Role of nuclear medicine in cancer therapy

Ritik Tiwari

January 2022

Abstract

Nuclear medicine is a multidisciplinary field that develops and uses instrumentation and tracers (radio pharmaceuticals) to study physiological processes and non-invasively diagnose, stage, and treat diseases. Particularly, it offers a unique means to study cancer biology in-vivo and to optimize cancer therapy for individual patients. A tracer is either a radio nuclide alone, such as iodine-131 or a radiolabel in a carrier molecule such as F-18 in fluoro deoxyglucose, or other feasible radio nuclide attached to a drug, a protein, or a peptide, which when introduced into the body, would accumulate in the tissue of interest. Nuclear medicine imaging, including single-photon emission computer tomography and positron emission tomography, can provide important quantitative and functional information about normal tissues or disease conditions, in contrast to conventional, anatomical imaging techniques such as ultra-sound, computed tomography, or magnetic resonance imaging. For treatment, tumor-targeting agents, conjugated with therapeutic radio nuclides, may be used to deposit lethal radiation at tumor sites. This review outlines the role of nuclear medicine in therapeutic treatment of cancer.

1 Introduction

Nuclear medicine therapy is a cancer treatment that uses radioactive drugs that bind to cancer cells and destroy them. This therapy is an option for some people with neuroendocrine tumors, prostate cancer, meningiomas, thyroid cancer and lymphoma. It has proved to be successful in easing symptoms, improving quality of life and extending life. Nuclear medicine therapy is an approach to treating cancer that might be used with or after other treatment

options, such as chemotherapy and surgery. It won't usually lead to a cure unless combined with other therapies. But for many people it will control symptoms and shrink and stabilize the tumors, sometimes for years. Nuclear medicine therapy is sometimes the best option for people who no longer respond to other treatments.

What makes nuclear medicine therapy effective is the use of radioactive molecules as a drug (molecular radiotherapy). The drug recognizes tumor cells. It's injected intravenously, then circulates in the body, sticks to the tumor cells, delivers radiation directly and causes them to die. Some of the drug never attaches to cancer cells and keeps floating in the blood until the body gets rid of it, mostly in the urine. Over time, the radioactive drug stops giving off radioactivity and stops killing cancer cells. Nuclear medicine therapy is often repeated multiple times to achieve the most benefit.

Nuclear medicine therapy is also called peptide receptor radio-nuclide therapy (PRRT), targeted radiotherapy, radio-nuclide therapy, therapeutic nuclear medicine and a theranostic approach to treating cancer.

Nuclear medicine therapy uses radiopharmaceuticals targeting specific tumours, such as thyroid, lymphomas or bone metastases, delivering radiation to tumorous lesions as part of a therapeutic strategy to cure, mitigate or control the disease. It can be used either on selective targets or throughout the entire body.

Targeting the tumour :- The advancements in medical technology have led to a dramatic surge in the development and availability of new cancer treatments. The treatment of cancer involves different strategies, such as chemotherapy, surgery, radiation therapy and, most recently, targeted therapies, such as the use of radionuclide-based therapies employed in nuclear medicine. External radiotherapy with ionizing radiation is the most frequently employed radiation treatment of cancer patients. In this approach, the primary tumour and a limited area around it is treated through irradiation with high-energy X-rays.

Another treatment option available for certain types of cancer is the use of targeted radionuclide therapy, which is based on administering radioactive substances to patients. Just like chemotherapy, this therapy is a systemic treatment, reaching cells throughout the body by travelling through the bloodstream. However, unlike chemotherapy, these radioactive substances specifically target diseased cells, thus reducing potential side effects.

Radiopharmaceuticals :- The radiopharmaceuticals suited for therapeutic purposes are those that strongly bind with the tumour – also known as vehicles with a high tumour affinity. They can transport targeted doses of radiation directly to the tumours and its metastases, thereby sparing normal healthy tissue. The choice of the molecule that carries the radiation to the

tumour is determined by its affinity – or binding power – to the tumour's target structures, such as antigens or receptors. The ionizing radiation emitted by radionuclides linked to the carrier kill cancer cells by damaging their DNA, causing the tumours to shrink.

An ideal radiopharmaceutical for therapeutic purposes should:

- act exclusively in the cells of malignant tumours;
- reach all the cells of malignant tumours wherever they are localized;
- leave healthy tissues and organs unhurt while bringing maximum doses of radiation to the tumour;
- eliminate malignant tumour cells with great effectiveness.

How the therapy works :- The biological action of a radiopharmaceutical is determined by the form of ionizing radiation emitted by the radionuclide. While imaging procedures in nuclear medicine require radionuclides that will emit (gamma) radiation able to penetrate the body, a different class of radionuclides possessing optimal relative biological effectiveness is needed for radionuclide therapy. The radionuclides best suited for tumour therapy are those emitting ionizing radiation with short penetration into the tissue, such as (alpha) or (beta) emitters, which release their energy in the proximity of their targets.

2 Progression

2.1 Nuclear Medicine for Cancer Diagnosis and Treatment

Nuclear medicine can help diagnose and treat different conditions, including some forms of cancer.

In nuclear medicine, doctors put small amounts of radioactive material into your body so they can see your organs and tissues, as well as how well they work. That can help them spot tumors and see if your cancer has spread to other areas of your body. It can also help target cancer cells.

Doctors also use nuclear medicine to see if a treatment is working.

2.2 How It Diagnoses Cancer

Like X-rays, nuclear medicine is a type of radiology. But while X-rays give doctors a "big picture" view of your anatomy, nuclear imaging shows the amount of activity in your organs and tissues.

When doctors use nuclear medicine to diagnose or monitor a disease like cancer, they put things in your body called radionuclides (or "tracers") that release low levels of radiation.

You can take radionuclides by mouth or through an intravenous (IV) drip. After you take these radionuclides, you'll have what's called a nuclear scan. Scans take pictures of a specific area of your body to help doctors find tumors and other things, like infection. For example, a tumor may show up as a "hot spot" on the picture, meaning the radiation collects in greater amounts in areas where the tumor is active. Or a tumor might show up as a "cold spot," meaning there's actually less cell activity. That can also be a sign of cancer.

The type of scan you receive depends on what your doctors want to see. Some of the more common types of scans used to diagnose and monitor cancer include:

Bone scans : These look for cancer that has gone to your bones from other areas of your body. Nuclear medicine can sometimes find signs of bone cancer earlier than X-rays can. **Gallium scans:** A radioactive substance called gallium goes into your vein through an IV.It can help your doctor spot cancer throughout your body. Gallium scans can also find other problems, like infection or inflammation.

MUGA scans: Doctors use radionuclides to see how your heart is pumping blood. That helps them figure out how well your heart works before, during, and after certain types of chemotherapy. That's important because chemotherapy, particularly high amounts of it, can affect how well your heart works.

PET (positron emission tomography)scan : When you have this, you get an IV injection of radioactive sugar. The amount of that sugar that your cells absorb can help your doctors learn how fast your cancer cells are growing. In some cases, you would get PET scans along with computerized tomography (CT) scans. Together, these tests help doctors figure out exactly where your tumors are.

Thyroid scans : To get one of these, you swallow radioactive iodine or receive an injection. The iodine collects in your thyroid gland and helps doctors find thyroid cancer.

Nuclear medicine scans aren't painful. The scans usually involve lying on a table while a doughnut-shaped scanning machine takes photos. The whole thing usually takes 30 minutes to an hour. In some cases, you may need to

stop eating or drinking for a certain amount of time before your scan.

2.3 How Nuclear Medicine Treats Cancer

There are several types of nuclear medicine that treat cancer. They include:

Radioimmunotherapy : If you have non-Hodgkin's lymphoma that doesn't respond to chemotherapy, your doctor may recommend this, also called RIT.

It combines radiation therapy and something called immunotherapy, a type of treatment that uses your body's immune system to fight your cancer. Through an IV, a doctor gives you something called monoclonal antibodies. These are man-made proteins that target certain parts of cancer cells. You also get a radioactive substance attached to those antibodies.

Together, these things latch on to cancer cells and deliver radiation directly to the tumor to kill it.

Researchers are looking to see if radioimmunotherapy can help with other cancers, like:

- Prostate cancer
- Melanoma
- Leukemia
- Colorectal cancer
- High-grade brain glioma

Radioactive iodine therapy : Your thyroid gland absorbs almost all the iodine you take in. In this treatment, radioactive iodine (also known as RAI or I-131) collects in thyroid cells, where it destroys the gland and the cells.

Unlike some other forms of radiation, radioactive iodine (also known as radioiodine) therapy does this without hurting the rest of your body. Doctors often use radioactive iodine to destroy thyroid tissue that surgery can't remove. It sometimes also helps kill thyroid cancer cells that have spread to your lymph nodes or other parts of the body.

Brachytherapy : This procedure involves delivering high doses of radioactive material inside your body to kill cancer cells. In most cases, brachytherapy is more targeted, causes fewer side effects, and has doesn't take as long as conventional radiation therapy, which uses an external beam outside of your body to project radiation into your cells.

Sometimes, you'll get brachytherapy with other forms of cancer treatment, like chemotherapy or surgery.

Brachytherapy treats several types of cancer, including:

1. Bile duct cancer
2. Brain cancer
3. Breast cancer
4. Cervical cancer
5. Endometrial cancer
6. Esophageal cancer
7. Eye cancer
8. Head and neck cancers
9. Lung cancer
10. Pancreatic cancer
11. Prostate cancer
12. Rectal cancer
13. Skin cancer
14. Soft tissue cancers
15. Vaginal cancer

Y90 radioembolization: This liver cancer treatment happens in two steps. In the first, a catheter goes in the artery that supplies blood to your liver. Your doctor then uses a special dye so they can "map out" the other arteries that have anything to do with your liver. The second step is when the radiation goes in. It's put onto tiny particles that can be made of glass or resin. Then, after double-checking the positioning, the radiation goes into the liver artery. The particles stick into the cancer and release the radiation directly into the tumor.