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Review Article

Nuclear medicine imaging in oral diseases: A review

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A R T I C L E I N F O

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A B S T R A C T

Nuclear medicine is the discipline of medicine that deals with the use of radionuclides in research, diagnosis, and treatment. It works on molecular & functional level and uses radiopharmaceuticals in its procedure helping in detection of lesions before morphologic change is evident. Radiopharmaceuticals also known as Radionuclides/ Radioisotopes are unstable atoms of a chemical element, actively emit radiation. These emitted radiations are absorbed by photomultiplier tube and reconstructed by a computer system followed by display of an image. The rationale of writing this article is to understand about Nuclear Medicine and its applications in oral diseases.

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1. Introduction

Nuclear medicine is the discipline of medicine that deals with the use of radionuclides in research, diagnosis, and treatment. WHO has defined Nuclear Medicine as “incorporating all applications of radioactive materials in the diagnosis or treatment of the disease, and in medical research.[1]” It works on molecular & functional level and uses radiopharmaceuticals in its procedure. Therefore, it helps in detection of lesions before morphologic change is evident. Radiopharmaceuticals are introduced into the patient usually by intravenous injection, swallowing & inhalation has also been used.

Radiopharmaceuticals also known as Radionuclides/ Radioisotopes are unstable atoms of a chemical element, which have a different number of neutrons in the nucleus (same number of protons and the same chemical properties). Existence is measured in “half-lives.” (Time taken for half of the isotope to disappear), actively emit radiation. Beta particles (positrons or electrons) or gamma rays are usually emitted by diagnostic interventions. Auger electrons or alpha particles (helium nuclei) emitted by compounds are generally used for therapeutic interventions.[2] Appropriate nuclide selection is most important, as the specific nuclide has a specific half-life and decay mode.

1.1. Basic principle

The principle of radiation detection is based on the interaction of the radiations emitted by body after introduction of radiopharmaceuticals with the matter. Gamma photon loses its energy mainly in the form of ionizations or excitations when it interacts with detector material.[3] The atoms which have been excited return to their ground state with the emission of secondary low energy gamma photons. The incident gamma photon can be partially or totally absorbed by photoelectric effect.

2. Scintigraphy

Uses Gamma Camera, also called a scintillation camera or Anger camera. Gamma Camera is used to image gamma radiation emitting radioisotopes.[3] It is made from one or more flat crystal detectors optically

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coupled to an array of photomultiplier tubes in an assembly known as a "head", mounted on a gantry. A computer system is connected to the Gantry that both controls the operation of the camera and acquires and stores images. The whole system gathers counts of gamma photons that are absorbed by the crystal in the camera. Usually, sodium iodide with thallium doping in a light-sealed housing is used in flat crystal. In response to incident gamma radiation the crystal scintillates (When a gamma photon leaves the patient, it knocks an electron loose from an iodine atom in the crystal.)

After the dislocated electron again finds a minimal energy state, a faint flash of light is produced. The initial phenomenon of the excited electron is similar to the photoelectric effect and (particularly with gamma rays) the Compton effect. Photomultiplier tubes (PMTs) detects the faint flashes and the computer connected sums the counts. The computer then reconstructs and displays a two-dimensional image of the relative spatial count density on a monitor. The distribution and relative concentration of radioactive tracer elements present in the organs and tissues imaged is displayed by the computer screen.[4]

3. Uses in Oral & Maxillofacial Pathologies

1. Inflammatory lesions of the jaw.
2. Cysts of the jaw.
3. Benign tumours of the jaw.
4. Malignant neoplasms of the jaw.
5. Fibro-osseous lesions of the jaw
6. Salivary gland diseases
7. Fracture
8. Condylar hyperplasia.

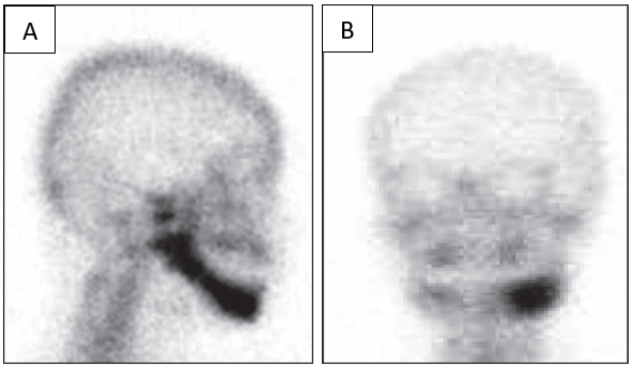

Fig. 1: A: Scintigram of skull showing an extensive area of hot spot over the body, ramus, and condyle with the right lateral view; **B:** Scintigram of skull showing an area of intense hot spot over the left body of the mandible with the front view.[3]

Various studies conducted on scintigraphy showed high sensitivity, but lacking in specificity, positive predictive value, and efficiency. Radiography, has good sensitivity and relatively better specificity, positive predictive value, and efficiency. Clinical, radiological, and histopathological findings must be correlated for a proper diagnosis.[3]

4. Single-Photon Emission Computed Tomography (SPECT)

Uses gamma rays and very similar to gamma camera with its ability to provide true 3-Dimensional information. Most radiopharmaceuticals used in nuclear medicine and SPECT are labelled with radionuclides that emit γ-ray photons. Conventional two-dimensional nuclear medicine images (as in scintigraphy), in SPECT are acquired at different views around the patient. A computer is then applying a tomographic reconstruction algorithm to these multiple projections, and yields a 3-D data set. Hence, it provides an evaluation of the three-dimensional radioactivity distribution using methods of image reconstruction from multiple projections. SPECT differs from x-ray computed tomography (CT) in that the radiation source is within the patient in SPECT instead of outside the patient.[5]

5. Uses in Oral & Maxillofacial Pathologies

1. Bone scans are available in planes (axial, coronal and sagittal), which thereby facilitates more accurate interpretation and better localization of bone pathology.
2. Useful in localizing small lesions.
3. A positive bone scan image is seen in inflammatory conditions such as osteomyelitis, osteoarthritis, traumatic injuries, periapical lesions and periodontal lesions.
4. Fibrous dysplasia: - Increased tracer uptake on 99m Tc bone scans.
5. Paget disease: - Increased uptake of radiotracer. The bone scan may demonstrate marked uptake throughout the entire mandible from condyle to condyle when mandible is affected, this feature has been termed black beard or Lincoln's Sign.

6. SPECT/CT

SPECT in combination with CT enables a direct correlation of anatomic information and functional information, resulting in better localization and definition of scintigraphy findings.

Besides anatomic localization, the added value of CT co-registration carries out all attenuation correction of CT.

7. Positron Emission Tomography (PET)

Detects altered metabolism in biological tissues. PET uses tracers that target physiological mechanism such as glucose metabolism and enables imaging and quantification of cellular function.[6] PET scan detects the disease at the metabolic level unlike anatomical imaging techniques like CT or MRI, that detect the disease at the structural level. Positron emitting radio-isotopes – C11, O15, F18, N13, K38, CU62, CU68, GA68. 18F-fluorodeoxyglucose (FDG) is a radiopharmaceutical commonly used in PET scans for studying glucose use in brain, heart and to look for cancer metastasis.

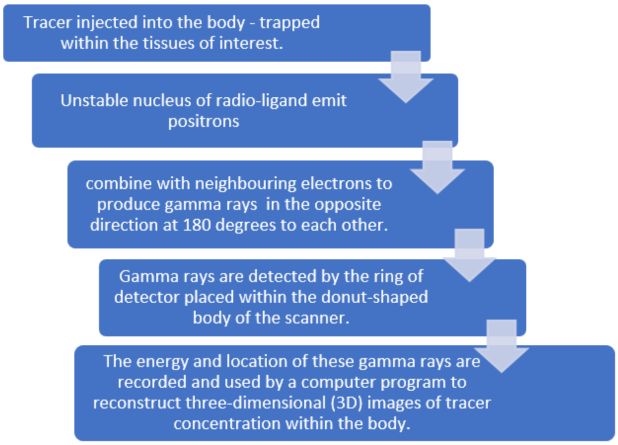

Fig. 2: Basic mechanism of PET

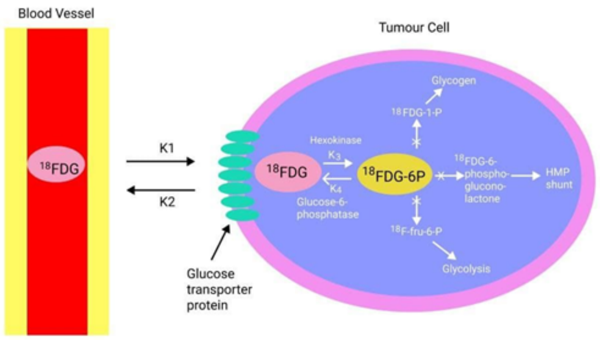

Fig. 3: Molecular Mechanism of Radiopharmaceutical in PET Scan- 18 FDG (an analog of glucose); cancer cells show up regulation of glucose & glucose analogs -> deoxyglucose is labeled with 18F radionuclide -> 18FDG transported to cells as glucose but at higher rate -> 18FDG is phosphorylated to FDG-6-phosphate (enzyme- hexokinase) -> this does not enter std metabolic pathways because of fluorine at 2^{nd} carbon -> Trapped into the tumour cell[7]

8. Uses in Oral & Maxillofacial Pathologies

1. Oral squamous cell carcinoma (OSCCA).
2. Is able to detect pathology earlier than CT scan or a MRI, a stage when there are no palpable nodes in the neck and is considered promising in this respect.
3. Response to tumour treatment, diagnosing recurrence, detecting residual pathology and distant metastases are effectively done by PET scan.
4. However, PET scan gives false positive results too. Specificity in PET scan is high, sensitivity is an issue.

9. PET/CT and PET/MRI

Combined FDG PET/ computed tomography (CT) has an established role in head and neck (HN) squamous cell carcinoma (SCC) in staging.

1. Detecting occult primary tumours,
2. Assessing response post chemoradiotherapy at 3-6 months,
3. Helps in differentiating relapse and treatment effects in patients.

PET/CT is highly sensitive (>95%), for identifying malignancy in the head and neck region. The diagnostic performance for the detection of the primary tumours in the oral cavity was 96.3% for PET/CT, 77.8% for CT, and 85.2% for MRI. The fused PET/MRI images offered higher sensitivity and specificity to the presence of malignancy, when compared with MRI and PET separately.[5]

9.1. Advantages of nuclear medicine

1. Diagnosis before any morphologic changes occur.
2. Primarily gives images of function, including physiology, biochemistry or metabolism, by analysing the dynamic behaviour of molecules in organs and tissues at different levels.
3. With the help of interactive display it allows easy demonstration of whole body images, which helps in detecting the metastatic activity.
4. After the injection of the tracer isotope, detailed examinations can be performed on different sites and at different times to elucidate findings without repeated radiation exposure.

9.2. Disadvantages of nuclear medicine

1. As compared to other imaging modalities (CT/MRI) the spatial resolution is in general poor
2. The cost of machine used is relatively high.
3. The cost of examination is also high and depends on the cost of radiopharmaceuticals used.
4. Patients are exposed to ionizing radiation administered to the bodies.
5. 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.
6. There is a risk of unavoidable high irradiation from PET tracers to the personnel when interacting with

radioactive patients, 6 mm thick lead shielding is advisable.

10. Conclusion

Nuclear medicine imaging, means of assessing physiologic changes in combination with traditional anatomic imaging such as computed tomography scan and magnetic resonance imaging (MRI) scan, provide precise localization of functional abnormalities. These imaging techniques allow the measurement of tissue function and provide an early marker of disease through measurement of biochemical change. Radiopharmaceuticals which are the elements found on earth exists in different atomic configurations used in medicine. These agents are useful to get diagnostic and therapeutic details about those tissues.

11. Source of Funding

None.

12. Conflict of Interest

The authors declare no conflict of interest.

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