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Nuclear Medicine in Oral and Maxillofacial Diagnosis: A Review for the Practicing Dental Professional

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Abstract

Nuclear medicine studies often play a significant role in the diagnosis and treatment of oral and maxillofacial diseases. While not commonly used in everyday dental practice, the dental provider should have a conversational knowledge of these imaging modalities and understand the indications and limitations of these studies. The purpose of this review is to discuss the nuclear medicine studies that have applications in the head and neck region as well as their indications, limitations, and diagnostic conclusions that can be drawn from these studies.

Keywords: Nuclear medicine, bone scan, SPECT, PET, lymphoscintigraphy, sentinel node

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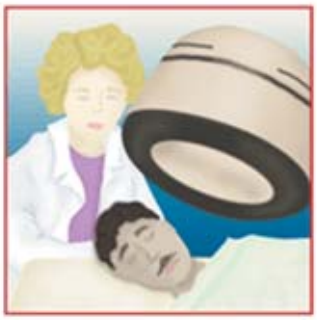
Introduction

In general healthcare, the speciality of nuclear medicine has contributed noteworthy diagnostic advances in such areas as positron emission tomography (PET), single photon emission computed tomography (SPECT), and lymphoscintigraphy/sential node biopsy. However, nuclear medicine studies are often poorly understood and relatively underutilized in oral healthcare. The purpose of this paper is to provide an overview of modern nuclear medicine, and by sampling the literature, exemplify its application in the diagnosis and treatment or oral and maxillofacial diseases.



Areas where a dental care provider may utilize diagnostic isotopes include head and neck tumors, salivary gland disease, and various metabolic and infectious processes of the head and neck region. Computed tomography (CT) and magnetic resonance imaging (MRI) with, and without, contrast enhancement can provide high quality static images of the soft and hard tissue under study. However, these imaging modalities provide little physiologic information about a disease process. On the other hand, nuclear medicine scans have the ability to dynamically detect abnormalities at an earlier stage, well before morphological changes are evident.[1]

The intent of this review is to familiarize dental healthcare providers with several nuclear medicine studies that can be used as diagnostic modalities in the disease of the head and neck.

The principle of nuclear medicine is intuitively simple. A radioisotope is injected into a patient. At some later predetermined time, a specialized camera is used to detect and image the quantity and distribution of radioactivity.[2]

Bone Scanning

Bone scanning is one of the most frequently performed nuclear medicine studies. Bone scans can be used to diagnose and differentiate osteomyelitis from cellulitis, as well as detect primary and metastatic malignant disease. They can also be used to assess the vascularity of bone grafts and contribute to the diagnosis of various metabolic bone diseases such as fibrous dysplasia, Paget's disease, osteoarthritis, and rheumatoid arthritis (RA). It is important to keep in mind a bone scan can detect 10-15% mineral loss, while standard radiographs will only visualize a bony defect after 35-50% mineral loss.[3] Overall the scan has a high sensitivity but low specificity.

The bone scan uses a technetium 99 m methylene diphosphonate radiopharmaceutical with a half-life of 6 hours and a total radiation dose of 0.3 rads. It is thought the diphosphonate molecule is taken up in areas of increased osteoblastic activity and vascularity. The metabolic activity of osteoblasts incorporates calcium phosphate during the process of ossification. It is thought the diphosphonate molecule preferentially accumulates in areas of increased osteoblastic activity as it binds to calcium ions to form calcium phosphate. A normal bone scan should demonstrate symmetry around the midline with uniform uptake of the radiopharmaceutical. There is usually increased activity at joint margins and vertebral bodies. Uptake is typically visualized in the kidneys and bladder.[4]

A three-phase bone scan is often performed to obtain additional diagnostic information, especially when the clinician is trying to distinguish osteomyelitis from cellulitis. The three phases include:

- The dynamic vascular flow phase, where imaging is performed every 2-3 seconds for the first 30 seconds. In this phase, each side can be compared and differences in vascularity can be seen.
- The blood pool image at five minutes, where the radiopharmaceutical is mostly in the vascular compartment but is starting to appear in bone. This phase demonstrates regional differences in blood flow and vascular permeability.
- Two to four hours later, the osseous delayed static image is obtained usually for the entire body demonstrating regional distribution in the skeleton. This phase reflects the metabolic activity of the bone in question. In non-inflammatory conditions, the third phase is usually the only image obtained.[5,6,7]

Occasionally, a fourth phase study is performed 24 hours later when there may be improved contrast between normal bone and inflammatory conditions. In osteomyelitis there is abnormal accumulation of the radiopharmaceutical in all three phases, with a more focal bony uptake in the third and fourth phases. Cellulitis presents as a diffusely increased uptake in phases one and two, followed by a decreased activity in phase three. In addition to osteomyelitis, bony lesions that are "hot" (increased accumulation) in all three phases are seen in acute fractures and hypervascular tumors.[5,6,7]

Both benign and malignant bone tumors as well as metastatic lesions to bone demonstrate increased uptake of technetium 99. However, areas of increased uptake are non-specific, since a fracture, neoplastic lesion, and inflammatory lesion all produce images of similar appearance. In metastatic bone lesions, the most common sites of the primary tumor are lung, breast, prostate, thyroid, and kidney. Metabolic diseases such as fibrous dysplasia (Figure 1) and Paget's disease also show increased uptake on the scan.[2]

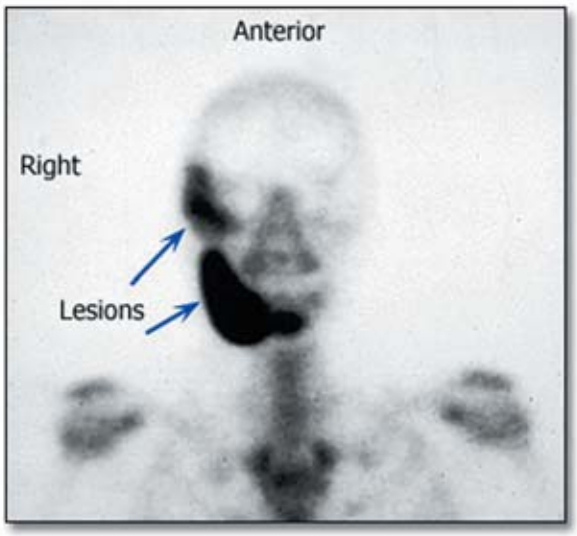


Figure 1. Bone scan of a 30-year old female with a history of fibrous dysplasia. Scan shows uptake in right mandible and right temporal bone.

Inflammatory conditions of the TMJ demonstrate increased uptake as does condylar hyperplasia. The clinician must carefully assess the history, clinical exam, laboratory data, and imaging data to arrive at the proper diagnosis.

Certain conditions and situations can confound the results of the bone scan. For example, active periodontal disease can result in an increased uptake of the radiopharmaceutical in the alveolar processes of the mandible and maxilla. Increased activity in the cervical spine can be due to arthritis. In growing children, there is increased activity in the epiphyseal plates.

Photopenic (areas of decreased uptake) lesions can also be seen on the bone scan. Those most commonly observed include lesions resulting from radiation treatment, local vascular compromise, prosthetic joint, early osteomyelitis, multiple myeloma, and avascular necrosis. A slow growing lesion may demonstrate a lack of uptake. Activity can occasionally occur in the soft tissue of a bone scan. In the head and neck region, the clinician should consider such causes as dystrophic calcifications, chronic inflammatory changes, infarction, hyperparthyroidism, hematomas, and renal failure.[5,6,7]

Up to this point, we have discussed bone scans in terms of static imaging, where the distribution of radioactivity does not change appreciably during acquisition of the image, and dynamic imaging, where a series of images are obtained as the distribution of radioactivity of changes.[7] Bone scans can also use Single Photon Emission Computed Tomography (SPECT) technology where tomographic images obtained in three planes (axial, coronal, and sagittal) allows a more accurate interpretation and better localization of bone pathology. SPECT images are obtained from different angles and then reconstructed by a computer. SPECT can be used for evaluation of TMJ disease, with sensitivity equal to that of a MRI[8,9] for bone pathology.

Gallium Scan

Gallium 67 citrate, once given intravenously, accumulates non-specifically in areas of inflammation, infection, and neoplasm having an affinity for rapidly dividing cells, i.e., WBC and tumor cells.[10] Gallium can be used in evaluating abscesses, lymphomas, sarcoid, and osteomyelitis. Because of Gallium's long half-life (78 hrs), if a technetium bone (half-life of 6 hours) scan is being contemplated, it should be performed first.[1]

Although no longer a common test, Gallium is especially useful in the evaluation of suspected osteomyelitis. A triple phase bone scan is the diagnostic test of choice for confirming the diagnosis of osteomyelitis. However, the triple phase bone scan, while highly sensitive, is non-specific. Gallium imaging may increase the specificity of a positive bone scan, especially if osteomyelitis is superimposed on another underlying acute or chronic bone disease.[5,11,19] A positive Gallium scan with concomitant technetium uptake is highly suggestive of osteomyelitis. A normal Gallium scan with a positive or normal bone scan is not suggestive of an infection. The Gallium scan is also useful for monitoring the response to treatment, with a reduction in Gallium 67 accumulation a good indicator of a resolving osteomyelitis.[1,20,21]

Salivary Gland Studies

The major salivary glands with a functioning parenchyma have the ability to take up technetium 99m pertechnetate in sufficient quantities to be imaged, since the Te99 mimics chloride influx into the acinar cells.[12] Scintigraphy of these glands is used for functional evaluation and evaluating mass lesions. Scintigraphy involves administering a radioactive tracer with an affinity for the organ or tissue of interest; the distribution of the radioactivity is then recorded with a scintillation camera. Other uses include detecting aplasia or agenesis of the gland, evaluating obstructive disorders, traumatic lesions, fistulas, or function after surgery.[22] By itself, this study is rarely diagnostic but is a useful adjunct. Initially, images are obtained five minutes after injection of technetium 99m pertechnetate. After ten minutes, the gland is stimulated by a sour drink or candy.[13] Repeat images are then obtained.

Mass lesions in a gland usually present as areas of decreased uptake, with the notable exception of Wharthin's tumor and oncocytomas which demonstrate increased uptake and decreased washout time. Patients with Sjogren's Syndrome may have poor uptake of the radiopharmaceutical and poor response to stimulation.[7] Acute inflammation of the glands usually demonstrates increased uptake and increased washout, whereas chronic inflammation shows decreased uptake.[4]

PET Scan

The use of positron emission tomography (PET) metabolic imaging has increased significantly over the last several years. PET imaging has value in cardiovascular, neurological, psychiatric, and oncological diagnosis. PET is a functional imaging modality that allows the measurement of metabolic reactions within the whole body.[4]

18F-fluorodeoxyglocose (FDG) is the radiopharmaceutical most commonly used in PET scanning. FDG is a glucose analog that is transported into cells and phosphorylated like glucose, but the metabolism stops at this point and the phosphorylated FDG becomes trapped in the cell and starts to accumulate. Most tumors, with a more rapid growth rate, have an increased rate of glucose use due to an increased rate of glycolysis compared to normal tissue or scar tissue. Consequently, FDG preferentially accumulates in tumor cells and demonstrates an increased uptake especially in poorly differentiated tumors.[5] The accumulated FDG is detectable to the PET camera. To assure adequate uptake of FDG, the patients are required to fast to prevent hyperglycemia which would confound the result.[13]

There are many clinical uses for PET in head and neck cancer. PET can detect nodal neck disease in oral squamous cell carcinoma (OSCCA), often at an earlier stage than CT or MRI which rely on morphological change (Figure 2).

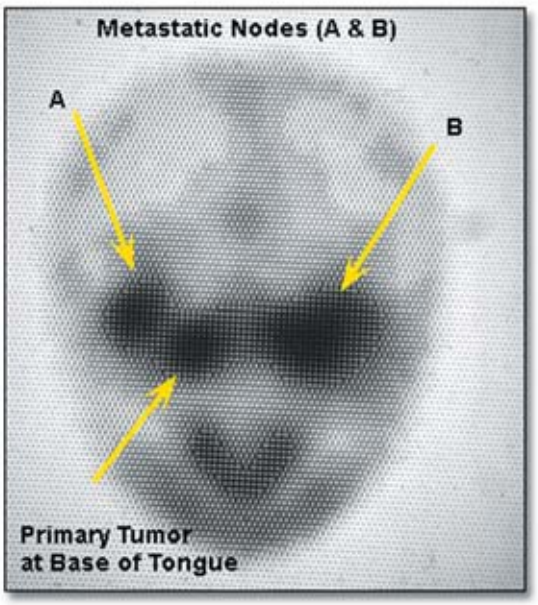


Figure 2. PET scan of 51-year old male with base of tongue OSCCA. Primary tumor is demonstrated along with metastatic nodes.

PET can be used to assess the response of a tumor to treatment, diagnose recurrence, detect residual disease, or detect distant unknown metastases.[14] PET scanning is helpful in evaluating a neck mass or evaluating a neck without palpable adenopathy (staged as a N0 neck) in oral squamous cell carcinoma. PET is especially useful when trying to localize an occult primary tumor.[15] PET has not shown any usefulness in pre-operative evaluation of salivary gland neoplasms.[23]

In OSCCA, there has been a great deal of interest in using PET to evaluate the clinically N0 neck for occult or micrometastasis before any changes are visible on CT or MRI.[16] Preliminary studies in this area have been very encouraging.[17] If the sensitivity and specificity of PET in evaluating nodal neck disease in OSCCA is found to be clinically acceptable, then many patients will be spared an elective neck dissection.

However, PET can give false positive results. FDG may accumulate in non-neoplastic tissue such as new granulation tissue, areas of inflammation, and early post-op scarring. For example, the OSCCA patient with a recently irradiated neck would likely have a false positive result for two to three months after the conclusion of radiation treatment. False positives can also occur in conditions such as tuberculosis and sarcoidosis. Overall, while the sensitivity can be lacking, the specificity is high.

Lymphoscintigraphy

Lymphoscintigraphy is an exciting technique that is receiving much clinical research attention in the treatment of oral and head/neck malignancy, especially OSCCA. Lymphoscintigraphy is already used routinely in the treatment and staging of breast cancer and malignant melanoma.[24-26] Briefly, technetium 99m sulfur-colloid is injected in four to six subcutaneous sites around the neoplastic lesion. The radioactive colloid will be carried away in the lymphatic channels to the first echelon lymph node draining that area, the so-called sentinel node. The sentinel node is felt to be the best predictor of nodal spread of the tumor. The pattern of lymphatic spread and the sentinel node can then be imaged using a gamma camera. One to two hours later, in the operating room, the surgeon using a hand held gamma counter is able to localize the node and remove it. The sentinel node is evaluated for metastatic disease. If the sentinel node is free of disease, it is presumed the remaining nodes in the regional nodal basin are free of disease. On the other hand, if the sentinel node is positive for disease, then the remaining nodes are removed. Because of sentinel node mapping, many women with breast cancer have been spared full axillary nodal dissections and the sequella of persistent upper extremity lymphadema.[18] The sentinal node is any node that receives drainage from any given anatomic location. It can be located in the neck, axillae, groin, or elsewhere in the body. It can theoretically be in any of the 6 levels of the neck, if it is the primary first echelon node draining the site of a primary malignancy.[24-26]

Currently there are numerous clinical research protocols being performed at centers across the country where the accuracy of sentinel node biopsy in the treatment of OSCCA is being evaluated. This again could play an important role in the management of the N0 neck, where the sentinel node is removed and evaluated. If the node is disease free, the patient is spared an elective neck dissection. On the other hand, if the node is positive, the patient goes on to a more formal neck dissection.

Conclusion

This review has been an attempt to familiarize the dental practitioner with some commonly used nuclear medicine studies along with the indications, shortcomings, and interpretations.

Disclaimer

The views and opinions expressed herein are those of the author, Dale A. Baur, and do not necessarily reflect those of the Department of Defense or the Department of Army.

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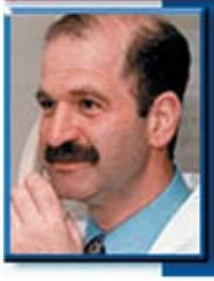

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