HEAD AND NECK LESIONS
Radiologic-Pathologic Correlations

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This article demonstrates the strengths and weaknesses of CT and MR imaging with respect to pathologic correlation. The article is divided into two sections. In the first, we correlate unusual density or signal intensity characteristics with the histopathologic findings of various head and neck lesions. In the second section, we explore how reliable imaging is in demonstrating the true extent of a lesion using pathology as the gold standard.

PART 1: imaging appearances

CT

In the head and neck, lesions of various densities may appear. These include lesions of very low density (thyroglossal duct cysts, branchial cleft cysts, mucous retention cysts, Tornwaldt’s cysts, dermoids and lipomas); low-intermediate density (tumoral necrosis or nodal necrosis); intermediate density (most neoplasms); and high density (hemorrhagic, hypercellular, calcified, or ossified lesions).

Lesions of Very Low Density

It may be startling to note that cystic lesions that contain thyroglobulin, hyperproteinaceous secretions, cerebrospinal fluid, mucus, or serous fluid may appear identically on CT. CT can not distinguish differences in the histology of the cyst wall that could separate such lesions as sialoceles, pseudocysts, branchial cleft cysts (Fig. 1), lymphoepithelial cysts, thyroglossal duct cysts, or colloid cysts of the thyroid gland. Occasionally, there may be slight hyperdensity to a cystic mass that might suggest superimposed trauma with hemorrhage or infection. More often, one must rely on infiltration or edema of the subcutaneous tissue or surrounding fat planes to suggest superimposed infection.

For many classically-appearing benign cystic lesions, preoperative histologic sampling is not necessary to confirm a specific diagnosis suggested by imaging. Some cystic lesions (e.g., nodes from papillary cancer of the thyroid gland or adenoid cystic carcinoma) however, may reflect a malignancy (Fig. 2).

With the rare exception of teratomas and liposarcomas, lesions that have fat density are benign processes. Lipomas are the most common benign tumors of the head and neck in adults and are most commonly found in the subcutaneous tissues of the posterior neck. Dermoids may contain fat and are usually seen in children around the nose or orbits. By virtue of their negative Hounsfield unit they are usually easy to diagnose. A soft tissue component raises the specter of a liposarcoma.

Low-Intermediate Density

The presence of necrosis within a lymph node is highly suggestive of malignancy in patients with primary head and neck carcinomas. The presence of necrosis within a metastatic lymph node bodes poorly from the standpoint of patient outcome. Although it has been said that 23% of lymph nodes less than 1 cm, 56% of lymph nodes 1 to 2 cm, and 73% of lymph nodes over 3 cm in size show nodal...
signal intensity characteristics on MR imaging have been ascribed to the presence of paramagnetic ions, specifically manganese, iron, and calcium (Fig. 10). The hyperdensity on CT may be due to the affects of these ions or due to hyperproteinaceous secretion formation.

**Isointensity on T1-Weighted Scans**

Most nonmucosal soft tissue masses and squamous cell carcinomas of the head and neck are isointense to neighboring muscle. This is the MR imaging equivalent of isodensity on CT and is nonspecific as far as histologic characterization of a lesion. Those associated with edema are more commonly hypointense to muscle on T1-weighted scans. Therefore, inflammatory entities are often dark on T1-weighted scans, although not as dark as lesions that have true signal voids on MR imaging.

**Hypointensity on T1-Weighted Scans**

Absolute signal voids may be seen with lesions that have dense calcification, bone, air, or rapidly flowing blood within them on conventional T1-weighted scans. Signal voids may be seen with arteriovenous malformations of the head and neck; aneurysms; paragangliomas (though interspersed with solid tissue); bone-forming or odontogenic masses; or calcified lesions (sarcomas). Occasionally, extremely hyperproteinaceous secretions (concretions) or rhinoliths have a signal void on T1-weighted MR imaging (see Fig. 9).6,13

**Hyperintensity on T2-Weighted Scans**

Most inflammatory lesions of the head and neck are hyperintense on T2-weighted scanning due to their associated edema. Fluid levels from acute sinusitis, mucosal thickening, and abscesses are among these bright inflammatory findings. Most cysts (ranulas, mucous retention cysts, thyroid cysts, branchial cleft cysts) and many benign masses, including pleomorphic adenomas, polyps, lymph nodes, hemangiomas and so forth, are bright on T2-weighted scans. Any neoplasm demonstrating necrosis shows high intensity on long TR sequences. Rhabdomyosarcomas, synovial sarcomas, adenoid cystic carcinomas, and other salivary gland malignancies are among the malignancies that can be quite high or low in T2-weighted intensity (Fig. 11).

**Intermediate Intensity on T2-Weighted Scans**

Isointensity on T2-weighted scanning often implies hypercellularity or lesions that have high nucleus to cytoplasm ratios. In the head and neck, most malignant lesions have these signal intensity characteristics. On the benign side, schwannomas may have mixed intensity and this most likely corresponds to areas of hypercellularity (Antoni A) and hypocellularity (Antoni B) within the same tumor (Fig. 12). Many salivary gland neoplasms, both benign (Warthin’s tumors, oncocytomas) and malignant (adenoid cystic carcinoma, adenocarcinoma), may have similar signal intensity to the fat-suppressed parotid tissue on T2-weighted scans. Similarly, inverted papillomas (Fig. 13) and minor salivary gland tumors of the sinonasal cavity are often of intermediate intensity. Squamous cell carcinoma is usually low to intermediate in its T2-weighted intensity characteristics; an area of necrosis within the tumor may appear brighter.

**Hypointensity on T2-Weighted Scans**

Just as with T1-weighted scans, signal voids may be seen with lesions that have dense calcification, bone, air, or rapidly flowing blood, such as
Figure 9. The effect of the concentration of protein on T1-weighted and T2-weighted signal intensity is demonstrated in this graph (A). Note the initial increase in T1-weighted intensity with increasing protein concentration followed by a decline in both T1-weighted and T2-weighted intensity. B, The high intensity of this sphenoid sinus mucocele (asterisk) can be explained on the basis of elevated protein content. (Part A from Som PM, Dillon WP, Fullerton GD, et al: Chronically obstructed sinonasal secretions: Observations on T1 and T2 shortening. Radiology 172:515–520, 1989; with permission).
Figure 10. Fungus in the sinus. A, Allergic mucin in patient with allergic fungal sinusitis. The specimen pictured here consists of mucin (m) with numerous entrapped eosinophil (open arrows) (high power). Charcot-Leyden crystals and fungal forms also may be seen in the allergic mucin but are not seen here. No deep invasion is present. B and C, See page 996. D, Invasive aspergillus involving the sinonasal mucosa. In this case, which was seen in an immunosuppressed individual, fungal forms (arrows) infiltrate the submucosal tissues (high power). E, The silver stain demonstrates the fungi (arrows) invading deeply. This patient subsequently died of invasive aspergillosis. F, See page 996.

Figure 11. Tumors and T2-weighted signal intensity. A and B, See page 997. C, This rhabdomyosarcoma presented as a parapharyngeal mass in a 17-year-old man. Note the spindle-shaped cells (arrows) (medium power). D, Immunohistochemical staining for desmin confirms the presence of muscle differentiation in this tumor. E and F, See page 998. G, Intermediate grade mucoepidermoid carcinoma of the parotid gland. Note nests of intermediate (squamoid) and mucus cells surrounded by dense fibrous tissue (arrows) (low power). H, See page 998.
Figure 10. Fungus in the sinus. 

A, See Color Plate 2. B, A CT scan shows complete opacification with dense material. C, Note how the T2-weighted MR image shows a near signal void from the susceptibility associated with the ions deposited in the fungal sinusitis. D and E, See Color Plate 2. 

F, Note the aggressive bone invasion seen along the left sphenoid wing, the left lateral orbit, the clivus, and the left fronto-ethmoidal region.
Figure 11. Tumors and T2-weighted signal intensity. A, Adenoid cystic carcinoma of the parotid gland can demonstrate a cribriform growth pattern (medium power). B, Some adenoid cystic carcinomas are bright (seen here in left maxillary antrum) and some are intermediate in intensity on T2-weighted scans. This is the exception to the rule that malignancies are not bright in the paranasal sinuses. C and D, See Color Plate 2.

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Figure 11 (Continued). E, The lesion (R) on T2-weighted MR image is brighter than parotid glandular tissue and muscle, but not as bright as cerebrospinal fluid. F, Note the tumoral growth through the foramen ovale (arrow) along fifth cranial nerve branches on this enhanced T1-weighted scan. G, See Color Plate 2. H, Note the very low signal intensity on T2-weighted scans (lower than parotid tissue) of this mucoepidermoid carcinoma (M).

Figure 12. Schwannoma. A, This benign peripheral nerve sheath tumor arose in the pterygopalatine fossa. The tumor is characterized by highly cellular areas (Antoni A) in (A) as well as hypocellular zones (Antoni B) in (B) (both low power). C, The CT scan showed that the lesion arose in the pterygopalatine fossa (arrow) on the left.
Figure 13. See legend on opposite page
arteriovenous malformations, aneurysms, paragangliomas, or chondroid, osseous, or odontogenic masses (Fig. 14).

Other lesions may be dark on a T2-weighted scan including melanotic melanomas (due to T2 shortening by the paramagnetic melanin); amyloidomas (due to protein content and lack of hydration protons); fibromatous lesions, such as malignant fibrous histiocytomas; nodular fasciitis; aggressive fibromatosis (again, thought to be due to scarce unbound protons); acutely hemorrhagic lesions (from proton relaxation enhancement by deoxyhemoglobin); fungal and actinomycotic infections (due to paramagnetic ions and sulfur crystals, respectively); myositis ossificans; and lesions with high protein content (Tornwaldt's cysts and some mucocles).

Vascularity and Enhancement of Lesions

Hypervascular Lesions

In the head and neck region paragangliomas (glomus jugulare, glomus vagale, and carotid body tumors) and juvenile nasopharyngeal angiofibromas are the neoplasms that may demonstrate flow voids due to hypervascularity (Fig. 15). Sometimes the lesions may actually represent arteriovenous malformations or fistulae, with the high flow states demonstrating the signal void characteristics. There are very few neoplasms that demonstrate the prominent flow voids that are seen in paragangliomas; however, a highly vascular meningioma, metastasis or hemangiopericytoma may have these appearances.

Enhancement Characteristics

In general, lesions that show marked contrast enhancement on CT or MR imaging are hypervascular lesions in the head and neck. These lesions include paragangliomas, juvenile angiofibromas, hemangiomas, and hemangiopericytomas. On histopathologic sectioning, numerous blood vessels are seen coursing through these lesions; however, in some instances, the lesions are devoid of signal voids representing larger blood vessels. This is particularly true of hemangiomas, angiofollicular hyperplasia, small paragangliomas, and hypervascular metastases of thyroid or renal origin. Para-
gangliomas have an enhancement pattern on dynamic studies that is characteristic: a dip in the dynamic curve at the 20- to 50-second mark after administration of contrast agents (Fig. 16). No such early drop-out effect is seen with lesions usually included in the same differential diagnosis (schwannomas, meningiomas, or carcinomas), which instead show a more gradual increase in intensity.

Most soft tissue neoplasms enhance to a much milder degree than the lesions described previously. Squamous cell carcinomas enhance and may be well demonstrated on T1-weighted fat-suppressed scans, particularly those in the tongue and nasopharynx. Tracking of tumors to the meninges or along the nerves is often particularly well depicted after contrast administration. On the other hand, we define necrosis in primary tumors or lymph nodes based on the absence of central enhancement and the presence of rim enhancement. Clearly, this pattern may also be seen in abscesses.

Lack of enhancement is characteristic of most of sclerotic osseous lesions and most cysts. One can often distinguish the inflammatory, postobstructive component of a sinonasal tumor from the true neoplasm by the solid enhancement of the tumor as opposed to the absence of, or rim enhancement of, the obstructed secretions.

PART 2: THE EXTENT OF LESIONS

Most requests for head and neck scans are performed to stage head and neck cancers. Because the superficial and surface characteristics of the lesions are best evaluated at endoscopy, imaging's main role is to assess the submucosal and deep extent of the tumors.

Bone and Cartilage Invasion

Unfortunately, in many instances imaging cannot distinguish between neoplasm and the peri-tumoral edema or inflammation of the tissue adjacent to the cancer. This has been demonstrated in the mandible with oral cavity and oropharyngeal cancers where infiltration of the mandibular marrow signal may be present with neoplastic invasion, periodontal inflammatory disease, radiation fibrosis, osteoradionecrosis, and osteomyelitis (Figs. 17 and 18). In a similar fashion, laryngeal cartilage invasion (Fig. 19) may be misdiagnosed when reactive inflammatory changes in the cartilage occur secondary to adjacent tumor. This is a particular problem with the evaluation of the thyroid cartilage, which appears to have a greater potential for reactive change than the arytenoid or cricoid cartilage. Unfortunately, CT findings of cartilaginous sclerosis, erosion, and signal intensity replacement are compromised by a 20% to 30% rate of false-positivity in the thyroid cartilage and 10% to 20% rate in the arytenoid and cricoid cartilage. On the other hand, when one has completely normal-appearing laryngeal cartilages the chance of neoplastic infiltration is less than 5%. MR imaging is significantly more sensitive (>7%) but less specific than CT in detecting neoplastic cartilage invasion. MR imaging tends to overestimate neoplastic cartilage invasion leading to unnecessary laryngeal resections; however, CT underestimates neoplastic cartilage invasion leading to inadequate therapy.
Pre-epiglottic Fat and Prevertebral Muscle Invasion

With respect to the soft tissues of the head and neck, false-positive studies in the evaluation of the pre-epiglottic fat and prevertebral musculature may also occur despite imaging features that suggest their invasion (Fig. 20). Uninvolved epiglottic and retropharyngeal fat on a T1-weighted scan shows high negative predictive value over 95%, but replacement of the pre-epiglottic fat with soft tissue density or signal intensity may occur with and without invasion of the fat. The accuracy of MR, when infiltration of the bright fat on T1-weighted scans is present, is approximately 90%. Causes of false-positive studies include reactive edema, lymphoid hypertrophy, or partial volume effects even with 3-mm contiguous sections. In a similar fashion, we have found instances in which high signal intensity on T2-weighted scanning and contrast enhancement in the prevertebral musculature, thought to be

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Figure 15. Hypervascular masses. A, Juvenile angiofibroma. The lesion is characterized by the presence of widely open blood vessels (arrows) surrounded by dense fibrous tissue (high power). B, Paraganglioma. This carotid body paraganglioma is characterized by neuroendocrine cells (arrows), which occur as nests or as single cells surrounded by a rich vascular network (high power). C and D, See page 1002.

Figure 17. Bone invasion. A, B, C, and D, see page 1006. E, In this case, the tissue in the bone represented the meningiomas (arrows) rather than reactive change.

Figure 19. Cartilage invasion. A, Laryngeal squamous cell carcinoma invading thyroid cartilage (arrow) (high power). B, C, and D, See page 1008.

Figure 22. Perineural invasion. A, Adenoid cystic carcinoma with extensive perineural and focal intraneural invasion (medium power). The nerves (N) are surrounded by tumor (arrows). B, C, and D, See page 1011.

Figure 23. Dural invasion. A, Poorly differentiated squamous cell carcinoma (arrow) involving dura (high power). The original tumor arose on the skin of the left ear. B and C, See page 1011.
Figure 17. Bone invasion. A, Although the normal bone marrow fat’s high intensity on T1-weighted scan was replaced on the right side of the mandible, the cause was radiation-induced fibrosis. B, Osteomyelitis in a patient with a floor of mouth cancer was the cause of this false-positive study that was read as showing mandibular bone marrow invasion. C, In the case of meningiomas, there is some controversy as to whether the thickening of the bone, as seen here along the sphenoid wing (b), is caused by neoplastic invasion or osteoblastic reactive change. D, The meningeal-based tumor (arrows) is better seen on the enhanced MR image. Note the lack of bony enhancement. E, See Color Plate 3.
Figure 18. Bone invasion. A, Squamous cell carcinoma (C) invades the maxilla (arrow) (medium power). B, T1-weighted MR image demonstrates invasion by a retromolar trigone cancer into the maxilla (solid arrow) and mandible (open arrow) as evidenced by replacement of bright marrow fat with intermediate intensity tumor.
Figure 19. Cartilage invasion. A, See Color Plate 3. B, This patient’s CT scan was unremarkable with respect to findings suggestive of thyroid cartilage invasion by the left-sided laryngeal lesion (arrow). CT tends to suffer from a lack of sensitivity compared with MR imaging. The left arytenoid is sclerotic. C, In a different patient, the T2-weighted MR image suggests invasion of the anterior commissure (arrow), a common route for cartilaginous spread. D, Rarely, thyroid cancer (T) can invade the laryngeal cartilage. This papillary carcinoma of the thyroid, tall cell variant, invaded the thyroid cartilage (arrow). The tall cell variant of these tumors carry a worse prognosis than typical papillary carcinoma. The tumor presented as a laryngeal mass and a laryngeal carcinoma was suspected. The diagnosis of a thyroid primary was made only on analysis of the laryngectomy specimen.
Figure 20. Pre-epiglottic fat invasion. A, Laryngeal squamous cell carcinoma (S) involving the pre-epiglottic fat (arrows) (low power). B, The sagittal T1-weighted MR image is a nice study to evaluate the patient's pre-epiglottic fat. Here it is invaded (arrow) by squamous cell carcinoma. C and D, Paraglottic (open arrows) and pre-epiglottic (solid arrows) fat are infiltrated on the axial scans. E, This CT was falsely positive for pre-epiglottic fat invasion. On pathology, the tissue in the fat (arrow) represented abundant minor salivary glands.
**Figure 21.** Vascular wall invasion. A, Note the complete encasement of the common carotid artery (solid arrow) and vertebral artery (open arrow) by this thyroid malignancy. B, Sparing of the posterior wall of this carotid artery (arrow) may save it from having to be resected with the primary tumor.

**Figure 22.** Perineural invasion. A, See Color Plate 3. B, Note the spread up the seventh cranial nerve (arrows), through the stylomastoid foramen by this adenoid cystic carcinoma (C). C, In a different case of adenoid cystic carcinoma, one sees abnormal enhancement in the pterygopalatine fossa (arrow). D, The same patient had an enhancing orbital mass (asterisk) (via spread from the pterygopalatine fossa through the inferior orbital fissure) and infiltration of the maxillary nerve (curved arrow) in foramen rotundum.
suggestive of neoplastic infiltration, have represented reactive changes.\textsuperscript{76} The parapharyngeal fat may be replaced by soft tissue in cases of squamous cell carcinoma with submucosal growth. As opposed to the subtle findings in the cartilage, replacement of the parapharyngeal (paraglottic) fat tends to be a more reliable finding than low intensity in the cartilage on T1-weighted scans.

**Vascular Invasion**

Carotid artery wall invasion may also be a critical issue at the time of treatment planning. It has been shown that when tumor involves the internal or common carotid artery for over 270 degrees of its circumference, the likelihood is low that one will be able to scrape the tumor off of the carotid artery without leaving macroscopic disease behind.\textsuperscript{77} In cases where the carotid is completely encircled by tumor, preoperative temporary balloon occlusion is performed to assess for whether the carotid artery can be sacrificed at the time of extirpation of the tumor. Alternatively, a bypass procedure around the area of infiltration can be performed. On the other hand, if tumor involves less than 270 degrees of carotid artery circumference, surgeons are usually able to remove the tumor from the carotid artery without macroscopic disease left behind (Fig. 21). Radiation therapy might still be necessary to sterilize the operative bed of microscopic tumor.

**Perineural Extension**

The extent of a lesion is also critical with respect to those tumors that have a propensity for perineural spread. Although adenoid cystic carcinoma is the histologic type most commonly associated with perineural spread, squamous cell carcinoma, other malignant salivary gland tumors, basal cell carcinoma, and lymphoma can potentially spread along the cranial nerves of the head and neck (Fig. 22).\textsuperscript{4,5} Skip lesions can occur when one has perineural spread; in most instances the surgeons pursue the tumor as far as possible until they have a wide negative surgical margin. Perineural spread on imaging is best demonstrated by MR imaging as enlarged contrast-enhancing nerves with or without enlargement of the foramina of the involved nerve.

**Dural Invasion**

When preoperative MR images of patients who had resection of skull base neoplasms were evaluated for dural and pial enhancement, some interesting findings were noted. Dural enhancement showing focal nodules was highly accurate (95%) in predicting the presence of neoplastic dural invasion.\textsuperscript{7} Pial enhancement and dural enhancement wider than 5 mm were also accurate predictors of dural invasion by neoplasm (82% and 91%, respectively). Linear enhancement of the dura was a poor predictor of dural infiltration by tumor (41% accuracy). The extent of dural invasion of skull base tumors has been shown to be an important prognostic indicator. Dural invasion of tumor also

Figure 23. Dural invasion. A, See Color Plate 3. B and C. The enhanced MR image shows a nodular thickening of the dural margin (arrows) where the tumor had infiltrated the temporal bone.
Figure 24. See legend on opposite page
guides the surgical approach; if dura is to be excised, preparation of pericranial flaps or fascial grafts is important. MR imaging has been shown to be an accurate method of evaluating for dural invasion when dural enhancement meets the criteria of either focal nodules or width greater than 5 mm or when pial enhancement is present (Fig. 25).

Cytology

On-site cytology has been increasingly utilized for image-guided aspirations of head and neck masses. (Fig. 24.) At the aspiration site, the cytologist can make a determination both of a preliminary diagnosis as well as the sufficiency of the material in the specimen. This has increased the yield of the procedure into the 90% range. At our institution, the experience with over 125 CT-guided aspirations of head and neck masses has produced an accuracy rate of 86.5%, an insufficient material rate of 7.5%, and an indeterminate-incorrect diagnosis rate of 7%. This has obviated the need for core biopsy histology specimens and has allowed the use of small-bore needles (22- to 25-gauge needles). These specimens can be obtained from locations that are inaccessible to the head and neck surgeons' fingers and their endoscopes. A coaxial needle system using an 18-gauge introducer needle and a 22-gauge aspiration needle has allowed single punctures of the face while enabling multiple specimens to be obtained from different sites within a mass. The procedure has also decreased the number of open biopsies performed for deep lobe parotid, parapharyngeal, and skull base masses. Diff-quick specimens on-site of paragangliomas versus different tumors. Radiology 174:73, 1990

References


Figure 24. Fine needle aspirates. A, The aspiration of a superficial parotid mass shows mucoidaline stroma and epithelial cells compatible with a pleomorphic adenoma (medium power). B, This aspirate from the parapharyngeal space of a lung transplant recipient shows large atypical lymphoid cells. The diagnosis was post-transplant lymphoproliferative disorder (high power). C, The approach to this parapharyngeal mass (asterisk) was from a retromaxillary direction. The arrows represent the needle tract.