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Original research article

Determination of boundaries between ranges of high and low gradient of beam profile

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ABSTRACT

Aim: This work addresses the problem of treatment planning system commissioning by introducing a new method of determination of boundaries between high and low gradient in beam profile.

Background: The commissioning of a treatment planning system is a very important task in the radiation therapy. One of the main goals of this task is to compare two field profiles: measured and calculated. Applying points of 80% and 120% of nominal field size can lead to the incorrect determination of boundaries, especially for small field sizes.

Materials and methods: The method that is based on the beam profile gradient allows for proper assignment of boundaries between high and low gradient regions even for small fields. TRS 430 recommendations for commissioning were used.

Results: The described method allows a separation between high and low gradient, because it directly uses the value of the gradient of a profile. For small fields, the boundaries determined by the new method allow a commissioning of a treatment planning system according to the TRS 430, while the point of 80% of nominal field size is already in the high gradient region.

Conclusions: The method of determining the boundaries by using the beam profile gradient can be extremely helpful during the commissioning of the treatment planning system for Intensity Modulated Radiation Therapy or for other techniques which require very small field sizes.

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1. Background

A number of official publications,[1,2] papers[3–8] and verification audits[9–11] confirm that the commissioning of the treatment planning system (TPS) is very important in radiation therapy. On the one hand, this task requires at least a basic control of TPS, and on the other hand, performing the verification of measurements involves consideration and preparation. The measurements for modeling have to be performed with high precision and accuracy as well. Unfortunately, very often, the TPS does not contain any useful tool for the verification purpose. Even if the tool exists, it is either very simple and the data (for example, dose profile as numbers in a text file) need to be processed in external software or it turns out to be very complex in use.

This article presents our experiences with TPS commissioning. In particular, we describe our method, tools and results of comparing beam profiles generated in TPS with the ones from measurements. The method we used to design boundaries between regions of low and high gradient is based on the real value of the profile gradient. For each profile, the gradient is numerically determined and its given value is the boundary between regions of low and high gradient. Another method based on field size (for example 80 and 120% of the field size) fails in small fields. As we show below, it is because small field profiles practically do not contain the plateau in the middle part of the profile. Applying recommended tolerances to these fields, leads to large errors. The proposed method allows such errors to be avoided.

2. Aim

The aim of the study is developing a method to determine areas of large and small gradient dose rate in the beam profile. Further, the aim is to use the developed method to verify the calculations of the planning system.

3. Materials and methods

The Elekta linac with 160 leaves MLC has been recently installed in the Opole Oncology Center. Our two older machines have different collimators with only 80 leaves. All linacs installed in the Opole Oncology Center have three photon energies – 4, 6, and 18 MV. All profile measurements, both for modeling purposes and for verification, were performed using a full scattering 3D water phantom. Two completely separate collections of profiles were performed. We used two ionization chambers CC13 by Wellhofer, recommended by the producer of TPS.[12] The first chamber was designated as the field detector, the second as the reference detector for all measurements. For commissioning purposes, for each photon energy we measured two profiles with at least 8 cm margins, which were averaged at the end. Both sets of measurements were collected with a constant resolution of 1.2 mm.

The TPS recommendations for data collecting for the modeling purposes were as below: for cross plane and in plane four field sizes: 5 cm × 5 cm, 10 cm × 10 cm, 15 cm × 15 cm and 20 cm × 20 cm at four depths: 1.5, 5, 10 and 20 cm. In addition to that, so-called star profiles and diagonal profiles were collected for maximal field (40 cm × 40 cm) at 10 cm depth. Star profiles were measured in 10° increments from 0° to 180°. We chose SSD = 90 cm for all measurements.

For the TPS verification, the following set of symmetric open fields was chosen (all sizes are in cm in isocenter): 5 × 5, 10 × 10, 30 × 30, 20 × 5, 5 × 20 and for wedged fields: 10 × 10, 20 × 5 and 5 × 20. In addition, a few asymmetric open fields were checked: half-beams 5 × 10 and 2 × 10 and one fourth of the 10 × 10 field – 5 × 5. All of the above measurements were executed for the surface – source distance equals to 90 cm. We also checked different distances between source and water surface: 75, 100 and 109 cm. All profiles were done at four different depths: depth of the maximum dose rate for given energy, 5, 10 and 20 cm. We collected data along major axes – cross plane and in plane.

Once the models of photon beams were obtained, the Oncentra External Beam 4.3 TPS by Nucletron[13] was verified. The plans with appropriate beams were made for the set of measurements described above. For the profile comparison, we used recommendations from Ref. 1 The Oncentra TPS allows exporting a dose distribution as a single column of numeric values. In such a form, the data can be further processed in a spreadsheet. However, navigation in this type of data is rather unintuitive, especially when a dense dose grid and a large phantom are used.

In the process of verification, we used dedicated software packages which use the DICOM dose files originating from TPS. The DICOM standard we used is described in detail on the website.[14] First, the measured profiles were averaged and smoothed. After that, each profile was normalized to 100% in the axis for the open fields and to 100% in the point of maximal dose rate for the wedged fields. A significant speedup in the verification process was possible due to the fact that the initial preparation was done simultaneously for a large number of profiles. Data from TPS was generated with a cuboid dose grid (2 mm resolution). Contrary to the measured profiles – the calculated profiles did not require smoothing. The differences between profiles were calculated with 1 mm resolution using the following formula from Ref. 1:

$$\delta = 100 \times \frac{D_{calc} - D_{meas}}{D_{meas,point}} \quad (1)$$

where δ is the difference (in %); D_{calc} is the calculated dose in a given point; D_{meas} is the measured dose in a given point; $D_{meas,point}$ is the measured dose on the central axis for open on-axis beams and in the point of maximum dose for off-axis beams and wedged beams.

The process of comparison was multistage. In the first stage, we calculated differences in beam sizes for open fields (distances between 50% intensity for the profile normalized to 100% in the axis of beam). This allowed to both evaluate the positioning of the jaws and determine real field sizes obtained from TPS. The differences in beam sizes were not calculated for wedged beams.

In the next stage, the field sizes were centered and renormalized. The software used in the centering process determined 50% of profile intensity (normalized to 100% in the beam axis) and defined distances of these points from the