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Computer Simulations Applied to Small-Field Dosimetry in Radiotherapy

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ABSTRACT

With the advancement of radiotherapy techniques, we find some challenges in small field dosimetry that are widely used in head and neck treatments, so computer simulations with the Monte Carlo method, already well established in medical physics, are a great tool for studying small field dosimetry. The present work aims to report the validate of the geometry model used for the simulations of a 6 MV LINAC beam, in addition to estimating the PDD curves and the PDD 20,10 for several regular and small fields, allowing comparisons with experimental data.

Keywords: **MCNPX, Small Fields, Dosimetry.**

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1. INTRODUCTION

Computer simulations with Monte Carlo codes have become the gold standard in radiotherapy treatment dosimetry, as they are capable of reproducing the most diverse scenarios with great precision [1, 2].

Small fields in radiotherapy have been widely used mainly in head and neck treatments, as they provide an extremely localized treatment, despite having an abstract definition, small fields in radiotherapy are understood as those fields whose size is smaller than 4x4 cm, in which the penumbra overlaps the area of the field and that the field is closed to the size of the detector [3].

The main objective of the present work is the validation of the simulation scenario using the Monte Carlo MCNPX code, thus the beam of a linear accelerator with a nominal energy of 6 MeV was reproduced with the above code, with which we simulate several regular fields to perform the validation. In addition to the validation, small field simulations were performed and used to estimate the deep dose percentage curves of the 6 MeV beam, allowing a future comparison with curves obtained experimentally.

2. MATERIALS AND METHODS

When using a Monte Carlo computational code, such as Monte Carlo N-Particle eXtended (MCNPX) [7], the first step is to validate the simulated scenario and MC code used, thus ensuring that the developed model is adequately for the proposed simulations. The validation consists of comparing the results obtained to the published in literature and calculate the deviation found due to the comparison.

The geometry modeled using the MCNPX code for the simulations consisted of a water phantom of 40×40×40 cm^3 box filled with water and with acrylic walls of 0.5 cm thickness, positioned at 80 cm from the radiation source. The source was set as a 6 MeV photon beam, pointed to a 10x10 cm field size at the surface of the water phantom, as used in the reference paper [4, 9], the spectrum used was taken from the electronic tables provided by Brualla et. al. 2019 [5].

The detector's geometry was changed in shape to sphere instead of cylinder geometry but keeping its volume. The idea was to compare the effect on the detector response while using different surface geometries.

After the validation, the simulations were also carried out for different field sizes, namely 10x10cm, 5x5cm, 4x4cm, 3x3cm, 2x2cm, and 1x1cm, with the water phantom positioned at 100 cm away from the 6 MeV energy photon source, and the detector geometry was the same used in the validation simulation. The dosimeter cells were positioned with a variation of 1 in 1 mm to the depth of 2cm, while for depths from 2 to 10 cm the detector cylinder was positioned from 0.5 in 0.5 cm, from a depth of 10 cm, the position of the detector was varied from 1 in 1 cm to a depth of 15 cm, then a detector was positioned at a depth of 20 cm, in order to allow the estimation of the Percentage Depth Dose20,10 (PDD20,10) parameter. Another simulations performed were using detectors with volume equal to 0.125 cm^3 for fields sizes equal to and larger than 3x3 cm^2, while for fields smaller than 3x3 cm^3 we used detectors with volumes equal to 0.016 cm^3. For these field sizes, as well as in the validation simulations the PDD20,10, the tissue–phantom ratio in water (TPR20.10) and PDD curves were obtained and compared.

The *F8 Tally was used in the simulations to score the energy deposited in MeV in the detectors. The results obtained from the simulations were normalized using the technique of division by the highest value and then multiplied by 100 to obtain the PDD values. By the definition, the PDD is calculated as shown in Equation 1[8].

$$PDD = Dp/Dmax \times 100 \qquad (1)$$

where Dp is the dose at any depth and Dmax is the dose at depth of maximum dose. To obtain the PDD20,10 the ratio between the result obtained from the deposited energy at 20 cm and at 10 cm were obtained. The tissue–phantom ratio in water (TPR20.10) was also calculated using the Equation 2 [8].

$$TPR20{,}10 = 1.2661 \times PDD20{,}10 - 0.0595 \qquad (2)$$

3. RESULTS AND DISCUSSION

Table 1 shows the results obtained from the simulations for validation process. It is observed that the simulated values obtained have a slight difference while compare to the results of the reference paper [9]. The difference is less the 0.5% which indicates the accuracy of the model developed. It was also observed that the two geometries modeled, the sphere and the cylinder surfaces, of the detector have no significant changes in the results obtained. Furthermore, it is important to emphasize that the validation process presented a relative error of less than 1%.

Table 1: Validation Results

Simulation		Reference	Δ%
PDD 20,10	55.2%	55.4%	0.467
TPR 20,10	63.9%	64.2%	0.416

Figure 1 show the PDD curve for the validation simulation using the 6 MeV photon beam. It is observed that the maximum dose depth obtained was closed to 1.5 cm which it is in accordance to the literature [9] and expected depth.

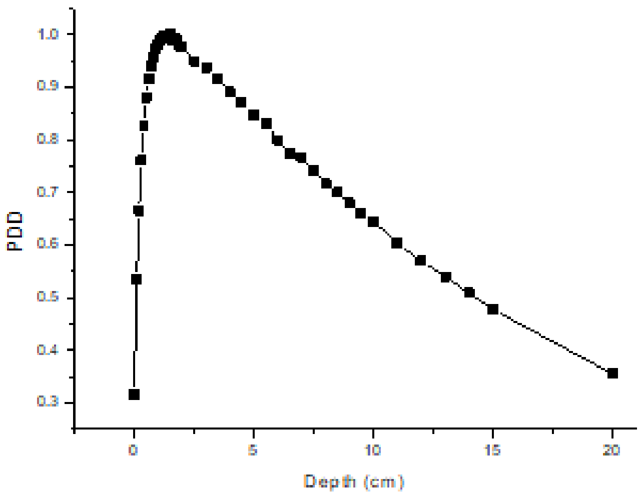

Figure 1: *PDD Curve 6 MeV.*
Source: Author

Figure 2 shows the results for the PDD curves using the detector volumes equal to 0.125 and 0.016 depending on the field size.

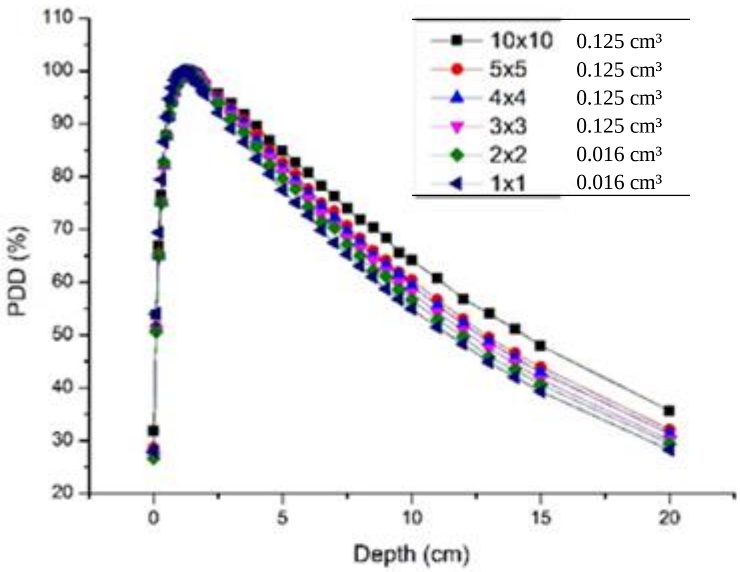

Figure 2: *PDD curves with detector volume equal a 0.125 or 0.016 cm³.*
Source: Author

Table 2 shows the estimated PDD20,10 for each field.

Table 2: PDD 20,10

Field Size (cm)	**10x10**	**5x5**	**4x4**	**3x3**	**2x2**	**1x1**
PDD 20,10 (%)	55.6	53.1	52.7	51.8	52.0	51.4

It is evident that PDD20,10 for the 10x10 cm field size presents an excellent approximation of the values obtained in the validation and compared with the validation reference.

4. CONCLUSION

We can say that the code presented satisfactory results in the validation simulations, showing the great usefulness of Monte Carlo codes in medical physics, however, the simulation with the 1x1 field leads us to realize the need for more simulations in order to show itself, with a greater resolution the PDD curves.

As a continuation of the present work, it is also intended to observe the influence of the detector geometry variation on the measurements, in addition to obtaining the PDD curves with higher resolution.

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