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Effects of virtual source width and collimator aperture on the dose profile for 6 MV beam fields

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1. Introduction

Since the beginnings of radiotherapy, sources that produce ionizing radiation have been used to treat diseases, with a special focus on the treatment of cancer. Devices that provide photon beams can be constituted, for example, by a radioactive isotope source, such as Cesium-137 or Cobalt-60, which emit radiation naturally; or by a source consisting of a linear accelerator, powered by an electrical energy supplier.

The advancement of radiotherapy brought the optimization of conventional clinical accelerators and the development of new accelerator models. Both aiming to obtain a better radiation treatment of the patient, delivering the planned dose to the tumor while minimizing the dose to the healthy neighboring cells as much as possible.

An important tool for research on these devices are Monte Carlo codes [1-7]. However, for reliable simulations to be carried out, information such as geometry, elementary composition and density of the objects that make up the simulated environment are necessary. Unfortunately, this information may not be available in the case of linear accelerators, often making it difficult for those who want to study topics involving the equipment.

Rucci et al. (2014, 2016) showed that an alternative approach is the construction of Virtual Source Models (VSM) [6, 7]. VSM are simplified versions of linear accelerators that aim to reproduce real models based on physical parameters of interest. If the VSM reproduces, for example, dose profile curves, percentage depth dose (PDP) and flux measurements of clinical linear accelerators, it could be a good tool to evaluate situations not easily accessible experimentally.

In many cases, the construction of the VSM involves modeling the virtual source (geometry and characteristics of the radiation beam) and the collimator (geometry, elementary constitution, density, position relative to the source and position relative to the target). Therefore, this work aims to evaluate the influence of virtual source width and collimator aperture on the dose profile of a 6 MV photon beam using the MCNP6 code.

2. Methodology

In this work, the Monte Carlo MCNP6 code was used to simulate the dose profile measurements. The initial parameters used to build the VSM are referenced in the literature [6]. They correspond to the beam of a 6 MV photon linear accelerator.
According to Rucci et al. (2014), a 6 MV photon beam can be represented by a virtual source that emits three monoenergetic beams of 1, 3 and 5 MeV with 76.36%, 19.36% and 4.28% probability, respectively.
The virtual source has s x s two-dimensional planar shape, with the s value ranging from 0.01 cm to 0.07 cm. The collimator was positioned 30 cm from the virtual source and has an aperture in the shape of a regular square base prism at its center, whose planes were rotated at angles of 1°, 2°, 3°, 4° and 5° towards the center. The water phantom has dimensions of 40 cm x 40 cm x 40 cm and is positioned 100 cm from the virtual source. Dose profile values were estimated at 1.5 cm depth in the water simulator object. *F8 tally was used to estimate the relative deposited energy (dose) with the MCNP6 program.

3. Results and Discussion

In Fig. 1 shows the results of the profile curves for different virtual source width values.

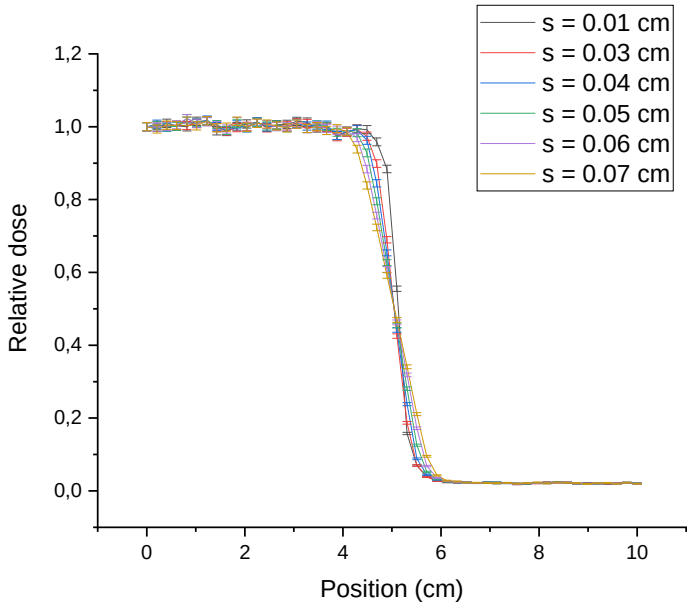

Figure 1: Variation of the "shoulder" slope of the dose profile curve depending on the size of the virtual source.

One can observe the decrease in the slope of the curve with the increase in the source size. In addition, the larger the source width the larger the penumbra size for the same size field. This is in accordance with the formula given by Johns, whose font size prediction for a conventional clinical field can be given by equation 1 associated with equation 2 of the article by Rucci et al (2014) [6,8]. Furthermore, all other source sizes have a slope that varies by intercepting at the 0.5 point of relative dose intensity, with the exception of the smallest virtual source width (s = 0.01 cm). The information that the font size can shape both the penumbra size and the font slant can help in building a VSM. Furthermore, one area that benefits from this type of study is small fields in radiotherapy [9, 10].
Fig. 2 presents the dose profile curve for five different angle values. From the graph, the change in the slope of the 'shoulder' of the profile curve is noticeable, as in the previous case of increasing the size of the virtual source. However, this variation has a distinct behavior.

Changing the angle of the collimator plane generates a variation in field size, but without changing the position where the curves intersect. The 3° angle is what generates the largest field size. On the other hand, the 1° and 5° angles and the 2° and 4° angles have equivalent curves to each other, which indicates a symmetrical response around the 3° angle.

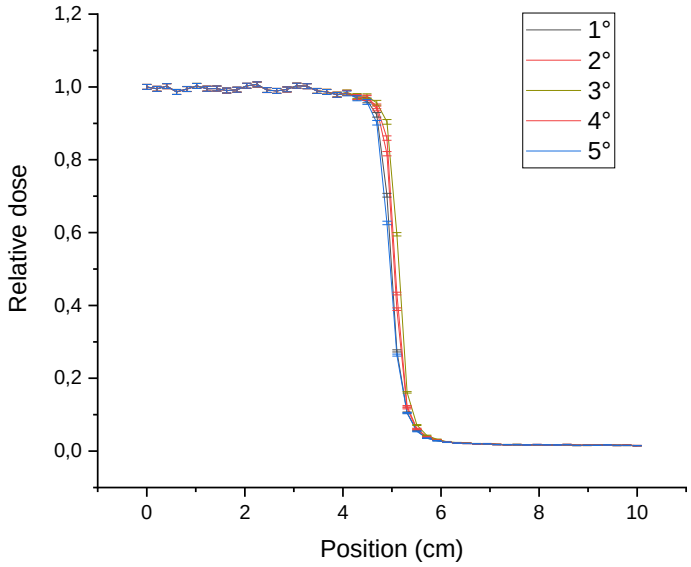

Figure 2: Variation of the shape of the dose profile curve with the variation of the angle of the collimator opening planes.

Controlling the shoulder slope and the position of the simulated dose profile curve can help you adjust it to an available reference dose profile curve (experimental, phase space, or theoretical). This is especially useful when studying small fields, where the font size directly influences the penumbra generated and, consequently, the measured output.

4. Conclusions

The construction of a good VSM goes through the verification of the physical parameters of interest and their relationship with the characteristics of the virtual source and the collimator. A good agreement between the simulation and the literature is shown here for estimating the penumbra size in relation to the source width. In addition, there is the possibility to adjust the slope of the dose profile curve shoulder shape from the virtual source size. These data are in line with the creation of a good methodology that helps in the construction of VSM from available experimental or phase space simulated or theoretical dose profile. Another relevant information is the behavior of the dose profile curve with the variation of the inclination of the planes that form the collimator opening. This can serve as a tool for the user to manipulate their simulated dose profile curve and fit it to a reference dose profile curve.

Acknowledgements

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