of the mouth. Ranulas and sublingual gland tumors tend to arise off midline, while dermoid complex lesions tend to be midline within the genioglossus/geniohyoid complex. The relationship of a lesion to the mylohyoid muscle is key to surgical planning as well as to diagnosis (Fig. 4).

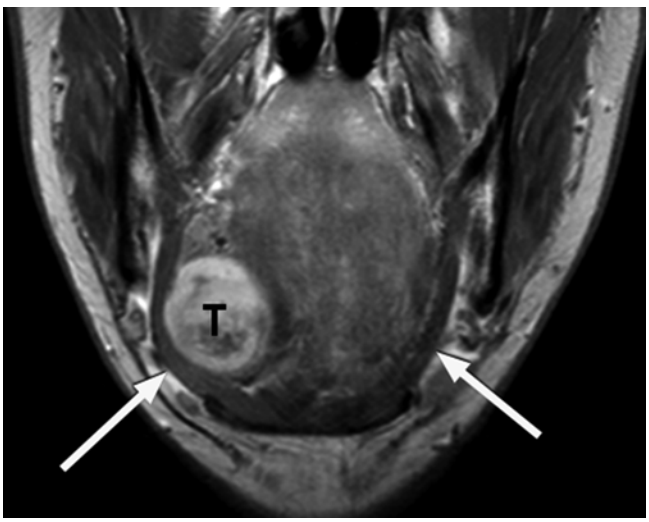

Fig. 4 Schwannoma arising in the sublingual space. The tumor (*T*) fills much of the sublingual space. Note the lesion is superior to the mylohyoid muscle (*arrows*)

Hypopharynx and Larynx

Hypopharyngeal and laryngeal disorders can cause a variety of symptoms, depending on the site of origin as well as the type of disease. In neonates laryngeal abnormalities such as tracheomalacia, tracheoesophageal fistula, or congenital cysts are the most common causes of congenital lower airway obstruction. Another frequent congenital laryngeal abnormality is vocal cord paralysis due to peripheral or central neurologic deficits. Laryngeal infections are the most common diseases of the larynx, related to an upper respiratory tract infection. Hoarseness is a main complaint of patients suffering from a variety of laryngeal diseases including laryngeal infection.

For the clinician, the rapidity of the progression as well as associated symptoms and risk factors (nicotine abuse) is important to be able to develop an adequate diagnostic and therapeutic approach. Normally, an acute infection of the larynx should not last for more than 3 or 4 weeks. If a hoarseness of unclear origin lasts longer, it must be seen by the otorhinolaryngologist to exclude a malignancy.

Imaging of the larynx and upper airway is done in many situations. At our institution, most laryngeal imaging studies relate to tumor evaluation or to trauma.

Tumors of the Larynx

Most tumors of the larynx are squamous cell carcinomas and arise from the mucosa [1, 2, 9]. A few tumors arise from the cartilaginous skeleton or from the other submucosal tissues [10].

The endoscopist almost always detects and diagnoses the mucosal lesions. Indeed, imaging should not be used in an attempt to "exclude" squamous cell carcinoma of the larynx. In squamous cell carcinoma, the role of the radiologist is almost always determination of depth of spread and the inferior limit of spread. Submucosal tumors are, however, somewhat different. The endoscopist can usually visualize, but since they are covered by mucosa, there may be considerable difficulty in making the diagnosis, and in these cases the clinician relies on the radiologist to determine the identity of the lesion.

Squamous Cell Carcinoma Much of imaging is determination depth of extension. Radiologists can see submucosal disease which can make a difference in the choice of therapy. It is important to know some of the indications and contraindications of various alternatives to total laryngectomy. The following represents the standard classic partial laryngectomies [11]. Most surgeries are now done via endoscopic approaches [11]. However, if the information needed for these classic procedures is gathered through imaging, then there is more than enough information for radiotherapists and other clinical specialists as well.

Supraglottic Laryngectomy This procedure, done for supraglottic tumors, removes everything above the level of the ventricle. Tumor may obstruct the endoscopist's view of the lower margin of the tumor or tumor can cross the ventricle by "tunneling" beneath the mucosal surface. Such submucosal spread can travel along the paraglottic pathway around the ventricle. Such extension is a contraindication to supraglottic laryngectomy, and since it can be missed by direct visualization, the radiologist must try to detect this phenomenon (Fig. 5).

Cartilage involvement is another contraindication, but this is extremely rare in supraglottic cancers unless the lesion has actually crossed the ventricle to become transglottic. Other contraindications include significant extension into the tongue or significant pulmonary problems. These mostly relate to difficulty in learning how to swallow once the key part of the laryngeal protective mechanism has been removed.

Vertical Hemilaryngectomy The vertical hemilaryngectomy was designed for lesions of the true vocal fold. The aim is to remove the tumor but to retain enough of one true fold so that the patient can still create speech using the usual mechanism. Actually, the lesion can extend onto the anterior part of the opposite fold and there can still be a satisfactory removal. In these areas, the radiologist looks most closely at inferior extension. Does the tumor reach the upper margin of the cricoid cartilage (see Fig. 5c)? In most institutions such extension would mean that the patient is not a candidate for vertical hemilaryngectomy but rather should have a total laryngectomy or alternative therapies. However, recently some surgeons have taken a part or even a section of the cricoid with secondary reconstruction.

Lesions of the anterior commissure may extend anteriorly into either the thyroid cartilage or through the cricothyroid membrane into the soft tissues of the neck. This may be invisible to the examining clinician and is again a key point to evaluate.

Radiotherapy or Combination Rads/Chemotherapy Radiation, with or without chemotherapy, is another speech conservation treatment. Here the therapist wants to know the extent of the lesion using the same landmarks used for potential surgical planning. Cartilage invasion and the volume of the tumor are also important [12]. Many tumors previously treated with advanced surgery are now treated with organ preservation radiation chemotherapy protocols.

Imaging Laryngeal Squamous Cell Cancer At this institution we begin with CT. CT scanners give excellent resolution and give good coronal and sagittal plane image reformats. Modern scanners can perform the entire study during a single breath hold. Magnetic resonance is reserved for evaluation of lesions close to the cartilage or ventricle. A limited study may be done to clarify a particular margin and to evaluate the cartilage.

Imaging of cartilage involvement is controversial [13–18]. Some favor CT and some MRI. At CT, sclerosis of the cartilage and obliteration of the low-density fat in the medullary space can indicate involvement. The negative finding, intact fat in the medullary space, with a normal cortex is considered reliable. On MRI, one begins with the T1-weighted image. If there is high signal (fat) in the medullary space, the cartilage is considered normal. If the area is dark, then one examines the T2-weighted image. Nonossified cartilage remains dark where tumor is usually brighter. High signal on T2-weighted images can mean tumor or edema related to tumor. More research is needed to determine the significance of signal changes to prognosis. Dual energy may give the ability to evaluate the cartilage more easily than previously possible.

Submucosal Tumors Submucosal tumors may arise from the cartilages or from minor salivary glands or the other soft tissue structures and can be of neural, vascular, adipose, muscular, or fibrous tissue origin [9, 10].

CT with intravenous contrast can be very helpful. Chondromatous lesions can arise from any cartilage and often have demonstrable cartilage matrix [19]. The lesions

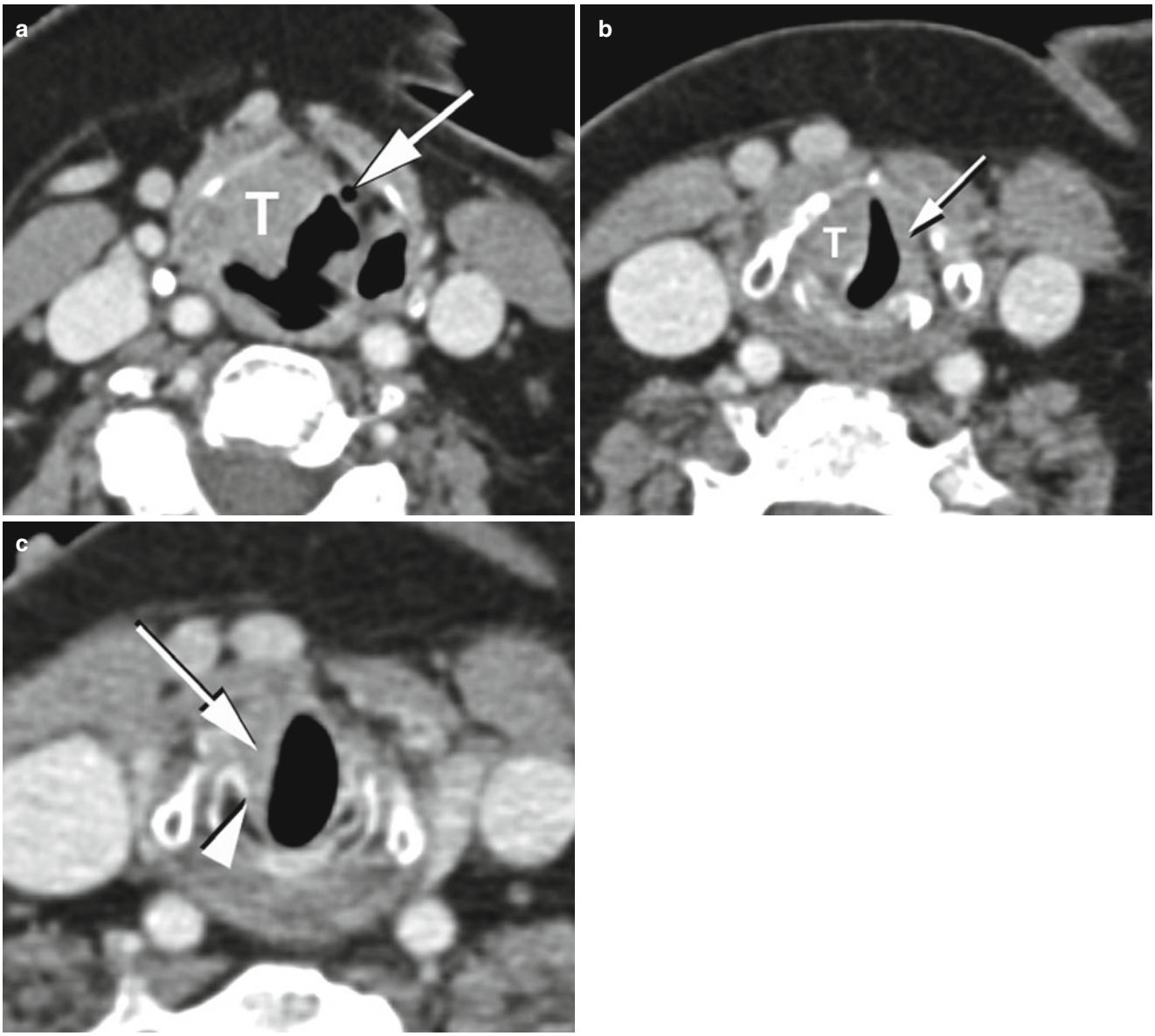

Fig. 5 Carcinoma of the larynx crossing the laryngeal ventricle (transglottic). (**a**) Axial image; supraglottic level. Tumor (*T*) is seen obliterating the right supraglottic fat in the paraglottic and pre-epiglottic areas. Note the small amount of air in the ventricular appendix (*arrow*) in the normal paraglottic fat on the left. (**b**) Axial image; true cord (glottic) level. Tumor (*T*) enlarges the cord on the right side. Note the typical appearance of the thyroarytenoid muscle (*arrow*) on the left indicating that the image is at the level of the cord. (**c**) Axial image; subglottic level. The tumor (*arrow*) spreads along the inner cortex of the cricoid cartilage (*arrowhead*)

tend to expand the parent cartilage. Hemangiomas enhance intensely as do the very rare glomus (paraganglioma) tumors. There are other lesions which arise in the submucosal region but do not enhance as avidly and do not involve the cartilage. In these cases, the identity cannot be made precisely, but it is very helpful to the clinician if one has excluded a very vascular lesion or a chondroid lesion.

Another submucosal lesion which is very important is the laryngocele or saccular cyst. Both represent dilatation of the ventricular appendix but the latter does not communicate with the lumen of the larynx and is filled with mucus. Terminology varies and some refer to the saccular cyst as a fluid-filled laryngocele. Laryngoceles usually occur later in life and can be classified in three subtypes (internal laryngocele, external laryngocele, combined internal). A laryngocele is a benign lesion; however, relationships between laryngoceles or saccular cysts and laryngeal carcinomas at the level of the ventricle have been described. The lesions can be thought of as a supraglottic, paraglottic cysts.

Trauma

Trauma to the airway can obviously be life-threatening. Most patients that have a demonstrable fracture of the larynx have endoscopy looking for mucosal tears. If there is a fragment of cartilage exposed to the airway, then chondritis and eventual chondronecrosis can be expected. One should carefully evaluate the integrity of the thyroid cartilage and the cricoid ring. These fractures are associated with edema or hemorrhage of the endolarynx, and this can be very helpful especially when, as in a young patient, the cartilages are not completely calcified.

Fractures

Fractures of the cricoid usually involve "collapse" of the ring. The anterior arch of the cricoid is pushed posteriorly into the airway, and there is usually swelling indicated by fluid/soft tissue density within the cricoid ring. The thyroid can fracture vertically or horizontally. Hemorrhage in the adjacent pre-epiglottic fat may be a clue to the horizontal type of fracture. The arytenoid does not commonly fracture but can be dislocated.

Summary

For the nasopharynx, the oropharynx, and the oral cavity, MRI is usually preferred for the evaluation of benign and malignant lesions. For the hypopharynx and larynx, we begin with CT and use MRI for additional evaluation of cartilage.

The detailed knowledge of the anatomy is crucial for the radiological assessment of this area.

For trauma we use CT looking for fractures or dislocations.

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