

«RECORD» – REGIONAL SYSTEM FOR THE RADIOACTIVE ISOTOPE DIAGNOSTICS

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Abstract

The “RECORD” system is intended for the mass radioactive isotope (MRI) diagnostics of the cardiological, oncological and neurological diseases, which determine the average value of inhabitants’ lifetime. The potentialities inherent in the MRI diagnostics enable a disease to be identified at the initial stage, which is very important for the successful treatment and gives considerable social and economic effects.

The system consists of a cyclotron with target systems to produce short-lived and ultra short-lived radionuclides, modules for radiopharmaceuticals’ synthesis built in protection boxes, tomographs for SPECT and PET, which are networked to the regional computer database. The system has no domestic analogues.

The delivery of the «RECORD» systems to the regions of the country will allow the problem of the clinical examination of the population of Russia on the modern level of medical diagnostic and information technologies to be successfully solved.

INTRODUCTION

One of the main problems of clinical medicine is timely diagnostics of a disease. The mass radioactive (MRI) diagnostics provides most complete and reliable information on pathologies; it is characterized with a high sensitivity, high-speed analysis and no pain in the process of patient examination. It is well known that the identification of a disease at the initial stage is very important for its successful treatment, and the present-day MRI diagnostics allows a disease to be diagnosed in due time and the course of a disease to be controlled.

The Russian Federation is one of the countries, few in number, with vast territories and extremely non-uniform density of population. This makes economically inefficient the transport of short-lived isotopes over the country. It seems to be expedient to ensure the modern level of MRI diagnostics in the regions of the Russian Federation by using self-contained radioactive isotope systems in large regional clinics. This system consists of a cyclotron and diagnostic apparatus. The parameters of the cyclotron are chosen so that to ensure the production of short-lived isotopes for SPECT and ultra short-lived isotopes for PET.

As short-lived isotopes can be transported to a distance of up to 500-1000 km, each such system can ensure the functioning of several tomographs for SPECT, the number of which depends on the density of population in a particular region. Communication by electronic mail with regional clinics and polyclinics will allow the

problem of the clinical examination of population to be successfully solved.

MODERN APPARATUS FOR RADIOACTIVE ISOTOPE DIAGNOSTICS

SPECT, a single-photon emission computerized tomograph, is one of the apparatus for modern radioactive isotope diagnostics. Thousands of similar tomographs function all over the world; tens of millions treatment procedures are carried out each year. Practically any organ of a patient can be diagnosed by using SPECT. Radiopharmaceuticals, labeled short-lived isotopes (technetium-99m, iodine-123, gallium-67, indium-111, thallium-201 and others) with the half-life from thirteen hours to five-six days are used for diagnostics.

For recent 12-15 years, an intensive increase in the number of the tomographs for PET is observed. Nowadays, there are more than six hundred of these tomographs all over the world; in developed countries their number approaches one per million people. PET has unique potentialities for diagnostics of cardiologic, oncological and neurological diseases by investigating 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 cardiac muscle viability, which increases appreciably the efficiency of surgical repair of myocardium. In oncology, the accuracy of detecting a malignant growth of practically any localization is 97-100%. Radiopharmaceuticals “labeled” with ultra short-lived isotopes (carbon-11, nitrogen-11, oxygen-15, fluorine-18) with the half-life from two to one hundred and ten minutes are used for PET.

Nowadays, out-of-date equipment is used in the MRI-diagnostic laboratories in the regions of the Russian Federation, which unfortunately cannot ensure the modern - level diagnostics of the population of Russia. To meet the needs of the national medical diagnostics, which are dictated by the level of sickness rate in our country, the MRI-diagnostic laboratories in Russia should be equipped with SPECT, totally no less than three hundreds. To ensure their proper functioning, short-lived isotopes should be delivered in time without any delay. PET at present are available only in Moscow and Saint-Petersburg and in the amount not sufficient even for these megapolises.

High costs of foreign diagnostic equipment, as well as excessively high cost of its servicing, restrict its application in the clinics and hospitals of the Russian Federation.

“RECORD” SYSTEM

The suggested “RECORD” system is intended for diagnostics of patients with cardiological, oncological and neurological diseases, which mainly determine the average lifetime of the population. The system is designed for using in clinics and hospitals in the regions of the Russian Federation; all the equipment of the “RECORD” system are produced domestically. The infrastructure we have today makes possible, proper software provided, the transfer, receiving, processing and storage of medical information in regional polyclinics, which should increase the effectiveness of treatment.

The use of innovative diagnostic methods practiced worldwide in the public health service in our country will inevitably raise the level of professional skill of practicing physicians and will contribute to the advancement of treatment methods and techniques.

The “RECORD” system consists of a cyclotron with target systems, modules for radiopharmaceuticals’ synthesis built in protection boxes, one single-photon emission tomograph and one positron emission tomograph.

Figure 1 shows the block diagram of the “RECORD” system.

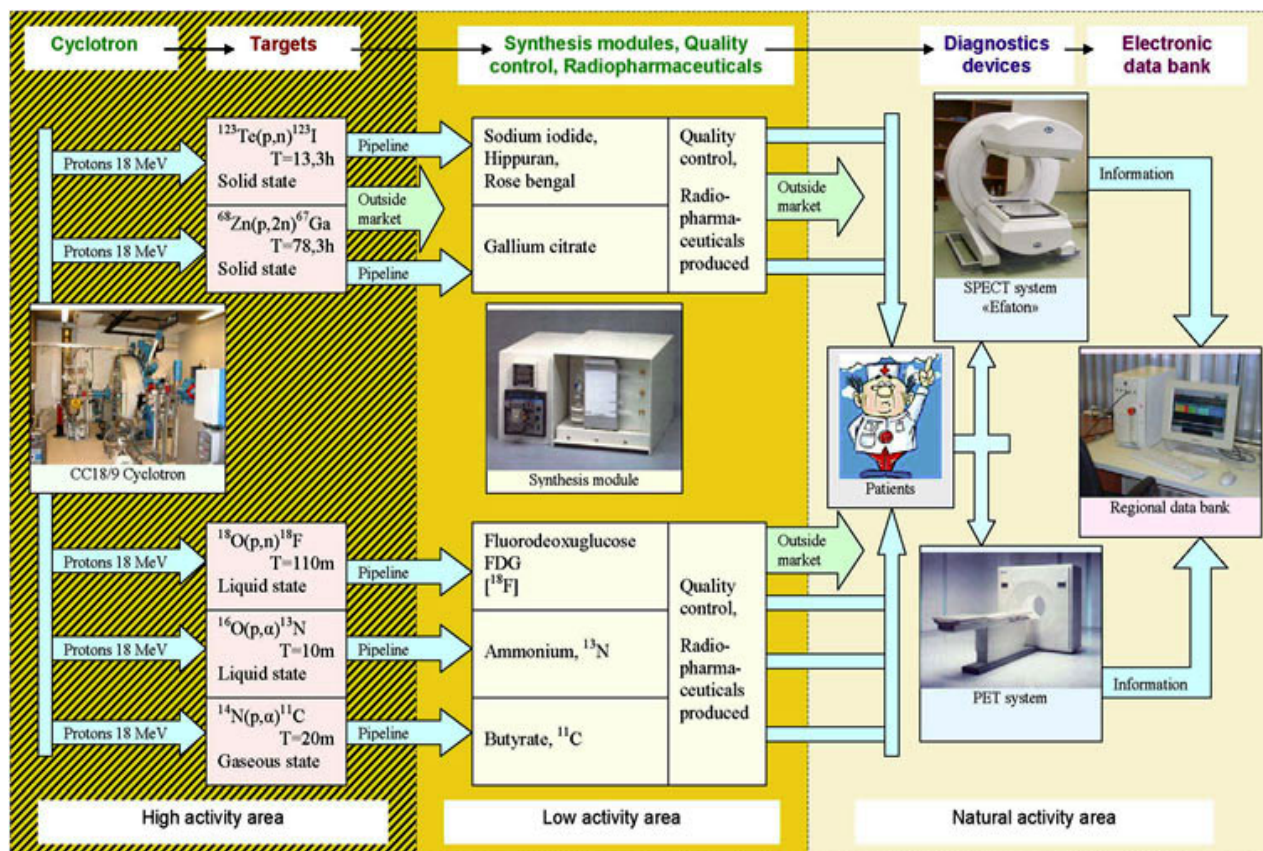


Figure 1: Diagram of the regional system “RECORD”

In this system, a cyclotron of CC-18/9 type [1] is a source of hydrogen and deuterium ions accelerated up to 18 and 9 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 target systems of three types 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); the targets should be irradiated for relatively long time, of the order of their half-life. For example, when producing I-123, the optimal time of irradiating the target is thirteen hours. As the yield of activity is proportional to the beam current, it is desirable to have the maximum current on target. At present, the beam current on target is limited by its design features: the area of the surface irradiated the

allowable temperature of the target material under irradiation and the intensity of the working zone cooling. It is expedient to use the possibility of simultaneous irradiation of two targets to produce both short-lived and ultra short-lived isotopes.

Short-lived isotopes produced (hundreds of Curie per year) meet the needs of the system and, in addition, allow radiopharmaceuticals to be delivered to the laboratories of MRI diagnostics located at a distance of 500-1000 km on a commission basis.

To produce ultra short-lived isotopes for PET, liquid and gaseous targets are used. In connection with a high activity yield, beam currents on targets are no more than 10-15 μA . When producing F-18, the maximum time of target irradiation is 1-2 hours; for the rest radionuclides less time is needed to reach the “saturation activity”.

The activity yield of ultra short-lived isotopes (several Curies) provided by the cyclotron can ensure proper functioning of several PETs.

Ultra short-lived isotopes produced are delivered in liquid or gaseous states to automated modules intended for the synthesis of particular radiopharmaceuticals.

When an irradiated head has been automatically thrown into a protection container, short-lived isotopes are also

delivered to the synthesis modules installed inside special protection boxes. The process of automated synthesis, packing and quality control of radiopharmaceuticals lasts for no more than 10-15 minutes for ultra short-lived isotopes.

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.

Table 1: Radionuclides used in nuclear medicine

Field of application	Type of radionuclides
SPECT (single-photon emission computerized tomograph)	<i>Ga-67</i> , <i>Tc-99m</i> , <i>In-111</i> , <i>I-123</i> , <i>Tl-201</i> -are used for diagnostics <i>Cu-64</i> , <i>Cu-67</i> , <i>Pd-103</i> , <i>Re-186</i> , <i>At-211</i> - are used for therapy
PET (positron emission tomograph)	<i>C-11</i> , <i>N-13</i> , <i>O-15</i> , <i>F-18</i> – are used <i>Cu-64</i> , <i>I-124</i> – are in immediate reserve <i>K-38</i> , <i>Ti-45</i> , <i>Co-57</i> , <i>Cu-62</i> , <i>Se-73</i> , <i>Br-75</i> , <i>Rb-82m</i> , <i>Tc-94m</i> – are used for research
Standards and sources	<i>Na-22</i> , <i>Co-57</i> , <i>Ga-68</i> , <i>Cd-109</i> , <i>Ge-139</i>
Commercial medical radionuclides	<i>F-18</i> , <i>Ga-67</i> , <i>Rb-81</i> / <i>Kr-81m</i> , <i>Tc-99m</i> , <i>Pd-103</i> , <i>Xe-123</i> / <i>I-123</i> , <i>I-131</i> , <i>Pb-201</i> / <i>Tl-201</i> , <i>I-124</i> - are in reserve

The main advantages of the “RECORD” system are its universality and autonomy, as the radiopharmaceuticals used for diagnostics are produced directly by this system. Modern diagnostic facilities allow early diagnostics of the majority of diseases and their efficient treatment at the initial stage. By using the equipment of home manufacture, domestic technologies and a distributed servicing network and by building standard premises, 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 requirements of the World Health Organization.

CONCLUSION

Designing and manufacturing of cyclotrons is a traditional field of activity of the D.V. Efremov Institute, NII-EFA. To date, more than 30 cyclotrons for various applications have been put into operation and successfully function nowadays in scientific institutions of 13 countries, on the territory of the former Soviet Union and abroad. The most interesting recent projects are MGC-20 and CC-18/9 machines, which are used to produce radionuclides for medicine. On the basis of these cyclotrons, a domestic system of apparatus to produce radiopharmaceuticals “labeled” with ultra short-lived isotopes for PET has been constructed in the Central Roentgen Radiological Institute (CRRI) in Pesochaya [2, 3]. Besides, at CRRI, cyclotrons are used to produce short-lived isotopes (*I-123*, *Ga-67* and others) and radiopharmaceuticals on their basis for SPECT.

In 2005, two prototypes of a single-photon emission tomograph were manufactured in the D.V.Efremov Institute, NII-EFA; efforts are underway to construct a domestic positron emission tomograph.

NII-EFA is granted the State License certifying the production of medical facilities and the International Quality Certificate ISO 9001.

It seems that most expedient first step in solving the problem is the organizing of two demonstration centers: one in CRRI, St.Petersburg, on the basis of available equipment and one more new centre in the N.N. Blokhin Russian Oncological Science Centre, in Moscow, to have possibilities to bring diagnostics of diseases to a higher level, to organize permanent training courses for personnel and to advertise available domestic facilities and promising projects under development in our country.

As the problem is rather intricate, we suggest at the next stage (for the following 3-4 years) building of one “RECORD” system in each Federal District of the Russian Federation. In future, for 10-12 years, these systems can be delivered to large regional clinics, 45-50 systems. In this way, the medical institutions in all the regions of the Russian Federation will be equipped with modern domestically produced diagnostic equipment.

The world experience shows that application of innovation technologies in medicine is repaid a hundredfold and gives appreciable economic and social effects.

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