Assessing of a Radiation Therapy Session's Duration at the Stage of Pre-Radiation Preparation

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Abstract

The treatment planning process includes a review of the radiation treatment plan which leads to a decision on the patient's treatment technique. The scope of this study was to create a mathematical model for calculating of a radiation therapy session duration during the pre-radiation planning stage.

For dosimetric planning of radiation treatment the authors provided a formula and an algorithm for determining of a patient's irradiation session duration. Radiation therapy session parameters such as radiation technique, number of monitor units, characteristics of radiotherapy equipment, number of radiation fields, radiation field parameters (angles of rotation of the radiotherapy coach, collimator, gantry), presence/absence of dose-modulating devices, dose rate, and duration of patient position verification procedures have all been taken into account during the development of software. The developed application explains how to define typical timing characteristics for various items as well as how to select a template from a built-in drop-down menu. If the dosimetric plan does not match for one of the templates, the program provides a space for defining of all parameters manually.

The anticipated deviations of the true indicators from the expected indicators of the duration of the radiation therapy session were assessed. A total of 300 cases have been completely measured, with 100 cases studied for each irradiation technique (IMRT, VMAT, 3D). The maximum detection confidence value for the 3DCRT irradiation technique is 2.3 %, while the deviation for the IMRT and VMAT irradiation techniques is less than 1 %. The magnitude and degree of the deviation of the measured value from the expected one for a variety of characteristics and features have been revealed to depend on the actions of the personnel.

The program developed allows medical physicists to analyze the timing parameters of the specified dosimetric planning methodologies directly on the treatment planning workstation. Evaluation of the duration of a radiation therapy session during the treatment planning stage, selection of various radiation treatment modalities, and consideration of the characteristics of the radiation session in each clinical case are available for analysis and further justified action.

Keywords: treatment session, linear accelerator, radiation therapy, timing.

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Оценка продолжительности сеанса лучевой терапии на этапе предлучевой подготовки

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Анализ плана лучевого лечения является неотъемлемой частью процесса предлучевой подготовки, в результате которого принимается решение о методике лечения пациента. Целью данной работы являлась разработка математической модели определения продолжительности сеанса лучевой терапии на этапе предлучевой подготовки.

Авторами предложены формула и алгоритм расчёта продолжительности сеанса облучения пациента на этапе дозиметрического планирования лучевого лечения. Разработано программное обеспечение расчёта продолжительности сеанса облучения, учитывающее значения всех параметров сеанса лучевой терапии: методику облучения, количество мониторных единиц, характеристики радиотерапевтического оборудования, количество радиационных полей, параметры полей облучения (углы поворота радиотерапевтического стола, коллиматора, штатива аппарата), наличие/отсутствие дозомодулирующих устройств, мощность дозы, продолжительность верификации положения пациента. В программе предусмотрена установка стандартных параметров плана облучения для различных локализаций и методик путём выбора конкретного шаблона из выпадающего списка. В случае, если дозиметрический план не соответствует ни одному из шаблонов, в программе предусмотрен ввод параметров плана вручную.

Произведена оценка отклонений, рассчитываемых разработанной программой значений продолжительности сеанса лучевой терапии от истинных значений. Измерения проведены для 300 случаев: исследованы по 100 случаев для каждой методики облучения (IMRT, VMAT, 3D). Максимальное выявленное отклонение рассчитанного значения от истинного составило 2,3 % для методики облучения 3DCRT, для методик облучения IMRT и VMAT отклонение составило менее 1 %. Выявлено, что с увеличением количества процедур, напрямую связанных с действиями персонала, увеличивается и величина отклонения рассчитанного значения с измеренным.

Разработанное программное обеспечение позволяет оценивать временные параметры выбранных подходов дозиметрического планирования на рабочем месте медицинского физика. Оценка длительности сеанса лучевой терапии на этапе предлучевой подготовки способствует выбору оптимальной методики лучевого лечения с учётом индивидуальных параметров сеанса облучения в каждом конкретном клиническом случае.

Ключевые слова: сеанс облучения, линейный ускоритель, лучевая терапия, временные характеристики.

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Introduction

Modern radiation therapy is not complete without the use of high-performance computing facilities [1, 2]. Thanks to the development of computer technology, modern dosimetric planning systems make it possible to model structures within an anatomical object, radiation targets and dose distributions, and to estimate their dose. Over the past decade, computer planning systems have been repeatedly improved by introducing of new components into their structure which make it possible to use a significant amount of input data at the stage of pre-radiation preparation of a patient in the generation of an irradiation plan [3]. Analysis of the radiation treatment plan is an integral part of the pre-radiation preparation process, on the basis of which a decision is made including of the patient's treatment method [4–7]. It is important to assess the parameters influencing the quality of the dosimetry plan since the safety and effectiveness of the medical care provided to the patient depends on it [8–9]. Nowadays the process of determining of a radiation therapy session duration at the stage of pre-radiation preparation is difficult [10]. The authors did not identify methods and approaches to determine of a radiation therapy session duration at the stage of evaluating of a radiation treatment plan, published in printed publications. It should be noted that the possibility of assessing of a radiation therapy session duration at the stage of pre-radiation preparation will make it possible to choose the optimal radiation therapy technique taking into account the individual parameters of the radiation session in each specific clinical case.

In this regard, the purpose of this work is to develop a mathematical model for determining of a radiation therapy session duration at the stage of pre-radiation preparation.

Mathematical model of irradiation session

In [11] the authors established the time characteristics of the radiation session components, which have a dominant influence on its duration and proposed an algorithm that allows determining the duration of radiation treatment of cancer patients depending on the use of different radiation therapy techniques and tumor localizations. In [12] the authors established the numerical values of dominant components of radiation therapy session for each of the most used in clinical practice of the Department of Radiation Therapy of N.N. Alexandrov National Cancer Centre of Belarus.

Based on the results obtained in [11] and [12], the components of a radiation therapy session that directly influence its duration are: laying the patient and centering in the position prescribed for irradiation, setting the required mechanical parameters of the gas pedal under visual control from the procedure room, setting/removing wedge filters, time spent on the process of preparation for irradiation generation, verification of the patient position, initializing the gas pedal with irradiation parameters, relevant.

Let us introduce the notation of time parameters for each of the procedures, which will be taken into account when determining the total time of the radiation therapy session:

T_{ses} – radiation therapy time;

t_{pl} – laying the patient and centering in the prescribed position for the irradiation;

t_{set} – setting the necessary mechanical parameters of the gas pedal under visual control from the procedure room;

t_{fil} – installation/removal of wedge filters;

t_{turn} – turning on the irradiation;

t_{ver} – patient position verification;

t_{init} – initialization of the gas pedal with irradiation parameters relevant to the second and subsequent treatment fields;

t_{tbl} – rotation of the therapeutic table;

t_{gan} – rotation of the tripod;

t_{coll} – rotation of the collimator;

t_{irr_f} – time of irradiation of one irradiation field;

t_{irr} – time of irradiation of the patient;

t_{fin} – patient out of the treatment room.

To describe a mathematical model of a radiation therapy session, the authors proposed the following formula (1):

$$\begin{aligned} T_{ses} = {} & t_{pl} + t_{set} + t_{fil} + t_{turn} + t_{ver} + t_{init\_1} + \\ & + t_{irr\_f1} + t_{fil\_2} + t_{turn\_2} + t_{init\_2} + \\ & + t_{tbl\_2} + t_{gan\_2} + t_{coll\_2} + t_{irr\_f2} + \ldots + \\ & + t_{fil\_n} + t_{turn\_n} + t_{init\_n} + t_{tbl\_n} + \\ & + t_{gan\_n} + t_{coll\_n} + t_{irr\_fn} + t_{fin}. \end{aligned} \quad (1)$$

Using the proposed formula, it is possible to estimate the radiation therapy session time at the stage of dosimetric treatment planning.

Software

To estimate the duration of the irradiation session in accordance with the chosen approach of dosimetric planning at a medical physicist's workplace, a computer program was developed, the mathematical algorithm of which is based on the proposed formula (1). Figure 1 shows the interface of the program for calculating the duration of the irradiation session according to the three-dimensional conformal irradiation technique (3D CRT).

The program algorithm is shown in Figure 2.

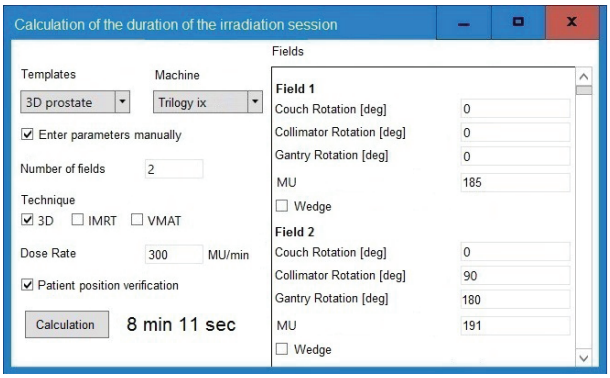

Figure 1 – Interface of the computer program for calculating the duration of an illumination session

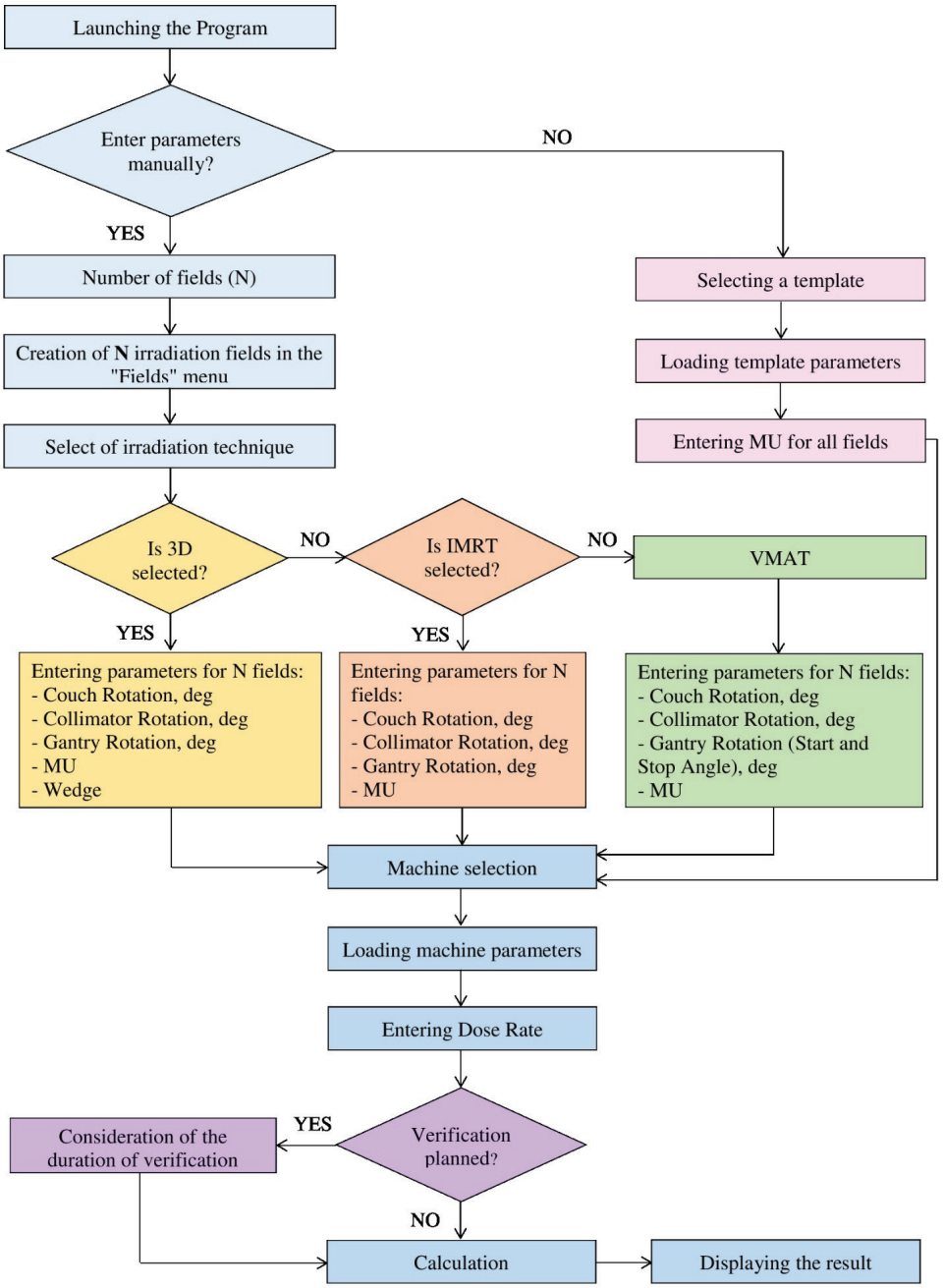

Figure 2 – Program algorithm

The computer program provides for setting standard parameters of the irradiation plan for different localizations and techniques by selecting a specific template from the drop-down list. After selecting a particular template, the parameters of the radiation treatment plan are automatically loaded, and then the number of monitor units for each radiation field must be entered. If the dosimetric plan does not correspond to any of the templates, the program provides the possibility to enter the plan parameters manually. In this case it is necessary to enter the required number of radiation fields in the area "Number of fields" and select the irradiation technique (3D, IMRT or VMAT), then enter the parameters of each field in the corresponding cell: table rotation angle, collimator rotation angle, tripod rotation angle, number of monitor units (MU) and presence of wedge-shaped filter if it is provided by the patient's radiotherapy plan. Then you select the model of the radiation therapy unit in the "Machine" menu, and then the necessary parameters of the selected unit are automatically loaded. Then in the "Dose Rate" area the dose rate is specified. In case of implementing a radiation treatment plan with patient position verification the checkbox "Patient position verification" is set. After setting all parameters of the radiation treatment plan, the duration of the radiation session "Calculate" is calculated, the result of the calculation is displayed in the corresponding cell.

Research results

The authors analyzed the data obtained by applying the developed software to determine the duration of the radiation session. The analysis was carried out by comparing the data obtained using the developed computer program with the true data measured in real time during the radiation therapy session. Measurements were made for 300 cases: 100 cases for each irradiation technique (IMRT, VMAT, 3D) were studied. Figure 3 shows a graph showing the effect of the duration of the radiation session on the deviation of the calculated values from the true values.

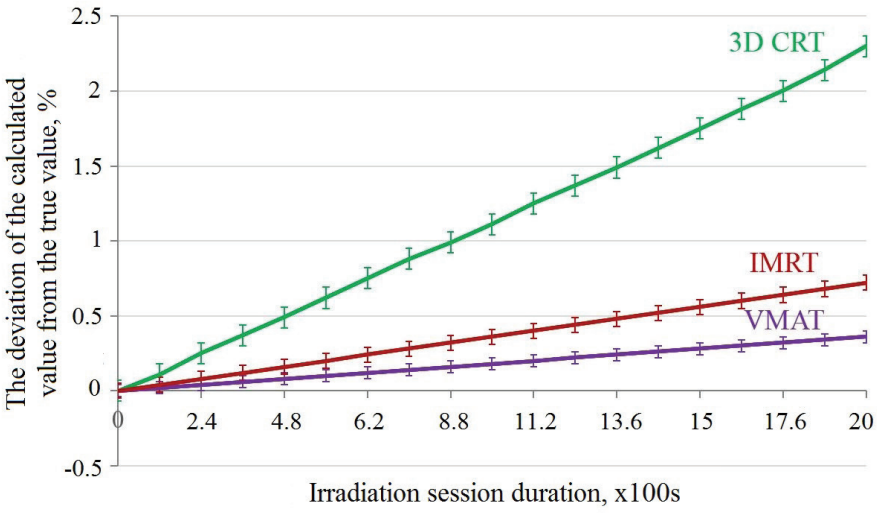

Figure 3 – Influence of irradiation session duration on the deviation of calculated values from true values for 3DCRT, IMRT and VMAT irradiation techniques

The maximum detected deviation of the calculated value from the true value was 2.3 % for the 3DCRT irradiation technique; for the IMRT and VMAT irradiation techniques the deviation was less than 1 %. The average deviation was 1.3 % for the 3DCRT technique and 0.4 % for IMRT and VMAT. It was found that with an increase in the number of procedures directly related to the actions of the personnel, the deviation of the calculated value from the measured one also increases. This is due to the different physical characteristics of the person involved in the implementation of the radiation therapy session.

Conclusion

The authors have proposed a formula for calculating the time of an irradiation session of patients at the stage of dosimetric planning of radiation treatment. Using this formula makes it possible to take

into account the time spent on procedures that make up a radiation therapy session, and thus minimize the probability of an error in the planned dose delivery related to the mobility of internal organs and biological processes of the irradiated biological object. Application of the approach focused on reducing the time cost of the radiation therapy session will also increase the throughput of radiotherapy equipment and in some cases reduce its wear and tear.

An algorithm for calculating the duration of a radiotherapy session is proposed. Software is developed which allows to estimate the time parameters of the selected dosimetric planning approaches at the medical physicist's workplace.

Deviations of the calculated values of radiation therapy session duration by means of the developed program from the actual values were evaluated. The maximum deviation of the calculated value from the true value is 2.3 % for 3DCRT technique, for IMRT and VMAT techniques the deviation was less than 1 %. The average deviation for the 3DCRT technique was 1.3 %, and for the IMRT and VMAT techniques was 0.4 %.

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