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European Journal of Radiology 66 (2008) 460–479

EJR
EUROPEAN JOURNAL OF RADIOLOGY

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Imaging of the larynx and hypopharynx

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Received 23 March 2008; received in revised form 24 March 2008; accepted 28 March 2008

Abstract

The purpose of this article is to review currently used imaging protocols for the evaluation of pathologic conditions of the larynx and hypopharynx, to describe key anatomic structures in the larynx and hypopharynx that are relevant to tumor spread and to discuss the clinical role of Computed Tomography (CT), Magnetic Resonance Imaging (MRI) and PET CT in the pretherapeutic workup and posttherapeutic follow-up of patients with squamous cell carcinoma of this region. A detailed discussion of the characteristic neoplastic submucosal invasion patterns, including extension to the preepiglottic space, paraglottic space and laryngeal cartilages and the implications of imaging for tumor staging and treatment planning is provided. The present article also reviews less common tumors of this region, such as chondrosarcoma, lymphoma, minor salivary gland tumors and lipoma. As the majority of non-neoplastic conditions do not require imaging the role of CT and MRI is discussed in some particular situations, such as to delineate cysts and laryngoceles, abscess formation in inflammatory conditions, to evaluate laryngeal and hypopharyngeal involvement in granulomatous and autoimmune diseases, and to evaluate the extent of laryngeal fractures due to severe blunt trauma.
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Keywords: Larynx: anatomy; Hypopharynx: anatomy; Larynx: neoplasms; Hypopharynx: neoplasms; Larynx: CT; Larynx: MRI; Larynx: PET CT; Larynx: trauma

The most common indication to perform a CT or an MRI examination of the larynx and hypopharynx consists in imaging a biopsy-proven or a suspected primary or recurrent neoplasm. Although diagnostic evaluation of the larynx and hypopharynx is primarily done with endoscopy and endoscopic biopsy, cross-sectional imaging either with Computed Tomography (CT) or with Magnetic Resonance Imaging (MRI) plays an indispensable complementary role, because it enables evaluation of the deep submucosal structures and spaces [1–5]. The purpose of this article is to briefly review currently used imaging protocols, key anatomic structures in the larynx and hypopharynx relevant to tumor spread, characteristic submucosal invasion patterns and implications of imaging for tumor staging and treatment planning. The present review mainly deals with tumors of the larynx and hypopharynx, whereas other, less common conditions, such as laryngoceles, trauma, recurrent laryngeal nerve paralysis and unusual infectious lesions are dealt with in less detail.

1. Cross-sectional imaging

In many institutions, CT is the preferred imaging method for evaluating the larynx and hypopharynx, whereas MRI is used as a complementary tool in those cases, where the CT study does not provide all information needed prior to therapy. A standard state-of-the-art CT examination is done using a multidetector CT (MDCT), the collimation varying from 4 mm × 1 mm to 64 mm × 0.6 mm depending on the CT equipment used. The patient is in the supine position, and he is instructed to resist swallowing or coughing. Axial slices are obtained from the base of the skull to the trachea with a scan orientation parallel to the true vocal cords. Iodinated contrast material (total dose, 35–40 g iodine) is given intravenously with an automated power injector. Images are obtained during quiet breathing rather than during apnea because the abducted position of the true vocal cords facilitates evaluation of the anterior and posterior commissures [1,5]. With MDCT scanners a slice thickness of 1.5 mm and overlapping reconstructions every 0.75 mm are used routinely by many investigators, including ourselves, allowing high quality 2D-reconstructions in the coronal or sagittal plane. Additional dynamic maneuvers during phonation or modified

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doi:10.1016/j.ejrad.2008.03.027

Fig. 1. PET CT performed for staging purposes in a patient with hypopharyngeal cancer. (A) and (B) Coronal PET CT fused images reveal a hypermetabolic focus in the left piriform sinus (thick arrow in A) corresponding to the known hypopharyngeal cancer and bilateral hypermetabolic foci corresponding to lymph node metastases (thin arrows in A). A rounded lesion with a hypermetabolic rim is seen in the liver (arrows in B) suggesting the presence of a liver metastasis. Biopsy confirmed bilateral lymph node metastases and the presence of a liver metastasis. PET CT findings changed patient care.

Valsalva maneuvers are used in selected cases to improve visualization of certain anatomic areas, such as laryngeal ventricle or hypopharynx.

To date, MR imaging of the larynx and hypopharynx is done using dedicated surface neck coils in a phased array configuration or with parallel imaging techniques. Two basic pulse sequences are currently used by most investigators, namely T1-weighted sequences and T2-weighted sequences. Axial T2-weighted FSE and T1-weighted SE or T1-weighted FSE images are obtained from the skull base to the thoracic inlet with a scan orientation parallel to the true vocal cords. Typical image parameters for a standard examination include a slice thickness of 3 or 4 mm with a 0–1-mm intersection gap, a field of view of 18 cm × 18 cm or less and with an acquisition matrix of 256 × 512 or 512 × 512. Additional axial T1-weighted images after intravenous administration of gadolinium chelates are obtained routinely. Fat-saturated T1-weighted images with or without contrast-material enhancement and fat-saturated T2-weighted images are optional. Images in the coronal or sagittal plane may be obtained in order to evaluate certain anatomic spaces, such as the preepiglottic space in the sagittal plane, or the paraglottic space and the ventricle in the coronal plane.

PET with the glucose analogue fluorodeoxyglucose (FDG) has become an accepted and widely used imaging modality for the staging and follow-up of head and neck cancer. It has been used successfully for the assessment of tumor aggressiveness, for staging nodal disease in the neck, and for detection of recurrent disease [6–8]. Combined PET CT is a recent imaging technique that allows almost simultaneous image acquisition and co-registration of anatomic and metabolic data sets. Recent studies have shown that this technique improves the anatomic localization of PET abnormalities and reduces the number of equivocal PET interpretations. At our institution, we use PET CT in the initial staging of advanced laryngeal and hypopharyngeal cancer (Fig. 1) and for the detection of tumor recurrences in those cases where the CT and MRI examinations are equivocal.

2. Squamous cell carcinoma

Over 90% of laryngeal and hypopharyngeal tumors are squamous cell carcinomas, which are strongly related to tobacco

and alcohol abuse. With very few exceptions, squamous cell tumors are located at the mucosal surface, and the clinical diagnosis is readily confirmed by endoscopic biopsy. However, submucosal tumor extension cannot be assessed reliably with endoscopy alone. Because the degree of infiltration into the surrounding deep anatomic structures has implications for treatment and prognosis, cross-sectional imaging – either CT or MRI – is required for the diagnostic workup of laryngeal and hypopharyngeal tumors. Unusual malignant neoplasms of the laryngo-hypopharyngeal region, such as chondrosarcomas, lymphomas or lipomas are often entirely located submucosally. The origin and extension of these tumors are difficult to diagnose with endoscopy, and planning of biopsy and treatment usually depend on imaging findings.

2.1. Anatomic structures relevant to tumor spread

When performing cross-sectional imaging for a laryngeal or hypopharyngeal tumor, the following questions have to be answered: Does the tumor invade the supraglottis, glottis, subglottis, piriform sinus, retrocricoarytenoid region or posterior pharyngeal wall? Is there invasion of the paraglottic space or preepiglottic space? Is there cartilage invasion or invasion of the soft tissues of the neck? Are there lymph node metastases or distant metastases present? Although a detailed review of the basic anatomy of the larynx and hypopharynx is beyond the scope of this article, a few remarks on the submucosal spaces and laryngeal cartilages are necessary for a better understanding of pathophysiologic mechanisms of tumor spread.

The most important pathways for submucosal tumor dissemination in the larynx occur along the paraglottic space and along the preepiglottic space. These two spaces also play an important role for the T classification, as neoplastic invasion of these spaces upstages laryngeal cancer to T3 according to the guidelines of the UICC [10]. The paraglottic space is a fat-filled space that lies between the mucosa and the laryngeal framework. It is paired and symmetrical. In the supraglottic region it mainly contains fat, whereas at the level of the false cords thin bands of muscle within fat may be visualized. The paraglottic space surrounds the laryngeal ventricle and merges superiorly with the

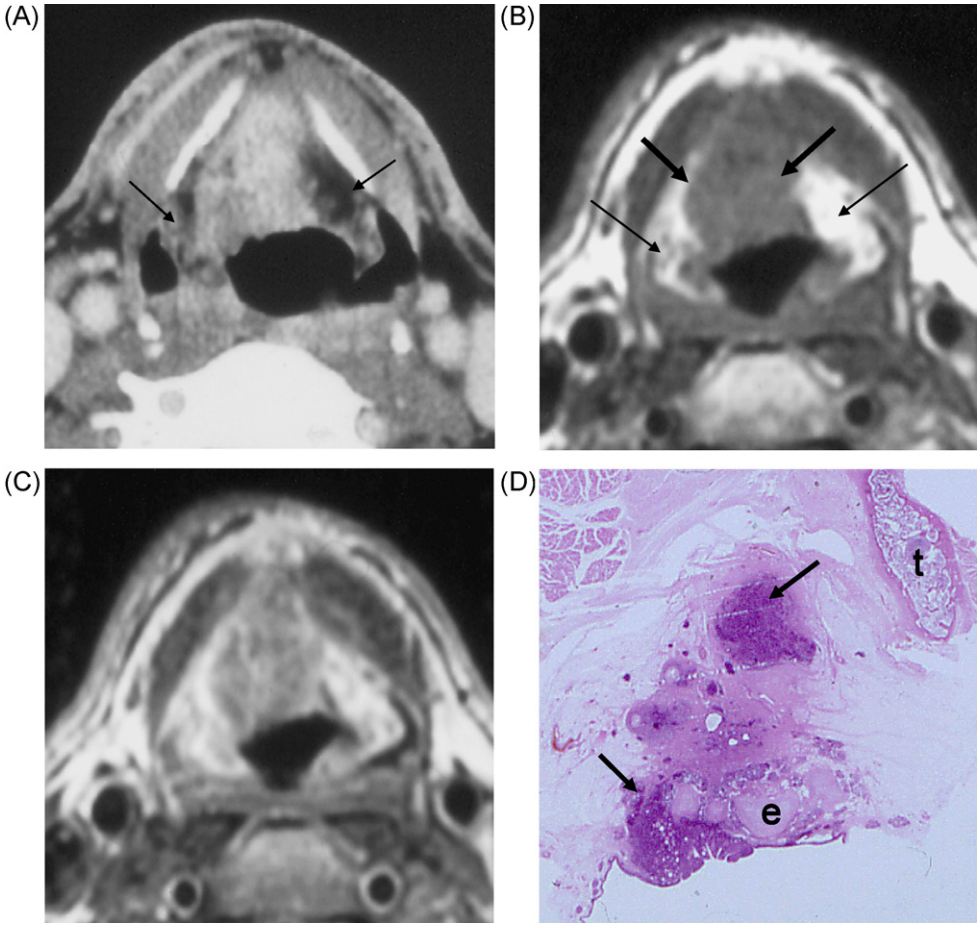

Fig. 2. Neoplastic invasion of the preepiglottic space due to anterior supraglottic cancer. (A) Axial, contrast-enhanced CT image at the supraglottic level shows an enhancing tumor mass as it invades the preepiglottic space. *Note*: normal fat with low attenuation values lateral to the tumor mass (arrows). (B) Axial, unenhanced T1-weighted SE image obtained in the same patient at the same level shows a tumor mass with an intermediate signal intensity as it extends into the preepiglottic space (thick arrows). Note the high signal intensity of the non-invaded paraglottic space due to the high content of fatty tissue (thin arrows). (C) Axial Gd-enhanced T1-weighted SE image at the same level shows enhancement of the tumor mass invading the preepiglottic space. (D) Whole organ, axial histologic slice from supraglottic horizontal laryngectomy specimen confirms tumor invasion of the preepiglottic space (arrows). Epiglottis (e), thyroid cartilage (t). Hematoxylin–eosin stain. Reproduced with permission from Ref. [14].

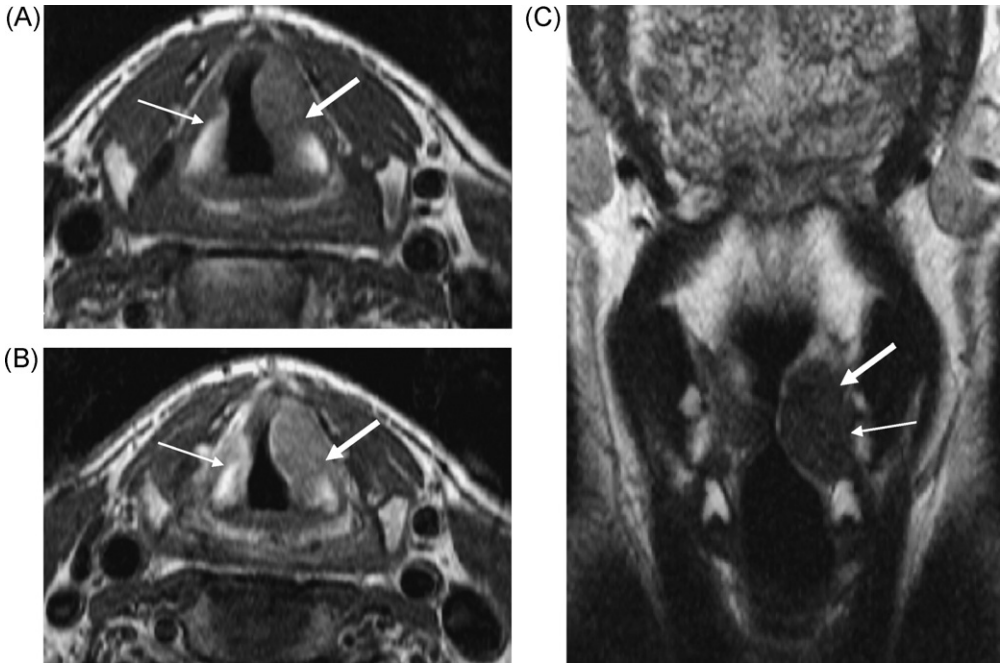

Fig. 3. Neoplastic invasion of the left paraglottic space due to ventricular cancer. Endoscopically only a very small mucosal lesion was present within the left laryngeal ventricle. Axial T1-weighted images obtained before (A) and after injection of gadolinium chelates (B) at the supraglottic level show a homogenously enhancing tumor mass obliterating the left paraglottic fat (thick arrow). *Note*: for comparison the normal aspect of the right paraglottic space (thin arrow). (C) Coronal T2-weighted FSE image shows a tumor mass which is relatively hypointense suggesting a high degree of cellularity invading the left paraglottic fat. There is involvement of both the supraglottis (thick arrow) and glottis (thin arrow) resulting in transglottic spread (see text).

preepiglottic space. The paraglottic space extends posteriorly into the aryepiglottic folds, which separate the endolarynx anteriorly from the piriform sinuses posteriorly. At the glottic level, the paraglottic space is located between the thyroarytenoid muscle, which forms the bulk and shape of the vocal cord medially and by the thyroid and cricoid cartilage laterally. The preepiglottic space is a pyramidal shaped space that consists entirely of fatty tissue. It is bounded anteriorly by the thyrohyoid membrane and thyroid laminae, posteriorly by the infrahyoid epiglottis, cranially by the hyoepiglottic ligament, and caudally by the petiole of the epiglottis. Both spaces are well assessed on axial images, but additional planes may be additionally used to better show the entire cranio-caudal extent of a lesion (coronal images for the paraglottic space and sagittal images for the preepiglottic space).

Invasion of the laryngeal cartilages is generally associated with a lower response rate to radiation therapy and a higher risk of tumor recurrence than involvement of soft tissue alone. It affects the T classification, as well as the choice of surgery (partial versus total laryngectomy, see below). The thyroid, cricoid and arytenoid cartilages of adults consist of two components: non-ossified hyaline cartilage and ossified cartilage. Ossified

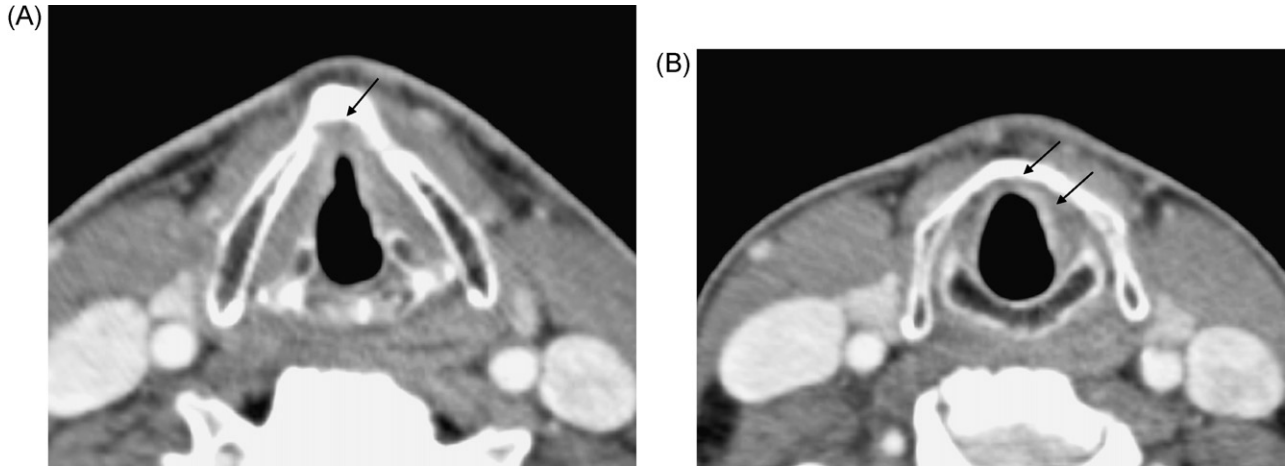

Fig. 4. Glottic cancer with invasion of the anterior commisure and subglottis. (A) Axial, contrast-enhanced CT scan at the glottic level shows a left-sided mass invading the anterior commissure (arrow) and the right vocal cord. The tumor mass also abuts the thyroid cartilage. (B) CT scan obtained at a lower level, shows tumor extension into the anterior and left subglottic region (arrows). The tumor abuts the lower margin of the thyroid cartilage.

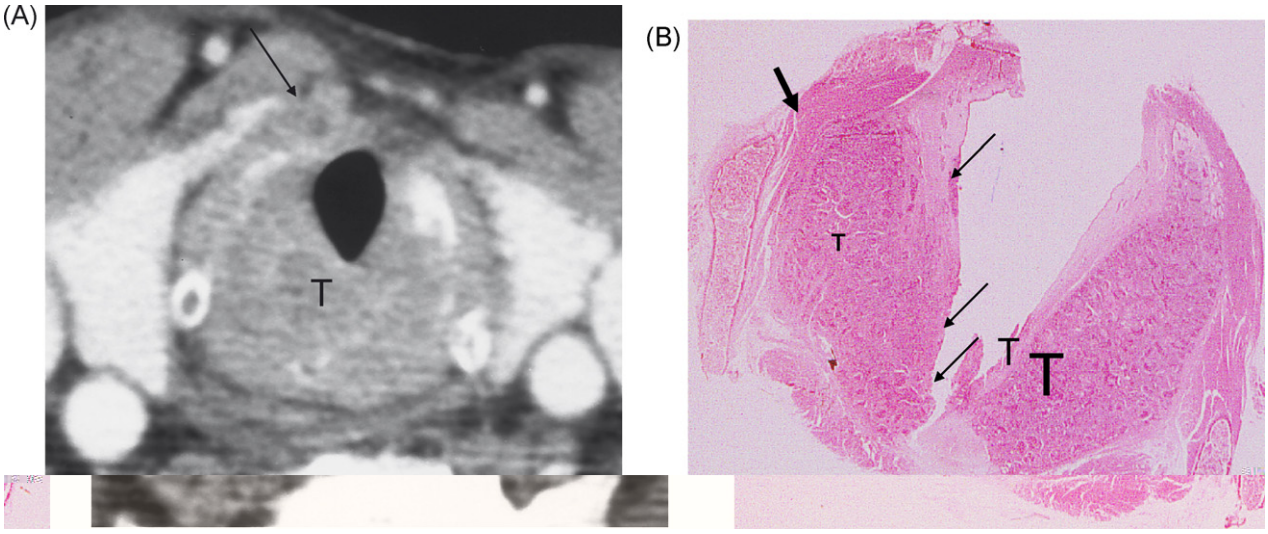

Fig. 5. Primary subglottic cancer. Patient presenting with dyspnea. Endoscopy revealed a relatively small mucosal lesion situated below the posterior commissure and in the right subglottis. The rest of the mucosa appeared tumor-free, however diffuse subglottic narrowing was observed endoscopically. (A) Contrast-enhanced CT at the subglottic level shows circumferential subglottic tumor (T) with destruction of the cricoid ring and invasion of paralaryngeal strap muscles (arrow). The rest of the larynx was tumor-free. (B) Corresponding histologic slice from specimen confirms circumferential subglottic tumor (T) with massive destruction of the cricoid cartilage. Note the relatively small mucosal component (arrows) as opposed to the extensive submucosal component. Invasion of the paralaryngeal strap muscles (arrowhead). Hematoxylin–eosin stain. Reproduced with permission from Ref. [13].

cartilage is essentially bone with an inner and outer cortex and a marrow cavity containing fatty tissue and scattered bony trabeculae. The epiglottis and the vocal processes of the arytenoids are composed of yellow fibrocartilage and they do not usually ossify. On CT, ossified cartilage has a high-attenuating cortex and a central low-attenuating medullary space, whereas non-ossified hyaline cartilage and non-ossified fibroelastic cartilage have attenuation values of soft tissue. On MRI, non-ossified hyaline cartilage has an intermediate to low signal intensity on T1-weighted and T2-weighted images. Cortical bone has a very low-signal intensity on all sequences, whereas the medullary cavity of ossified cartilage has the signal intensity of fat (high on T1-weighted images and FSE T2-weighted images). Normal ossified and normal non-ossified hyaline cartilage show no enhancement after intravenous administration of contrast material on CT or MRI.

2.2. Tumor origin and characteristic patterns of submucosal spread

Carcinoma of the larynx arises in the supraglottic region (30%), glottis (65%) or subglottic region (5%).

Supraglottic tumors originating from the epiglottis (anterior supraglottic cancers) primarily invade the preepiglottic space either through the preexisting natural perforations of the epiglottic cartilage or along its lateral border. Tumors that originate

Fig. 6. Invasion of the paraglottic space by hypopharyngeal carcinoma arising from the piriform sinus. (A) Axial, contrast-enhanced CT image at the supraglottic level shows a tumor mass arising from the medial wall of the left piriform sinus with invasion of the paraglottic fat (black arrow) and extension into the soft tissues of the neck (white arrow). The adjacent thyroid cartilage is sclerotic indicating possible invasion. (B) Corresponding whole organ axial slice from surgical specimen confirms the radiologic findings. The piriform sinus tumor invades the medial wall (thin arrow), the paraglottic space (thick arrow), the posterior thyroid cartilage and the adjacent soft tissues of the neck (asterisk).

mass is seen within the preepiglottic fat (Fig. 2). The reported sensitivity of CT and MRI to detect invasion of the preepiglottic space is 100%, and the corresponding specificities 93% and 84–90%, respectively [1,11,12]. Supraglottic tumors originating from the false cord, laryngeal ventricle, or aryepiglottic fold primarily infiltrate the paraglottic space. The primary sign of tumor spread to the paraglottic space on MRI or CT is replacement of fatty tissue by tumor tissue (Fig. 3). Although the sensitivity of MRI and CT for the detection of neoplastic spread to the paraglottic space is high (93–95%) the corresponding specificity (50–76%) is, however, limited due to the fact that peritumoral inflammatory changes may lead to overestimation of tumor spread with either methods, therefore resulting in false positive assessments. The primary lymphatic spread of supraglottic carcinomas is directed toward the superior jugular lymph nodes. Lymph node metastases are common and often bilateral.

Glottic carcinoma typically arises from the anterior half of the vocal cord and primarily spreads into the anterior commissure. Invasion of the anterior commissure is seen on CT and MRI as a soft tissue thickening of more than 1–2 mm. Once the tumor has reached the anterior commissure it may easily spread into the thyroarytenoid muscle, contralateral cord, paraglottic space, supraglottis or subglottis (Fig. 4). On axial CT or MR images neoplastic invasion occurring at the subglottic level below the anterior commissure appears as an irregular thickening of the cricothyroid membrane. Further spread occurs mainly in a cephalad or caudad direction or, via the cricothyroid membrane, into the perilaryngeal tissue. Paraglottic tumor spread in glottic cancer may be entirely occult clinically and detectable only by means of CT or MR imaging. Subglottic spread is relatively common in glottic cancer and may either occur superficial or deep to the elastic cone. Deep subglottic spread is very difficult to detect endoscopically, and underestimation of the tumor may occur unless CT or MR imaging is performed. The degree of subglottic spread is best displayed on axial images (Fig. 4); coronal images are of limited help in the assessment of subglottic spread, because they are difficult to interpret except in the midcoronal plane. Lymphatic metastases from glottic carcinoma are uncommon as long as the tumor is confined to the endolarynx. However, once the tumor has spread into the soft tissues of the neck the frequency of lymph node metastases increases significantly.

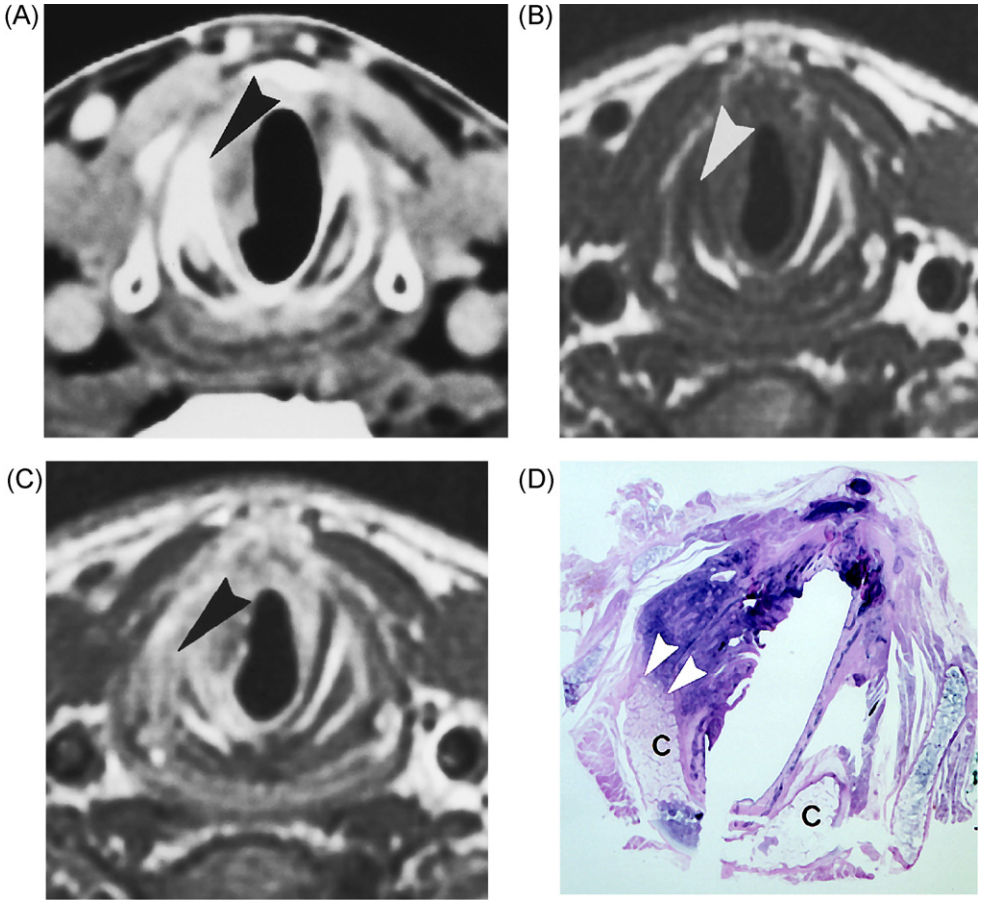

Fig. 9. Neoplastic invasion of the cricoid cartilage detected by both CT and MRI. Glotto-subglottic carcinoma of the larynx. (A) Axial, contrast enhanced CT scan at the subglottic level shows a mass with homogeneous contrast enhancement infiltrating the right subglottic region. The cricoid cartilage shows asymmetric sclerosis (arrowhead) indicating cartilage invasion. *Note*: preservation of its inner margin. (B) Axial T1-weighted image. A mass with intermediate signal intensity infiltrates the right subglottic region. The right cricoid cartilage shows a decreased signal intensity (arrowhead). (C) Contrast-enhanced axial T1-weighted image shows extensive contrast enhancement of the right subglottic tumor mass, as well as of the adjacent cricoid cartilage. The extensive enhancement of the right cricoid cartilage (arrowhead) suggests tumor invasion. (D) Axial slice from specimen at the same level shows a large subglottic tumor mass invading the right cricoid cartilage (arrowheads). C, cricoid cartilage. Hematoxylin–eosin stain. Reproduced with permission from Ref. [19].

The term "*transglottic carcinoma*" generally refers to tumors that involve both the glottis and supraglottis at the time of diagnosis. The submucosal growth pattern is readily recognized on CT and MR images although endoscopically it becomes visible only if it bulges the mucosa but remains entirely occult otherwise [14]. Transglottic tumors (Fig. 3) and particularly those spreading vertically in the anterior midline have a tendency to invade the laryngeal framework and the cricothyroid membrane. Transglottic carcinoma involving the anterior commissure can display a particularly aggressive behavior, resulting in infiltration of intact layers of perichondrium and replacement of the thyroid cartilage with neoplastic tissue. Such tumors are often underestimated at endoscopy and CT or MR images are necessary to demonstrate their true extent prior to treatment. Transglottic carcinoma is very often accompanied by lymph node metastases.

Primary *subglottic carcinoma* (Fig. 5) is uncommon and tends to spread to the cricoid ring and trachea or invade the thyroid gland and the cervical esophagus. Lymph node metastases are much more common than in glottic carcinoma and they affect the paratracheal and pretracheal nodes. These nodes drain to the lower jugular or upper mediastinal nodes. Cross-sectional imaging performed in patients with primary subglottic tumors should, therefore, routinely include the upper mediastinum and the chest.

Carcinoma of the *hypopharynx* may arise in the piriform sinus (65%), postcricoid area (20%), and posterior pharyngeal wall (15%). *Carcinoma of the piriform sinus* is readily detected with endoscopy while very early superficial spreading tumors that are limited to the mucosa may be invisible at cross-sectional imaging. In most cases, however, patients with piriform sinus tumors initially present with advanced lesions and diagnosis at CT or MRI is straightforward (Fig. 6). Because the piriform sinus is usually collapsed during quiet respiration the exact tumor location (medial wall versus lateral wall) may be difficult to determine radiologically and a very close cooperation with the head and neck surgeon is essential. Tumors originating from the medial wall or the angle of the piriform sinus may infiltrate the larynx by growing anteriorly into the paraglottic space (Fig. 6). Tumors originating from the lateral wall of the piriform sinus have a tendency to infiltrate very early the soft tissues of the neck. Very often, however, piriform sinus carcinoma not only invades the paraglottic space and the laryngeal cartilages but also tends to spread in a cranio-caudal fashion invading the apex and the esophageal verge (Fig. 7).

Postcricoid carcinoma is uncommon in general but observed in certain groups at risk (patients with the Plummer–Vinson syndrome). These tumors spread submucosally most often toward the cervical esophagus. Because tumor growth is mainly submucosal, the true extent only becomes apparent with axial or sagittal MR images (Fig. 8).

Carcinoma of the posterior pharyngeal wall commonly involves both the oropharynx and hypopharynx. On axial MR

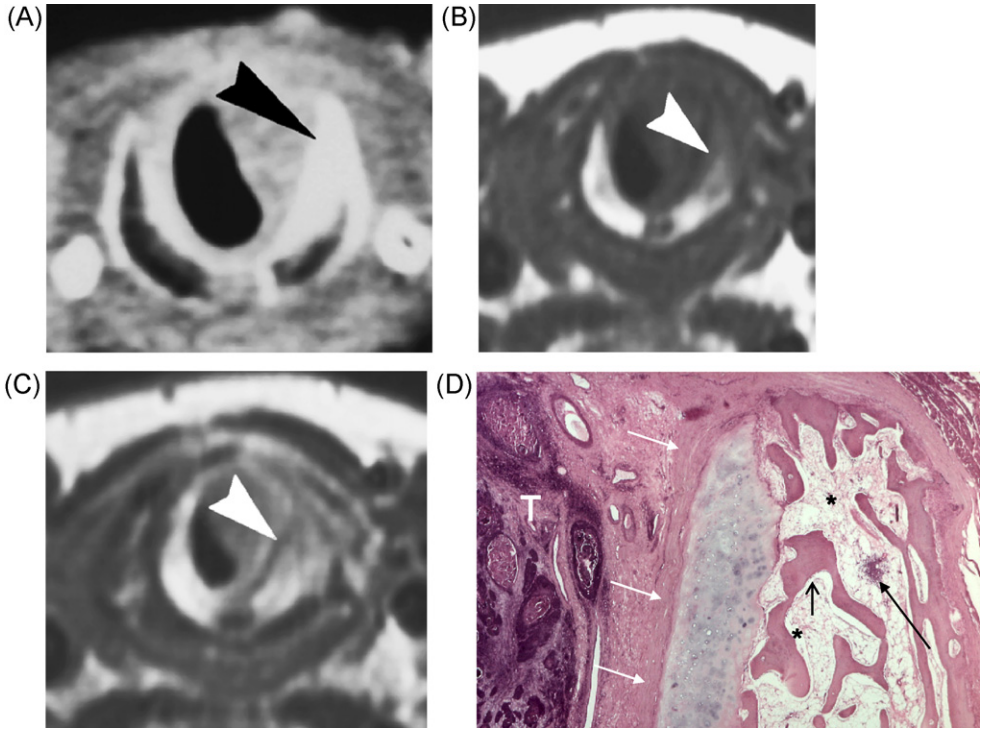

Fig. 10. CT and MRI false positive for neoplastic cartilage invasion due to inflammatory changes in the non-invaded cricoid cartilage. Glotto-subglottic carcinoma of the larynx. (A) Axial contrast enhanced CT scan at the subglottic level. A mass with homogeneous contrast enhancement is infiltrating the left subglottic region. The left cricoid cartilage shows extensive sclerosis in tumor vicinity (arrowhead) suggestive of cartilage invasion. (B) T1-weighted axial image. A mass with low signal intensity infiltrates the left subglottic region. The adjacent left cricoid cartilage shows a decreased signal intensity (arrowhead). (C) Contrast-enhanced T1-weighted image obtained at the same level. Contrast enhancement is seen within the left cricoid cartilage (arrowhead) as well as within the subglottic tumor mass. (D) Axial slice from specimen shows a large, left-sided subglottic tumor mass (T) but no evidence of cartilage invasion. The cricoid cartilage shows extensive inflammatory changes with lymph follicles (black arrow), fibrosis (asterisks), bone resorption (open arrows) but with an intact perichondrium (white arrows). Hematoxylin–eosin stain. Original magnification 6.25×. Reproduced with permission from Ref. [19].

images, these tumors appear as asymmetrical thickening of the posterior pharyngeal wall and invasion of the prevertebral muscles is unusual at initial presentation.

As a rule, squamous cell carcinoma of the hypopharynx has a relatively poor prognosis with up to 75% of patients having metastases to cervical lymph nodes at initial presentation and 20–40% of patients will also develop distant metastases.

2.3. Neoplastic cartilage invasion

Invasion of the hyaline laryngeal cartilage by squamous cell carcinoma alters staging, prognosis and, in most centers, the therapeutic approach. Most authors believe that radiation therapy cannot eradicate tumor within cartilage but may result in perichondritis and chondronecrosis, although some others believe that radiation therapy can sterilize tumor even in invaded cartilage [15–18]. Invasion of the thyroid, cricoid and both arytenoid cartilages precludes classical voice sparing partial laryngectomy in many institutions and total laryngectomy, an extremely invasive procedure may be required.

Direct comparison studies with histologic correlation have shown that CT has a high sensitivity and a high negative predictive value for the detection of cartilage invasion provided that the following criteria are used: sclerosis, erosion, lysis and extralaryngeal spread [19,20]. *Sclerosis* is a sensitive sign for the detection of neoplastic cartilage invasion and enables diagnosis of early or microscopic intracartilaginous tumor spread (Fig. 9). It corresponds to bone remodeling and new bone formation induced by the presence of tumor cells in immediate tumor vicinity and sometimes preceeding actual invasion. The specificity of this sign varies considerably from one cartilage to another, being lowest in the thyroid cartilage (40%) and higher in the cricoid and arytenoid cartilages (76% and 79%, respectively). Therefore, if a tumor mass is seen adjacent to a sclerotic cartilage, this does not automatically imply that tumor cells are found within the remodeled marrow cavity (Fig. 10). Conversely, failing at surgery to remove a cartilage that exhibits sclerosis on CT carries a 50–60% risk of leaving tumor behind. Minor areas of osteolysis correspond to the CT criteria of *erosion*, while major areas of osteolysis correspond to the CT criteria of *lysis* (Fig. 11). Histologically, erosion and lysis correspond to destruction of bone due to osteoclastic activity. As a consequence, erosion and lysis can be considered specific criteria for the detection of neoplastic invasion in all cartilages. The overall specificity of erosion and lysis is 93% [20]. However, both of these criteria are not very sensitive as they are bound to the presence of more advanced invasion of laryngeal cartilage [4]. *Extralaryngeal spread* upstages a laryngeal tumor as T4 and occurs due to tumor invasion through a cartilage into the extralaryngeal soft tissues (Fig. 12). This CT criteria is highly specific (overall specificity, 95%), but because it is only seen very late in the disease process its sensitivity is as low as 44%. By applying the combination of extralaryngeal tumor, sclerosis, and erosion/lysis to all cartilages one may obtain an overall sensitivity as high as 91%. Because the negative predictive value of this combination is 95% CT may be considered as an excellent test to exclude cartilage invasion prior to treatment.

The reported sensitivity of MRI for the detection of neoplastic cartilage invasion is 89–94%, the specificity 74–88%, and the negative predictive value 94–96% [16,17,19,21]. Extensive tumor invasion with destruction of cartilage and invasion into extralaryngeal soft tissues can be diagnosed with a high accuracy with MRI. In addition, MR imaging enables detection of intracartilaginous tumor spread. If tumor is present only adjacent to the inner aspect of a cartilage, the radiologist can differentiate between tumor and non-ossified cartilage by comparing the different MR pulse sequences. Cartilage invaded by tumor displays an intermediate to low signal intensity on T1-weighted images, a higher signal intensity on T2-weighted images and areas of enhancement within the cartilage adjacent to the tumor after injection of gadolinium-chelates (Fig. 9). If these signs are absent, cartilage infiltration can be ruled out with a high level of confidence, since the negative predictive value of MR imaging

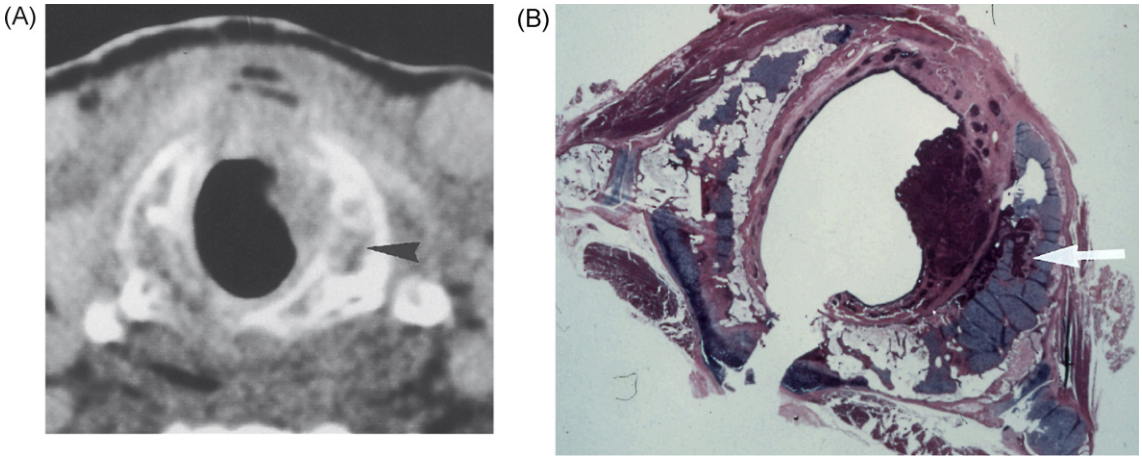

Fig. 11. Lysis and sclerosis of the cricoid cartilage in a glottic-subglottic cancer. (A) Contrast-enhanced CT scan obtained at the subglottic level shows a tumor mass that abuts the cricoid cartilage. The left cricoid lamina demonstrates an area of lysis (arrowhead) surrounded by extensive sclerosis. (B) Corresponding axial slice from surgical specimen at the same level confirms major intracartilaginous tumor spread (arrow) corresponding to lysis seen on CT. Hematoxylin–eosin stain. Reproduced with permission from ref [1].

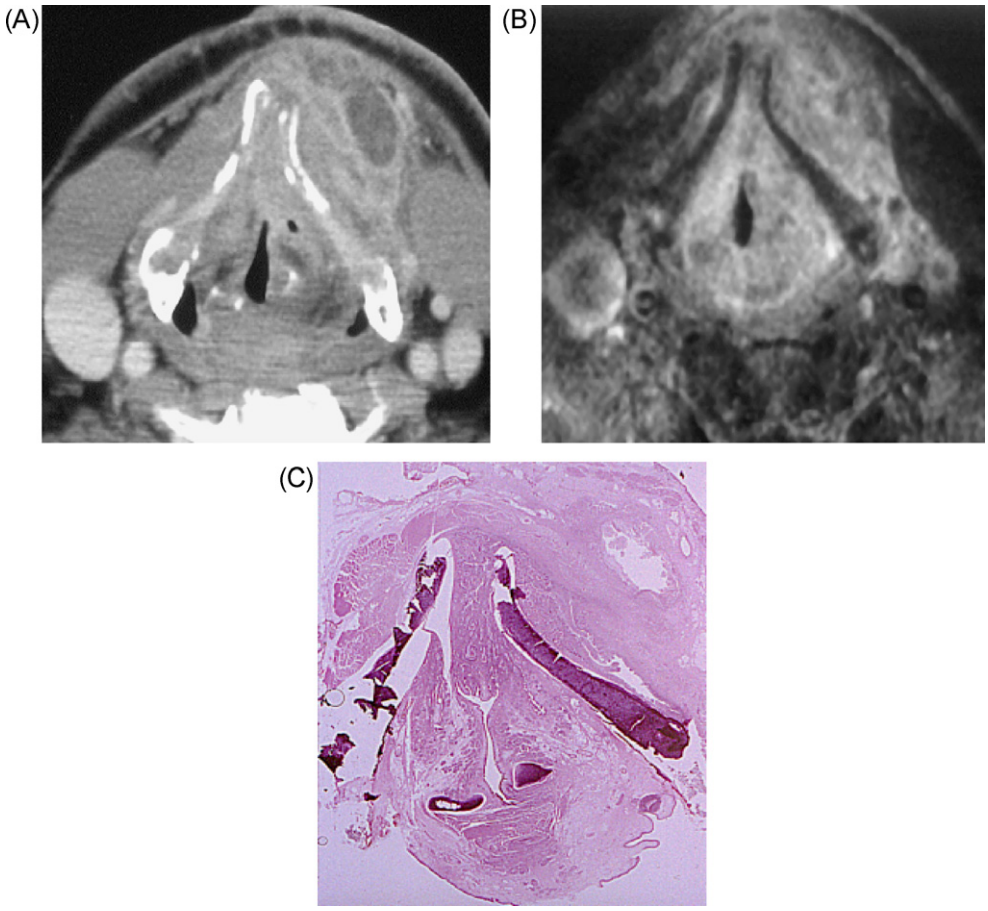

Fig. 12. Extralaryngeal spread as criteria at CT and MRI. (A) Axial contrast-enhanced CT image at the aupraglottic level shows a left squamous cell cancer (T) invading the false cord and paralaryngeal space and extending into the prelaryngeal soft tissues. (B) Axial, contrast-enhanced fat saturated image obtained at the same level in the same patient clearly shows extensive extralaryngeal tumor (T) spread. (C) Corresponding axial slice from surgical specimen at the same level confirms major extralaryngeal tumor spread (T) seen on both CT and MRI. Hematoxylin–eosin stain.

is very high (Fig. 13). Unfortunately, the MR findings suggesting neoplastic cartilage invasion are not as specific as expected initially, but may be false positive in a considerable number of instances; the positive predictive value is only 71%. This is because reactive inflammation, edema, fibrosis, and ectopic red bone marrow in the vicinity of the tumor may display similar diagnostic features as cartilage infiltrated by tumor (Fig. 10). Since inflammatory changes are most common in the thyroid cartilage, the specificity of MR imaging to detect neoplastic invasion of the thyroid cartilage is only 56%, as opposed to 87% and 95% in the cricoid and arytenoid cartilage, respectively. The positive diagnosis of neoplastic invasion of the thyroid cartilage should, therefore, be made with extreme caution at MRI.

2.4. Influence of imaging findings on local outcome after radiation therapy

In an attempt to predict the outcome of radiation therapy in patients with laryngeal cancer, several authors have tried to correlate pretherapeutic imaging findings with the local tumor control rate after radiation therapy [22–27]. The following imaging findings have been used as prognostic parameters: tumor volume, vocal cord mobility, sclerosis of laryngeal cartilage at CT and abnormal signal intensity of laryngeal cartilage at MRI. Several studies reported the prognostic value of CT determined tumor volume for outcome after definitive radiation therapy for both laryngeal and hypopharyngeal cancers [2], the increasing volume of the primary tumor correlating well with an increasing rate of local failure [23–27]. An abnormal signal intensity of laryngeal cartilages at MRI appears to correlate with a poor prognosis after radiation therapy if the tumor volume is $\geq$5 mL, but not if it is <5 mL [24,27]. However, isolated sclerosis of the arytenoid as seen on CT appears not to affect the outcome of radiation therapy in patients with laryngeal carcinoma [22]. The question why radiation therapy is efficient in a significant number of patients with abnormal signal intensity of the laryngeal cartilages on MRI or with isolated arytenoid sclerosis on CT may probably be answered by the results of radiologic–pathologic correlation studies: each of the latter diagnostic signs may not only be positive in the presence of tumor invasion, but also due to peritumoral inflammatory changes.

2.5. Tumor classification according to the TNM system

The purpose of tumor staging according to the TNM system is to help assess the prognosis and facilitate clinical research.

The staging criteria for laryngeal and hypopharyngeal carcinoma proposed by the International Union Against Cancer (UICC) and the American Joint Commission on Cancer (AJCC) are now almost identical [10]. The degree of invasion of the primary tumor is most accurately reflected in the postsurgical (pT) classification which is based on histopathologic analysis of the resected specimen. The clinical or pretherapeutic (T) classification of the primary tumor is used in patients who do not undergo surgery. It is based on all information available prior to treatment, including findings at physical examination, endoscopy, biopsy and cross-sectional imaging. The guidelines of both the UICC and the AJCC recommend the use of cross-sectional imaging and several studies as well as the experience at our institution have shown that the use of cross-sectional imaging greatly improves the accuracy of pretherapeutic T-classification of laryngeal and hypopharyngeal tumors [28,12,29]. However, no recommendations are made by the UICC or AJCC regarding the preference of one technique or another. In a prospective study we have compared the T and the pT classifications in 111 patients who underwent clinical examination with endoscopy as well as both CT and MR imaging prior to surgery. Using the pT classification as gold standard the staging accuracy of clinical examination with endoscopy was only 58% but it was increased significantly when combined with either CT (accuracy, 80%) or with MR imaging (accuracy, 85%). These results underline the usefulness of CT and MR imaging for pretherapeutic staging.

3. Non-squamous laryngeal neoplasms

A variety of benign and malignant tumors of non-squamous cell origin may affect the larynx and hypopharynx [1,5,30–34]. These tumors are rare and comprise less than 5% of all tumors of this region. Unlike squamous cell carcinoma that presents with obvious mucosal abnormalities and is therefore readily accessible for endoscopic biopsy, many of the less common neoplasms of the larynx and hypopharynx are located extramucosally, and the endoscopist may see nothing but an asymmetry or a bulge beneath an intact mucosa. Therefore, the diagnosis of these submucosal tumors is difficult with endoscopy alone, and sampling errors may occur if only traditional superficial biopsies are performed. The discrepancy between an intact mucosa at endoscopic examination and an obvious mass at CT or MRI should, therefore, raise the suspicion of a tumor with an unusual histology [31]. Because the treatment of most of the uncommon laryngeal neoplasms differs from the treatment of squamous cell carcinoma, a correct preoperative diagnosis is very important. The role of imaging in unusual laryngeal and hypopharyngeal tumors is to detect or confirm the presence of a submucosal mass, to determine the deep structures involved and to guide the endoscopist to the most appropriate site where to obtain deep agressive biopsies. Some submucosal masses can be further characterized with regard to their etiology when they display the typical features of chondroid, lipomatous or hypervascular-

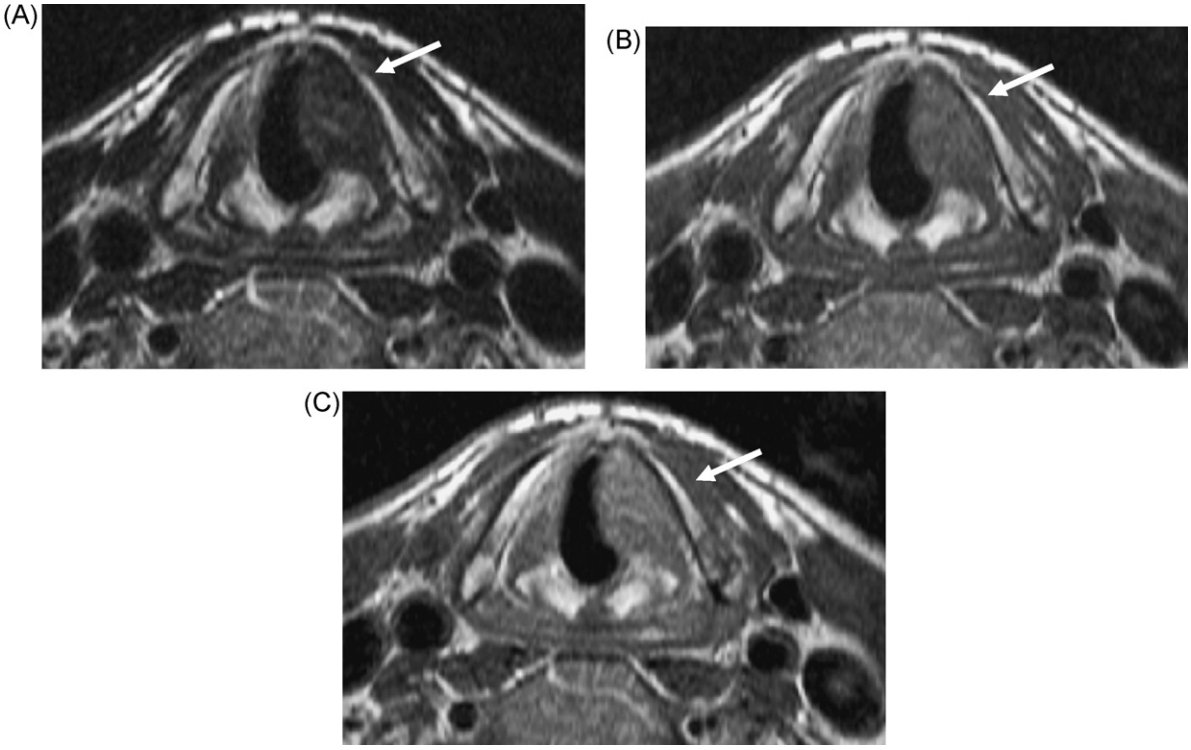

Fig. 13. MRI findings true negative for neoplastic invasion of the thyroid cartilage. (A) T2-weighted FSE image obtained at the glottic level shows a left-sided tumor with a relatively low signal intensity (probably high cellularity) abutting the left thyroid lamina. The thyroid lamina has a low signal intensity cortex and a high signal intensity marrow (arrow). (B) T1-weighted SE image obtained at the same level shows that the tumor has an intermediate to low signal intensity, whereas the adjacent thyroid lamina has a high signal intensity (arrow). The thyroid lamina is therefore composed of normal ossified cartilage with fatty marrow. (C) Corresponding T1-weighted SE image obtained after intravenous administration of contrast material shows moderate enhancement of the tumor mass. The arrow points to the adjacent normal ossified thyroid cartilage.

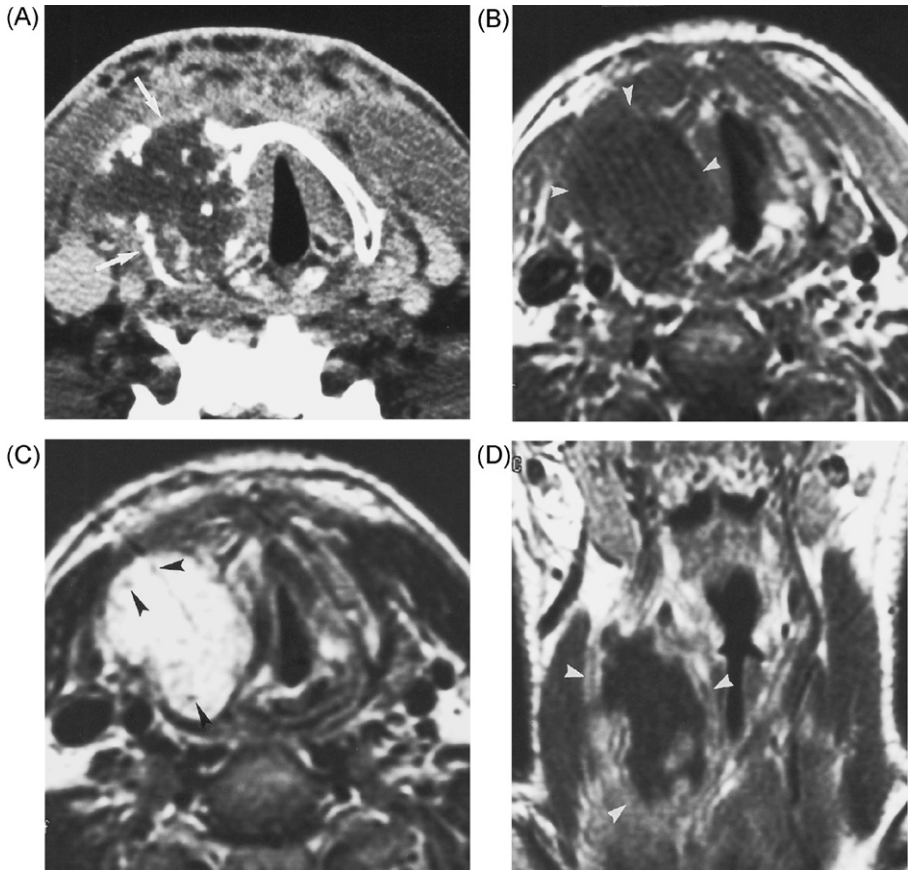

Fig. 14. Chondrosarcoma of the thyroid cartilage: CT and MRI appearance. (A) Axial contrast-enhanced CT scan shows a large, lobulated mass with coarse and stippled calcifications characteristic of chondrosarcoma (arrows). (B) T1-weighted, axial MR image shows a lobulated mass with low signal intensity that arises from the right thyroid lamina (arrowheads). *Note*: normal aspect of the left thyroid lamina. (C) T2-weighted FSE image. The tumor mass has a very high signal intensity due to a high water content. The hypointense areas within the tumor correspond to intratumoral calcifications (arrowheads). (D) T1-weighted, contrast-enhanced, coronal image. Moderate peripheral enhancement (arrowheads). *Note*: extramucosal tumor location. (A) reproduced with permission from Ref. [1]. (B–D) reproduced with permission from Ref. [31].

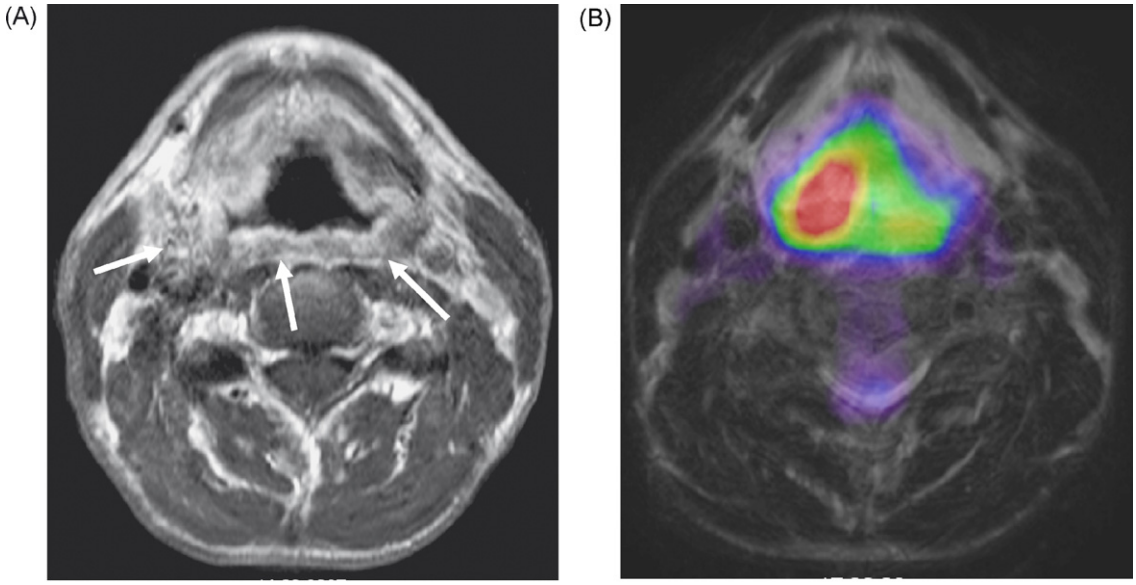

Fig. 15. Lymphoma of the larynx and pharynx in an immunocompromized patient. (A) Axial T1-weighted contrast-enhanced image at the supraglottic level shows a diffusely infiltrating mass with moderate enhancement involving the posterior pharyngel wall (arrows) and the constrictor muscles and extending anteriorly into the supraglottic larynx. (B) Corresponding axial PET MRI fused images show an extensive, highly hypermetabolic lesion corresponding to the biopsy-proven MALT lymphoma (mucosa-associated lymphoid tissue lymphoma). The hypermetabolic area is larger than the area of abnormal enhancement seen in (A) suggesting a more extensive submucosal dissemination. Several deep biopsies confirmed this finding.

ized tissue or those of non-tumoral lesions, such as a cysts or laryngoceles.

Laryngeal *chondrosarcoma* predominantly affects males in their sixth or seventh decade and more commonly originates from the cricoid than from the thyroid cartilage [33,34]. As in chondrogenic tumors of other locations, the tumor matrix has a high-signal intensity on T2-weighted images corresponding to hyaline cartilage with its low cellularity and high water content (Fig. 14). Small areas of low signal intensity correspond to stippled calcifications; these changes are, however, not as well demonstrated as with CT, where characteristic "pop-corn" calcifications may be seen. Although the injection of gadolinium-chelates may lead to a diffuse central or peripheral enhancement on T1-weighted images, these findings are non-specific and do not help in differentiating low-grade chondrosarcomas from benign chondroma. Although the diagnosis of laryngeal chondrosarcoma can be strongly suspected on CT or MR imaging, it must be confirmed with deep biopsy. Surgery is regarded as the treatment of choice and is increasingly done in the form of function-preserving laryngeal resection. Imaging studies are important for follow-up after treatment, since chondrosarcoma has a tendency to recur locally.

Lymphoma involving the Waldeyer ring is relatively common in the head and neck. However, lymphoma involving primarily the larynx and without other head and neck manifestations is rare (Fig. 15). In these patients a multimodality pretherapeutic work-up is done involving CT or MRI and PET and the combined data are used to monitor treatment response after chemotherapy.

Strongly vascularized laryngeal tumors include *hemangioma* and *paraganglioma*. On CT, both hemangioma and paraganglioma appear as well-circumscribed soft tissue masses that display intense contrast enhancement. Phleboliths are

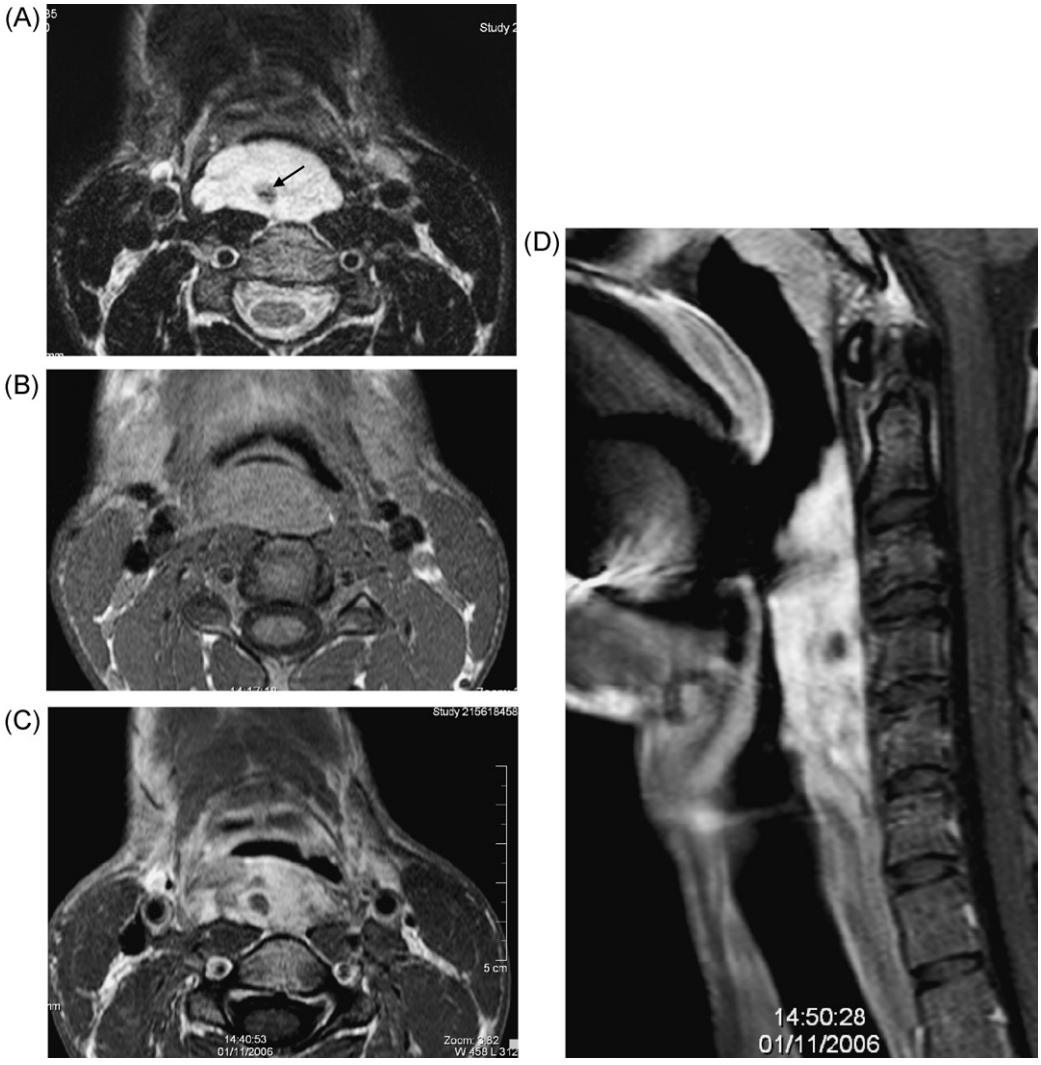

Fig. 16. Hemangioma of adult type (venous malformation). (A) Axial T2-weighted image obtained at the level of the suprahyoid epiglottis shows a hyperintense mass involving the posterior pharyngeal wall and leading to near-total airway obstruction. *Note*: a hypointense oval-shaped area in its center (arrow). (B) Axial T1-weighted image obtained at the same level shows that the mass is slightly hyperintense to muscle. (C) Axial T1-weighted image obtained after injection of gadolinium chelates shows inhomogenous enhancement. The central hypointense oval-shaped area does not enhance. It probably corresponds to a phlebolith. (D) Sagittal, contrast-enhanced fat saturated image shows the cranio-caudal extent of the hemangioma with a large phlebolith and with strong but inhomogenous enhancement.

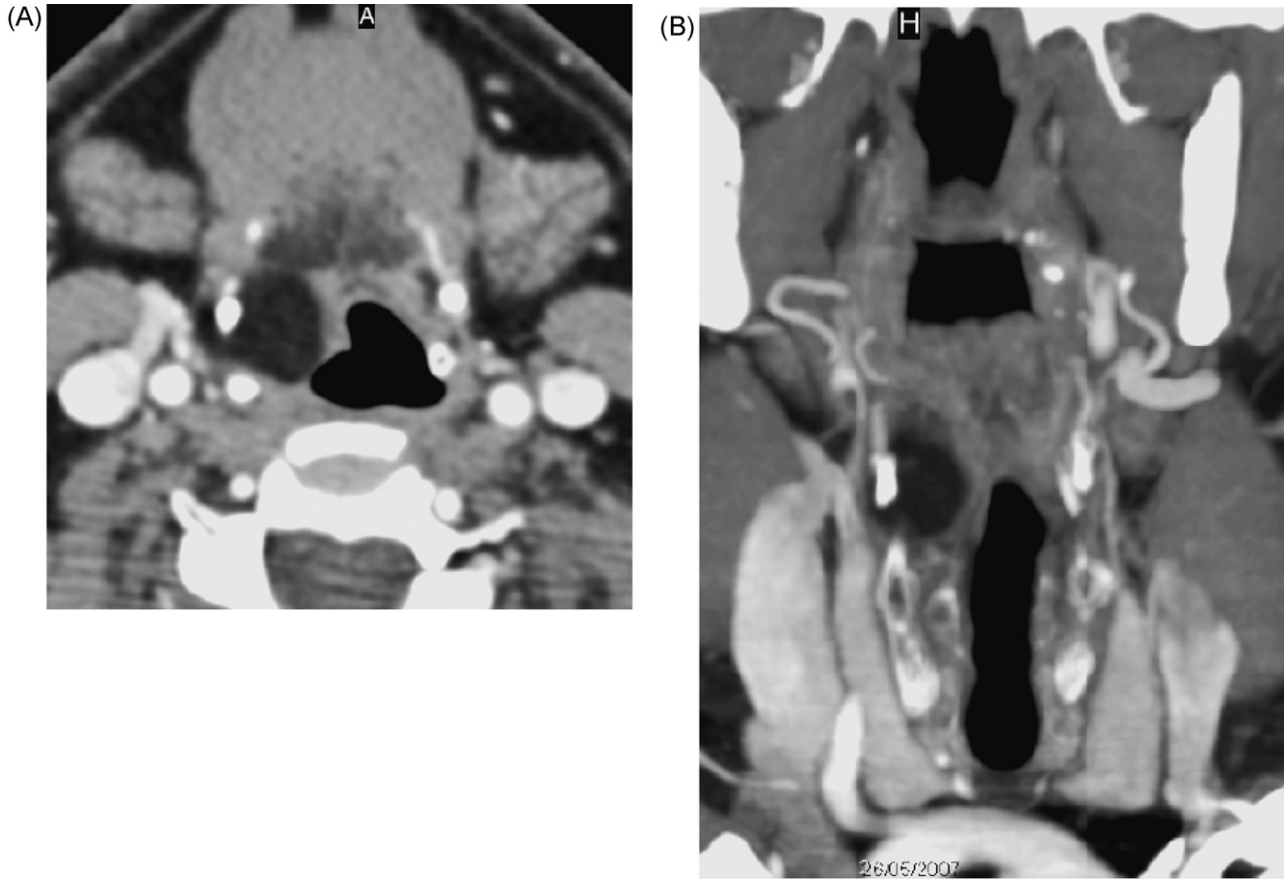

Fig. 17. Lipoma: axial contrast-enhanced CT image (A) and coronal 2D reconstruction (B) show a hypointense well-delineated lesion located in the right paraglottic space. The attenuation values of the mass are similar to those of the subcutaneous fat.

pathognomonic for hemangioma (Fig. 16). On MRI, laryngeal hemangiomas display a very high-signal intensity on T2-weighted sequences and strong but often inhomogenous enhancement on T1-weighted images after administration of gadolinium chelates. Larger paragangliomas typically display multiple curvilinear signal voids on both T1- and T2-weighted images. The conspicuity of these signal-void areas is directly proportional to tumor size.

Lipomas of the larynx and hypopharynx are rare. The radiologic diagnosis is straightforward: the typical CT features are those of a homogeneous, non-enhancing lesion with attenuation values from −65 to −125 HU (Fig. 17). On MRI, lipoma has the same signal intensity as subcutaneous fat and shows no significant enhancement after administration of intravenous contrast material.

Adenocarcinoma, *adenoidcystic carcinoma* and *mucoepidermoid carcinoma* arise from the minor salivary glands. Adenoidcystic carcinoma is typically found in the subglottis of patients without a history of smoking. These tumors can be located beneath a completely intact mucosa and display a characteristic pathway of perineural spread along the recurrent laryngeal nerve. None of these unusual types of carcinoma has any imaging characteristics allowing its distinction from squamous cell carcinoma and deep, aggressive biopsy is mandatory to clarify the diagnosis.

4. Treatment options and detection of treatment failure

The main options for treatment of malignant tumors of the larynx and hypopharynx currently consist of surgery, radiation therapy, surgery followed by radiation therapy, and radiation therapy combined with chemotherapy. The choice is influenced, besides clinical parameters, by the histology, primary site, extent of the primary lesion and the presence or absence of metastases.

Surgical treatment of laryngeal carcinoma has two goals, namely oncologically adequate excision of tumor tissue and preservation of the essential functions of the larynx as far as possible. Total laryngectomy is a very invasive procedure and impairs the quality of life after surgery considerably. Techniques of “voice-sparing” or “partial laryngectomy” are based on the capability of most patients to retain ability to breathe, swallow and speak despite the loss of substantial portions of the larynx. Only few studies have evaluated the CT appearance of the operated larynx and no data are currently available for comparing the relative advantages and drawbacks of CT and MRI. Management of early complications after partial or total laryngectomy, e.g., infection or aspiration, does not usually require CT. Late postoperative complications, e.g., laryngeal stenosis or granuloma formation present clinically in the form of dyspnea or changes in the quality of voice and must be distinguished from tumor recurrence. Because the operated larynx may be easily evalu-

ated by indirect inspection or flexible endoscopy the role of serial cross-sectional imaging for the detection of tumor recurrence is not yet clearly defined. In a retrospective study Maroldi et al. have evaluated postoperative CT scans of 73 patients with partial or total laryngeal surgery and correctly identified 27 recurrent tumors that were already evident endoscopically and one recurrent tumor that was clinically and endoscopically occult [35]. In view of this relatively low diagnostic yield it appears that CT is not warranted as a screening examination in asymptomatic postoperative patients but should rather be used selectively, e.g., to assess the depth of extension of an endoscopically proven recurrent tumor. Although familiarity with the expected anatomic changes after partial or total laryngectomy and their appearance on CT or MRI greatly facilitates radiologic interpretation (Fig. 18), evaluation of the postoperative larynx remains difficult. PET CT appears to facilitate detection of recurrent tumors due to increased lesion conspicuity [9].

Tumor recurrence occurring after radiation therapy usually becomes clinically manifest within the first 2 years. Physical and endoscopic examination is often limited by the changes induced on the mucosa and the underlying soft tissues by radiation therapy, and recurrent carcinoma originating extramucosally may be entirely invisible with endoscopy. Patients with a low risk of tumor recurrence after radiation therapy should rather be followed clinically with imaging studies performed only when tumor recurrence is suspected (changes in the quality of voice, pain, dyspnea, vocal cord fixation or tumor mass on endoscopy), whereas follow-up of high-risk patients should routinely include imaging studies. Successful radiation therapy leads to a substantial reduction of tumor volume within 4 months, and treatment failure must be suspected if 50% or more of the tumor mass is still visible after this period [36–38]. The relatively high radiation doses (>60 Gy) that are required for treatment of squamous cell carcinoma of the larynx and hypopharynx lead to marked edema and persisting fibrosis of the head and neck region. The characteristic CT and MR appearance of the larynx and hypopharynx after radiation therapy includes symmetric thickening of the epiglottis, aryepiglottic folds and false cords, anterior and posterior commissure, subglottis, posterior pharyngeal wall, and retropharyngeal space. Edema and, later, fibrosis result in an increased density of the preepiglottic and paraglottic fat on CT and a decreased signal intensity with a streaky or reticulated pattern on T1-weighted MR images. On both CT and fat-suppressed gadolinium-enhanced T1-weighted images the mucosa and the deeper structures of the larynx exhibit a very strong and diffuse enhancement which may either resolve after approximately 12 months or persist indefinitely. In general, diffuse changes in the larynx and hypoharynx should not be regarded as evidence

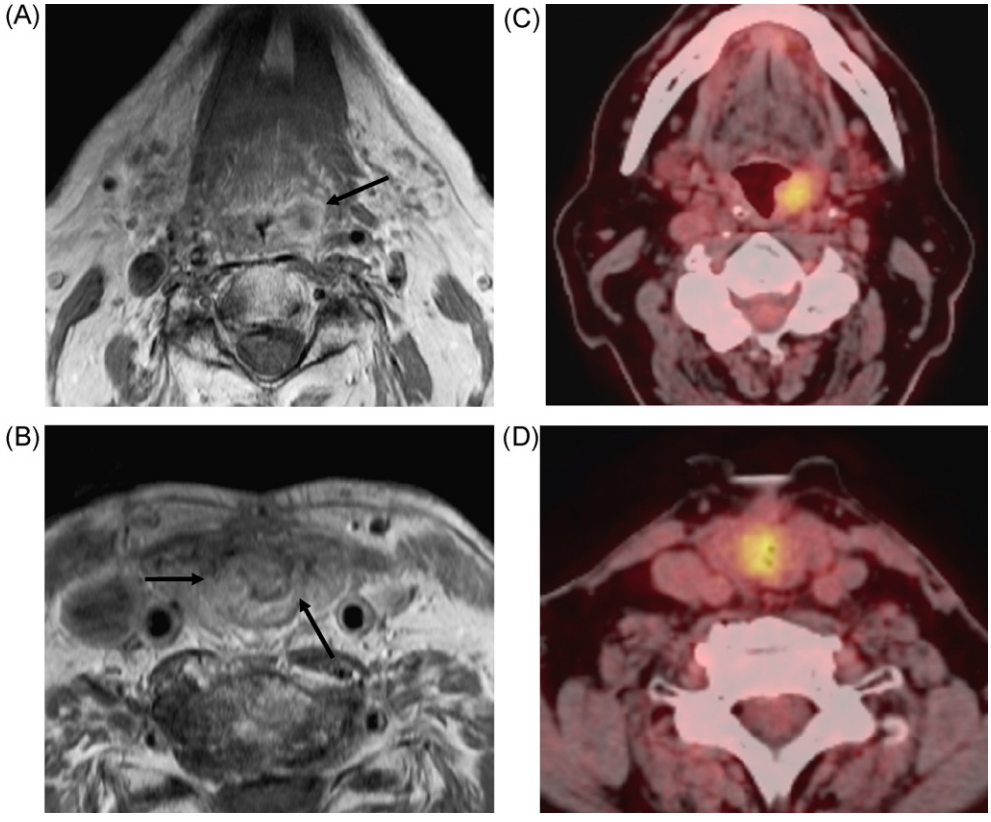

Fig. 18. Tumor recurrence at two distinct anatomic sites after total laryngectomy. MRI obtained three years after total laryngectomy and radiation therapy because of slowly progressing dysphagia. (A) Axial contrast-enhanced T1-weighted image obtained at the junction between the cranial portion of the neovestibule and oropharynx. A left-sided hypointense mass with peripheral contrast enhancement (arrow) consistent with tumor recurrence is seen. (B) Axial contrast-enhanced T1-weighted image obtained at the level of the inferior neovestibule shows major thickening and irregular enhancement (arrows) suggesting a second inferiorly located tumor recurrence. (C) and (D) Corresponding axial PET CT fused images show two distinct highly hypermetabolic lesions corresponding to probable tumor recurrences in the same location as suspected on MRI. Surgery confirmed the radiologic findings.

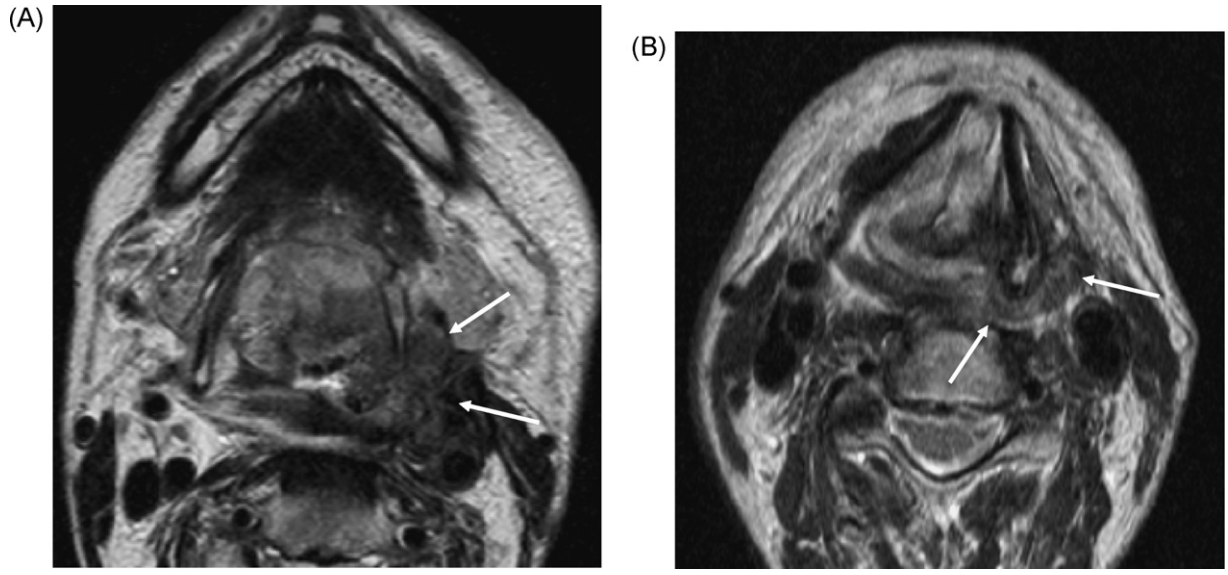

Fig. 19. Tumor recurrence after radiation therapy. (A) and (B) Axial T2-weighted FSE images obtained 2 years after radiation therapy for squamous cell carcinoma of the piriform sinus show recurrent disease (arrows) originating from the left piriform sinus and extending into the soft tissues of the neck. *Note*: the low signal intensity of the recurrent tumor due to its high cellularity. There is still massive edema at the level of the false cords and the characteristic reticulated pattern of the subcutaneous fat typically seen after radiation therapy.

of tumor recurrence. However, obvious or subtle focal masses on CT or MRI should alert the radiologist of the possibility of recurrent tumor (Figs. 18 and 19). PET CT holds promise to facilitate the differentiation between radiation-induced changes and recurrent tumor [9] (Fig. 18).

5. Cysts and laryngoceles

Laryngeal cysts arise from the mucosa and are related to minor salivary glands, whereas laryngoceles (also called saccular cysts) are dilatations of the saccule of the laryngeal ventricle.

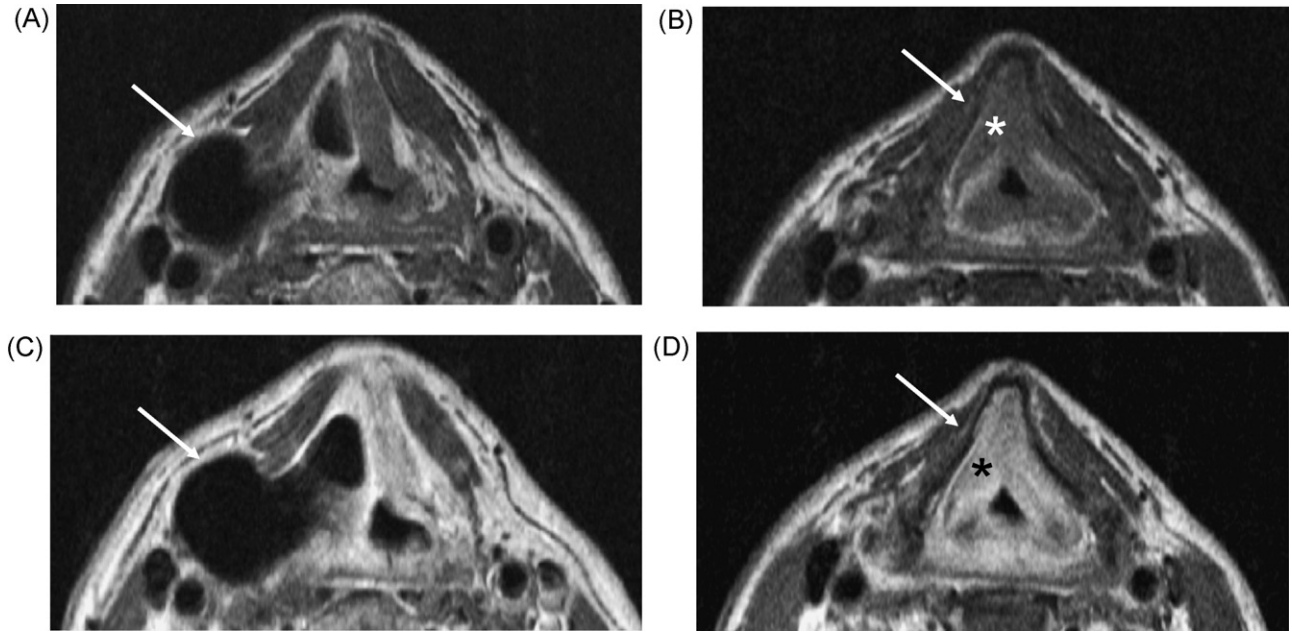

Fig. 20. External laryngocele caused by ventricular cancer. (A) and (B) T1-weighted SE images obtained at the supraglottic level show an air-filled external laryngocele (arrow in A) and an abnormal hypointensity at the level of the right paraglottic space and ventricle (asterisk). The adjacent thyroid cartilage is hypointense (arrow in B). (C) and (D) Corresponding axial images obtained after injection of gadolinium chelates show the air-filled external laryngocele with smooth margins (arrow in C) and enhancement of the right paraglottic space and ventricle (asterisk in D) suggesting the presence of a mass arising at this level and causing the laryngocele. The adjacent thyroid cartilage remains hypointense and does not enhance (arrow) suggesting that it is composed of non-ossified hyaline cartilage. Biopsy confirmed a squamous cell carcinoma arising in the ventricle.

A laryngocele occurs when there is obstruction of the ventricle, sometimes by a small cancer located near the neck of the saccule. Laryngoceles may contain air or fluid. An internal laryngocele extends superiorly in the paralaryngeal space, and may present as a submucosal supraglottic mass at endoscopic evaluation. If the laryngocele extends through the thyrohyoid membrane into the soft tissues of the neck, it is called an external laryngocele (Fig. 20). On CT or MRI, a laryngocele presents as a well-circumscribed, air- or fluid-filled structure extending from the laryngeal ventricle into the paralaryngeal space or through the thyrohyoid membrane into the soft tissues of the neck.

6. Vocal cord paralysis

Vocal cord paralysis can be categorized as superior laryngeal nerve deficit, recurrent laryngeal nerve deficit or total vagal nerve deficit. Paralysis of the recurrent laryngeal nerve is the most common type of vocal cord paralysis. The CT and MRI features of recurrent laryngeal nerve paralysis are explained by atrophy of the thyroarytenoid muscle and include an enlarged ventricle, ipsilateral enlargement of the piriform sinus, paramedian position, decreased size and/or fatty infiltration of the true vocal cord. Although the most common cause of recurrent laryngeal nerve paralysis is iatrogenic (most often secondary to thyroid surgery) additional differential diagnostic considerations include mediastinal, thyroid, and esophageal masses and aneurysms. In a patient with recurrent laryngeal nerve paralysis of unknown origin cross-sectional imaging should be extended to the skull base and the mediastinum to include the entire pathway of the vagus and recurrent laryngeal nerve (Fig. 21).

7. Inflammatory lesions

Epiglottitis and croup are diagnosed clinically and do not require imaging. In the Western hemisphere the larynx is rarely affected by granulomatous diseases. Tuberculosis, leprosy and syphilis appear to be more common in Asia and Africa and may affect the larynx and pharynx (Fig. 22). These entities have recently gained increasing importance in immunocompromized patients. If granulomatous tissue becomes visible on CT and MRI it cannot usually be differentiated from neoplasia. Nonetheless, the combination of pulmonary tuberculosis and bilateral diffuse laryngeal soft tissue lesions without destruction of the laryngeal architecture should raise the suspicion of laryngeal tuberculosis (Fig. 22) [39].

Relapsing polychondritis may affect laryngeal cartilages [40], and rarely rheumatoid arthritis may affect the cricoarythenoid joints, the cricothyroid joints and the pharynx. On MRI massive thickening of the mucosa and contrast enhancement of the entire pharyngeal wall may be seen (Fig. 23). Although diagnosis and treatment of pharyngitis is straightforward in general, the situation may be more complex in the immunocompromized patient with pharyngitis due to opportunistic infection involving unusual pathogenic organisms. In such situations cross-sectional imaging may be indicated to assess whether the disease is limited to the mucosa or whether abscesses are present. *Necrotizing*

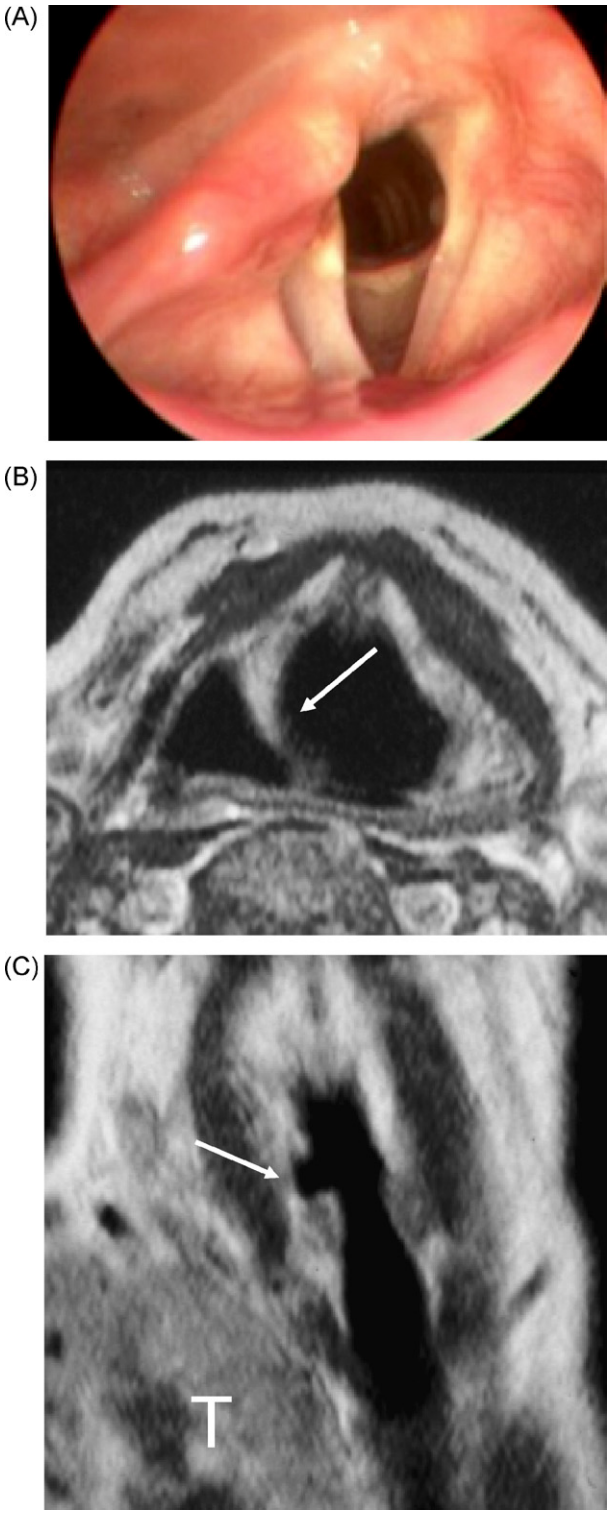

Fig. 21. Recurrent laryngeal nerve paralysis. (A) Endoscopic image of a patient investigated for hoarseness and a palpable neck mass shows the paramedian position of the right vocal cord and enlargement of the ipsilateral piriform sinus suggesting recurrent laryngeal nerve paralysis. Axial (B) and coronal (C) contrast-enhanced T1-weighted images show atrophy of the right aryepiglottic fold (arrow in B) and enlargement of the ipsilateral piriform sinus. The right laryngeal ventricle is also enlarged (arrow in C) and the right thyroarytenoid muscle is slightly hyperintense due to denervation atrophy. The radiologic findings are characteristic for recurrent laryngeal nerve paralysis. The cause is a thyroid tumor compressing the recurrent laryngeal nerve (T in C).

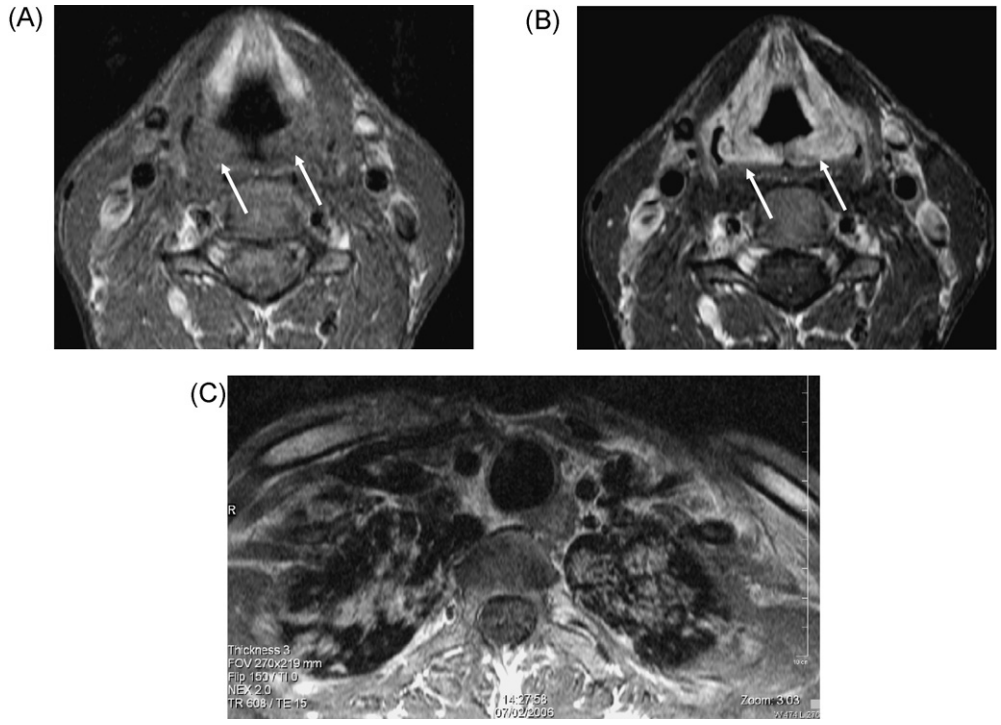

Fig. 22. Laryngeal tuberculosis seen in a young male. Endoscopically large ulcerating lesions were seen on the mucosa of both aryepiglottic folds and on the laryngeal surface of the epiglottis. (A) and (B) Axial images obtained at the supraglottic level show that both aryepiglottic folds have an abnormal low signal intensity on the unenhanced T1-weighted image (arrows in A) and that they enhance substantially after administration of contrast material (arrows in B). Axial image from the same examination obtained further caudally (C) shows bilateral infiltrative lung lesions. The laryngeal and pulmonary findings were highly suggestive of tuberculosis. Microbial cultures confirmed the diagnosis and the patient underwent medical treatment.

fasciitis of the head and neck is a severe, acute, and potentially life-threatening bacterial soft tissue infection with a very rapid clinical evolution. It affects both immunocompetent and immunocompromized patients and, unless immediate surgical treatment is given, leads invariably to mediastinitis and fatal sepis. CT or MRI findings include cellulitis, multiple fluid collections with or without gas in various neck compartments, diffuse enhancement of neck fasciae and myositis [41]. The larynx is often involved by the inflammatory, edematous process, necessitating intubation and myositis with or without abscess formation or myonecrosis is seen in the pharyngeal constrictor muscles. In the acute and subacute phase, CT and MRI may demonstrate contrast enhancement of the pharyngeal constrictor muscles or frank disruption of the pharyngeal wall.

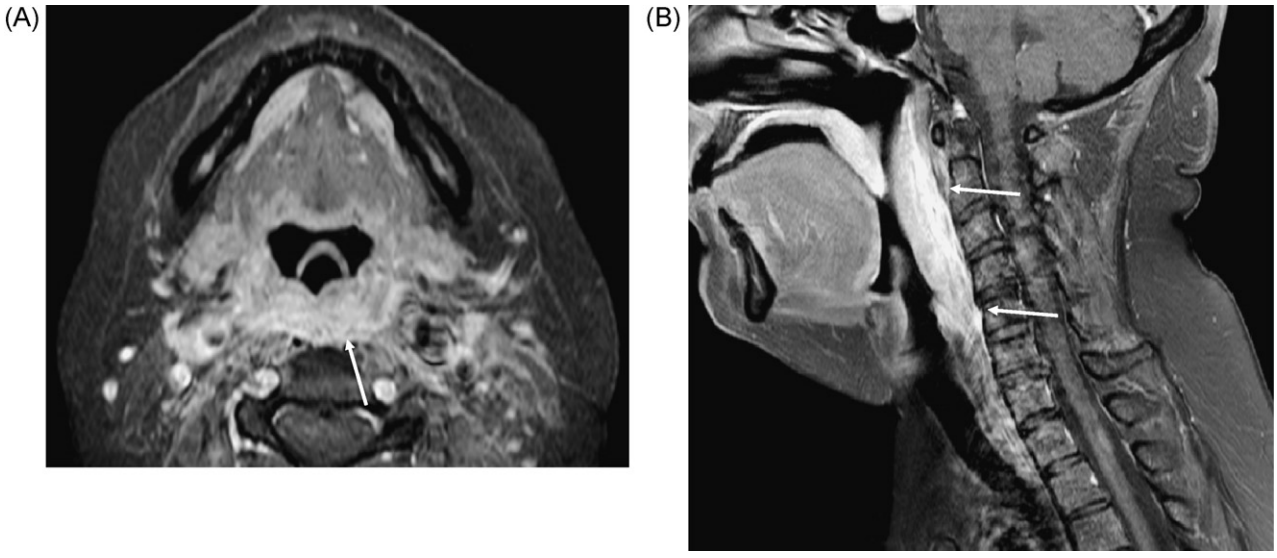

Fig. 23. Juvenile polyarthritis with extensive pharyngeal involvement in a young female presenting with major dysphagia. Fat-saturated contrast-enhanced T1-weighted images in the axial (A) and sagittal plane (B) show massive thickening and contrast material enhancement of the entire pharyngeal wall involving the constrictor muscles and additionally the retropharyngeal space (arrows). The patient was treated with high dose corticosteroids and the radiologic findings regressed.

Fig. 24. Laryngeal trauma. This patient was involved in a motor vehicle accident and sustained a dashboard injury. Axial CT images (A) and (B) show a tiny fracture line involving the left thyroid lamina with inward displacement of the inferior cornu of the left thyroid cartilage. (C) Coronal 2D reconstruction better shows the nearly horizontal bilateral fracture line (arrows). The airway is not narrowed significantly and there is no soft tissue emphysema.

8. Trauma

Trauma to the larynx can cause mucosal tears, submucosal hematomas, avulsion of the epiglottis, fractures of the laryngeal cartilages and joint dislocation [42,43]. Both fractures and hematomas may lead to severe airway compromise. Fractures of the thyroid cartilage may be vertical, horizontal or the entire thyroid cartilage may be shattered. Fractures of the cricoid cartilage tend to occur bilaterally. Cricothyroid dislocations tend to occur with severe trauma, while cricoarytenoid dislocations tend to occur with minor trauma. Most patients with laryngeal trauma undergo CT, which allows excellent delineation of most traumatic lesions (Fig. 24). However, MR imaging may provide significant additional information in young patients, where laryngeal cartilages are not ossified and therefore not well visualized on CT.

9. Conclusion

The most important clinical role of CT, MR imaging and more recently PET CT lies in the pretherapeutic workup and posttherapeutic follow-up of patients with squamous cell carcinoma of the larynx and hypopharynx. Adequate interpretation of the CT and MR images requires a thorough knowledge of the patterns of tumor spread within the different regions of the larynx and hypopharynx as well as the predictive value of the diagnostic signs that may indicate neoplastic invasion with each modality. In addition, the radiologist needs to be familiar with expected changes induced by surgical resection and radiation therapy and with findings indicating recurrent disease. Although non-squamous cell carcinoma and other neoplasms are relatively uncommon in the larynx and hypopharynx, CT and MR imaging usually play a key role for their diagnosis since these lesions are almost always situated submucosally. In addition, their appearance on CT and MR images may be quite typical, as it is the case with chondrosarcoma, hemangioma, or lipoma, therefore allowing correct lesion characterization. The majority of non-neoplastic conditions do not require imaging although CT is useful in some situations, such as to delineate abscess formation in inflammatory conditions and to evaluate the extent of laryngeal fractures due to severe blunt trauma. Cysts and laryngoceles can usually be readily distinguished from neoplastic changes on CT and MR images although granulomatous inflammation may sometimes appear similar to neoplastic disease.

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