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The Transformative Role of Radioisotopes in Medicine

Nuclear technology is prevalent across various industries, ranging from agriculture to space. Nevertheless, its most crucial application is within the medical field, where it is used to save lives. In fact, about one-third of all patients admitted to United States hospitals are diagnosed and treated using radiation or radioactive materials (Office of Nuclear Energy, 2018). Nuclear technology is most commonly used to provide scans of the body's organs and tissues, thus allowing healthcare professionals to diagnose patients with diseases such as Alzheimer's and heart disease. This novel technology also has therapeutic applications and is often used as a cancer treatment method to destroy tumors. We can attribute most nuclear technology's success in medicine to the diverse isotopes used to diagnose and treat diseases.

Medical radioisotopes are made either with "materials bombarded by neutrons" in a reactor or by "protons in an accelerator" which is also known as a cyclotron (Australia's Nuclear Science and Technology Organisation, 2018). Isotopes made in nuclear reactors are typically neutron-rich whereas cyclotrons produce proton-rich isotopes. These radioisotopes can be used to create radiopharmaceuticals which is a radioisotope-trace connected to a pharmaceutical to treat certain diseases. Both reactor and cyclotron-produced radioisotopes play an indispensable role in the imaging and treatment process of various medical conditions.

Two crucial reactor-produced radioisotopes used for nuclear imaging are Molybdenum-99 and Technetium-99m. Molybdenum-99 is most often used as a 'parent' isotope and fosters the creation of Technetium-99m. Molybdenum-99 is created by irritating

Uranium-235 which fissions and produces this isotope. With about a 66-hour half-life, Molybdenum-99 decays into Technetium-99m which is recovered by adding a saline solution to the generator. Technetium-99m can then be produced as a radiopharmaceutical to image organs such as the brain, heart, lungs, and kidneys for disease detection while also not endangering the patients with a significant radiation dose due to its short half-life. While other medical imaging technologies may only display the anatomy of the patient's body, nuclear imaging measures the function of specific body parts such as the blood flow or the position of the radioisotope. This form of nuclear technology can be life-saving as tumors, heart conditions, and bone diseases can be detected at an early stage and as a result, be treated accordingly. Technetium-99m is used in the body by emitting gamma rays which are recognized by a gamma camera and then emit photons captured by Single-photon Emission Computed Tomography (SPECT) to assess the functionality of the body's tissues. SPECT scans create a 3D image of the brain's blood flow activity which can allow physicians to identify clogged blood vessels, seizure disorders, and even Parkison's disease. Additionally, they can also be used to detect clogged arteries in the heart and bone fractures. As many Americans face increased heart complications and disease, this form of imaging has become more popular and has proven to be extremely important in the management of cardiovascular conditions.

While Molybdenum-99 and Technetium-99m are used to generate images of the body's organs, Yttrium-90 has therapeutic applications and is used to damage and kill cancer cells and tumors by giving off radiation. This is known as Yttrium-90 internal radiation therapy or selective internal radiation therapy (SIRT) and is a common treatment used for patients battling cancer. This radioisotope is sourced by the bombardment of Yttrium-89 in a reactor which decays to produce Yttrium-90. Yttrium-90 is inserted into the body using a catheter and releases beads into blood vessels surrounding the malignant tumor to block blood flow while radiation is released. This minimally invasive and painless treatment helps to preserve healthy tissue while also attacking the cancer cells. Several types of cancer are treated using this therapy such as neuroendocrine tumors, metastatic colon cancer, and liver cancer.

Cyclotron-produced isotopes such as Fluorine-18 and Carbon-11 have gained prominence in Positron Emission Tomography (PET) imaging. PET scans can reveal the biochemical qualities of tissues and organs by using a radioactive tracer. The tracer is injected through a vein and will collect in areas of high metabolic activity. Images produced by PET scans show cancer cells which are represented as bright spots with high metabolic activity but must be examined carefully because noncancerous conditions may appear cancerous on the image. PET scans can also identify areas that have decreased blood flow which can assist in a patient receiving coronary artery bypass surgery or an angioplasty. Fluorine-18 is the most widely used PET radioisotope and is used in both clinical and pre-clinical research as well as radiotracing. This radioisotope is produced by proton irradiation of Oxygen-18, oxygen's naturally occurring isotope. Fluorine-18 can be used to produce molecular images of biological processes occurring in the body using PET scans. This is done by the PET system detecting pairs of gamma rays emitted by Fluorine-18 which is then used for early detection of tumors. The image produced by the PET scan using the radiotracer Fluorine-18 provides information about the metabolic activity of tissues, specifically glucose metabolism, which is increased in cancerous cells (Alauddin, 2011). This radioisotope is popular because of its short and favorable half-life of 109.8 minutes as well as its positron emitting abilities. In addition to Fluorine-18, Carbon-11 is used for brain imaging, specifically studying its physiology and pathology. Carbon-11 is generated by proton bombardment of Nitrogen gas alongside an alpha-particle ejection from the nucleus. One of the benefits of using PET imaging with a Carbon-11 radiotracer instead of an MRI or CT scan is that physicians are able to detect brain tumors sooner which leads to a quicker and more accurate diagnosis. This allows doctors to identify smaller changes and complications within the brain and prevent them from manifesting into larger abnormalities.

To conclude, radioisotopes have multiple applications within the medical field and are pivotal in life-or-death situations that many patients face. Its profound impact has forever changed the way diseases are diagnosed and treated and continues to revolutionize healthcare. The ability of nuclear imaging technology to identify fatal conditions earlier than other imaging systems is a testament to its unique, life-saving potential. Additionally, the critical role that radioisotopes play in radiation treatments has transformed cancer treatment methods and allows malignant tumors to be targeted and killed efficiently. As health outcomes continue to improve, radioisotopes will remain at the forefront of medical advancements, thus ensuring a future in which health and innovative technology coexist harmoniously.

Works Cited

Alauddin, Mian M. “Positron Emission Tomography (PET) Imaging with (18)F-Based Radiotracers.” *American Journal of Nuclear Medicine and Molecular Imaging*, U.S. National Library of Medicine, 2012, www.ncbi.nlm.nih.gov/pmc/articles/PMC3478111/.

National Research Council (US) Committee on Medical Isotope Production Without Highly Enriched Uranium. “Molybdenum-99/Technetium-99m Production and Use.” *Medical Isotope Production without Highly Enriched Uranium.*, U.S. National Library of Medicine, 1 Jan. 1970, www.ncbi.nlm.nih.gov/books/NBK215133/.

“Nuclear Medicine.” *Johns Hopkins Medicine*, 19 Nov. 2019, www.hopkinsmedicine.org/health/treatment-tests-and-therapies/nuclear-medicine#:~:text=Because%20X%2Drays%20pass%20through,structure%20as%20well%20as%20function.

“Positron Emission Tomography Scan.” *Mayo Clinic*, Mayo Foundation for Medical Education and Research, 18 Apr. 2023, www.mayoclinic.org/tests-procedures/pet-scan/about/pac-20385078.

“SPECT Scan.” *Mayo Clinic*, Mayo Foundation for Medical Education and Research, 5 Jan. 2024, www.mayoclinic.org/tests-procedures/spect-scan/about/pac-20384925#:~:text=A%20SPECT%20scan%20is%20a.

“What Are Radioisotopes?” *ANSTO*, www.ansto.gov.au/education/nuclear-facts/what-are-radioisotopes. Accessed 29 Feb. 2024.

"Yttrium-90 Internal Radiation Therapy." *UPMC Hillman Cancer Center*, hillman.upmc.com/cancer-care/surgical-oncology/koch-regional-cancer-therapy-center/treatments/yttrium-90. Accessed 29 Feb. 2024.

"5 Incredible Ways Nuclear Powers Our Lives." *Energy.Gov*, www.energy.gov/ne/articles/5-incredible-ways-nuclear-powers-our-lives. Accessed 29 Feb. 2024.