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NUCLEAR MEDICINE; A DIAGNOSTIC TOOL-

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ABSTRACT

The Nuclear medicine plays an major role in the diagnosis and treatment of oral and maxillofacial diseases. Although it is not frequently used in daily dental practice, the dental provider should have a knowledge of theseimaging modalities and understand the indications and limitations of these imaging. Radionuclide imaging is a form of noninvasive functional imaging technique, which provides information on pathophysiological and pathobiochemical processes. Radionuclide imaging uses radioactive isotopes that emit γ (gamma) rays. It provides as a early marker of disease, through measurement of biochemical change. After the radionuclides are administered, they get distributed in the body according to their clearance kinetics of that tracer. The gamma camera detects γ-rays and forms planar images showing the locations of the radionuclides in the body. 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 of it.

KEYWORDS: Nuclear medicine, Radionuclide imaging, Radionuclide, Isotopes, Gamma.

INTRODUCTION

Nuclear medicine is an autonomous medical specialty which the World Health Organization has defined as incorporating all applications of radioactive materials in the diagnosis or treatment of the disease, and in medical research.[1] The diagnostic modalities of nuclear medicine in oral and dental practice should be increasingly considered and an improved awareness for a dental surgeon is needed.[2]

These techniques are non-invasive and commonly of negligible risk to the patients and do not hamper with their daily activity. Some techniques are specific for particular conditions, whereas others are of more general application. The basis of each nuclear medicine technique is the administration of a incredibly small amount of a chemical agent which is labeled with a tiny amount of a radioactive isotope, a radionuclide, which is called radiopharmaceuticals. They are designed to demonstrate a normal or altered function of the organ, tissue or system for which they are chosen.[1]

Nuclear medicine techniques are used as an adjunct for the diagnosis of benign tumors, carcinomas, osteomyelitis, hair line fractures, microinfarcts in the bone marrow spaces and temporomandibular joint disorders.[3]

History

The multidisciplinary nature of nuclear medicine makes it intricate for medical historians to find out the birth date of nuclear medicine. This can most likely be best placed between the discovery of artificial radioactivity in 1934 and the production of radionuclides by Oak Ridge National Laboratory for medicine related use in 19461.

Many historians consider the discovery of artificially produced radionuclides by Frédéric Joliot-Curie and Irène Joliot-Curie in 1934 as the most significant milestone in nuclear medicine.Pioneering works by Benedict Cassen in developing the first rectilinear scanner and Hal O. Anger's scintillation camera (Anger camera) broadened the young discipline of nuclear medicine into a fullfledged medical imaging specialty.[3]

Radioisotopes in Nuclear Medicine

Radioisotopes or radionuclides are artificially produced, unstable atoms of a chemical element, which have a different number of neutrons in the nucleus, but the same number of protons and the same chemical properties. Many live for only minutes. Their existence is measured in “half-lives.” That is, the time taken for half of the isotope to disappear.[4,5]

The radioisotopes have many applications in the field of medicine and dentistry (Table 1). Many applications employ a special technique known as “tracer technique.” A small quantity of a radioisotope is introduced into the body usually by an intravenous injection. After the administration of the radiopharmaceutical, the patient typically lies on a couch. The imaging system - A gamma camera is placed over the relevant part or parts of the body to obtain images of the distribution of the injected radiopharmaceutical. For images of the whole body and or of sections through the body, single photon emission computed tomography (SPECT), may be undertaken. For the latter, the Gamma camera is rotated around the patient to collect such information.[7]

Bone imaging techniques

Conventional and digital radiographs remain the most easily available tool for the detection of diseases of teeth and bones of the oral cavity. Sometimes early detection of these jaw lesions becomes more difficult because they do not develop physical symptoms at an early stage when biochemical changes are taking place. The bone scan can show these early changes in the osteoblastic activity which would not appear on the radiographic images. Although the resolution of bone scintigraphy is not as good as that of radiographs, it can even detect approximately a 10% increase in the osteoblastic activity of the bone above normal.[8]

Standard bone scan, three phase bone scan and SPECT are the bone imaging techniques. The static images acquired by these scans are generally taken after 3 h - As delayed static images are useful in the evaluation of benign conditions (condylar hyperplasia). There is increase in the new bone formation with the bony lesions which have the highest morbidity. These areas of new bone formation can be detected by scintigraphy as there is increased uptake of the radiotracer known as “hot spots.”[8]

Radioisotopes	Uses
Reactor radioisotopes	
Technetium-99 m	To image the skeleton and heart muscle in particular, but is also used for brain and thyroid imaging
Cobalt-60	For external beam radiotherapy and used for sterilizing
Iodine-125	In cancer brachytherapy
Iodine-131	Used in imaging the thyroid function and thyroid cancer treatment
Iridium-192	Acts as source in internal radiotherapy for cancer treatment
Molybdenum-99	Used to produce technetium-99 m
Palladium-103	For brachytherapy in cases where early stage of cancers are detected
Strontium-89	For pain relief in osteochondromas
Caesium, gold and ruthenium	In brachytherapy as a treatment modality
Cyclotron radioisotopes	
Carbon-11, nitrogen-13, oxygen-15, fluorine-18	Used in PET scans through use of F-18 in FDG which help to detect, diagnose and know the prognosis of a tumor
Cobalt-57	Can be used as an detector for hypertrophy of cells, which indirectly determine the division and progression of cell growth to a stimuli
Copper-64	Is being used in PET scans and to check for the metabolism of copper
Copper-67	Used as an isotope for radiotherapy
Fluorine-18 as FLT (fluorothymidine), F-miso (fluoromisonidazole), 18F- choline	Used as traces, in radiotherapy
Gallium-67	For imaging of tumor size
Gallium-68	Used in PET scan to detect the metastatic activity
Germanium-68	Used to generate Ga
Rubidium-82	Used in PET scan to detect the cardiac myopathies
Strontium-82	Used to generate Rb-82

PET: Positron emission tomography, FDG: 18F-Fluorodeoxyglucose

Bone imaging techniques can be utilized to diagnose various disease processes in dentistry:

Inflammatory and infectious processes

A positive bone scan image is seen in inflammatory conditions such as osteomyelitis, osteoarthritis, traumatic injuries, periapical lesions and periodontal lesions.[8]

For detection of Early osteomyelitis

Early osteomyelitic changes that are not readily apparently seen in conventional radiographic techniques are readily appreciable on PET Scan. To differentiate between cellulitis and osteomyelitis.

A type of bone scan named focal -three phase imaging is used to differentiate cellulitis from osteomyelitis. The three phases are flow phase (1 minute after injection), the blood pool (5 minutes after injection) and the skeletal phase (2-4 hours after injection). Both cellulitis and osteomyelitis will have increased uptake in the first two phases of the bone scan however only osteomyelitis demonstrates increased activity in the third phase.[9]

Fibrous dysplasia

Fibrous dysplasia of bone may be monoosteotic (jaw bone) or polyosteotic. There is a slow and insidious enlargement of bone which may persist until growth cessation or continue to adulthood.[8,10] nuclear medicine demonstrates increased tracer uptake on99mTc bone scans.

Paget disease

In Paget's disease, there is abnormal resorption and apposition of bone in one or more bones. The disease is initiated by an intense osteolytic activity with resorption of normal bone followed by a vigorous osteoblastic activity forming woven bone. In addition to radiographs an increased uptake of radiotracer by scintigraphy demonstrates these lesions. When the mandible is affected, the bone scan may demonstrate marked uptake throughout the entire mandible from condyle to condyle, a feature that has been termed black beard or Lincoln's Sign.[8,10]

Fracture

Most fractures show increased uptake on bone scintigraphy within hours after trauma. In elderly patients, however, fractures may take several days to be seen on bone scan. The optimal timing for imaging of a fracture is unclear. Holder *et al*. reported a sensitivity of 93% and specificity of 95% for fracture identification if the bone scan is performed within 72 h and 100% sensitivity if performed 72 h or longer after injury. In addition to patient's age, the bone metabolic activity, mineral content, and imaging technique are all factors that can significantly affect the ability to detect a fracture. The scintigraphic appearance of fractures depends on the time elapsed since injury.[11,12]

Condylar hyperplasia

Condylar hyperplasia of the mandible is a pathological state of development that can lead to facial asymmetry, mandibular deviation, malocclusion, and articular dysfunction. This abnormality is important in dentistry due to induction of lateral open bite, midline shift, prognathism, temporomandibular joint dysfunction, and malocclusion. Bone scintigraphy has been used in the diagnosis and treatment planning of mandibular condylar hyperplasia for many years. This imaging modality has the ability to detect abnormalities at an earlier stage before morphological changes are evident.[13-15]

Gallium 67-citrate imaging

After the administration of the gallium 67-citrate intravenously, it gets accumulated in the areas of inflammation, infection and neoplasm, non-specifically. A gallium scan is used in the evaluation of abscesses, osteomyelitis, and lymphomas.[4,7] Although not a favorite test, suspicion of osteomyelitis in dental and other areas can be confirmed and diagnosed effectively by gallium scan. Although triple phase bone scan test is the choice for osteomyelitis, it is non-specific and gallium imaging increases the specificity of positive bone scan. Gallium scan is also used to monitor treatment response with reduced gallium intake/accumulation indicating improvements in osteomyelitis.[16]

Salivary gland scintigraphy

The use of a scintillation crystal for acquisition of data for image.

Formation has led to the labeling of this technique as scintigraphy. Several modalities are known for salivary gland imaging such as sonography, sialography, scintigraphy, CT and MRI. CT and MRI are well-established in oncological settings because of their high geometric resolution and their well-known differentiation of soft tissue from osseous structures. The parenchymal and excretory function of salivary glands can be simultaneously quantified by salivary gland scintigraphy. Moreover, this method is well-tolerated by the patient, reproducible and easy to perform.[17] Radioactive substance with affinity to particular tissue is administered with radioactivity measured by scintillation camera. The intact salivary gland parenchyma shows the uptake of 99mTc-pertechnetate. Gland aplasia/agenesis, obstruction, trauma, as well as fistulas in the glands can be detected, though there are exceptions. Further, acute inflammation usually shows increase in uptake while decrease intake is seen chronic inflammatory stages.[18]

Lymph node scintigraphy

The sentinel node is the one which first receives lymph the primary tumor. A radionuclide is used in the radioisotope method for sentinel lymph node mapping. Lymphoscintigraphy and gamma probe are used to detect the sentinel lymph node.[19]

Uses of Radio Isotope in Head and Neck Cancer

The oncologic imaging modalities aids in the detection of cancer, it's staging and in the assessment of prognosis. 18F-FDG PET has a significant in the diagnosis and management of head and neck cancer. It helps in the detection of distant metastasis. The possibilities of distant metastasis increase with locally advanced diseases (T3-T4), regional lymph node involvement (N2 or N3) with extracapsular involvement, and perineural invasion.[6] Chemoradiotherapy has a significant role in the treatment of head and neck cancer. Being a modality to assess the metabolic activity of the malignant cells, 18F-FDG PET plays a major role in detecting response to the treatment.[19,20]

Uses of Radioisotopes in Brachytherapy

Brachytherapy is one of the radio-therapeutic methods where the radioisotopes are directly placed at the site of the malignant tumor. These isotopes are placed in a protective capsule which prevents its movement and later the capsule may be left behind or removed. These isotopes emit ionizing radiation to the surrounding tissue and kills the cancer cells.[15]

For detection of viability of bone grafts

The study conducted by Berding *et al* concluded that [18F-] PET (fluoride ion and positron emission tomography) depicted increased blood flow activity in on lay grafts and regions of osteosyntheses, indicating bone repair in the graft and adjacent host bone early after surgery. For the regions of osteosynthesis, the decrease in both parameters corresponded to uncomplicated healing.[21] The lack of increased influx, although flow was increased in pedicle grafts, most likely indicates that some necrosis occurred in these grafts despite patency of anastomoses. It may be concluded that [18F-] PET provides further insight into the biology of graft incorporation.

There are other studies that show that bone scintigraphy performed within the first week after the mandibular reconstruction is a useful tool to monitor the viability and early complications of micro vascularized fibular grafts and plays an important role in the decision-making process during repeated surgical exploration.[22]

Advantages of nuclear medicine[23]

- These imaging modalities give the information on primarily displaying the structure of the human body and thereby provide anatomical information that can be used for diagnosis of diseases.
- Nuclear medicine imaging is based on tracer principles and primarily gives images of function, including physiology, biochemistry or metabolism, by analyzing the dynamic behavior of molecules in organs and tissues at different levels.
- Useful for early diagnosis of disease and for evaluation of treatment effects in the early post-therapeutic stage.
- Allows easy demonstration of whole body images and interactive display, which help in detecting the metastatic activity.
- Detailed examinations can be performed on different sites and at different times after the injection of the tracer isotope to clarify findings without increasing radiation exposure unlike other basic techniques wherein number of exposures are performed.

Disadvantages of nuclear medicine[23]

- Although contrast of a lesion versus surrounding tissues is high when radiotracers accumulate in the lesion, spatial resolution, in general, is poor compared with radiographs, CT or MRI.
- The cost of instruments used is relatively high.
- The cost of each examination also depends on the cost of radiopharmaceuticals used and the capability of the scanner.
- Patients are exposed to ionizing radiation administered to the bodies.
- The radiation exposures are different from radiographs and CT, which involve external and generally only partial body exposure, whereas radionuclide administered into patients causes internal whole body exposure in a non-uniform manner determined by the bio distribution and clearance kinetics of that tracer.
- Due to unavoidable high irradiation from PET tracers to the staff members when interacting with radioactive patients, it is recommended that a 6 mm thick lead shielding is advisable.

CONCLUSION

Nuclear medicine is an ideal imaging speciality to adapt to the new discipline of molecular medicine, because of its emphasis on function and its utilization of imaging agents that are specific for a particular disease process. Radionuclide bone imaging will likely remain a popular and important imaging modality.

Interpretation of the scan results, as well as shortcomings of the scan are important to understand, as they may be required at times to be done by the dental surgeons. Nuclear Medicine helps in diagnosing oral/dental pathologies and tumors in the oral maxillofacial regions, which may have to be dealt by dentists at initial stages, though may later require an oncologist Recently the combination of PET images with CT (Computed Tomography) images is referred to as Fusion imaging which has significant advantages over PET or CT alone by helping in discriminating Metastases from Physiological foci of activity, improving lesion detection, precisely localizing the metastatic foci, differentiating bone from soft tissue.

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