SYSTEM FOR THE RADIONUCLIDE DIAGNOSTICS

A.V. Stepanov, M.F. Vorogushin
FSUE "D.V. Efremov Scientific Research Institute of Electrophysical Apparatus",
Saint Petersburg, Russia, npkluts@niiefa.spb.su

Abstract

One of the main problems of the clinical medicine is to make a timely diagnosis of a decease. Compared to many other examination methods, the radionuclide diagnostics provides most complete and reliable information on pathologies; this method is characterized with a high sensitivity, high-speed analysis and a painless process of patients' examination. The high sensitivity of the radionuclide diagnostics allows a disease to be identified at the initial stage, which is very important for successful treatment. The unique specific feature of the radionuclide diagnostics is a possibility for choosing the most proper procedure of treatment and control of the treatment process.

MODERN APPARATUS FOR RADIOACTIVE ISOTOPE DIAGNOSTICS

A single-photon emission computerized tomograph, SPECT, is one of the apparatus used for modern radionuclide diagnostics. First it was used 30-35 years ago and nowadays it is one of the most widely applied apparatus for a large-scale examination of population. Tens of thousands of similar tomographs function all over the world (more than 15.000 installations in the USA only), and tens of millions treatment procedures are carried out each year. In advanced countries the number of diagnoses made by using SPECT (single-photon emission computerized tomograph) is more than 12-15 per thousand people; practically any organ of a patient can be diagnosed. Radiopharmaceuticals labeled with short-lived isotopes (technecium-99m, iodine-123, gallium-67, indium-111, thallium-201 and others) with the half-life from 13 hours up to 2-3 days are used for diagnostics. In the USA, Canada and European countries radiopharmaceuticals labeled with short-lived isotopes are regularly delivered to diagnostic rooms located at a distance up to 500-1000 km from the place of their production. Short-lived radiopharmaceuticals for medical diagnostics and therapy are produced in the amount of hundreds of thousand Curie per year, and there is a tendency towards year-to -year increase. In the USA alone the market of short-lived isotopes exceeds 4.5 milliards dollars per year.

For recent 12-15 years, an intensive increase in the number of tomographs for PET (positron emission tomograph) is observed. Nowadays, there are more than several thousands apparatus all over the world; in advanced countries their number approaches one per million people. A PET has unique potentialities for diagnostics of cardiological, oncological and neurological diseases by studying the spatial distribution of radiopharmaceuticals in a normally functioning human organism.

So, in cardiology it is possible to identify with a very high accuracy the viability of the cardiac muscle, which increases appreciably the efficiency of surgical restoration of myocardium. In oncology, the accuracy of detecting a malignant tumour of practically any localization is 97-100%. Radiopharmaceuticals "labeled" with ultra short-lived positron emitters (carbon-11, nitrogen-13, oxygen-15 and fluorine-18) with the half-life from 2 to 110 minutes are used for PET. The aforementioned half-lives exclude a possibility of commercial delivery of ready radiopharmaceuticals and the only possible way is their production at the place of using. Only radiopharmaceuticals "labeled" with F-18 can be transported with the delivery time of 1-2 hours.

Nowadays an out-of-date equipment is used in the laboratories of radionuclide diagnostics in the regions of the Russian Federation, which unfortunately cannot ensure the modern-level diagnostics. To meet the minimum needs of the national medical diagnostics, which are dictated by the level of sickness rate in our country, these laboratories should be equipped with no less than 300-400 SPECT. Short-lived radiopharmaceuticals should be delivered regularly to ensure their functioning. At present PET are available only in several medical institutes in Moscow and Saint-Petersburg. High cost of the imported diagnostic equipment, as well as a high cost of its servicing, restricts its application in the clinics and hospitals of the Russian Federation. Besides there are no reliable sources for the delivery of the radiopharmaceutical products.

DESCRIPTION OF THE SYSTEM

The suggested system is intended for large-scale diagnostics of patients with cardiological, oncological and neurological diseases. Early diagnostics in combination with modern therapeutical and surgical methods will result in a lower death-rate of the able-bodied citizens. The system is designed for using in medical institutions in the regions of the Russian Federation; the most part of the system equipment is produced domestically. The infrastructure we have today makes possible, proper software in the regions provided, the receiving, processing, transfer and storage of medical information in regional polyclinics, which should increase the effectiveness of treatment.

The system consists of: a tomographs for SPECT and for PET, modules for radiopharmaceuticals synthesis built in protection boxes, the CC-18/9 cyclotron with targets. The system has a completely automated control from a computer.

Figure 1 shows a block diagram of the system. In this system, the CC-18/9 cyclotron is a source of hydrogen and deuterium ions accelerated up to 18 and 19 MeV respectively. The maximum beam current on external targets is 100 μA for protons and 50 μA for deuterium ions. The cyclotron is equipped with three types of targets intended to produce ultra short-lived and short-lived isotopes. Solid-state targets are used to produce short-lived isotopes (I-123, Ga-67, Pd-103 and In-111). To produce short-lived isotopes, targets should be irradiated for a relatively long period of time (of the order of their half-life). For example, when producing I-123, the optimal time of irradiating the target is 10-15 hours. The quantities of short-lived isotopes produced (hundreds of Curie per year) allow the needs of the system to be satisfied and in addition allow commercial delivery of radiopharmaceuticals to 10-15 laboratories of radionuclide diagnostics located at a distance of 500-1000 km. At present, the beam current on target is limited by target design features; however, in future it can be several times increased due to target design optimization. To produce ultra short-lived isotopes, liquid and gaseous targets are used. In connection with a high activity yield, beam currents on targets are no more than 25-30 μA. The maximum time of target irradiation is 1.5-2 hours when producing F-18; for rest radionuclides less time is needed to reach the "saturation activity". The yield of ultra short-lived isotopes provided on the cyclotron can ensure proper functioning of several PET.

Table 1 shows the radionuclides used in nuclear medicine. The isotopes that can be produced on the cyclotron of this system are printed in italics. "Cyclotron" isotopes Xe-123/I-123 and Pb-201/TI-20 are excepted because the energy of the cyclotron is insufficient for their production.

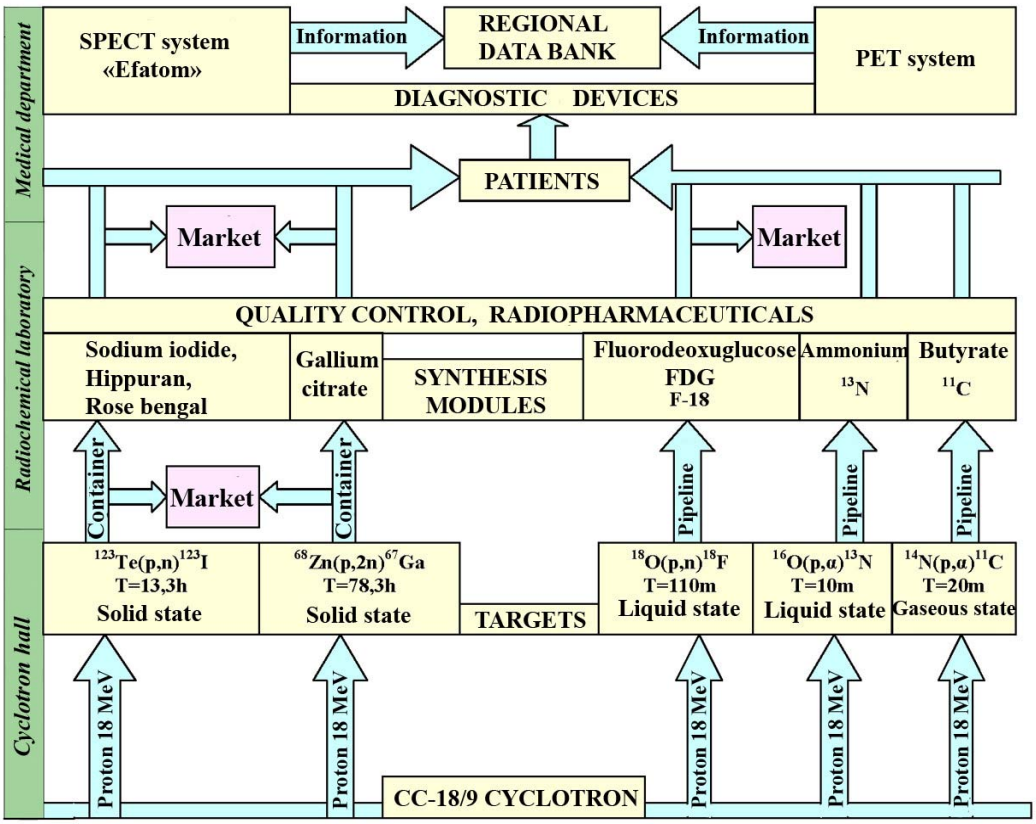

Figure 1: Block diagram of the regional system for the radionuclide diagnostics.

Table 1: Radionuclides used in nuclear medicine

Field of application	Type of radionuclides
SPECT, contact beam therapy	*Ga-67, Rb-81/Kr-81m,* Tc-99m, *In-111, I-123,* Tl-201 – for diagnostics *Cu-64, Cu-67, Pd-103,* Re-186, At-211 – for therapy
PET	*C-11, N-13, O-15, F-18* – are used *Cu-64, I-124* – are in immediate reserve *K-38,Ti-45,Co-57,Cu-62, Se-73, Br-75,* Rb-82m, Tc-94m – are used for research
Standards and sources	Na-22, *Co-57, Ga-68, Cd-109, Ge-139*

The system is a multi-purpose and self-sufficient, which is its main advantage. SPECT is a means for large-scale examination of people (5-7 thousand diagnoses per year are possible); it allows practically any organ of a patient to be diagnosed. A unique sensitivity of the PET allows a more precise and comprehensive diagnostics to be made of the patients from risk group. The cyclotron of this system allows both short-lived and ultra short-lived radionuclides to be produced, which are used for PET and SPECT diagnostics. By using the domestic equipment, domestic techniques for radiopharmaceuticals' production, a distributed servicing network and by building standard premises to house the equipment, we shall manage to reduce appreciably the cost of such systems compared with foreign analogues. The quality of domestically produced equipment completely conforms to the world standards and meets the GMP rules and regulations. The system satisfies the requirements of radiation and environmental safety.

CONCLUSION

Designing and manufacturing of cyclotrons is a traditional field of activity of the D.V. Efremov Institute, NIIEFA. To date, more than 30 cyclotrons for various applications have been put into operation, which successfully function nowadays in scientific institutions of 13 countries. The most interesting recent projects are the MGC-20 and CC-18/9 machines, which are used to produce radionuclides for medical diagnostics. On the basis of these cyclotrons, a domestic system for production of radiopharmaceuticals "labeled" with ultra short-lived isotopes for PET and SPECT operates in the Central Roentgen Radiological Institute (CRRI) in Pesochnyi (now the Russian National Center for Radiology and Surgical Technology). During the current year have been finished technical and clinical tests of the "EFATOM", a single-photon tomograph designed in NIIEFA. Efforts are underway on construction of a domestic PET tomograph. Targets and synthesis modules are planned to be manufactured and shielded boxes to be constructed together with the CRRI, ITEF and the Saint-Petersburg State Polytechnical University. NIIEFA has the State License certifying the production of accelerator facilities and the International Quality Certificate ISO 9001.

Thus, there is a sufficient background for construction of a domestic medical diagnostic system based on state-of-the-art technologies. In principle, such a system will allow us to organize a library of electronic data on diseases and the course of treatment of patients of a given region.

A decentralized system for production of short-lived radiopharmaceuticals and location of SPECT proportionally to the density of population are most efficient for our country with its vast territories and extremely non-uniform density of population. At the first stage, it is proposed to construct one system per each Federal District of Russia. Figure 2 shows a supposed location of the systems and areas covered with the delivery of short-lived radiopharmaceuticals for SPECT. So, the systems suggested and SPECT – satellites can solve the problem of fitting regional medical institutions with modern diagnostic equipment of home manufacture. The world experience has shown that the economical and social effect from application of advanced medical techniques several times pays off the investments so far as the health of millions of people is concerned.

Figure 2: Location of the systems for radionuclide diagnostics on the territory of Russia. Areas covered with the delivery of short-lived radiopharmaceuticals.

REFERENCES

[1] A.V. Stepanov, M.F. Vorogushin et al., "System for production of radiopharmaceuticals for radionuclide diagnostics", The 11th Int. Conf. on Charged Particle Accelerators Applied in Medicine and Industry (ICAA'05), St.Petersburg, October 2005, p.271-273.

[2] V.P. Belov, P.V. Bogdanov et al., "Compact medical cyclotron CC-18/9", The 11th Int. Conf. on Charged Particle Accelerators Applied in Medicine and Industry (ICAA'05), St.Petersburg, October 2005, p.237-239.

[3] O.A. Shtukovsky, M.I. Mostova et al., "Organization of cyclotron production of ultra short-lived radionuclides used in the synthesis of radiopharmaceuticals for PET", The 11th Int. Conf. on Charged Particle Accelerators Applied in Medicine and Industry (ICAA'05), St.Petersburg, October 2005, p.410-413.