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Review Article

A dentist's perspective on scintigraphy about its applications as a diagnostic tool for a myriad of diseases affecting oral health

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ABSTRACT

A "branch or specialty of medicine & medical imaging that uses radionuclides and relies on the process of radioactive decay in the diagnosis and treatment of disease" is known as nuclear medicine. Assessing physiologic change, which follows biochemical changes, is made easier with the use of radionuclide imaging, which is sometimes referred to as a functional imaging approach. Scintigraphy is a diagnostic procedure used in nuclear medicine where radioisotopes are administered internally into the body in liquid or gaseous forms, and the distinctive radiation that emerges is captured by external detectors known as gamma cameras, producing two-dimensional pictures. Bone scintigraphy, lymphoscintigraphy, salivary gland scintigraphy, and radio-immuno-scintigraphy are a few examples of scintigraphy techniques.

Nuclear imaging has the advantage of giving extremely high levels of diagnostic sensitivity, which is successful in identifying even the smallest pathophysiological changes that are highlighted in the process of diagnosing early-stage to progressive diseases, making it the preferred diagnostic modality.

1. Introduction

Scintigraphy is a nuclear medicine technique in which radioisotopes are ingested into the body in liquid or gaseous form, and the ensuing distinctive emitted radiation is detected by external detectors known as gamma cameras, producing two-dimensional images.[1] Furthermore, the Latin word "Scint" (which means "spark") made it feasible to use tracers for diagnostic imaging by detecting scanners like rectilinear scanners and anger or gamma scintillation camera scanners. Both of these devices capture the gamma emissions from individuals who have received the proper tracers in an injection. The use of a scintillation crystal in this method has led to the naming of the method "scintigraphy," as well as the development of cameras that use a scintillation crystal that fluoresces when it interacts with gamma rays. A photomultiplier tube detects the flash of light (or fluorescence), magnifies, and amplifies the signal several times to produce an image. Flat-plane images can be produced by stationary anger cameras or rectilinear scanners. Single photon emission computed tomography (SPECT), which consists of either multiple detectors or a single moving detector, which permits the acquisition of data from several contiguous trans-axial slices, similar to computed tomography by x-ray, revolutionized with anger cameras with rotating capability up to 360 degrees around the patient. This information may be utilized to create multiplanar images of the research region.[2] Principles for patient preparation include donning a patient gown and taking off any jewelry or pieces of clothing that need to be removed. Before beginning the procedure, questions concerning any prosthetic implants in the body should be made. The pharmaceutical radionuclide is then delivered intravenously or orally. This procedure can typically take anywhere between 15 and 60 minutes.

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Bone scintigraphy, lymphoscintigraphy, salivary gland scintigraphy, and radioimmuno-scintigraphy are a few categories of scintigraphy techniques.[3,4]

1.1. Bone scintigraphy

This method makes use of the bone-seeking ability of certain radiopharmaceuticals, which are integrated into the mineral matrix of bones (consists the calcium phosphate and hydroxyapatite). Additionally, it is the most widely used method in nuclear medicine, which is very effective in diagnosis due to mineral loss assessment feature, which allows for visualization of minute amounts of mineral loss up to 10-15% even at the earliest stages of disorders. Bone scans cannot detect morphological changes, but they can reveal reactive changes in osteoblastic activity that would not be visible on radiographic imaging. This technique allows for the observation and storage of images of the distribution of a radioactive tracer in the skeletal system.[5]

1.1.1. Different modalities of bone scintigraphy include:

1. Limited bone scintigraphy or spot views (planar images of a selected portion of the skeleton).
2. Whole-body bone scintigraphy (planar images of the entire skeleton in anterior and posterior views).
3. Single photon emission computed tomography (SPECT) includes a tomographic image of a portion of the skeleton,
4. Multiphase bone scintigraphy (immediate and delayed images to study blood flow).[6]

1.1.2. Bone scintigraphy benefits

1. Detects anomalies and verifies them earlier than radiography does. Additionally, abnormal alterations might be seen, which ultimately points to the underlying dubious results.
2. It is possible to determine the metabolic activity in or around a bone lesion. This technique can help to distinguish between osteomyelitis and cellulitis. Furthermore, it is possible to determine bone vitality, which aids in determining whether an infection or avascular necrosis is present.
3. Early detection of metastasis allows for decision-making on surgical procedures and prognosis by the physician.

1.1.3. Drawbacks

1. Although sensitivity is higher, specificity is lower.
2. Inability to showcase morphological changes.[7]

Details regarding the following bone-imaging methods are covered in this review article:

1. Standard bone scan (whole-body scanning or whole-body spot views)
2. Three-phase bone scan

1.1.4. Standard bone scans

In this technique, three hours after the tracer is administered, information regarding static images will be collected, which is helpful for evaluating benign disorders like Condylar hyperplasia.

1.1.5. Three-phase study

This procedure comprises flow assessment, 'blood pool image & and delayed static views acquisition. Tc99m MDP (Technetium Pertechnate methylene diphosphonate), administered intravenously, is the radioisotope that is most frequently utilized in this treatment because it binds to calcium ions and concentrates in locations with greater ossification and regions with abundant vascular supply. In Scintigraph imaging, Tc^{99m} can appear uniformly distributed, Cold: decreased intake, Hot: increased intake.

Immediately after injection, the tracer distributes intravascularly. The three-phase study includes flow phase, blood pool phase, and static bone phase. In the primary dynamic vascular flow phase or radionuclide angiography, the identification of variation in the vascular flow can be identified by imaging every 2-3 sec in the first 30 seconds, which lasts for the first 60 to 90 secs. The secondary blood pool phase images can be obtained within 5 min after injection and it shows tissue hyperemia. The tertiary phase is a static bone phase that is the bone scintigraphy phase which lasts for about 2 to 3 hours after injection. The methylene diphosphonate (MDP) buildup in the skeleton is influenced by both osteoclastic activity and blood flow. Bone turnover can be observed in the images made 2 to 3 hours after injection and also the metabolic activity of bone can be observed, this is an imperative phase for suspected metastasis and non-inflammatory conditions. Radionuclide imaging makes it possible to identify inconsistencies in bone turnover which impact physiological function. Additionally, radionuclide imaging shows enhanced or uncontrolled osteoblastic activity in the majority of cancers.

Interpretation of the images in radionuclide imaging mentioned as either hot spots or cold spots. In further detail, the images of areas with an upsurge in bone metabolism appear as areas of escalated radiotracer uptake, namely "hot spots". Depletion in the uptake represents the metabolically inactive bone, absence of osteogenesis, or scarcity of vascular supply. Zones of photon-deficient or photopenic abnormalities with meager uptake, are called "cold spots".[8]

Uses of bone scintigraphy in and around oral region

1. Bone scans can be used to diagnose inflammatory and metabolic disorders, bone malignancies, and other diseases.
2. Bone scintigraphy is useful in diagnosing, treatment planning, and estimating the prognosis level of various inflammatory or infectious diseases (lesions involving periapical lesions, osteomyelitis), diseases, trauma related or pathological injuries affecting oral and

maxillofacial region (maxilla, mandible, TMJ).

Moreover, other than diagnosing, treatment planning and estimating prognosis, biopsy site could be estimated in benign and malignant neoplasms (primary or secondary malignancies resulting in metastasis etc.), cystic lesions, metabolic diseases, fibro-osseous dysplasia.

Additionally, it is possible to determine a bone graft's bone vitality, or its capacity to develop and integrate with the surrounding tissue.

In further detail about Inflammatory and infectious processes like osteomyelitis can be detected earlier and prior to changes that are obvious on plain radiographs. Several agents have been used including technetium-99m–labeled methylene diphosphonate (99mTc-MDP), gallium-67 citrate, and indium-111–labeled white blood cells, which are highly sensitive. Hot spots represent hidden anomalies in ischemic osteonecrosis.When it comes to TMJ imaging, SPECT may be used to evaluate the deep-seated bone alterations, which helps to both confirm the degenerative changes and rule out other potential sources of high uptake, such as a tumor or trauma.

Benign and Malignant conditions: In images of benign bone lesions like fibrous dysplasia, hot spots that signify the area that is metabolically active can be seen. Furthermore, one or more randomly dispersed foci of markedly enhanced radiotracer uptake, or "hot spots," is the scintigraphy pattern most frequently seen in malignant bone lesions."[9,10]

According to a study done by Anshuman Jamdade and Ani John on 20 patients, in the histologically proven benign lesions of the jaws, the expense and nature of benign jaw lesions were investigated pre-operatively by panoramic radiography and bone scintigraphy, revealed that most of the benign lesions presented radiographically well-defined bone destructions with fine sclerotic rims were found to be silent on scintigraphs and the extent of radionuclide uptake was in accordance radiographically. Aggressive lesions, on the other hand, were not consistent; on radiographs, they showed poorly defined bone destructions without sclerotic rims, and their scintigraphic uptake was greater than the radiographic extent of the bone involvement.[11]

1.2. *Salivary gland scintigraphy (SGS)*

Salivary gland function and abnormalities in gland uptake and excretion are examined using technetium (Tc) 99m pertechnetate. Additionally, it provides quantitative data, functional capacities, and forecasts the severity and functional abnormalities, which morphological damage may not adequately portray.

After absorbing Technetium radionuclide, an intravenous injection that is a pure gamma ray emitter, salivary glands are variably visible. The scans clearly show the parotid and submandibular glands, two major salivary glands, as well as the uptake and secretion phases. Moreover, technetium (Tc) 99m pertechnetate is also taken up by the thyroid gland. Absorption of Tc 99m by Salivary gland and duct cell aids in the detection of numerous functional problems. Additionally, salivary gland absorption demonstrates the presence of functioning epithelial tissue and is consistent with salivary output. This might be employed as a technique to calculate the flow of fluid via the salivary acinar cells.[12]

1.2.1. *Indications of salivary gland scintigraphy*

1. Evaluation of the salivary gland's functionality in xerostomia patients.
2. Diagnosis of a variety of illnesses affecting the salivary glands and ducts, including ductal blockage, sialolithiasis, Sjogren's syndrome, and gland aplasia.
3. Recommended when sialography is not advised due to an acute gland infection or an iodine allergy or when the main duct cannot be effectively cannulated.

1.2.2. *Advantages of salivary gland scintigraphy*

1. Minimal non-invasive technique.
2. Assess salivary gland function and quantification of function.
3. Identification of abnormalities in gland absorption and excretion is possible because it provides quantitative data on the functional capabilities of the glands after a single intravenous injection.
4. Tc 99m uptake and secretion are calculated by computer analysis of user-defined regions of interest but mostly done by visual exploration and clinical assessment.
5. Abnormal results were adopted in the American–European Consensus Group (AECG) criteria for diagnosing Sjögren's syndrome (SS).

1.2.3. *Disadvantages of salivary gland scintigraphy*

1. This is a time-consuming procedure.
2. It is a costly procedure and radiation exposure will be there.
3. No morphologic data will be available.[13]

Salivary gland scintigraphy phases include the flow phase, concentration phase, washout phase:-

1. Flow phase: It lasts about 15 to 20 seconds and isotope accumulation in the salivary gland reaches a submaximal rate.
2. The concentration (or uptake) phase: In this phase, at least after 10 to 15 minutes tracer activity should be evident in the oral cavity and there should be a plummet in the salivary glands even without stimulation which is regarded as normal salivary function. In addition, uptake of Tc 99m should be there by both parotid & submandibular glands and should be symmetric which is considered as standard without abnormalities, but sublingual glands cannot be

differentiated clearly.

3. The last phase is the excretory or washout phase: Stimulating agents like lemon drop or citric acid are applied to the tongue, to encourage secretion.

Imaging features normal verses abnormal:

1. Images without anomalies include uniform and even normal Tc 99m clearance.
2. Retention will be present in the event of any irregularity, interfering with normal cleansing. Following stimulation, the retention of tracer activity in the salivary glands is a sign of a number of conditions that affect the glands, including inflammation, blockages, and some types of cancer.
3. In the vast majority of cases, salivary gland neoplasms that develop in the glands do not concentrate Tc 99m. The exceptions include oncocytomas and Warthin's tumors, which grow from ductal tissue and are able to concentrate the tracer. Moreover, they appear as regions of enhanced activity on static imaging and distinction is highlighted during the washout period, when activity is kept in the tumors while the glandular signal declines after stimulation. On scintiscans, other salivary cancers could show up as gaps or regions of reduced activity.
4. Salivary gland imaging evaluates the salivary gland function & pathologies. Decreased uptake of the radionuclide can be observed in patients with xerostomia-containing disorders like Sjogren syndrome, chronic inflammation, and increased uptakeassociated with acute inflammations.[14,15]

1.3. Lymphoscintigraphy

The first node draining the primary tumor where a malignancy is most likely to spread is known as the sentinel lymph node (SLN). The staging of many malignancies might be made easier by identifying the SLN for biopsy and pathological examination. Easy to manufacture and provide, 99mTc-labelled Nanocoll offers the right qualities for SLN localization in oral malignancies, with quick migration to the SLN and protracted retention. A variety of colloidal and soluble tracers have been used over the years for lymph studies.[16] Incorporating radioactive nuclide has made it possible to identify the sentinel node before surgery and additional benefit will be there for surgical team because they may validate external sampling techniques by simply listing the numerous lymph nodes found through a tiny incision thanks to the intra operative use of gamma probe detectors. These methods give a large improvement in sentinel node identification accuracy. Moreover, there will be plummet in the surgical process time to minutes from hours, and a definitive advantage of decreased morbidity pertaining to the staging operation.[17] The identification of all draining nodal basins in the sequence of manifestation from the main tumor is made possible by wide-field-of-view, dynamic imaging. Radical neck dissection and consequent morbidity are avoided in the event that the sentinel node's excisional biopsy is negative. It is possible to sample many sentinel nodes in several nodal basins.[18]

1.4. Radioimmunoscintigraphy

Radio immune-scintigraphy is a method for imaging and describing the nature of the disease process in vivo utilizing radio-labeled antibodies. The use of nuclear medicine procedures is renowned for their sensitivity in recognizing any functional change brought on by an illness, but not for their precision in identifying the kind of disease process. In Nuclear medicine, with the advent of novel techniques, tissue characterization and functional evaluation became easier.[19,20]

2. Conclusion

Nuclear medicine is an emerging technique that can be utilized for both diagnostic and therapeutic purposes. Scintigraphy can be regarded by dental healthcare providers as a primary diagnostic technique because it is essential in the early detection of diseases that hamper the human's existence. In order for this to happen, more study in this area is required, and it is crucial to train as many professionals in dentistry as possible. This will be achievable if financing is provided by both the public and private sectors, ultimately motivating the concerned experts to do research and educate as many specialists in dentistry as possible. Additionally, it motivates the diagnostician to regularly suggest as a diagnostic tool whenever necessary.

3. Source of Funding

None.

4. Conflict of Interest

None.

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