MAIN TENDENCIES OF DEVELOPMENT OF RUSSIAN ONCOLOGY RADIOTHERAPY SYSTEM EFARAD

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Abstract

The EFARAD complex incorporates therapeutic irradiators-linear medical electron accelerators LUER-20M and SL75-5-MT; TSP-100-anatomic and topometric device which provides necessary information in the form of digital projection images of patient at different angles; "Scan-plan"-treatment-planning system and computerized dose field analyzer with water phantom.

The EFARAD complex is integrated into a processing line with the help of a flexible information computer system comprising, in addition to the above components, local systems for the treatment verification, physicists' and physicians' workstations, files and data bases for various applications, patient tracking system, etc. When applying the conformal beam therapy technologies and wider arsenal of beam-forming devices, the requirements for the volume of topometric information necessary for treatment planning, for the treatment planning system, beam forming devices and accelerator systems, procedures for treatment simulation and verification becomes more stringent. The concept of EFARAD application for solution of problems both of conventional and conformal radiotherapy has been worked out in NPKLUTS.

At this point a problem of radiotherapy quality guaranty is successfully resolved in USA and in a number of western countries. In Russia the problem of radiotherapy quality guaranty is very far from resolving in routine clinical practice because of inadequate provisions of radiotherapy equipment. Experience of world-advanced radiotherapy centres shows that required quality level could be achieved only by implementation of integrated computer-based technology, which covers all stages of radiotherapy treatment.

Computer-based radiotherapy system EFARAD is being developed at Scientific and Production Complex of Linear Accelerators and Cyclotrons (NPKLUTS) of the FSUE "D.V. Efremov Scientific Research Institute of Electrophysical Apparatus" (NIIEFA).

The system is built as per module principle. This allows flexible distribution of functions between the system hardware and upgrading the system by additions of new modules. The system modules are integrated through standard interfaces; they form flexible adjustable automated information system.

Figure 1: Computer-based radiotherapy system EFARAD

The EFARAD system (see Fig. 1) contains the following:

- Irradiators: linear medical accelerators LUER-20M, which generate 5 to 20 MeV electron and photon beams, and 6 MeV photon linear accelerators SL75-5-MT;
- Anatomic & topometric preparation equipment: radiotherapy topometric system TSR-100;
- Treatment planning system ScanPlan;
- Information system InfoRad: this system contains computer-based work stations for doctors and radiology physicists which are connected with the treatment system units, with databases and archives;
- Treatment verification system VeriRad, which contains dosimetric equipment and devices for comparison of factual and prescribed treatment plan.

Preparations of treatment prescriptions include collection of anatomic data with topometric system TSR-100 and calculations of dosimetric plans with treatment planning system ScanPlan using transversal X-ray computer tomograms. Topometric system TSR-100 performs functions of either digital simulator or computer tomography.

Anatomic & topometric images, generated by TSR-100, are transferred to the treatment planning system ScanPlan. The information system InfoRad supports operation of database and operation of clinic personnel with information of earlier made diagnostic procedures and about current treatment process.

NPKLUTS NIIEFA looks into alternatives of realisation of conformal treatment technique. Multi-leaf collimator with computer control system for the LUER-20M accelerator is being designed. Opportunities for expansion of TSR-100 capacities for supporting topometry and verification of conformal treatment are investigated.

Linear electron accelerator LUER-20M (Fig.2) is intended for distance radiotherapy with photon beams and electrons in static and arc modes.

Figure 2: LUER-20M linear accelerator

Linear electron accelerator SL75-5-MT (see Fig. 3) is basic therapy machine, which is intended for radiotherapy with photon beam in static and arc modes. Control system of the SL75-5-MT accelerator is being up-graded.

Figure 3: SL75-5-MT linear accelerator

Both linear electron accelerators are integrated in general information system.

New radiotherapy technology approaches and new radiotherapy equipment with advanced capabilities in the world market leads to reviewing role and place of various equipment for treatment preparations and for treatment verification.

Leading experts of radiation physics from Canada estimated suitability of the following four types of equipment for realisation of various radiotherapy technologies of treatment preparations and their functional parameters:

- Standard X-ray simulator;
- Computer diagnostic X-ray tomography system (CT);
- Computer X-ray tomography & simulator (CT-simulator);
- X-ray simulator with computer X-ray tomography option.

Results of the analysis indicate tomography & simulator on the top position. Simulator with tomography option takes the second place; Standard simulator and tomography are on the third place. The analysis also indicates that the main drawback of the simulator with tomography option is low capacity and poor quality of tomograms. Operation speed in the tomography mode should be increased to a level of routine tomography. Quality of the tomograms should be equal to quality of routine tomograms.

The X-ray topometric system for radiotherapy TSR-100 (Fig. 4) is intended for package solution for biometry of oncology patients and for verification of treatment plans. The system provides either projection images of a patient body in geometry of radiotherapy machine with contouring radiation field or transversal computer tomograms at required levels. Thus, the system combines X-ray simulator and CT. Operation principle is based on digital system for radiation registration which equipped by movement mechanism and collimators for fan-shaped X-ray beam scanning. The system sensor is array of solid detectors of scintillator-photodiode type.

Figure 4: TSR-100 topometric system for radiotherapy

TSR-100 allows the following:

1. Localisation of tumour and healthy tissues. Determination of size/configuration of a tumour and adjacent critical organs.
2. Collection of topometric information for treatment planning with possibility to create transversal slices of patient body and projection images without patient re-setting.
3. Treatment simulation. On the base of its result the treatment plan is approved or some required corrections of the treatment plan would be made.
4. Verification of treatment plan, which allows radiographic confirmation of correct covering of target and minimum radiation of healthy tissues. This procedure is mandatory when treatments plans are realised which are calculated with use of limited topometric information (from one or two slices).
5. Treatment monitoring for control of repeatability of treatment plan using reference marks of the patient body. Monitoring of dynamics of growing/regressing the tumour, change of the patient's weight, swellings, etc.

Standard procedure of application of EFARAD system for conventional radiotherapy is developed in the N.N. Petrov Scientific Research Oncology Institute. Implementation of conformal radiotherapy techniques and use of wide range of beam forming accessories (such as shaped shadow blocks, individual shaped diaphragms, etc.) require increasing volume of topometric information. For example, implementation of multi-leaf collimator (MLC) even in static modes from different directions treatment planning is required with 3D presentation of anatomic structures and targets. Implementation of MLC also requires dramatically more complicate techniques of treatment simulation and verification and more accurate anatomic & topometric data. This problem should be resolved with technique of conformal treatment preparations based on multi-slice computer tomography with 3D object reconstruction virtual simulation of radiation beam edges.

Direct verification of treatment plans would require too complicate design of X-ray simulator. Therefore advanced approaches to the simulation tend toward virtual technologies.

TSR-100 can operate in conventional radiotherapy system with two linear accelerators SL75-5-MT and with distance gamma-therapy machine. With implementation of individual treatment plans and conformal radiotherapy capacity of equipment become very critical. Slow collection of topographic data impedes treatment-planning process considerably.

To improve technology of topometry a prototype of topometric system with two gantries was developed in the N. N. Petrov Scientific Research Oncology Institute in 1995 &1996 (Fig. 5).

Figure 5: Prototype of two-gantry topometric system

The second unit is topographic X-ray option whish was based of principle of computer tomography system of the 3rd generation. Time of data collection for reconstruction of one tomogram is 10 second. Experience of the N.N. Petrov Institute shows that capacity of two-gantry simulation & tomography system can be very close to capacity of specialized tomography system with virtual simulation function.

At this point the EFARAD system is equipped with ScanPlan treatment planning system, which provides treatment planning of conventional radiotherapy therapy with photon beams.

For implementation of conformal radiotherapy the EFARAD system should be equipped with 3D treatment planning system. Implementation of conformal radiotherapy will allow assuring quality guaranty of radiotherapy when the most complicate treatment techniques are used.