RADIOLOGICAL CENTRE BASED ON INR PROTON LINAC

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Abstract
The radiological centre based on INR proton linac is now going to be built in Troitsk. The unambiguous variation of proton energy and average beam current will allow to irradiate many types of tumors. On the first stage, one treatment room with fixed proton beam, as well as another treatment room with medical electron 6 MeV accelerator, will be put in action. Some perspectives of the centre are discussed.

PROTON THERAPY AND INR LINAC

It is known that about 20% of all the oncological patients die because of their primary tumors without metastases. In many of these cases, the loco-regional treatment with the help of surgery and conventional radiotherapy is complicated by difficult localizations of tumors when neighbor critical organs prevent the application of conventional methods.

The hadrontherapy alone or in combination with conventional methods may allow us to significantly reduce the above number. The principal advantages of radiotherapy with proton beams, as a particular case of hadrontherapy, are due to physical properties of proton beams in matter: 1) protons, as all ions, have a unique inverse dose profile (the Bragg peak) and loose a large fraction of their initial kinetic energy in a narrow region near the end of their path in matter, 2) protons do not produce any irradiation behind the Bragg peak, which has an energy-dependent position, 3) protons have a relatively small range and lateral scattering, 4) protons, as all charged particles, can be steered by magnetic fields allowing precise shaping of the treatment volume by means of dynamic scanning of the beam. Although these advantages of proton beams are known since 1946, technical difficulties prevent a wide application of hadrontherapy. By now about 30000 patients have been treated using this method in the world and about 4000 - in Russia. Each year, only 1% of patients with prescriptions for proton therapy will have a chance to get this kind of treatment. Since proton and heavier ion accelerators (as well as beam delivery, monitoring and control systems) are quite complicated facilities, all working hadrontherapy centres, except LCUMC in Loma Linda, are based on physical research institutes. For example in Germany, the Pilot project for proton therapy was realized in GSI on a basis of research synchrotron prior to construct the Heidelberg ion beam medical centre. In Russia, three proton therapy centres are now in action in nuclear research institutes (see Table 1) and the fourth is now under construction in INR.

Table 1: accelerators for proton therapy

institute	**beam energy, MeV**	**beam pulse, μsec**	**pulse frequency, Hz**	**patients treated**
ITEP, Moscow	70-200	0,14	< 1	3500
PINP, St.Peter.	1000	300	40	1200
JINR, Dubna	660	30	250	200
INR, Troitsk	70-250	50-200	50-100	-

In order to irradiate targets at different depths, the beam energy must be variable in the range 70 – 250 Mev. From the other side, for the purposes of beam monitoring and scanning, the pulse duration and the pulse frequency (the duty cycle) must be as large as possible. From the Table 1 it follows that only the INR linac may fulfill these requirements and may be used for the development and application of such new techniques as beam scanning and beam rotation with the help of ganry . The selected beam energy is obtained by a simple switching of a necessary number of accelerator sections. Though the linac was designed for higher beam intensities with average current in the range of several μA, the necessary therapeutic currents of about 1 nA are simply obtained with the help of collimators in the initial part of accelerator. Moreover, the additional injector for H^--ions, which is now under construction, will allow to simultaneously produce two different beams: one low-intensity beam for therapy and another high-intensity beam for other applications.

PRESENT STATUS OF THE CENTRE

The first stage of the Centre, which may be built and completed by the equipment in the end of 2005, includes one treatment room with horizontal fixed proton beam and one treatment room with 6 MeV medical electron accelerator SL-75-5-MT. The patient positioning system in the proton treatment room, as well as control systems, are designed in a way to allow the irradiation of any targets from small eye tumors up to large deep-sited tumors of the body. This means that a patient may be fixed in a sitting and lying positions. However, the passive dose formation system, which will be initially realized in the Centre, gives an upper limit for the target size of the order of 8-10 cm because it is difficult to provide an accurate dose delivery for larger targets. The electron accelerator, which will be in action by the end of 2004, will increase the effectiveness of the Centre. For many reasons, the proton beam time is quite expensive, in particular for research accelerators. The fact that for larger tumors the number of irradiation fractions may exceed 20 significantly reduces the perspectives of large application of proton therapy. On the other hand, the so called *boost*-method of tumor irradiation, when more than half of the dose is delivered using conventional radiotherapy and only the remaining part of the dose will be delivered by a more expensive proton beam, makes the perspectives of the Centre more promising. In average, the *boost*-method reduces the number of proton irradiation fraction by more than 50% without reducing the effectiveness of the treatment. For the needs of the Centre, the ambulatory with modern engineering equipment, including air conditioning and other supply systems, was constructed in the main experimental building of the Institute. This ambulatory will allow the treatment of more than 50 patients per day. The radiological section of the Troitsk hospital, which will provide the clinical support of patients, is now being organized.

PERSPECTIVES OF THE CENTRE

The first stage of the Centre will not be able to provide the application of some new achievements in hadrontherapy, in particular of beam scanning and rotation. However, as it was already mentioned, the parameters of the accelerator allow us to further develop the irradiation techniques. For example, the beam scanning equipment may be installed already in the existing treatment room. The main experimental hall of the INR Meson factory complex, where both present treatment rooms were installed, is a unique building, which allow to install without huge investments such additional systems as a proton gantry and/or a treatment room with fixed vertical proton beam. Another perspective of the Centre is connected to isotope production at the INR linac. At present, several isotopes for medical application are produced or can be produced at INR. Among them are Pd-103, Sr-82, Cu-67, Sn-117 and other isotopes. In the domain of isotope production, INR is one of the leading accelerator centres in the world. The new laboratory for isotope extraction from irradiated samples, whose project is now approved, will allow to complete the technology of medical isotope production. In this case, the INR Radiological centre may become an universal radiological centre, where most modern methods of radiology may be developed and applied.