NUCLEAR ENERGY THE BETTER ENERGY

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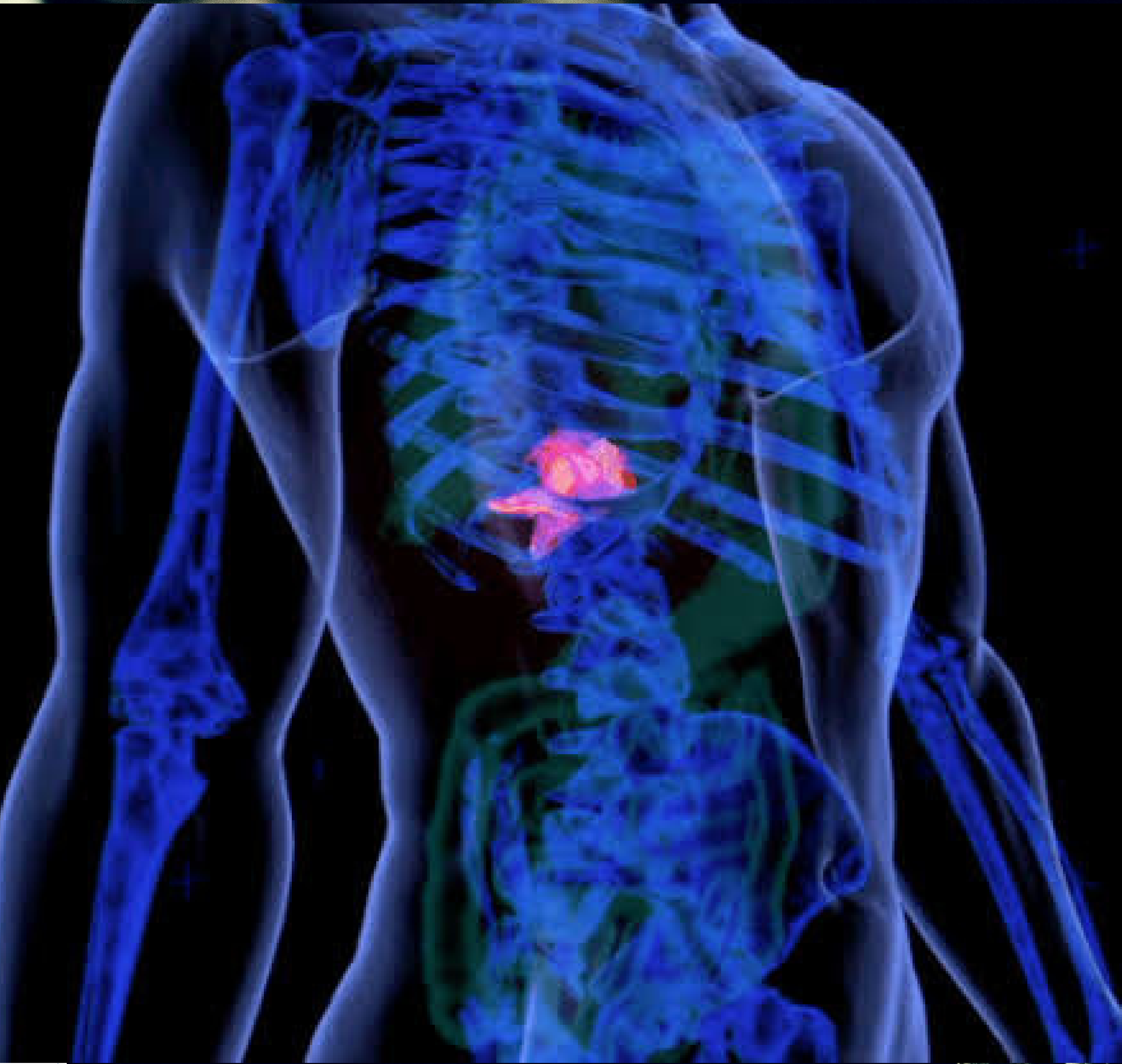


Letter From The Founder

In a world that is infested with Covid and where normalcy still feels like a distant reality, I often think about how nuclear technology can be helpful. I raised this question in front of my team and the result is what you see in this magazine.

The feature article - Radioisotopes in Medicine *from diagnostics to therapy* – written by Ashabari Majumdar and Vaishnvi Tiwari will bring to light everything you need to know about the recent trends in nuclear medicine and how it has evolved into a reliable technology to treat some otherwise life-threatening diseases.

Another major achievement in this field has been the development of Plasma Medicine. Written by Pranjal Singh, this article will tell you how plasma can be used to kill viruses and bacteria and can hence be used to treat diseases ranging from cancer to a mild tooth cavity.

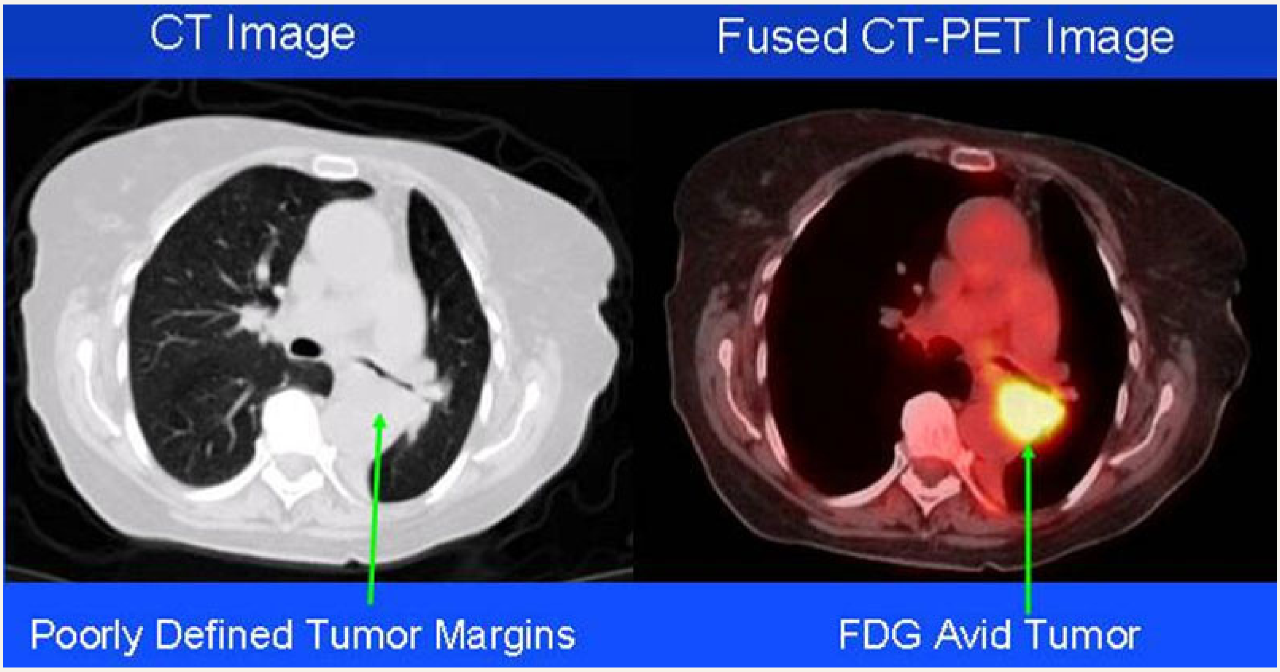
I hope this magazine helps you see nuclear medicine in a new light and welcome its developments with open arms. Happy reading!

Radioisotopes in Medicine

FROM DIAGNOSTICS TO THERAPY

Authors: Ashabari Majumdar & Vaishnvi Tiwari

Nuclear medicine is an interdisciplinary subject which is developed by combining the knowledge of nuclear physics, chemistry, engineering and physiology to utilize radioactive materials for medical diagnostics and therapeutic purposes. Primarily nuclear medicine can be categorized into two divisions - diagnostic imaging and radiation therapy.

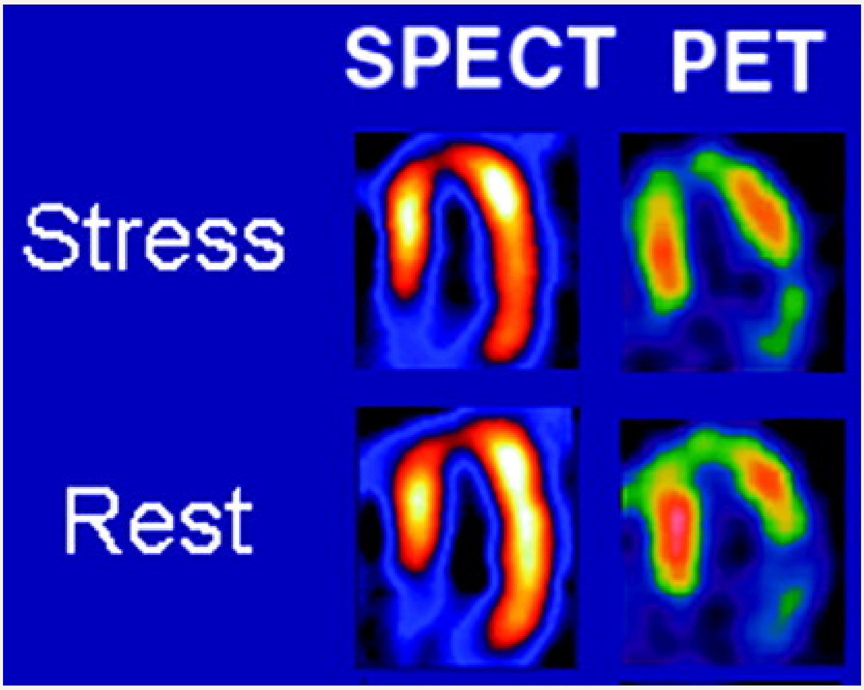


PET imaging combined with CT scan more precisely defining the tumor location compared to the only CT scan image (ref: https://www.nibib.nih.gov/)

Nuclear diagnostic processes are painless, non-invasive techniques for imaging the functionality of different internal organs and tissues. In this case, a small amount of radioactive substance, attached to a biocompatible chemical compound (called radiotracer), is injected into the patient's bloodstream or swallowed or inhaled by the patient. The radiotracers are chosen specific to the organ and tissues under investigation and emits radiation while participating in usual physiological activities of the concerned organ. The emitted radiation is detected and used to monitor any unusual metabolic activity in the body.

For example, fluorodeoxyglucose (FDG), a molecule similar to glucose containing radioactive fluorine (18F), is used to detect cancerous cells. Cancer cells have higher metabolic activity than normal cells and tend to absorb more glucose. When FDG enters the body, it is preferentially absorbed by the cancer cells and the gamma rays emitted helps in detecting the affected area.

2-D (scintigraphy) and 3-D (Single Photon Emission Computed Tomography or SPECT and Positron Emission Tomography or PET) images are the major nuclear imaging techniques. An example of 2-D imaging is bone scintigraphy where a radioactive Technetium 99m isotope is used for tracing any abnormal physiological activity in the bones. Scintigraphy has applications in the evaluation of the functioning of heart, lung, urinary tract and various other organs and tissues. On the other hand, SPECT and PET provide a 3-D view of the activities of a specific organ. These procedures take multiple 2-D images from different directions and a 3-D image is then reconstructed. The main difference between SPECT and PET is the radiation emitted by the tracers, spatial resolution of the images constructed and the cost of the procedure. The SPECT procedure is cheaper and detects the emitted gamma radiations. The PET process, however, produces positron and provides a higher spatial resolution thus giving more accurate information of the activity in the concerned organ/tissue. Each of these procedures have their own advantages and are recommended by doctors depending on the requirements of each specific case.



SPECT and PET imaging for the same patient in different situations (ref: M. E. Merhige et. Al, Journal of Nuclear Medicine, July 2007)

The diagnostic imaging process in nuclear medicine is an inverse process as compared to the other standard radiological processes. For example, while doing X-ray imaging, an external source generates the radiation and it is passed through the body to construct an image of the targeted organ. In nuclear diagnostic processes, however, the radiation is emitted from inside the body and then recorded with radiation detectors to provide information on the functioning of the corresponding organs. This allows visualization of the activity within the organ(s) instead of reconstruction of the anatomy done using other radiological imaging processes (ex. MRI).

Nuclear diagnostic imaging procedures have been used for the last five decades with no known long-term adverse effects so far. Usually the radiotracers are chosen such that the radioactivity level inside the body goes back to normal within a few days. The radiotracers go under quality check for purity and proper functioning before being administered to the patient. The doctors weigh the benefits of conducting nuclear medical procedure with respect to the potential risks before recommending these procedures and follow "*as low as reasonably practicable*" or ALARP approach to minimize exposure to radiation.

These imaging processes are therefore safe and are used for preemptive diagnosis of various diseases by detecting changes in in the functionality of organs and tissues before any anatomic changes take place.

While radioisotopes are used in diagnostic imaging techniques to detect and provide information on a person's biological functioning, they also play a vital role in the treatment of diseases through the medium of Radiation Therapy. Although radiation therapy is primarily focused on treating cancerous cells, it has also proven to be useful in various non-malignant disorders. In such therapies, a calculated dose of radioisotope is used as a concentrated source of radiation and is frequently localized within the diseased cells to yield maximum therapeutic effects without harming adjacent healthy tissues.

Radiation therapy falls under two categories: external irradiation (also known as teletherapy) and internal radionuclide therapy. Teletherapy procedures use a gamma beam from a radioactive cobalt-60 source, delivered from a distant source outside the body and directed at the cancer site. This process can be used to treat many types of tumors including cancers of the head and neck area, breast, lung, colon, and prostate. Depending on the tumor location, different levels of radiation are used. The process is painless and is more effective in the ablation of tumors rather than their removal as it is not finely tuned. However, newer and improved techniques are capable of obtaining extremely accurate shaping of the target that receives the prescribed dose of radiation, thus increasing their effectiveness in the removal of tumors.

On the other hand, Internal radionuclide therapy (also known as Brachytherapy) is administered by planting a small radiation source (a gamma or beta emitter) in the target area to allow for short-range radiotherapy. The radioisotope sources used for this therapy are in the form of wires, seeds (or molds), or rods that are introduced to the target area through a catheter. Once the correct dose has been administered, the implants are removed, depending on the duration for which the source needs to stay in the target location. For example, in cases of early-stage prostate cancer treatment, the patient requires permanent implant seeds of Iodine-125 or Palladium-103. On the other hand, more-radioactive Iridium-192 needles may be inserted for up to 15 minutes, two or three times when treating head and breast regions. Brachytherapy procedure is advantageous over Teletherapy as it gives less overall radiation to the body while being more localized to the target tumor and it is cost-effective.

A new approach in radiation therapy is Targeted Alpha Therapy (TAT) or Alpha Radioimmunotherapy, which is especially useful for controlling dispersed cancers such as leukemia, pancreatic, ovarian, and melanoma cancers. An experimental development of this technique is Neutron Capture Enhanced Particle Therapy (NCEPT), which involves injecting a patient with a radioisotope source (such as boron-10 or gadolinium-157) that absorbs low energy neutrons. Shortly after injecting the source, it is irradiated with neutrons, causing energetic alpha emissions in the vicinity of the target to kill the cancer. As alpha emissions have very less penetrating power (i.e., they lose their energy after travelling a distance as small as the thickness of a piece of paper), this approach boosts the target dose without increasing the dose to healthy tissue.

In summary, radioisotopes play an important role in medicine - while diagnostic techniques requiring small harmless quantities of many isotopes serve as tools for gaining information about normal and abnormal life processes, the therapeutic uses of radioisotopes require utmost attention to the fact that radiation damages many kinds of cells, especially while they are in the process of division. Therefore, cancerous cells (with uncontrolled division rate) are more susceptible to radiation damage.

The field of Nuclear Medicine is ever evolving with continuous improvement being made to the overall knowledge base, techniques and apparatus through research and experiments in laboratories all over the world. This has had a positive impact by increasing the number of cases where nuclear medicine procedures have been successful. Moving forward, steady improvement and growth in all uses of radioisotopes in medicine is foreseen.

Plasma to kill new viruses and bacteria

Author: Pranjal Singh

Plasma is an ionized gaseous state widely known as the fourth state of matter after solid, liquid and gas. When a gas is energized by an electric field, it gets ionized by free electrons and forms plasma. Plasma consists of neutral atoms, molecules, ions and electrons coupled with electromagnetic radiation.

Plasma medicine is an emerging concept where cold plasma is used to heal biological tissues non-invasively for cancer treatment to quick wound healing. The temperature of plasma produced in a laboratory range from *very hot* (as in Sun) to *very cold* (close to room temperature). Medical plasma is hot enough to produce the reactive species that helps to inactivate bacterial growth and cold enough to leave tissues unharmed as shown in the figure below.

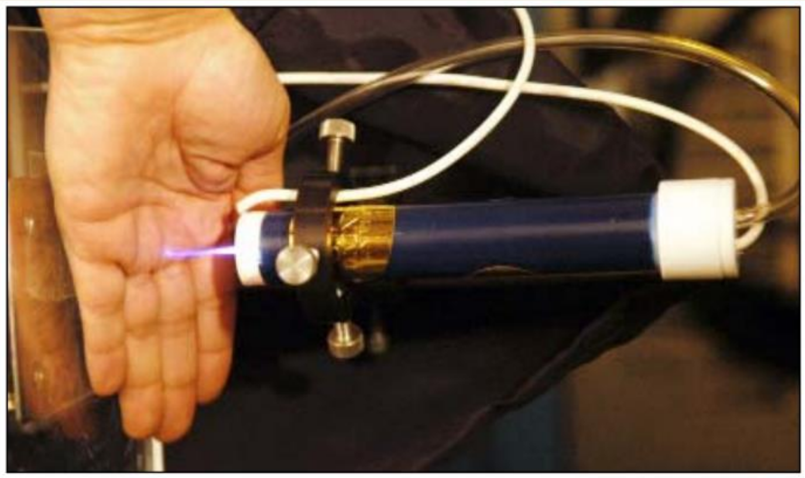


Figure showing cold plasma in contact with skin without harming it.

Plasma can be applied directly to living tissues to disinfect wounds and accelerate healing without damaging any healthy tissues and provides a painless way to heal wounds. Within a couple of minutes of plasma treatment, a 99.9 % reduction of bacterial and viral growth without harming the human cell is seen. Plasma has an antiseptic effect on the human skin and helps to remove the carpet of viruses and bacteria. Ultraviolet (UV) radiation is a well-known germicidal and is widely used to disinfect and sterilize surfaces of medical tools and instruments. However, UV-emitters in combination with an operating gas can be used to generate plasma that provides adequate UV dose along with additional chemical action necessary to enhance the inactivation process of any pathogenic microorganism. This plasma ability to kill new viruses and bacteria has led scientists to investigate the use of plasma-based technologies for the successful treatment of some types of chronic wounds and to kill multi-drug resistant microorganisms from surfaces, liquids or air before they enter the human body.

Moreover, plasma optimized with the right combination of reactive species can be used to selectively kill some types of cancer cells and inhibit the rapid proliferation of cancerous cells with tolerable damage to living human cells. Also, there is an exciting development wherein cold plasma can be used in dentistry to effectively control oral biofilms and prevent tooth decay as shown in the figure below.

Figure showing that plasma can be used to control tooth decay.

Plasma could potentially remove infected tissues from the tooth cavity, ultimately replacing the universally feared dentist drill. These recent developments indicate that not too far in the future, plasma-based devices could be available to solve some of these pressing medical challenges.

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