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ROLE OF DIAGNOSTIC IMAGING TO MALIGNANT SINUS TUMORS IN PRESURGICAL STAGING

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SUMMARY

Role of diagnostic imaging to malignant sinus tumors in presurgical staging

The aim of this study is to describe the current role of imaging in pre-surgical planning, reporting 25 cases of paranasal sinus tumors examined in our Institute. Between June 2006 and May 2008, we identified 25 patients with malignant tumors of the paranasal sinuses. All of the patients were evaluated with CT and/or MR exams. US were used to assess regional lymph node involvement. When necessary CT-PET scanning using FDG, was done. Diagnostic imaging is essential during the initial work-up of a patient suspected of having a paranasal sinus tumor. The role of imaging is to define the tumor extension, nodal involvement, metastases and recurrences in the postoperative patient. CT and MR imaging are the primary modalities employed; each have advantages and disadvantages but tend to be complementary. The involvement of fine bone structures is best evaluated with CT. In assessing the extent of the tumor, MR provides excellent soft tissue detail, allowing for delineation of neoplasm from surrounding inflammatory tissue and secretions. For evaluation of lymph node enlargement color-Doppler US, CT and MR provide morphologic data, while CT-PET provides metabolic data. CT-PET can be used to stage nodal and metastatic disease and for assessing the efficacy of therapy or recurrent disease.

Key words: paranasal sinus neoplasm, paranasal sinus cancer, CT-sinus cancer, MR-head and neck tumors, PET/CT.

RIASSUNTO

Ruolo della diagnostica per immagini nello staging preoperatorio delle patologie neoplastiche dei seni paranasali

Lo scopo del lavoro è descrivere il ruolo attuale della diagnostica per immagini nella pianificazione chirurgica, nella patologia neoplastica dei seni paranasali. Tra giugno 2006 e maggio 2008 sono giunti alla nostra osservazione 25 pazienti con tumori maligni dei seni paranasali. Tutti i pazienti hanno effettuato un esame TC e/o RM. L'esame ecotomografico è stato utilizzato per valutare il coinvolgimento linfonodale mentre un esame PET o PET/TC con FDG è stato effettuato se necessario. L'imaging radiologico risulta essenziale nella valutazione iniziale di un paziente con sospetto di tumore dei seni paranasali. Il ruolo dell'imaging è definire l'estensione del tumore, l'interessamento linfonodale e la valutazione di eventuali metastasi e recidive locoregionali in fase post-operatoria. La TC e la RM sono le indagini diagnostiche di prima istanza; entrambe presentano vantaggi e svantaggi, ma insieme risultano complementari. Il coinvolgimento delle fini strutture ossee è valutato in miglior modo dalla TC. Nella valutazione dell'estensione tumorale, la RM offre un eccellente dettaglio dei tessuti molli, permettendo la differenziazione della neoplasia dal circostante tessuto infiammatorio e dalle secrezioni. Per lo studio di linfonodi aumentati di dimensioni, l'esame eco Color-Doppler, la TC e la RM forniscono informazioni relative alla morfologia, mentre la PET permette una valutazione di tipo metabolico. La PET/TC con FDG può essere utilizzata in fase di stadiazione per valutare il coinvolgimento linfonodale o metastatico, per monitorare l'efficacia della terapia e nello studio della recidiva neoplastica.

Parole chiave: neoplasie dei seni paranasali-carcinoma sinusale, TC-carcinoma sinusale, RM-tumori della testa e del collo, PET/TC.

Introduction

The paranasal sinus tract gives rise to a large variety of neoplasms derived from a multitude of tissue types. Paranasal sinuses neoplasias can be classified as epithelial or mesenchymal. The epithelial tumors arise from the epithelial lining of the nasal and sinus cavities, the accessory salivary tissue, the neuroendocrine tissue or the olfactory mucosa, and the mesenchymal tumors arise from the supporting tissues. Carcinoma of the paranasal sinuses cavity is rare representing 3-4% of head and neck tumors and less than 1% of all malignancies (1). 80% of these tumors are squamous cell carcinoma with adenocarcinoma and adenoid cystic cancers accounting for 10%. The maxillary sinus is most commonly involved with tumor, followed by the nasal cavity, the ethmoids, and then the frontal and sphenoid sinuses.

Since the last 30 years endosseous implants are a well established treatment technique in maxillofacial surgery. Implants are used in the rehabilitation of Patients having lost parts of maxilla or mandible due to tumor surgery or which due to radiotherapy have problems tolerating mucosaborne dentures (2). This progression has been possible by the detailed information provided by imaging techniques (3).

A multidisciplinary team approach is often requested to correctly assess these tumors. The diagnosis of paranasal sinuses tumors is based on the history and physical examination. The physical examination should include a fiber optic endoscopic evaluation. Radiologic imaging is essential during the initial work-up of a patient suspected of having a paranasal sinuses tumor. These studies should be obtained prior to biopsy of the lesions to avoid surgical artefact. Plain films are inadequate for the assessment of sinus masses and a combination of CT and MR is required (4, 5).

US imaging is very accurate in assessment of nodal localization. CT-PET can be used to stage the primary tumor including nodal involvement and distant metastases, to assess the response to treatment and look for recurrence (6, 7). In this article, we describe the present role of imaging, reporting 25 cases of tumor of the paranasal sinuses that were examined in our Institute.

Materials and methods

Between june 2006 and may 2008, we identified 25 Patients with malignant tumors of the paranasal sinuses. Patients ranged in age from 20 to 85 years (mean: 56), and 60% were male. The diagnosis was based in most Patients on the history and physical examination. Plain radiographs are inadequate and rarely used. All Patients underwent CT and/or MR exams. US were used to assess regional lymph node involvement. When necessary CT-PET scanning using FDG, was done.

CT technique

Thin-section helical scan of the nasal cavity and paranasal sinuses was performed on a Volumetric 64 slices CT (Light Speed VCT, General Electric, Medical Systems, USA). CT examinations were obtained with a thickness of 0.6 mm, a 0.4-milimeter interval, rotation time of 0.5 s, 150 mA, 120 Kv, standard and high resolution algorithms for bony structures and a field of view (FOV) of 15 cm.

CT exams were performed following the injection of iodine contrast medium (Iomeron-350mgI/ml, Bracco, Milano, Italia) with volume: 100-120 ml and flow: 2-3 ml/s.

Start delay greater than 60-70 sec. are necessary.

The data acquired are subsequently sent to the workstation and processed with the dedicated software for Multiplanar Reconstructions (MPR), 3D view and virtual rhinosinus endoscopy (VRS), a new method capable of simulating the endoscopic vision obtained with optic fiber instruments.

Coronal and sagittal MPR reconstructions are helpful in the evaluation of base of the skull, the orbital floor and palate.

MR technique

The study was conducted using a 1,5 Tesla Philips Gyroscan ACS-NT MRI magnet (Philips Medical-Systems, Best, The Netherlands). Spin-echo (SE) and Turbo-Spin-echo (TSE) technique was used in the axial, coronal and sagittal planes. Axial T1-weighted [TR/TE 700/15; repetition time (TR) msec/echo time (TE) msec] and T2-weighted [TR/TE 2730/80] images were obtained. T1-weighted images were also performed in the coronal plane. Images with fat suppression (SPIR technique) are also obtained.
Axial, coronal and sagittal sections were performed following the injection of gadolinium diethylene triamine pentaacetate (G-DTPA) paramagnetic contrast material (Magnevist, Schering, Berlin, Germany).
Slice thickness are as follows: axial and coronal images, 5 mm sections with 2 mm interslice gap; and sagittal images, 4 mm sections with 1 mm gap. The imaging matrix was 192 x 256 in all scanning planes and sequences.

CT-PET technique

Imaging was performed on a GE PET/CT scanner (General Electric Medical Systems, Milwaukee, WI) a new integrated PET-CT system that combines a multi-slice helical CT with a PET tomograph. PET images were obtained from the skull base through the midthigh after intravenous administration of 370 MBq of [(18)F] fluorine-18-fluoro-2-deoxyglucose. The FDG images were recorded after 45 min-1 hour. A CT examination is used for attenuation correction of PET images. No contrast CT images were obtained with 140 kV, 80 mA, 0.8 s/CT rotation, 3.75 mm slice thickness and a table speed of 22.5 mm/s. Subsequently another CT scan was performed following the injection of contrast medium (130 ml, flow of 2-3 ml/sec, delay of 60 sec.) using 140 kV, 300 mA, 0.8 s/CT rotation, 3.75 mm slice thickness (reconstruction at 0.625 mm) and a table speed of 22.5 mm/s.
Patients were grouped into the following stages: stage I, limited to site of origin; stage II, extension to adjacent site (orbit, nasopharynx, paranasal sinuses, skin, pterigomaxillary fossa); stage III, base skull or pterygoid plate destruction and/or intracranial extension.
Twelve (48%) patients were treated with irradiation alone, 7 (28%) with surgery and postoperative irradiation, 3 (12%) with preoperative irradiation and surgery, and 2 (8%) more advanced cases with chemotherapy in combination with irradiation and surgery.

Results

Our results were divided in: histologic typing, site and staging at diagnosis.

Histologic typing (Table 1): the histologic analysis revealed that 20 (80%) of the 25 were epithelial tumors and 4 (16%) were non epithelial tumors and 1 (4%) metastatic tumor.
Of the 20 epithelial tumors, 18 were epidermoid carcinomas and 2 were malignant melanomas. Of the 18 epidermoid carcinomas, 10 were squamous cell carcinomas, 1 was undifferentiated carcinoma, 2 were adenocystic carcinomas and 5 were adenocarcinomas.
About non-epithelial tumors 3 were lymphoreticolar tumors and 1 was sarcoma. Of 3 lymphoreticolar tumors 2 were non-Hodgkin's lymphomas and 1 plasmocytoma. The sarcoma was fibrosarcoma.

Site (Table 2): tumor sites were maxillary sinus in most cases (70%), ethmoid sinus (10%), sphenoid sinus (6%) and frontal sinus (4%). In 10% of cases had extensive tumor spread, which made it impossible to determine the site of origin.
Of the 20 epithelial tumors 16 arose in the maxillary antrum, 2 in the ethmoid sinus, 2 were discovered at an advanced stage and none arose in the frontal or sphenoid sinus.
Of the 4 non-epithelial tumors 2 arose in the maxillary sinus, 1 in the frontal sinus and 1 was extensive at diagnosis. 1 metastasis occurred in the sphenoid sinus.

Table 1 - Distribution by histology: type and number of patients.		
Epithelial tumors (20 Pts)	Epidermoid (18)	Squamous cell carcinoma (10) Adenocarcinoma (5) Adenocystic carcinoma (2) Undifferentiated carcinoma (1)
	Melanoma (2)	
Non-epithelial tumors (4 Pts)	Linforeticolari (3)	Non-Hodgking's lymphoma (2) Plasmocytoma (1)
	Sarcoma (1)	Fibrosarcoma (1)
Metastasis (1 Pt)		

Table 2 - Distribution by site.	
Primary site (%)	Maxillary sinus (70%) Ethmoid sinus (10%) Sphenoid sinus (6%) Frontal sinus (4%) Indeterminate origin (10%)

Staging at diagnosis: regional nodes were involved in 15% of cases. Disseminated metastases were found in 2% of cases.
Patients were grouped into the following stages: stage I 90%; stage II, 75%; stage III, 42%. The prognosis for cases with involved nodes was severely reduced and for those with metastases it was significantly poorer.

Discussion

The role of imaging in pre-surgical staging of Patient with paranasal sinuses tumors is to define the tumor extension, nodal involvement, metastases and recurrences in the postoperative Patient.

Tumor extension

In the diagnosis of paranasal sinuses tumors MR imaging is a vital tool in the diagnosis of these lesions and is used in conjunction with computed tomography to precisely delineate the extent of these neoplasms. Involvement of the skull base, the orbits, the intracranial compartment and perineural spread of tumor are important informations in anticipation of following reconstructive implantologic treatment (8).
In assessing the extent of the tumor MR is superior to CT for its essential characteristic of best contrast resolution. Therefore, it is important to differentiate tumor from secretions and this may be difficult with CT. Post contrast scans may be helpful in distinguishing tumor from secretions and assessing orbital extent and brain involvement.
Most tumors are hypointense or hysointense on T1 images, slightly higher signal intensity on T2 weighting images and enhance with a solid pattern after contrast administration when compared with muscle or brain. Secretions are of high water content and are hypointense on T1 weighting and higher signal intensity than tumors on T2 weighting and mucosal disease shows similar characteristics with peripheral enhancement after contrast medium.
Small tumors are often indistinguishable from adjacent secretions and may be missed but larger tumors are usually associated with bony changes, which may be helpful in diagnosis. In fact, radiologists are reluctant to diagnose a tumor in the absence of adjacent bone involvement.
The involvement of fine bone structures is best

evaluated with CT (9) thanks to its excellent spatial resolution (Fig. 1). CT provides excellent details about the thin bony paranasal sinuses walls separating the ethmoid from the anterior skull base and the orbit (3).
In addition, with new CT scans, which work with slip-ring technology and multiple detector rows, acquisition time is ulteriorly reduced and movement artifacts are quite completely suppressed improving images quality. Therefore, multislice-CT offer advanced reconstruction algorhitms such us multiplanar reformatting, 3D reconstruction and virtual rhinosinus endoscopy that permit a more precise measurement of the mass size and a best pre surgical evaluation and virtual post-surgical result (10, 11).
Bone involvement can cause aggressive changes, commonly seen in squamous cell carcinoma. This pattern produces invasion and irregular destruction of the bone with only small fragments remaining. If tumor growth is slow the pattern can we see is bony remodeling.
Either CT and MR angiography techniques or ecocolor-Doppler US are enable to show direct infiltration of vascular adventitia, so the radiologic criterium for vascular involvement is the surrounding of more than 270° of vascular wall circumference.
Orbital invasion is a very important parameter to assess because it alters surgical planning radically. If the periosteum is involved orbital exenteration is required, whereas if the periosteum is intact the eye can be preserved and the risk of local recurrence is reduced (12). In presence of bony destruction and involvement of the orbital fat we can confirm certainly orbital invasion (Fig. 2). However, in absence of these signs neither CT or MR can exclude invasion with reported positive predictive values of 80% (MR) and 86% (CT) (13).
MR is superior to CT in assessing perineural spread and intracranial extension. With contrast enhanced T1 weighted in coronal and sagittal views we can see the destruction of the cribriform plate and the enhancement of dural envelope that confirm intracranial invasion (Fig. 3).

Nodal involvement

For evaluation of lymph node enlargement Ecocolor-Doppler US, CT and MR provide morphologic data, while PET provides metabolic data. Radiologic criteria to define lymphadenopathy are dimensions greater than 10 mm, round morphology, presence of intranodal necrosis and extracapsular diffusion. US is more accurate than CT and MR in assessment of lymphadenopathy, because it's able to characterize micrometastatic foci and lymph node localization up to 3 mm. CT showed a sensitivity of 74% and a specificity of 100% to assess lymph nodes greater than 3 mm. Furthermore, ecocolor-Doppler US is the best technique to differentiate reactive lymph nodes, that present oval morphology and central hilum with vessels and fat; from pathologic nodes that present structural alterations, not assessable hilum, rupture of

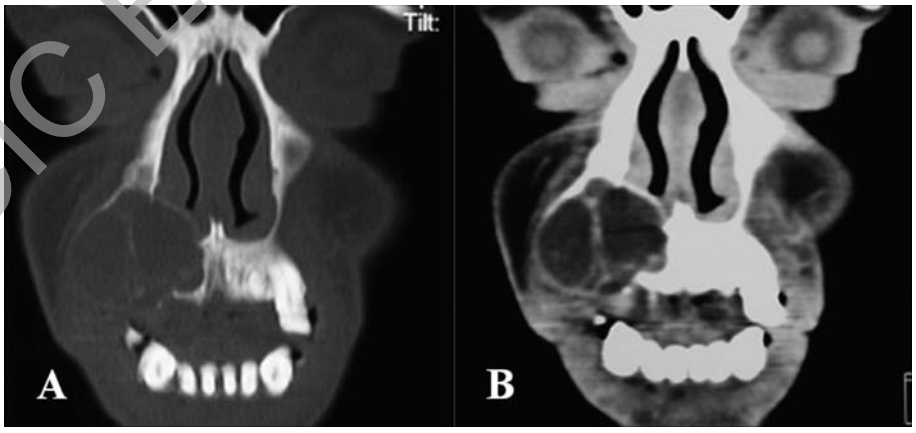

Figure 1
Bone expansive soft tissue mass of cystic appearance with irregular trabecular structures inside. CT coronal images examined with bone window (A) and soft tissue window (B) show high sensitivity in the assessment of focal bone erosion (arrow).

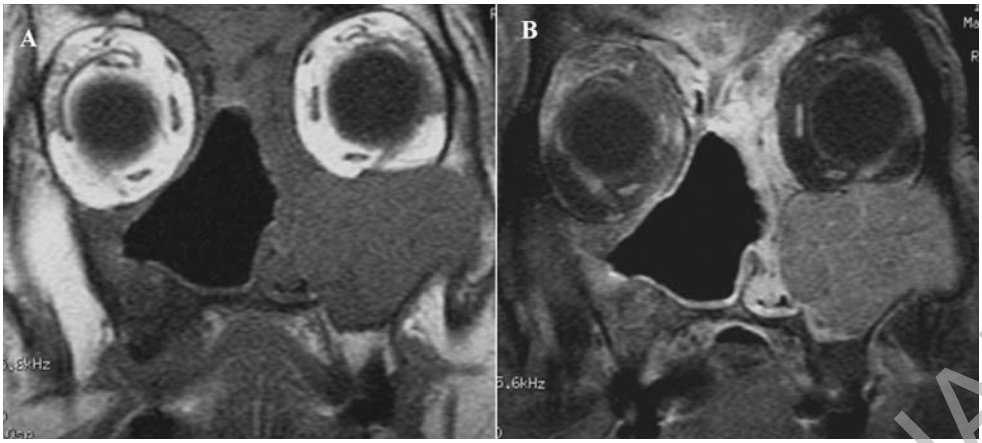

Figure 2
Coronal T1 weighted (A) and T1 fat sat weighted images after contrast medium (B). Soft tissue mass filling completely the left maxillary antrum. Mass enhances more than muscle and causes interruption of periorbital continuity: it represents the overcoming of the periosteal barrier with orbital invasion.

capsule and irregular margins (Fig. 4). The last two signs are also indicative of extra capsular diffusion that can be only evaluate with US. Necrosis is the most indicative parameter to define as pathologic lymph nodes. It's best evaluate with ecocolor-Doppler US or CT and MR after contrast medium. The transverse-to-longitudinal diameter ratio in combination with texture and margin analysis resulted in a correct diagnosis in approximately 80% of the nodes. Hilar vessels with branching indicated lymphadenitis and predominantly peripheral vessels indicated metastasis. However, in metastatic as well as benign enlarged lymph nodes, a Doppler signal is not always detectable. The use of a contrast medium for US has enhanced the signal in perfused vessels improving the differential diagnosis of inflammatory and metastatic enlarged lymph nodes (14, 15) (Fig. 5). CT-PET has a high sensitivity in identifying the primary tumor and loco regional lymph node metastases in patients with tumors of the paranasal sinuses district (16). The reported sensitivity for nodal detection using CT-PET is 80-96% with specificity of 90-94%, superior to both CT and MR for cervical nodal metastases (17), although micrometastases, which may be present in a significant number of patients, may be missed by all methods (Fig. 6).

Distant metastases and recurrence

The presence of cervical nodal disease is predictive of distant metastases. In presence of cervical lymph node metastases a chest CT should be included in the staging (18). After tumor resection the rate of recurrency depends on tumor biology and treatment planning. Furthermore, patients with paranasal sinuses tumors tend to undergo therapies that result in significant anatomical alterations, which often make it difficult to evaluate persistence or recurrence of disease by conventional imaging. CT-PET can map functional and metabolic activity before structural changes have taken place differentiating malignant from normal tissue based on enhanced glycolysis by tumor cells, but will also show increased uptake in active infection or inflammation. CT/PET can be used to stage the primary tumor including nodal involvement and distant metastases. However, the diagnostic potential of CT/PET is particularly evident in the follow-up phase, as it involves significant added value in terms of accuracy (sensitivity and specificity of 94% and 85% as against 54% and 46% of conventional imaging) (19) in differential diagnosis between recurrence and hypervascular

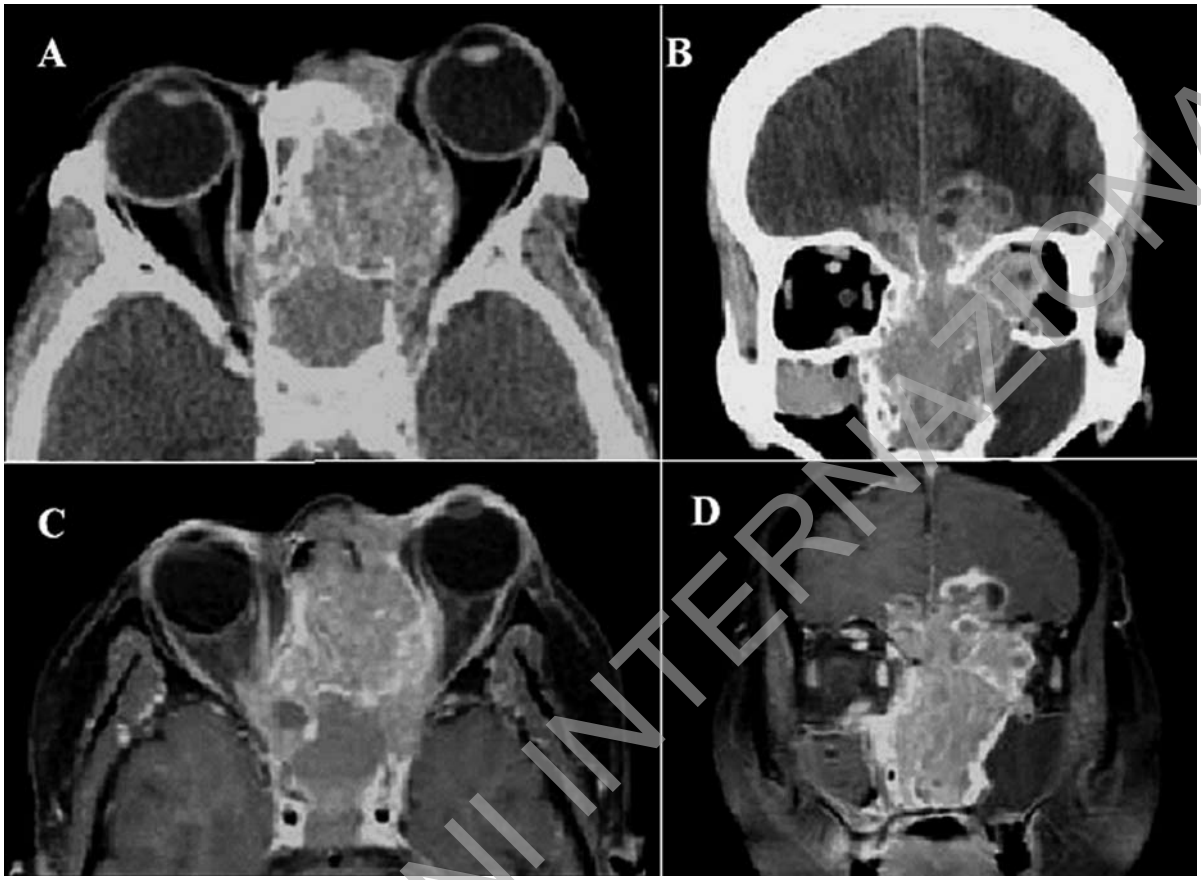

Figure 3
Neoformation in the nasal cavity with bowing of the medial wall of the maxillary antrum. CT axial (A) and coronal reformation after contrast medium (B) demonstrate bony destruction better. MRI T1 weighted after contrast medium in the same planes (C,D) better show intracranial invasion and periorbital involvement.

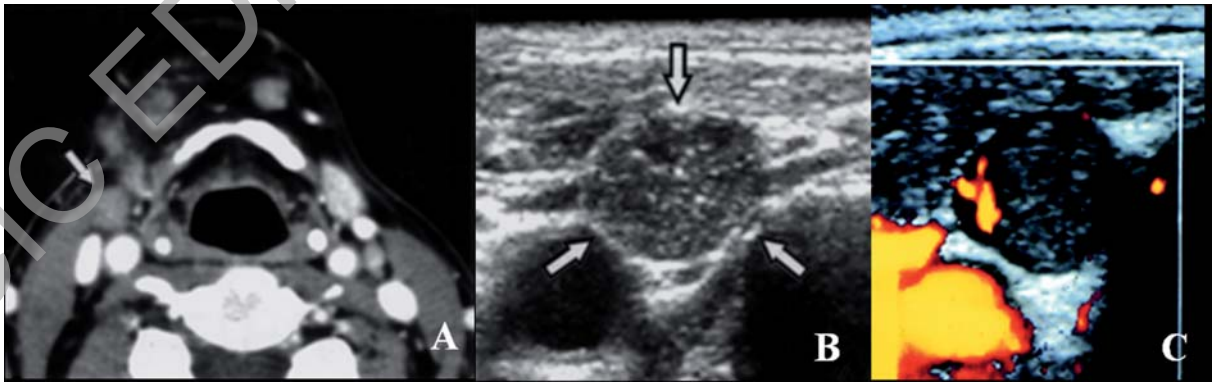

Figure 4
CT (A) Ultrasonography (B) and ecocolor-Doppler sonography (C) show a lymph node with patologic appearance: disomogeneous texture, not assessable helium and irregular margins. Moreover, it shows predominantly peripheral vessels.

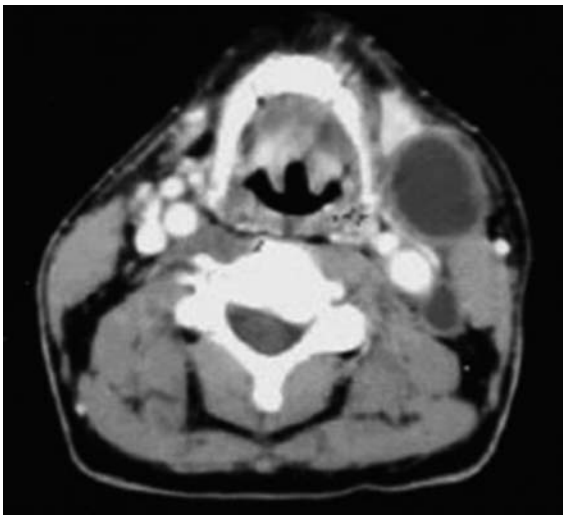

Figure 5
CT axial image post-radiotherapy in patient with paranasal sinus tumour and latero-cervical nodal involvement. The image shows a large lymph node necrosis.

fibrosis (Fig. 7). Recent studies have demonstrated that CT/PET can also be used to monitor the efficacy of medical therapy (chemotherapy), particularly as an early prognostic index of response or non-response to treatment

Conclusions

The ideal malignant paranasal sinuses tumor diagnostic test should have high sensitivity, high specificity, local staging capabilities (primary mass extension, bone involvement, soft tissue invasion and perineural spread), distant staging capabilities (assessment of lymphadenopathies and metastases), and characterization of post-treatment recurrence. No diagnostic examination meets all of these criteria.

So, the assessment of paranasal sinuses malignancies requires a multidisciplinary team approach. Advanced in diagnostic imaging have significantly contributed to the management of paranasal sinuses tumors that requires thorough assessment of location and extension in order to plan appropriate treatment (20). To provide the tumor mapping necessary for decisions regarding resectability and curability, the radiologist must know the critical areas of tumor extension that will alter a surgical or irradiation treatment plan. These areas include tumor extension into the floor of the anterior and middle cranial fossae, the pterygopalatine fossae, the orbits, and the palate.

Thus the radiologist must describe in detail the sinus and the precise areas in which the neoplasm is developed. Never treatment-planning computers are now able to utilize the raw data of the images provided by the radiologists to help prepare treatment plans. As mentioned, although the radiologist is constantly tempted to offer pathologic diagnoses, there are only rare instances in which the CT and MR imaging is specifically pathognomonic. Cross sectional imaging is rarely diagnostic, but there are features that can be used to differentiate benign from malignant disease. There-

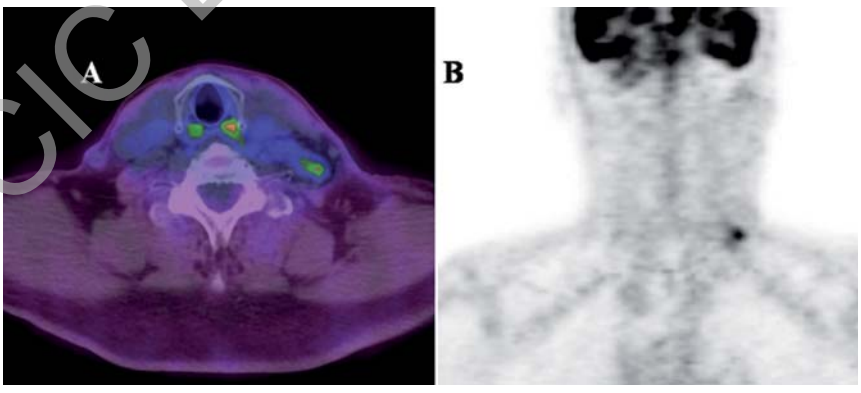

Figure 6
Fusion image CT-PET (A) and corresponding PET-FDG image (B) in staging of nodal metastases. The images show an area of intense radiopharmaceutical uptake in left latero-cervical seat confirming the presence of nodal matastasis.

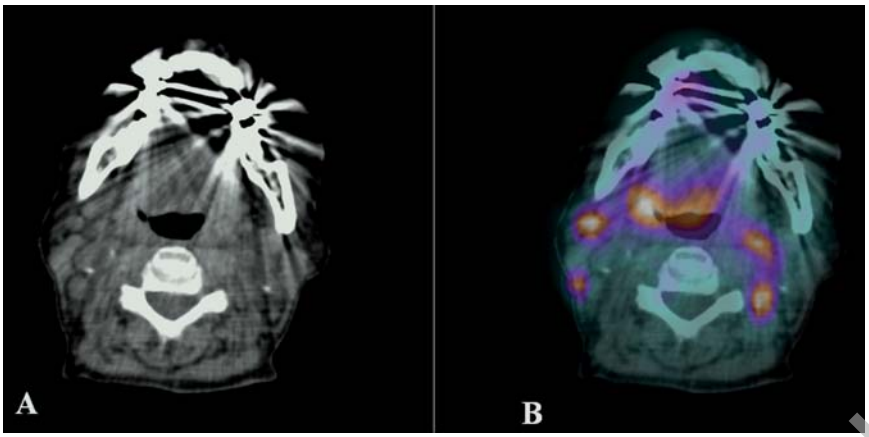

Figure 7
CT attenuation image (A) and fusion CT-PET image (B) demonstrate bilateral latero-cervical nodes with intense metabolic activity in a patient with story of sinonasal neoplasm.

fore, the primary contribution of imaging is accurate tumor mapping, with awareness of the critical anatomic sites that will influence treatment planning. Final treatment planning must await pathologic diagnosis. FDG-PET/CT can be used to stage nodal and metastatic disease and for assessing the efficacy of therapy or recurrent disease.

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