REVIEW ARTICLE

Imaging in Head and Neck Cancers

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Abstract

This article reviews the role of imaging, imaging characteristics and significance of individual imaging modalities as well as the newer imaging modalities in the evaluation of head and neck cancer. In the pretreatment evaluation, imaging is performed primarily to determine the stage of tumor and to look for an occult primary. It helps in obtaining tissue samples to establish the diagnosis, and treatment planning if radiotherapy is considered. Postsurgery and radiotherapy changes can be differentiated from residual or recurrent pathology on imaging. Imaging also plays an important role in assessing the response to treatment.

Keywords: Head and neck cancer (HNC), squamous cell carcinoma (SCC), computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET), ultrasonography (USG).

INTRODUCTION

Head and neck cancer (HNC) encompasses a variety of cancers, squamous cell carcinoma (SCC) being the major group, arising from various sites which can be divided as:

- Nasal cavity and the paranasal sinuses
- Thyroid
- Larynx
- Oral cavity, which includes the lips, buccal mucosa, anterior tongue, floor of the mouth, hard palate, retromolar trigone, tongue, upper and lower gingiva
- Pharynx, which is divided into the oropharynx, nasopharynx, and hypopharynx
- Skull base
- Major and minor salivary glands.

SCC accounts for majority of head and neck cancers. Other cancers include adenocarcinomas, adenoid cystic carcinomas, mucoepidermoid carcinoma and metastases. Mesenchymal tumors include lymphoma, leukemia, melanoma and sarcomas. Some tumors are specific to certain regions, for example, esthesioneuroblastoma (olfactory neuroblastoma).

Ultrasonography (USG), computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET), radionuclide imaging are the various modalities available for imaging of head and neck cancers. In different cancers and in specific situations, certain imaging modality is superior to others. Individual modality has its own pros and cons. Ultrasonography is a good modality to differentiate solid from cystic lesions and to look at superficial structures especially thyroid and lymph nodes. It is readily available, portable and cheaper. However, it is difficult to localize the deeper pathologies with ultrasonography. CT and MRI are the cross-sectional modalities useful to better evaluate the entire extent of the pathology. MRI is better in specific situations due to its inherent superior soft tissue contrast and lack of radiation. CT has upper hand in identifying subtle areas of calcification and subtle bony cortical erosion. PET and radionuclide imaging provide the functional information which combined with the structural imaging modalities help in better evaluation of the pathology.

NASAL CAVITY AND PARANASAL SINUS (PNS) CANCERS

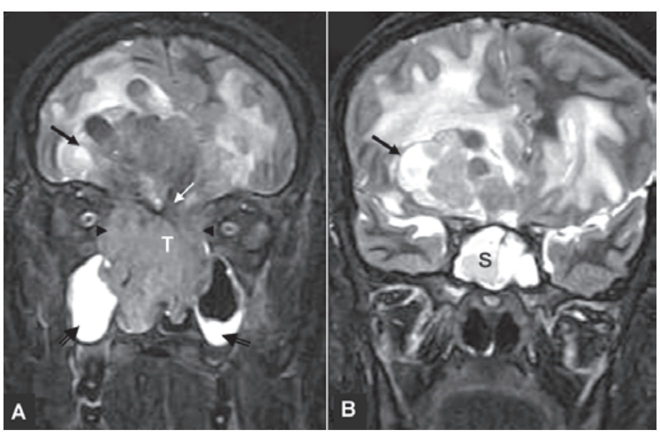
Malignant sinonasal tumors account for 3% of head and neck malignant neoplasms.[1] Squamous cell carcinoma is the most common histological type of PNS malignancies. Others include adenocarcinoma, adenoid cystic carcinoma, mucoepidermoid carcinoma and olfactory esthesioneuroblastoma. The most common sinus involved is maxillary sinus.

Cross-sectional imaging modalities like CT and MRI determine the extent of involvement of adjacent structures by the pathology. It is important to detect orbital invasion as it changes the management. Orbital invasion is indicated by the presence of obvious osseous destruction of the orbital walls, orbital fat involvement, extraocular muscle enlargement or signal alterations. But, no single criterion is highly accurate and frozen biopsy is recommended in cases of diagnostic dilemma.[2]

MRI helps in differentiating tumor from secretions. It is the best modality to assess the intracranial extension. Contrast enchanced MRI in multiple planes is the accurate modality to detect dural involvement which is seen as enhancing thick, irregular, nodular dura and also involvement of brain parenchyma. Cavernous sinus involvement and perineural spread is better assessed on MRI.[3] In case of adenoid cystic carcinoma, it is important to look for perineural spread to skull base and CNS through foramen ovale, rotundum and vidian canal.

Postsurgery, if the cavity or the margins of the graft shows nodularity, irregularity or thickening, biopsy should be performed.[4] PET-CT is more sensitive to detect the post-therapeutic tumor reccurence.

Olfactory neuroblastoma (Esthesioneuroblastoma) is of neural crest origin. It arises from olfactory epithelium of nasal cavity. It is seen as a homogeneously enhancing mass in the nasal cavity that extends to maxillary and ethmoid sinuses. It may have intracranial extension. Peripheral tumoral cysts with broad base are highly suggestive of this tumor (Figs 1A and B).[5]



FIGURES 1A and B: Coronal STIR MR images (A and B) show a heterogenous signal intensity mass lesion(T) involving the nasal cavity and the ethmoid air cells. Intracranial extension is seen through the floor of the anterior cranial fossa (white arrow) with extensive perilesional edema. Bilateral intraorbital extension(arrow heads) is seen. Obstructive bilateral maxillary sinusitis is seen(open black arrows). Sphenoid sinusitis(S) is seen. This patient had an olfactory neuroblastoma. Presence of cysts at the periphery of the lesion is characteristic of this tumor (black arrows)

THYROID CANCER

Thyroid neoplasms include papillary, follicular, medullary and anaplastic carcinomas. Lymphoma and squamous cell carcinomas are rare. Metastases to thyroid also has been reported. Various imaging modalities are available for the evaluation of thyroid cancer.

The initial imaging modality is ultrasonography. It helps in distinguishing solid from cystic lesions, to look for coexistent nodules, for biopsy guidance of the nodules and the lymph nodal metastases. Imaging may not always differentiate benign and malignant lesions.[6] It plays a significant role in the follow-up of patients treated for papillary carcinoma.

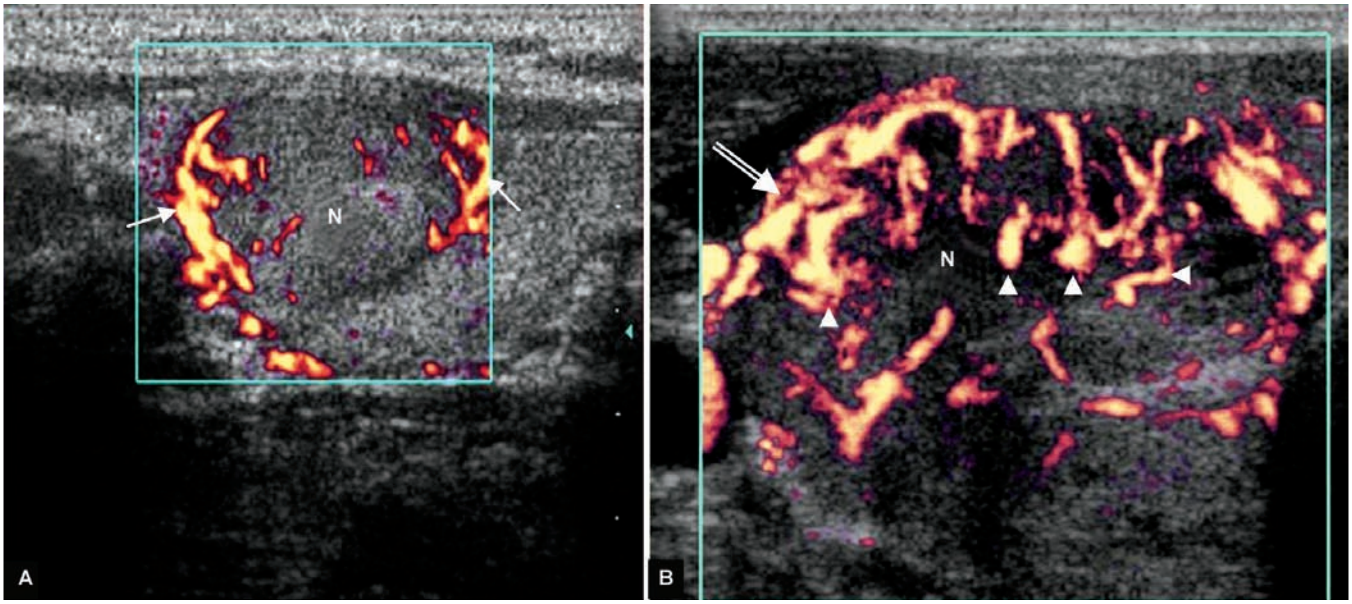
The features which favor malignancy are presence of solid nodule with microcalcification, lack of halo and internal vascularity (Figs 2A and B).[7]

Few recommendations have been made by the society of radiologists in ultrasound for the management of thyroid nodules which should undergo FNAC.[8]

Feature on ultrasonography	*Recommendation*
Microcalcification.	Strongly consider ultrasound-guided FNA if > 1 cm
Solid (or almost solid) with coarse calcifications.	Strongly consider ultrasound-guided FNA if > 1.5 cm
Mixed solid and cystic or almost entirely cystic with solid mural component.	Consider ultrasound-guided FNA if > 2 cm
None of the above but substantial growth since previous ultrasound examination.	Consider ultrasound-guided FNA
Almost entirely cystic and none of the above and no substantial growth (or no previous ultrasound).	Ultrasound-guided FNA probably unnecessary
Multiple nodules.	Consider ultrasound-guided FNA of one or more nodules, with selection prioritizing selection based on criteria for solid nodules

Disadvantages of ultrasound are difficulty in evaluation of entire extent of the lesion especially the deeper tissues which are out of reach to ultrasound waves like substernal region, deeper paratracheal tissues.[9] CT and MRI are superior in this aspect.

There are certain advantages of MRI over CT in addition to the routine advantages of soft tissue resolution and lack of radiation, gadolinium based MR contrast media do not interfere with the diagnostic and or therapeutic iodine uptake in contrast to the CT iodinated contrast media which interfere with the iodine metabolism for atleast 6 weeks.[10]



FIGURES 2A and B: Power Doppler ultrasonographic image (A) shows a predominantly isoechoic nodule (N) in right lobe of thyroid with peripheral vascularity (white arrows) suggestive of its benign nature. This patient had a benign adenoma of thyroid gland. Power Doppler ultrasonographic image (B) shows a heterogeneously echoic nodule (N) in left lobe of thyroid with both central (white arrow heads) and peripheral vascularity (open white arrow). Histopathological examination revealed follicular carcinoma

Radionuclide imaging gives functional information. It is used to differentiate cold and hot nodules, in determination of residual thyroid tissue following surgery and to determine the residual, recurrent and metastatic disease. But as diagnostic radionuclide imaging has low sensitivity, ultrasonography combined with serum thyroglobulin determination is the recommendation in postoperative monitoring of thyroid cancer patients.[11]

PET helps in identifying poorly differentiated cancers with low iodine uptake.[12]

LARYNGEAL CANCER

The role of radiology in imaging of laryngeal cancer is to detect involvement of submucosa and also tissues beyond it, as mucosal surface can be seen on laryngoscopy.[13] It also helps in identifying cancer in endoscopic blind spots like cartilage, deep portion of ventricle and extralaryngeal spread with nodal and systemic metastases.

CT and MRI are the cross-sectional imaging modalities used in evaluating laryngeal cancer. In addition to the routine protocol of CT, imaging is done with maneuvers like e-phonation to assess laryngeal ventricle, anterior commissure and aryepiglottic folds or modified valsalva to better evaluate the pyriform sinus and postcricoid region.[14]

In supraglottic tumors, it is important to determine the inferior border of the lesion as it is a contraindication for supraglottic laryngectomy if paraglottic space and ventricle are involved. Imaging is helpful in determining the involvement of tongue base which is an endoscopic blind spot.[15]

In glottic tumors, determining the inferior border of the lesion and involvement of cricoid cartilage is important as it alters the surgical management. Invasion of paraglottic space is significant as it may further spread into subglottic or supraglottic region. Anterior commissure involvement should be looked for in laryngeal cancer. The soft tissue should normally be only 1 to 2 mm thick in the region of anterior commissure.[16]

Criteria for involvement of laryngeal cartilage involvement include presence of soft tissue on both sides of cartilage, presence of erosion or altered attenuation within the medullary cavity. Bone windows should be evaluated to look for involvement of laryngeal cartilage (Figs 3A to C).[13]

MRI is used to assess the laryngeal cartilage involvement in case of equivocal findings on CT and to better define the margins of the tumor. However, the high signal on T2 weighted MR images can be due to reactive change even without tumor involvement and thus is not specific.[17]

FIGURES 3A to C: Axial contrast enhanced CT images. (A) Heterogeneously enhancing mass lesion in the region of the right false cord (T). There is extension into the paralaryngeal fat (black arrow). The lumen of the laryngeal airway is narrowed. (B) Inferiorly, it is seen to involve the right true cord (T) Anterior commissure (arrow head) and right cricoarytenoid joint (black arrow) are involved. (C)Bone window image shows erosion of the thyroid cartilage(white arrow).This patient had squamous cell carcinoma

ORAL CAVITY, TONGUE AND OROPHARYNGEAL CANCER

These cancers are diagnosed clinically and the role imaging is to stage the tumor and plan treatment. Cross-sectional imaging plays an important role due to complex anatomy of the oral cavity and delineates the exact location and extent of the tumor.

Malignant lesions of oral cavity and oropharynx are usually superficial, ill-defined and invasive, without calcification. These are isointense to muscle on T1WI and hyperintense on T2WI with variable enhancement. Invasion and destruction of bone and perineural spread are features of malignancy.[18]

CT is the usual imaging modality used and MRI is helpful in specific situations. Involvement of mandible has therapeutic implication. Panoramic views of the mandible are clinician friendly, not degraded by dental amalgam artifacts and are of low cost.[19] But due to lack of its sensitivity, cross-sectional imaging is essential**.** In cancer of oral cavity and oropharynx, both MRI and CT should be performed. Tumors of the floor of the mouth can involve the orifices of sublingual and submandibular glands and lead to infection and inflammation of submandibular gland. Radiologically dilated ducts without obvious calculous disease should prompt a search to look for any mucosal tumor causing obstruction to the duct.[18]

In cancer of tongue, MRI should be the initial imaging modality. If there is suspicion of mandibular involvement, CT should be done. Extension into geniohyoid and genioglossus muscles and extension across median raphe has therapeutic implications as it indicates the possible involvement of the entire tongue (Fig. 4). Lesions which are confined to the anterior tongue clinically can be better assessed with MRI so that these patients can be subjected to partial glossectomy.[20]

FIGURE 4: Carcinoma of tongue. Axial STIR MR image shows a hyperintense lesion (T) involving the left half of tongue. It is seen to involve the median raphe (white arrow) and extends across the midline to the right

NASOPHARYNGEAL CANCER

Imaging helps in staging and planning of therapy. MRI and CT are complementary in staging of nasopharyngeal cancer. MRI helps in identification of early invasion of pharyngobasilar fascia, and thus helps in indentifying spread

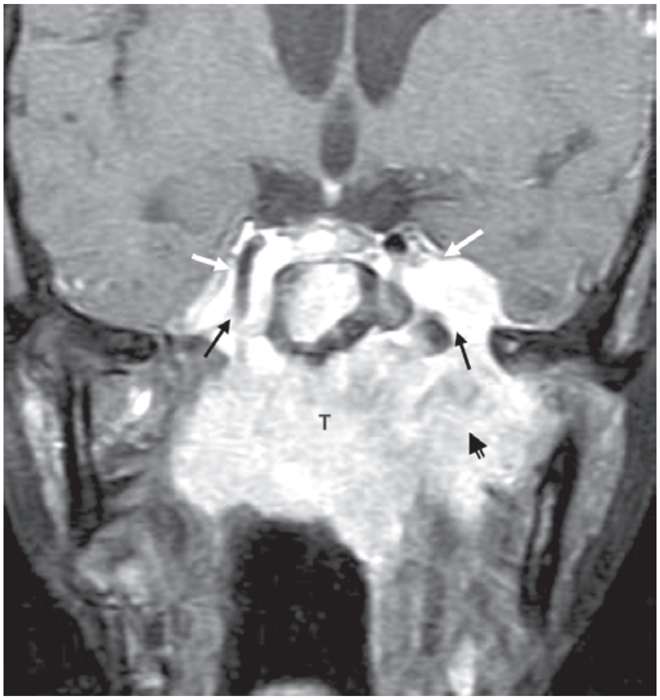


FIGURE 5: Carcinoma of the nasopharynx. Coronal T1 weighted, fat suppressed, contrast enhanced MR image shows an enhancing lesion (T) in the nasopharynx with extension into bilateral cavernous sinuses(white arrows) via foramen ovale (black arrows). Both cavernous internal carotid arteries are encased by the lesion. There is also extension into left infratemporal fossa(small open black arrow)

to parapharyngeal space and also better depicts the perineural spread as it alters the staging.[21] MRI helps in identification of marrow involvement whereas subtle cortical erosion is better seen on CT. The extent of the tumor into the surrounding structures is well-evaluated using these cross-sectional imaging modalities (Fig. 5).

SKULL BASE CANCER

As it is a difficult area to evaluate clinically, imaging plays a very important role in evaluation of skull base lesions. It helps in evaluating the extent of lesion especially subtle bony involvement and the contiguous intracranial extension.

CT is more useful to look for involvement of thin cortical bone whereas MRI is better to look for involvement of bones like clivus, petrous apex, sphenoid bone and pterygoid process.[22] MRI shows T1 hypointense signal with loss of normal intermediate signal intensity fatty marrow due to marrow involvement. The abnormal marrow also shows enhancement.

Head and neck cancers can spread via foramina of skull base, along the structures which course through the foramina like perineural spread or cause destruction of the bone.[23] Perineural spread is well-evaluated by MRI compared to CT. Knowledge of anatomy of the neural structures is important for evaluation of the spread of the potential sites of tumor. Perineural spread is seen as enlargement of nerve, enlargement and destruction of foramina. The involved nerve shows enhancement which is best appreciated on MRI (Fig. 6). Secondary atrophy, cavernous sinus enlargement, and soft tissue in the subarachnoid cistern and obliterated fat planes at the foraminal openings are other radiologic findings.[24]

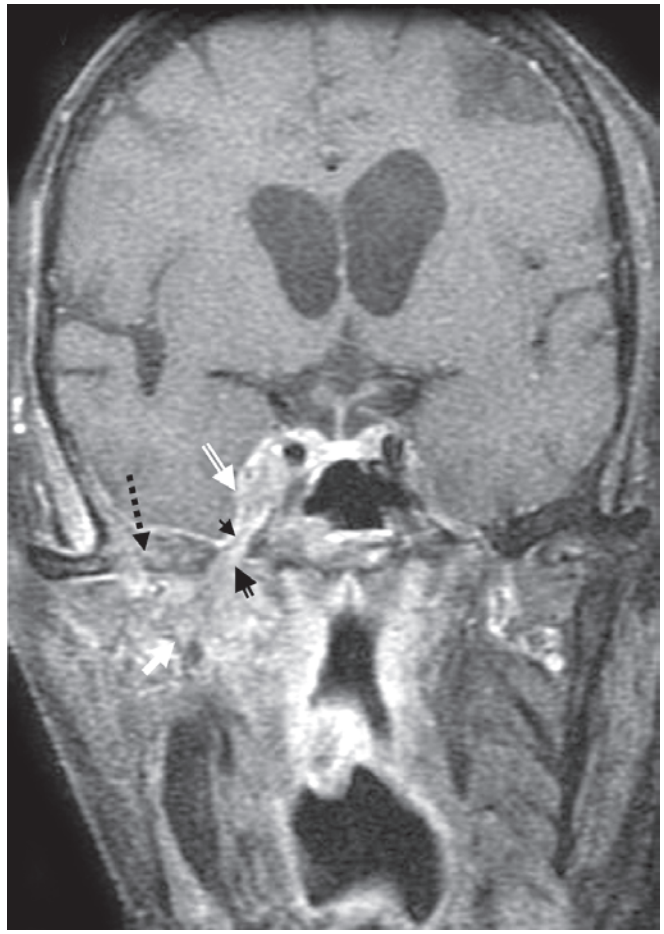


FIGURE 6: Coronal, T1 weighted, fat suppressed, contrast enhanced MR image shows an abnormal enhancement of the diploe of floor of middle cranial fossa (dashed black arrow) on right side with associated soft tissue component in the infratemporal fossa (white arrow) Extension of soft tissue is seen via the foramen ovale (open black arrow) with enlargement and enhancement of the trigeminal nerve in the region of the Meckel's cave (small black arrow). Cavernous sinus is involved (open white arrow). This patient is a known case of carcinoma oropharynx with skull base metastases with perineural spread. He presented with right sided trigeminal neuralgia and ptosis

SALIVARY GLAND CANCERS

CT and MRI are the imaging modalities to look at the extent of the tumor especially the involvement of deep lobe of parotid gland and erosion of the mandible or skull base. MRI is the preferred imaging modality as it can better define the margins and the character of the lesion (Fig. 7). However, calcification may not be identified on MRI for which CT is the modality of choice as presence of calcification helps in narrowing the differential diagnosis of salivary gland lesions.[25]

Evaluation of Lymphadenopathy

Metastasis to lymph nodes is an important prognostic factor in the management of head and neck cancers.[26] In cases of negative clinical examination for nodes, imaging plays a major role in identifying them in considerable number of patients.[27] Imaging based lymph nodal classification system has been proposed for better reproducibility of the location of nodes.[28]

Various standard radiologic criteria used to diagnose the metastases are size, shape, presence of necrosis, extracapsular spread, invasion of adjacent structures.[28] Presence of necrosis strongly favors metastases unless proved otherwise.[29] It is important to look for primary head and neck cancer especially faucial or lingual tonsil SCC or papillary thyroid cancer if isolated necrotic or cystic lymph nodes are seen in an adult (Fig. 8).[18,29] Punctate microcalcification has been reported in metastatic papillary and medullary thyroid carcinomas. Calcification can be also be seen in treated lymphoma and granulomatous disease in which case, it is coarse in morphology.

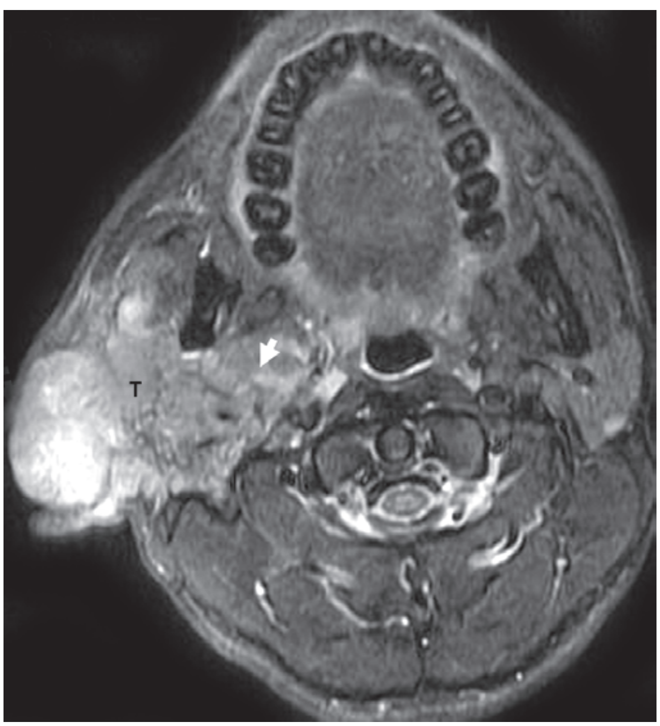


FIGURE 7: Axial T1 weighted, fat suppressed, contrast enhanced MR image shows heterogeneously enhancing solid mass lesion (T) involving both superficial and deep lobes (small white arrow) of right parotid gland. The portion of the lesion in the lateral aspect is infiltrating the skin (dashed white arrow) and shows more enhancement. This was a carcinoma ex pleomorphic adenoma

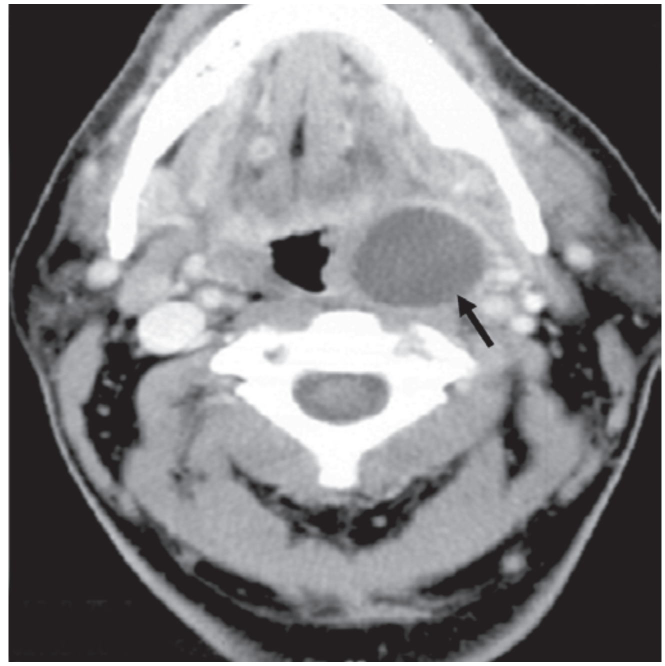


FIGURE 8: Axial contrast enhanced CT image shows a well-defined hypodense lesion (black arrow) in the left parapharyngeal space medial to the carotid vessels and internal jugular vein representing a lymph node with cystic change. Histopathology revealed metastatic node from papillary carcinoma of thyroid

Extracapsular spread is seen as ill-defined nodal margins or presence of fat stranding or infiltration into adjacent soft tissues.[18,29] Definite carotid invasion is indicated when tumor encases the vessel by 270 degrees or more. In some cancers, metastasis to both sides of neck is common. So, it is important to look for contralateral nodes as in carcinoma tongue.[18] Knowledge of predictive lymphatic drainage of cancers is helpful especially in cases of unknown primary.[30]

On sonography, benign nodes are oval or oblong with echogenic central hilar fat with no detectable flow or only central flow.[31,32] Peripheral or both central and peripheral vascularity strongly favors malignancy. Ultrasound guided fine needle aspiration helps in accurate diagnosis in 95 to 97% cases.[33,34]

On CT, necrotic lymph nodes show low density (0-20HU) in the center with enhancing peripheral rim. Cystic lymph nodes have density similar to water with thin wall.[29]

MRI assesses the involvement of skull base and the prevertebral space by the nodes. Preserved fat plane between the prevertebral muscles and the mass on T1 weighted images indicates lack of involvement.[35]

It has been reported that size is not a reliable criterion as even subcentimeter lymph nodes can harbor metastases and viceversa. SPIO contrast agents detect nodes with microinfiltration. SPIO enhanced T2W gradient echo-sequence reveals marked decrease in signal intensity in normal nodes as macrophages take up the contrast agent. Due to lack of macrophages, metastatic nodes remain hyperintense.[36] Role of DWI has been studied and is found to have higher accuracy in detecting nodal metastases than conventional MR imaging especially in subcentimeter nodes but needs further investigation.[37]

Imaging for Distant Metastases

Distant metastases are usually rare at presentation. The incidence depends on the location of the primary as well as initial T and N stage of the tumor. Pulmonary metastases are more common. Bone, liver, mediastinal and skin metastases are the other less common sites. Preoperative chest radiography is done in all cases. CT chest is usually done in those with high-risk for pulmonary metastases.[38] With the introduction of PET imaging, it may be considered for initial staging. It also helps in identifying associated second primary cancers. However, further studies are required to prove the cost effectiveness of PET CT in comparison to the cross-sectional imaging for the initial staging of these tumors.[39]

Role of Fusion Imaging: PET-CT

PET imaging is based on the principle of increase in glucose uptake in highly metabolically active tissues. PET-CT provides both the anatomic and metabolic information. It is the modality with combined advantages of PET and CT. PET-CT is definitely more accurate than PET or CT alone in the diagnosis of head and neck cancer and improves the radiologist's confidence.[40,41]

It is particularly useful in the immediate post-treatment period when CT cannot differentiate scar tissue from the recurrent or residual neoplasm. It is also helpful to detect an occult primary and helps in assessing the aggressiveness of the tumor.

Major disadvantage is lack of anatomic detail which leads to difficult interpretation due to physiologic uptake, complex anatomy and postsurgical distorted anatomy. Metabolically inactive tumors are not seen with PET. CT has better advantage in these circumstances.[41]

Applications of PET-CT

1. To detect unknown primary carcinoma. PET-CT should be performed before performing biopsy and endoscopy as post biopsy inflammatory changes can lead to false positive diagnosis and thus has low specificity. It helps to locate the site of biopsies for maximum yield.[39,42]
2. To detect recurrent disease and to differentiate residual disease from post-therapeutic scar tissue. It has been shown that negative predictive value of PET is high and a negative scan is able to exclude recurrent or residual disease.[43]
3. Detection of metastatic nodes.[44,45]
4. Measures of PET like standard uptake value and tumor metabolic rate have prognostic value to predict the response and the survival thus indicating the aggressiveness of tumor.[46]

Role of Imaging in Planning Radiotherapy

Three-dimensional representation of tumor volume and organs at risk is provided by CT and MRI imaging helps in accurate positioning of the radiation portals targeting the tumor and shielding of the adjacent organs. The electron density information provided by CT helps in altering the dose.[47] However, CT has less contrast resolution and images are degraded by dental fillings. Due to inherent soft tissue contrast of MRI, it helps in better differentiation of normal and abnormal tissue helping in accurate planning.[48] Functional imaging including PET, PET-CT, MR spectroscopy and dynamic contrast enhanced studies improve localization of tumor, its extent and detection of radioresistant areas due to hypoxia or accelerated proliferation thus modifying the dose or the radiation technique used.[47]

In conclusion, imaging plays a significant role in the staging of head and neck cancers thus influencing treatment options. The superiority of individual imaging modality varies according to the situation. Ultrasonography is useful in evaluating superficial pathologies especially of thyroid and lymph nodal involvement. CT and MRI better demonstrate the extent of pathology. Imaging can be used to obtain tissue samples for establishing the diagnosis. Radiotherapy planning can be done using CT and MRI. Imaging also plays an important role in assessing the response to treatment. PET and radionuclide imaging provide the functional information. With the combined advantage of structural and functional imaging aspects, PET-CT is especially useful to in post-therapeutic evaluation to differentiate treatment induced changes and recurrent or residual pathology with high negative predictive value.

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