Application Prospect of Radionuclide Tracer Technology in Clinical Imaging Therapy and Drug Development

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Abstract. In the field of clinical medicine, radionuclide tracer technology is widely used, and it is the research hotspot of imaging diagnosis and drug development. Therefore, radionuclide tracer technology has a very broad application prospect in the clinical field. Radionuclide tracer technology is mainly used in medical imaging tracer imaging to assist clinical departments to diagnose diseases. At the same time, radionuclide tracer technology has been widely used in drug research and development, which is one of the focuses of clinical research.

Keywords: Radionuclide tracer technique; Radiopharmaceuticals; Medical imaging; Clinical treatment

1. Introduction

Radionuclide tracer technology has been applied in imaging diagnosis, clinical treatment and drug development for many years in the past. In particular, radionuclide targeted therapy has been recognized by the market, showing great potential in the treatment of cancer and other malignant tumors[1]. In terms of imaging diagnosis, radionuclide examination is one of the most important imaging examination methods, which is mainly used in clinical examination and research of related diseases[2]. At the same time, new techniques and ideas about radionuclide tracing are emerging in clinical treatment. Radionuclide therapy is to use the specific enrichment and distribution of radionuclide in the tissue or the targeted specific binding of the carrier to the lesion site, and to achieve the purpose of treating or destroying the diseased tissue by relying on the biological effect produced by the radionuclide transmitted by the ray particles[6]. Radiopharmaceuticals refer to radionuclide preparations or their labeled compounds used for clinical diagnosis or treatment. Radiopharmaceuticals can be used as effective diagnostic and therapeutic methods. It can be seen that radionuclide tracer technology has a very broad development prospect in medical imaging, clinical treatment and drug development.

2. Principle of radionuclide tracer technique

Radionuclide tracer technique is related clinical imaging diagnosis, treatment methods and the basis of radioactive drugs. The basic principle of radionuclide tracing technology is to trace the radiation emitted by the decay of the radionuclide, and detect the radiation emitted by the radionuclide with the nuclear ray detection instrument to show the trace of the radionuclide [1]. At present, the application of radionuclide tracer technology in the medical field is one of the key directions of its development. There are about 100 kinds of radionuclides with potential for clinical diagnosis and treatment of various diseases, including radionuclides emitting α particles, β particles, Auger electrons and X-rays [2,3].

Some nuclei are not very stable, and these unstable nuclei mainly emit several types of radiation, namely α, β and γ radiation, or X-ray radiation after orbital electrons are captured. Radioactive nuclides are called radionuclides [3]. Radioactivity is associated with the spontaneous transformation of atomic nuclei from one structure or energy state to another. The transition of a system of microscopic particles from one state to another is called a transition. The particles emitted by radionuclides are the result of spontaneous transition of nuclei [4]. The main types of radiative decay include α decay, β^- decay, β^+ decay, orbital electron capture (EC) decay, γ decay and internal

conversion (IC) nucleus decay, which can be roughly divided into three types [5]. One type of radiation is composed of charged particles, such as β^- rays, β^+ rays, α rays, and internal conversion electrons and Auger electrons as indirect products of nuclear decay. The other is electromagnetic radiation, such as γ rays and X-rays. The third category is neutrons. These rays interact with matter as they pass through it. The process by which charged particles interact with matter is complex. There are mainly ionization, excitation and scattering, while other processes include bremsstrahlung, actinic radiation, Cherenkov radiation and so on [4,5]. Radionuclides emit specific rays through decay to trace the objective existence and changes of labeled chemical molecules in biological system or external environment, so as to be used for imaging diagnosis, clinical treatment and radiopharmaceuticals. Principle of radionuclide tracer technique is shown in Figure 1.

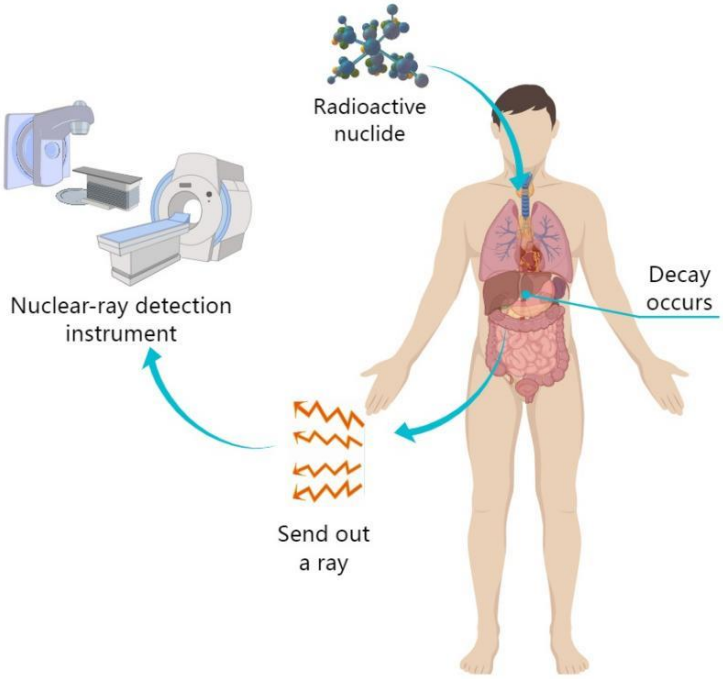


Figure 1. Principle of radionuclide tracer technique

3. The application prospect of radionuclide tracing technology in imaging

Principles-based application of radionuclide tracer technology is shown in Figure 2.

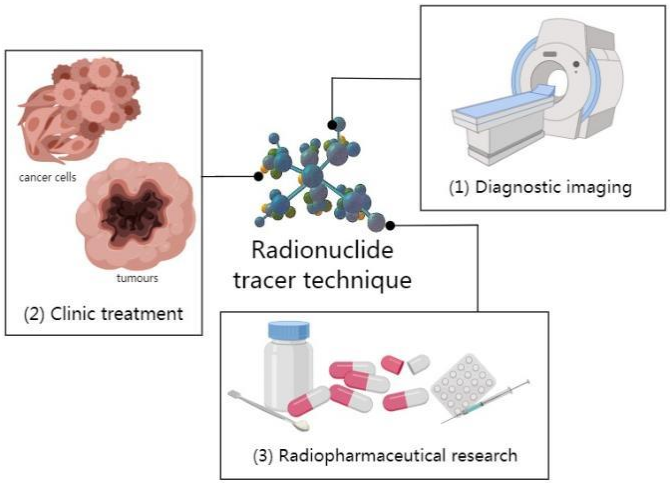


Figure 2. Principles-based application of radionuclide tracer technology

3.1. Application prospect in PET and SPECT

Radionuclide imaging technology in imaging applications mainly include single photon emission tomography (SPECT) and positron emission tomography (PET). Many PET and SPECT tracers have been approved for clinical diagnosis, and other tracer drugs are actively under development for potential clinical applications. PET imaging is generally considered superior to SPECT because of its accurate attenuation correction, higher spatial resolution, lower radiation dose, and faster imaging time[7]. The development of new PET tracers has been progressing over the years and has promising applications. Ideally, the tracer is taken up by the tissue and retained or trapped. Imaging is performed several minutes to an hour after tracer administration to provide sufficient time for the tracer to be cleared from the blood and accumulate in tissues [1].

The application of radionuclide imaging technology in PET and SPECT is developing continuously. Notably, the study by YiuMingKhor et al. [8] is an innovative addition to the literature on imaging muscle perfusion using various PET and SPECT tracers, showing for the first time the correlation between calf muscle perfusion reserve and indicators of exercise capacity and cardiovascular health. In addition to examination imaging, peripheral limb imaging was also performed with PET imaging. The radioactive tracers used included N-13ammonia for measuring perfusion in the upper extremities and O-15 water for blood flow in the calf muscles. This indicates that there is still a good room for further research in the imaging of lower limb blood flow. In addition, a study by FilipGemmel et al. [9] found that Fluoro-2-deoxy-D-glucose (FDG)PET was superior to general radionuclides in diagnosing spinal infections. The study also shows that radionUClide imaging has a promising future in PET and SPECT.

3.2. Application prospect in local phenomenon diagnosis

The main application of radionuclide tracer technology in imaging also includes local imaging, which can be used for imaging of heart, brain, lung, liver, spleen, bone, testis and tumors to assist in the diagnosis of related diseases [10]. For example, in a recent study of myocardial perfusion imaging (MPI) [2], tracers played a crucial role. This study showed that radiolabeled tracer imaging in combination with vasodilator drugs has proved to be a powerful combination method to detect local myocardial ischemia and infarction. The MPI with radionuclide imaging continues to develop, which is largely based on the development of new tracers. Another study showed that radionuclide imaging combined with ultrasound can be applied in the diagnosis and differentiation of thyroid nodules [11]. The combined diagnosis sensitivity of radionuclide imaging and ultrasound is higher than that of radionuclide imaging and ultrasound alone, and the specificity is lower than that of ultrasound diagnosis. This method has high accuracy and can significantly improve the diagnostic sensitivity, which is helpful to promote the early and effective treatment of patients. Radionuclide imaging combined with ultrasound has become one of the main research directions in the diagnosis of thyroid nodules. In addition, relevant studies have shown [12] that radionuclide hepatobiliary imaging evaluates gallbladder contractile function by calculating the count of radionuclides in bile, reflecting the whole process of bile secretion, storage and excretion. The advantages of GBEF are that the hepatobiliary imaging can be performed continuously during the predetermined imaging time, and the calculation of GBEF is not affected by the gallbladder geometry. Radionuclide hepatobiliary imaging has also become one of the focus of research. The above studies indicate that radionuclide tracer technology has great development space in local imaging diagnosis.

4. The application prospect of radionuclide tracing technology in clinical treatment

The use of radionuclide tracer technology for targeted treatment of related diseases has become a hot research direction in recent years. The principle of its treatment is that radionuclides are highly selective in the lesion site for irradiation. Cells exposed to a specific dose of irradiation will have metabolic disorders and lose the ability to divide, and then inhibit the lesion site, so as to achieve the

purpose of treatment. Commonly used radionuclides include ^{131}I in the treatment of thyroid diseases and ^{32}P in the treatment of blood diseases.

Radionuclide tracing technology is accelerating as new molecules are discovered. At present, the treatment of cancer and tumor has been one of the urgent problems in the field of medicine. In the field of cancer and oncology, the related research of its diagnosis and treatment is in full flow. The expansion of clinical indications stems from the development of new radiolabeled compounds and evidence of response to treatment from randomized clinical trials [13]. At the same time, relatively sensitive and reliable detection of tumor tissue is essential to prevent recurrence and improve surgical outcome. HathiDK's research on cancer has shown that tracer technology has great potential in imaging [14]. They found that fibroblast activator protein (FAP) was overexpressed in cancer-associated fibroblasts from a variety of tumor entities. This study, based on PET tracers as fibroblast activator protein inhibitors (FAPIs), showed promising clinical results.

In the field of cancer, the research focus is mainly on the use of radionuclides to help doctors identify malignant tumors and give adjuvant therapy. It is worth noting that the bimodal method combining radionuclide and near-infrared fluorescence (NIRF) imaging has a practicability that can hardly be ignored in preclinical studies [15], which is also another application prospect of radionuclide tracing technology. Caiyun Xu [16] according to a study, most of the neuroendocrine tumor (neuroendocrinetumors, NETs) with high expression level Somatostatinreceptors (SSTRs), according to the findings,Many researchers have investigated the possibility of using radiolabeled Somatostatin(SST) analogs for tumor imaging and treatment. Many tracers have emerged and are widely used in diagnosis and treatment. In particular, this line of research provides a new approach for the management of SSTR-negative or weakly positive tumors. At the same time, we are constantly promoting the application of radionuclide tracer technology in clinical treatment.

With the vigorous development of nuclear medicine, the production of radionuclide tracer technology will increasingly rely on research reactors and small and medium-sized cyclotrons with energy up to 30MeV. To produce new radionuclides, it is necessary to establish a medium-energy (about 100MeV) and high-throughput proton accelerator [17]. The future of radionuclide tracing technology lies in personalized medicine, that is, the attending doctor selects the appropriate radionuclide and carrier according to each patient's condition [18]. The use of ionizing radiation from radionuclides to kill tumor cells is one of the most promising treatments for cancer, both now and for the foreseeable future. As mentioned above, radionuclide tracer technology is widely used in clinical treatment, and also provides a new frontier for the diagnosis and treatment of some serious diseases, such as cancer and tumor. Therefore, the application of radionuclide tracer technology in clinical treatment is in the stage of vigorous development.

5. The application prospect of radionuclide tracer technology in drug development

Radionuclide tracing technology has obvious advantages in drug research and development. Radionuclide can release detectable ray signals through decay for substance quantification and localization, which can avoid the interference of biological matrix [19]. The high specificity of radionuclide tracing technology is one of the important reasons for its wide application in the study of body mass balance. This technology has two advantages. First, the total amount of all drug-related substances in the biological matrix can be obtained quickly and accurately without knowing the metabolite spectrum and without the need for standards. Second, the response values of 14C-labeled prototype drug and all its metabolites in tracer detection are consistent, so the proportion of each metabolite content can be determined according to the area normalization method, and then the quantification of each metabolite can be realized without standard [20].

The radionuclides commonly used in drug research and development include ^{14}C, ^{3}H, ^{125}I and ^{35}S, among which ^{14}C and ^{3}H are the most commonly used radionuclides in drug research. The advantages of these radionuclides are that the low-energy β rays emitted are safe and easy to protect, and the

operation and detection are also very convenient. In addition, ^{125}I, which can be chemically synthesized and covalently bound to tyrosine or histidine side chains, is a nuclide mainly used in protein and peptide studies. Radioactive probe drugs such as ^{14}C-PEG 4000, ^{14}C-mannitol, ^{3}H-propranolol can be used to detect cell integrity. ^{3}H-digoxin and ^{3}H-digoxin can be used for P-GP viability verification. It is worth noting that the radionuclide tracer technique with high specific activity, no carrier of radioactive drugs combined with single photon tomography (SPECT) and positron emission tomography (PET) can also be directly at the molecular level research them in normal body function and metabolic process, is the research of life science to provide sharp molecular probe. The labeling application of new nuclides and new labeling methods, such as the double labeling method to study pharmacokinetic characteristics and tissue distribution also make it more convenient and accurate to obtain relevant information.

With the rapid development of innovative medicine research and development in recent years, we can predict that the radionuclide trace technology will be widely used in the study of human material balance.

6. Conclusion

Radionuclide tracer technology has been rapidly developed in imaging imaging imaging and diagnosis, clinical treatment and drug research and development, which is complementary to the traditional medical testing and treatment methods. As an effective supplement to conventional testing techniques, radionuclide tracer technology is now widely used in all stages of the imaging diagnosis and drug development process. In particular, its high sensitivity and wide range of application make it cannot be replaced. In conclusion, isotope tracing technology has broad application prospects in clinical imaging, treatment and drug research and development.

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