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An alternative material for the human body for radiotherapy in diagnostic tests

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Abstract.
The advancement of technology in the field of radiation therapy now allows us to use precision and clinically high-quality radiotherapy techniques for oncological patient treatment to restrict irradiation of normal tissues and increase tumor control in the surrounding area. The rigorous adherence to the requirements for the precision of the dose supplied is a necessary condition for the application of the justification principle. The enhancement and careful adherence to the nice assurance (QA) application in the radiological department ensures high standards of radiation treatment. However, due to the complexity of QA programs, the standardized and widely used tests included in the first-rate administration machine are merely mechanical and dosimetric assessments that cannot determine the presence and degree of the critical error. in the dose delivered to the patient, which arises as a result of the execution of state-of-the-art radiation therapy procedures, as properly as to take into account the complexity of the implementation of cutting-edge strategies of treatment. The goal of the work is to advance a technique of complex dosimetric trying out of the radiation therapy procedure (end-to-end audit), primarily based on the utilization of the anthropomorphic phantom of the original design. The end result of this work is the creation of the modified anthropomorphic phantom for precision dosimetric measurements, designed for testing the following technological processes of the radiation remedy process: a laptop tomography acquisition; a computerized cure planning system, along with a contouring module and dose distribution calculation algorithm; imaging systems integrated with radiation treatment units; dosimetric and technical characteristics of the radiation treatment units. Regular dosimetric trying out of the radiation remedy technological system (end-to-end audit) with utilization of the technique proposed by way of the authors, based on the developed anthropomorphic phantom usage, will enable to verify the accuracy of dose distribution delivered to patients with all predominant malignant tumors localizations.

Keywords: quality control, quality assurance, clinical dosimetry, anthropomorphic phantom.

1. Introduction

Currently, radiation therapy is a highly selective, effective and patient-friendly method of treating malignant and benign neoplasms. Its effectiveness has been proven in the treatment of tumors of such localizations as the head, cervix, prostate, bladder, skin and some others. Another important area of application of radiation therapy is the provision of palliative care. Currently, for about 15% of all cancers, the main method of treatment is precisely radiation therapy [1].

The development of technologies in this industry makes it possible to implement precision, clinically effective and most patient-friendly techniques, such as intensity modulated irradiation (IMRT) or volumetric modulation sector irradiation (SLTMI), and also allows the use of non-standard methods of fractionation of dose distribution delivery (hypo- or hyperfraciconization, stereotaxic irradiation, etc.). In this scenario, careful adherence to the conditions for the precision of the supplied dose is a key criterion for achieving the principle of justification. The International Commission on Radiation Units and Measurements' rules govern dose release precision, saying that point values of the dose supplied to the irradiation target should be within 5% of the authorized value (in some clinical circumstances, 2%) [2]. The geometric precision of dose distribution delivery is determined by the part of the human body that is exposed to radiation, the type of malignant tumor, coexisting diseases, and other factors. When irradiating metastatic lesions in the brain, for example, it can range from a few millimeters in the pelvis to less than 1 mm. but on average it is about 5 mm [3].

Failure to comply with these requirements after a course of radiation therapy may cause unwanted radiation complications in patients, and the staff of the radiation therapy departments, as a rule, are well aware of the need to comply with all standards and rules for the implementation of radiation therapy.

A quality control (QA) program is developed and adhered to in the radiology department to ensure that treatment standards are met. Quality control in radiation therapy is a set of techniques, procedures and actions that ensure safe and effective delivery of a therapeutic dose to the target volume (tumor), while reducing the dose load on healthy tissues and organs, minimizing radiation exposure to personnel and adequate monitoring of the patient's condition. ... All these actions are aimed at achieving the required therapeutic effect in the provision of medical care [4].

From the point of view of medical physics, quality control is primarily aimed at medical equipment and specialized software used in radiation therapy procedures, including dosimetry planning systems, which allow, under the guidance of a qualified specialist in the field of medical physics, to create dosimetric exposure plans,

and devices for implementation of these plans and delivery of a therapeutic dose of ionizing radiation to patients (linear accelerators or devices with natural radionuclide sources).

However, due to their specificity (reproducibility, regularity, hardware time), standardized and applied worldwide exams protected in pleasant management structures are trivial mechanical and dosimetric tests [5, 6], controlling each separate unit of the apparatus or its functional action separately, but the effects of these assessments can't show the presence and magnitude of an imperative error in the transport of an individual dose distribution to a patient, which arises as a result of the implementation of measures during the whole technological chain of radiation therapy, and additionally take into account the complexity of the implementation of current treatment methods.The currently known and most widespread methods of quality control of IMRT technologies include a simple recalculation of the patient's irradiation plan in the volume of a geometrically simple homogeneous tissue-equivalent phantom. Such methods cannot take into account the errors in the delivery of the dose distribution to patients arising from the calculation of the interaction (absorption and scattering) of ionizing radiation with the heterogeneous structures in the patient's body, such as bones or lungs, or the establishment of realistic body contours by the computerized radiation planning system [2].

Currently, one of the ways to take into account all the above features and disadvantages of traditional QA is to conduct dosimetric (end-to-end) audits. Conceptually, dosimetry audits have their origins in standard quality management programs. In both cases, all actions are aimed at checking two main aspects of radiation therapy: the compliance of the treatment plan with clinical requirements and the adequacy of the treatment plan's presentation of the dose loads that a real patient will receive during the entire course of treatment [7].

Nevertheless, end-to-end audits use atypical, sophisticated equipment for these purposes. As a rule, these are anthropomorphic, modular phantoms that can be carried through the entire technological chain of radiation therapy: from primary simulation and visualization, to stacking and delivery of a dose. In addition, these phantoms not only accurately repeat the anatomical contours of the human body, but also contain various heterogeneities, and also allow the use of a variety of dosimetry equipment: radiochromic and radiographic films, thermoluminescent dosimeters, ionization chambers, etc. [7, 8].

This method of assessing quality control and improving procedures in radiation therapy has proven itself well, and dosimetry audits are regularly performed by large national and international organizations, for example, the International Atomic Energy Agency (IAEA) or the World Health Organization (WHO) [9]. However, as mentioned earlier, such audits require specialized and expensive equipment, and the participation of accredited organizations is paid by the inviting party. This can be a major obstacle to participation in end-to-end testing of cancer clinics operating in resource-limited settings.

Currently, there is no countrywide shape in the Republic of Belarus that conducts such a complete checking out of the technological process of radiation remedy in clinics for the duration of the country. Nevertheless, the implementation of an end-to-end audit, as was once proven earlier, can become a device that would make it possible to assess the accuracy of dose distribution for most cancers patients with specific localizations of malignant neoplasms and to establish those mistakes in the shipping of man or woman dose distributions that are not it is possible to identify other assessments that are phase of the usual radiotherapy fantastic assurance program. Thus, the motive of this work was to strengthen a methodology for comprehensive testing of the technological procedure of radiation remedy (end-to-end testing), based totally on the use of an anthropomorphic phantom of an original diagram and allowing to estimate the deviation of the absorbed dose fee at the reference factor for plans for irradiation of cancer patients of the fundamental therapeutic vary of radiation energies, dose prices and therapeutic sizes of radiation fields.

2. Experimental part

The methodology for end-to-end testing, developed at the N.N. NN Aleksandrova, the application of the modified anthropomorphic phantom of Alderson lies. This phantom is a model of a male body from head to groin, made of dense tissue-equivalent material. The phantom body is assembled from separate layers 1 cm thick with inserts of materials of various densities. The assembled phantom is a human body, in which three main components can be distinguished: soft tissues with an average density of about 80 Hounsville units (HU), bone structures (470 HU) with a dedicated spinal canal, and lungs (–650 HU).

In its original form, this phantom could be used for dosimetric purposes only with the use of a film placed between the layers of the phantom, or with thermoluminescent dosimeters (TLD), the slots for which are in soft tissues and organs at risk. Dose determination when using these types of detectors is difficult due to a rather complicated data processing procedure. Another disadvantage is that both TLD and dosimetric film are passive detectors, and it takes a lot of time and skilled personnel to establish the dose value. To carry out absolute dosimetric measurements using an ionization chamber (IR) (the most accurate method for measuring the point value of the absorbed dose), the phantom was modified: a through channel with a diameter of 8 mm was drilled using a milling machine to match the geometric characteristics of the channel with the IR diameter used in the Republican Scientific and Practical Center oncology and medical radiology. N. N. Alexandrova. The canal runs along the imaginary axis of the brain stem - mediastinum - prostate gland.

Using a LightSpeed RT CT scanner manufactured by GE HealthCare, a growth tomogram of the modified

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phantom with a 2.5 mm step was obtained, reconstructed to a slice thickness of 1.25 mm, the result of which is shown in Fig. 1. Before scanning, a waterproof marking (combined with X-ray contrast marks) was applied to the phantom, which can later be used to place the phantom on the linear accelerator table.

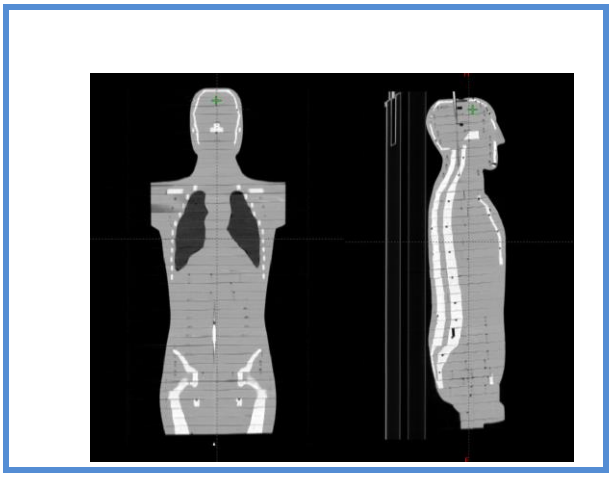

Fig. 1. Computed tomography of a modified anthropomorphic phantom

– Scanning was carried out with a pre-installed IR model PTW Freiburg 30010. According to the developed technique, this camera will be used for all absolute dose measurements during complex testing of the radiation therapy technological process.
– The rest of the channel volume was filled with a rod made of tissue-equivalent material (with a density of about 350 HU) of a suitable diameter and length.
– The resulting tomogram was imported into the Eclipse 13.7 Exposure Planning Computer System (VSS) (Varian Medical Systems, Palo Alto, California). The anthropomorphism of the phantom allows it to depict organs at risk and target volumes both in accordance with international guidelines for delineation and in accordance with national local protocols and requirements [10].
– Since the metal wire and braid of the IR camera create visual artifacts and distortions in the density distribution on a computed tomogram, it was decided to replace the volume occupied by a real IR camera with its geometric model. Thus, the following structures were included in the camera model, outlined using the corresponding software module of the KSPO Eclipse (Fig. 2):

- direct channel for positioning IR with a diameter of 8 mm and a density of 1000 HU (air);
- the cylinder of the measuring cavity of the chamber with a diameter of 7 mm and an assigned density of 450 HU;
- metal braid preceding the measuring cavity in the form of a cylinder with a diameter of 7 mm and a density of 3500 HU;
- a tissue-equivalent rod filling the rest of the canal with a diameter of 7 mm and a density of 350 HU.

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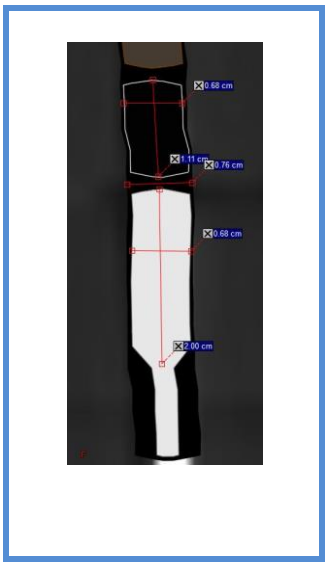

Fig. 2. Geometric model of the ionization chamber

The resulting set of structures (organs at risk, target volumes, and the IR model) can be used to create dosimetric irradiation plans using any technique used in practice in radiation therapy departments.

The main advantage of using this phantom to assess deviations in the value of the absorbed dose at the reference point for irradiation plans for cancer patients is the presence in it of volumes with a strong density gradient (tissues - bones - lungs - tissues). A number of well-known studies have shown that algorithms for calculating the dose of modern CSPO tend to incorrectly calculate the values of the absorbed dose in areas with low density (lungs) or in soft tissues immediately behind them [11–13]. such areas is of greatest interest.

In the future, the resulting irradiation plan can be implemented on a medical device (linear accelerator or gamma therapy device). The phantom positioning will be carried out according to the waterproof markings applied to the phantom surface before the initial scanning, and verified using X-ray images of the volume of the anthropomorphic phantom and X-ray contrast marks on its surface. Moreover, due to the X-ray contrast of the IR, it seems possible to verify its position using the visualization systems integrated with the radiotherapy device (MV or kV images, CBCT), with their help it is possible to verify the position of the phantom on the table due to the presence of contrasting bone structures.

The delivered dose and isodose distribution for any number of fractions can be estimated using the installation in the phantom of dosimetric films, TLD, or the results of IR measurements.

3. Results and discussion

Thus, carrying out complex dosimetric testing of the radiation therapy technological process (end-to-end testing) using the developed anthropomorphic phantom of the original design will make it possible to analyze errors in individual dose distributions delivered to cancer patients arising from the following aspects of the radiation therapy technological chain:

- computer tomograph: the clarity of the contours of the existing contrast structures, the accuracy of determining the densities of materials placed in the channel with different known density;
- KSPO contouring module: search and precise selection of anatomical structures for a given density interval in HU, the accuracy of determining the geometric dimensions and volume of these structures or artificial implanted materials;
- algorithm for calculating the dose distribution of the KSPO: the accuracy of calculating the isodose distribution, taking into account the heterogeneity and geometric contours of the phantom;
- visualization system on medical devices: the accuracy of the phantom positioning in accordance with the irradiation plan, the distinguishability of both individual anatomical structures and artificially introduced IR);
- dosimetric and technical characteristics of the radiotherapy apparatus: irradiation accuracy and delivered dose.

4. Conclusion

Regular complex dosimetric testing of the radiation remedy technological system (end-to-end testing) using the method proposed by means of the authors, primarily based on the use of the developed anthropomorphic phantom of the original design, will make it possible to determine the accuracy of transport of the dose distribution for cancer sufferers with exceptional localizations of malignant neoplasms and to establish these errors in the transport of man or woman dose distributions that cannot be detected by using other exams in the

QA application for radiotherapy and
radiation remedy in accordance to countrywide and international recommendations and, thus, enhance the quality of scientific care, retaining the accuracy of the absorbed dose delivered to the goal within ± 5% of the prescribed value.
The delivered dose and isodose distribution for any quantity of fractions can be estimated the usage of a system in a dosimetric movie developed via a phantom, TLD, or the results of IR measurements. The bought increase tomogram (a third-dimensional geometric model taking into account the heterogeneity of anatomical structures) and the proposed IC mannequin allow positioning the developed anthropomorphic phantom and measuring the value of the absorbed dose at the reference point for irradiation plans for cancer sufferers of the primary localizations for the complete therapeutic range of radiation energies, dose charges and therapeutic sizes. radiation fields.

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