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Radioisotopes: An overview

Kotya Naik Maloth, Nagalaxmi Velpula, Sridevi Ugrappa, Srikanth Kodangal

ABSTRACT

Many elements which found on earth exist in different atomic configurations and are termed isotopes which have same atomic number but differ in their atomic mass. These unstable element decay by emission of energy such isotopes, which emit radiation, are called radioisotopes. Using of these isotopes in various sectors like industries, agriculture, healthcare and research centres has got a great importance at present. In health care sector, these isotopes are used in nuclear medicine as diagnostic and therapeutic modalities. Radionuclide imaging (or functional imaging) is a branch of medicine which provides the only means of assessing physiologic changes that is a direct result of biochemical alterations and is based on the radiotracer method. In nuclear medicine procedures, radionuclides are combined with other chemical compounds or pharmaceuticals to form radiopharmaceuticals. These radiopharmaceuticals, once administered to the patient, can localize to specific organs or cellular receptors. This unique ability of radiopharmaceuticals allows nuclear medicine to diagnose or treat a disease based on the cellular function and physiology rather than relying on the anatomy.

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Keywords: Radioisotope, Nuclear medicine, Radiopharmaceuticals, Radionuclide imaging

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Kotya Naik Maloth[1], Nagalaxmi Velpula[2], Sridevi Ugrappa[3], Srikanth Kodangal[4]

Affiliations: [1]MDS, Assistant professor, Mamata Dental College and Hospital, Khammam, Telangana, India; [2]MDS, Professor & Head, Sri Sai College of Dental Surgery, Vikarabad, Telangana, India; [3]MDS, Postgraduate, Sri Sai College of Dental Surgery, Vikarabad, Telangana, India; [4]MDS, Associate professor, Sri Sai College of Dental Surgery, Vikarabad, Telangana, India.

Corresponding Author: Dr. Kotya Naik. Maloth, H.No.5-5-47/1, Mustafa Nagar, Khammam-507001, Telangana, India; Ph: +919885617131; Email: dr.kotyanaik.maloth@gmail.com

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INTRODUCTION

Radionuclide imaging (or functional imaging) is a branch of medicine which provides the only means of assessing physiologic changes that is a direct result of biochemical alterations. In most cases, the information is used by physicians to make a quick, accurate diagnosis of the patient's illness [1]. This imaging is based on the radiotracer method which assumes that radioactive atoms or molecules in an organism behave in a manner identical to that of their stable counterparts because they are chemically indistinguishable. Radiotracers allow measurement of tissue function in vivo and provide an early marker of disease through measurement of biochemical change. As, other X-rays imaging methods assess changes by their differential absorption in tissues (tissue electron density); only anatomical or structural changes —which are the later effects of some biochemical process— can be assessed by these methods. Nuclear medicine has applications in neurology, cardiology, oncology, endocrinology, lymphatic's, urinary functions, gastroenterology and pulmonology. Some forms of

radiation therapy are administered by nuclear specialists and these include radioisotope administration.

Isotopes have the same number of protons but different number of neutrons and these elements have same atomic number but differ in atomic mass. These unstable element decay by emission of energy in the form of alpha, beta (electron)/beta plus (positron) and gamma rays. Such isotopes, which emit radiation, are called radioisotopes [2, 3]. These radioisotopes are also known as radionuclides. These isotopes are used in various sectors like industries, agriculture, healthcare and research centres because of their characteristic nature of emitting radiation and their energies.

Radioactive products which are used in medicine are referred to as radiopharmaceuticals [4]. Radiopharmaceuticals differ from other medically employed drugs since they generally elicit no pharmacological response (owing to the minute quantities administered) and they contain radionuclide. They are prepared by tagging the chosen carrier component with an appropriate radioactive isotope. The carrier component of the radiopharmaceutical is a biologically active molecule used to localize the drug in a specific organ or group of organs to provide diagnostic information about those tissues such as pyrophosphate and methylene diphosphonate (MDP) compounds in skeleton bone tissues.

EVOLUTION OF RADIOISOTOPES

In 1898, discovery of polonium by Pierre and Marie Curie introduced the term “radioactive” [5]. Radium was discovered by the Curie six months after the discovery of polonium with the collaboration of the chemist G. Bemont [6]. Radium played by far a more important role than polonium. Its separation in significant amount opened the way to its medical and industrial application and also its use in laboratories. Later ‘uranic rays’ was discovered by Henri Becquerel in 1900 [5].

Overall 1800 isotopes are present, but at present only up to 200 radioisotopes are used on a regular basis, and most of them are produced artificially. Radioisotopes can be manufactured in several ways.

The most common is by neutron activation in a nuclear reactor. This involves the capture of a neutron by the nucleus of an atom resulting in an excess of neutrons (neutron rich) which leads to the production of desired radioisotope [2, 3].

Some radioisotopes are manufactured in a cyclotron, devised by Lawrence and Livingston in 1932 [7, 8] in which charged particles such as protons, deuterons and alpha particles are introduced to the nucleus resulting in a deficiency of neutrons (proton rich). These particles are accelerated to high energy levels and are allowed to impinge on the target material. 11C, 13N, 18F, 123I, etc. are some of the isotopes that can be produced in a cyclotron.

TYPES OF ISOTOPES USED IN MEDICAL FIELD

Various isotopes used in medical field as in diagnostic and therapeutic aspects (Tables 1 and 2) [9, 10].

In diagnostic application depending upon the type of production these isotopes can listed as follows reactor isotopes and cyclotron isotopes (Table 3).

Mode of administration

These isotopes either during diagnostic or therapeutic can be administered by inhalation (xenon, argon, nitrogen), oral (iodine) or intravenous (thallium, gallium).

The most commonly used liquid radionuclides are technetium-99m, iodine-123, iodine-131, thallium-201, and gallium-67.

The most commonly used gaseous/aerosol/ radionuclides are xenon-133, krypton-81m, Technetium-99M and DTPA (diethylene-triamine-pentaacetate).

APPLICATIONS OF RADIOISOTOPES

In diagnostic aspects

In nuclear medicine with advances included as positron emission tomography (PET), imaging has value in cardiovascular, neurological, psychiatric, and oncological diagnosis. Positron emission tomography is a functional imaging modality that allows the measurement of metabolic reactions within the whole body. F-18 in FDG (fluorodeoxyglucose) which is an analog of glucose has become very important in detection of cancers and the monitoring of progress in their treatment, using PET. The combination of PET scan and computed tomography (CT) scan in a single device provides simultaneous structural and biochemical information (fused images) under almost identical conditions, minimizing the temporal and spatial differences between the two imaging modalities and is called *Fusion imaging* [11, 12].

Single-photon emission computed tomography (SPECT) imaging technique was developed as an enhancement of planar imaging enables the exact anatomical site of the source of the emission to be determined. This technique involves the detection of gamma rays emitted singly (single photon) from radionuclides such as technetium-99m and thallium-201.

Radioimmunodetection/radioimmunoassay is an in vitro nuclear medicine, is a very sensitive technique used to measure concentrations of antigens by use of antibodies.

In therapeutics aspects

The radiations given out by some radioisotopes are very effective in curing certain diseases such as radiocobalt (^{60}Co) is used in the treatment of brain tumor, radiophosphorus (^{32}P) in bone diseases and radioiodine (^{131}I) in thyroid cancer [4].

Table 1: Reactor isotopes used for diagnostic purpose [9, 10]

Isotope	Half -life	Uses
Molybdenum-99	66 hours	Used as the 'parent' in a generator to produce technetium-99m. Most widely used isotope in nuclear medicine.
Technetium-99m	6 hours	Used in to image the skeleton and heart muscle in particular, but also used for brain, thyroid, lungs (perfusion and ventilation), liver, spleen, kidney (structure and filtration rate), gallbladder, bone marrow, salivary and lacrimal glands, heart blood pool, infection and numerous specialised medical studies.
Chromium-51	27.7 days	Used to label red blood cells and quantify gastrointestinal protein loss.
Copper-64	13 hours	Used to study genetic diseases affecting copper metabolism, such as Wilson's and Menke diseases.
Holmium-166	26 hours	Being developed for diagnosis and treatment of liver tumors.
Iodine-125	60 days	Used in diagnostically to evaluate the filtration rate of kidneys and to diagnose deep vein thrombosis in the leg. It is also widely used in radioimmunoassays to show the presence of hormones in tiny quantities.
Iodine-131	8 days	Used in diagnosis of abnormal liver function, renal (kidney) blood flow and urinary tract obstruction.
Iron-59	46 days	Used in studies of iron metabolism in the spleen.
Potassium-42	12 hours	Used for the determination of exchangeable potassium in coronary blood flow.
Rhenium-188	17 hours	Used to beta irradiate coronary arteries from an angioplasty balloon.
Selenium-75	120 days	Used in the form of selenomethionine to study the production of digestive enzymes.

Table 2: Reactor isotopes used in therapeutics [9, 10]

Isotopes	Half -life	Uses
Cobalt-60	10.5 months	Formerly used for external beam therapy.
Dysprosium-165	2 hours	Used as an aggregated hydroxide for synvectomy treatment of arthritis.
Erbium-169	9.4 days	Used for relieving arthritis pain in synovial joints.
Iodine-125	60 days	Used in cancer brachytherapy (prostrate and brain)
Iodine-131	8 days	Widely used in treating thyroid cancer.
Iridium-192	74 days	Supplied in wire form for use as an internal radiotherapy source for cancer treatment.
Palladium-103	17 days	Used to make brachytherapy permanent implant seeds for early stage prostate cancer.
Phosphorus-32	14 days	Used in the treatment of polycythemia vera.
Yttrium-90	64 hours	Used for cancer brachytherapy and as silicate colloid for the relieving the pain of arthritis in larger synovial joints.

Radioactive sources are also available for brachytherapy with many nuclides and in various shapes and size depending upon the type of their radiation energy and emission [13].

A new field is targeted alpha therapy (TAT) or alpha radioimmunotherapy, especially for the control of dispersed cancers. The short range of very energetic alpha emissions is targeted into cancer cells, with carrier such as a monoclonal antibody tagged with the alpha-emitting radionuclide. Lead-212 is being used in TAT for treating pancreatic, ovarian and melanoma cancers. An experimental development of this is boron neutron capture therapy (BNCT) using boron-10 which concentrates in malignant brain tumors. Radionuclide therapy has progressively become successful in treating persistent disease and doing so with low toxic side-effects.

Table 3: Cyclotron Radioisotopes

Isotope	Half -life	Uses
Carbon-11 Nitrogen-13 Oxygen-15 Fluorine-18	20 minutes 10 minutes 2 minutes 110 minutes	Positron emitters used in PET scan.
Cobalt-57	272 days	as a marker to estimate organ size and for invitro diagnostic kits.
Gallium-67	78 hours	Used for tumor imaging and localization of inflammatory lesions (infections).
Indium-111	2.8 days	Used for specialist diagnostic studies, e.g., brain studies, infection and colon transit studies.
Iodine-123	13 hours	Increasingly used for diagnosis of thyroid function, it is a gamma emitter without the beta radiation of I-131.
Krypton-81m	13 seconds	Can yield functional images of pulmonary ventilation, e.g., in asthmatic patients, and for the early diagnosis of lung diseases and function.
Rubidium-82	65 hours	Convenient PET agent in myocardial perfusion imaging.

With any therapeutic procedure the aim is to confine the radiation to well-defined target volumes of the patient. The doses per therapeutic procedure are typically 20–60 Gy [14].

Radioimmunotherapy is dependent on three principal interdependent factors: the antibody, the radionuclide and the target tumor, and host and is most commonly employed in the management of hematopoietic neoplasms, especially non-Hodgkin lymphoma (NHL) [15].

Indications for radioisotope imaging in head and neck region

The following are the indications for radioisotope imaging in head and neck region [16]:

- In assessment of sites and extent of bone metastases as in tumor staging.
- Bone scan scintigraphy as it is sensitive and non-invasive technique for demonstrating osteoblastic lesions of the skeletal system.
- Investigation of salivary gland function especially in Sjögren's syndrome (technetium-99m pertechnetate)-salivary gland scintigraphy.
- Investigation of thyroid gland.
- Brain scans and assessment of breakdown of blood brain barrier.
- Growth assessment-evaluation of bone grafts
- In growth pattern-assessment of continued growth in condylar hyperplasia
- Blood flow and blood pool examination into the specific tissue/organ.

Advantages of radioisotope imaging

- Target tissue function is investigated.
- All similar target tissues can be imaged during one investigation. For example, whole skeleton can be imaged in one bone scan.
- It can display blood flow.
- Assessment of physiologic or functional change in tissues, because of disease process.
- Computer analysis and enhancement of results are available.

Disadvantages radioisotope imaging

- Poor image resolution—often only minimal information is obtained on target tissue anatomy.
- The radiation dose to the whole body can be relatively high.
- Images are not usually disease-specific.
- Difficult to localize exact anatomical site of source of emissions.

CONCLUSION

Imaging technologies have become increasingly sophisticated in recent years. Nuclear medicine and molecular imaging, which provides the only means of assessing physiologic changes that is a direct result of biochemical alterations at cellular and molecular levels, and 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 are based on the radiotracer method, and allow the measurement of tissue function in vivo and provide an early marker of disease through measurement of biochemical change. Many elements which found on earth exists in different atomic configurations used in medicine are referred to as radiopharmaceuticals which are useful to get diagnostic and therapeutic information about those tissues.

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Author Contributions

Kotya Naik Maloth – Substantial contributions to conception and design, Acquisition of data, Analysis and interpretation of data, Drafting the article, Revising it critically for important intellectual content, Final approval of the version to be published
Nagalaxmi Velpula – Analysis and interpretation of data, Revising it critically for important intellectual content, Final approval of the version to be published
Sridevi Ugrappa – Analysis and interpretation of data, Revising it critically for important intellectual content, Final approval of the version to be published
Srikanth Kodangal – Analysis and interpretation of data, Revising it critically for important intellectual content, Final approval of the version to be published

Guarantor

The corresponding author is the guarantor of submission.

Conflict of Interest

Authors declare no conflict of interest.

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REFERENCES

1. Hayter CJ. Radioactive Isotopes in Medicine: A Review J. Clin. Path. 1960; 13:369-90.
2. Lilley J.S. Nuclear Physics- Principles and Applications. John Wiley and Sons, Ltd, Singapore (2002); Ananthakrishnan M, Seminar talk on Applications of Radioisotopes and Radiation Technology.
3. Bhubaneswar and Verma HC. Concepts of Physics – Part 2, Bharati Bhawan Printers, Patna (1996).
4. Sahoo S. Production and Applications of Radioisotopes Physics Education 2006; 3:1-11.
5. Becquerel H. Emission des radiations nouvelles par l'uranium metallique. C R Acad Sci Paris. 1896; 122:1086.
6. Curie P, Curie M, Bémont G. Sur une nouvelle substance fortement radio-active contenue dans la pechblende. C R Acad Sci Gen. 1898; 127:1215–18.
7. Roy RR and Nigam BP. Nuclear Physics- Theory and Experiment. John Wiley and Sons, Inc., New York (1967); Manchanda VK, Technical talk on Radiation Technology Applications and Indian Nuclear Programme: Societal Benefits, in Aarohan 2K5 at NIT, Durgapur; Beiser A, Concepts of Modern Physics, McGraw-Hill Book Company, Singapore (1987).
8. Agarwal BS and Kedar Nath Ram Nath. Meerut (1996); A report on Atomic Energy in India: A Perspective, Government of India, DAE, September (2002); and Kaplan I. Nuclear Physics, Narosa Publishing House, New Delhi (1992).
9. New reactor needed for medical imaging - why cyclotrons cannot do the job. Australasian Science Magazine, May 1999 edition.
10. Baum S and Bramlet R. Basic Nuclear Medicine (Appleton-Century-Crofts, New York, 1975).
11. Griffeth LK. Use of PET/CT scanning in cancer patients: technical and practical considerations Baylor University Medical Center Proceedings 2005;18:321–330
12. Zaidi H and Montandon ML. The Clinical Role of Fusion Imaging Using PET, CT, and MR Imaging. Magn Reson Imaging Clin N Am 2010;18(1):133-49.
13. Flynn A et al."Isotopes and delivery systems for brachytherapy". In Hoskin P, Coyle C. Radiotherapy in practice: brachytherapy. New York: Oxford University Press 2005.
14. Radioisotopes in Medicine. Nuclear Issues Briefing Paper 26, May 2004. http://www.uic.com.au/nip26.htm.
15. Goldenberg DM. Targeted Therapy of Cancer with Radiolabeled Antibodies, The Journal Of Nuclear Medicine 2002; 43(5):693-713.
16. Matteson SR, Deahl ST et al. Advanced Imaging Methods. Crit Rev Oral Biol Med 1996; 7(4):346-295..

ABOUT THE AUTHORS

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Kotya Naik Maloth is Senior Lecturer in the Department of Oral Medicine and Radiology at Mamata Dental College and Hospital, Khammam, Dr. NTR University of Health Sciences, Telangana, India. He has published eight research papers in national and international academic journals. His research interests include advance treatment modalities in oral cancer patients such as radiotherapy and radio immunotherapy.

Nagalaxmi Velpula is Professor and Head of the Department of Oral Medicine and Radiology at Sri Sai College of Dental Surgery, Vikarabad. Dr.NTR University of Health Sciences, Telangana, India. She has published 30 research papers in national and international academic journals. Her research interests include preventive measures and advance treatment modalities in oral cancer patients.

Sridevi Ugrappa is postgraduate student in the Department of Oral Medicine and Radiology at Sri Sai College of Dental Surgery, Vikarabad, Dr. NTR University of Health Sciences, Telangana, India. She has published six research papers in national and international academic journals. Her research interests include recent diagnostic advances in maxilla-facial radiology.

Srikanth Kodangal is Associate Professor in the Department of Oral Medicine and Radiology at Sri Sai College of Dental Surgery, Vikarabad, Dr. NTR University of Health Sciences, Telangana, India. He has published 10 research papers in national and international academic journals. His research interests include management and prevention of oral cancer.

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