2021 International Nuclear Atlantic Conference – INAC 2021
Virtual meeting, Brazil, November 29 – December 2, 2021

ISBN: 978-65-594-1256-3
9 786559 412563

Computer Simulations Applied to Small-Field Dosimetry in Radiotherapy

F. Gomes[1], A. Lima[2] and T. Fonseca[1]

[1] *fsgs@ufmg.br, Departamento de Engenharia Nuclear- Escola de Engenharia – Universidade Federal de Minas Gerais – Avenida Presidente Antônio Carlos, 6627, Pampulha, Belo Horizonte, MG, 31270-901*
[2] *radioterapia.andre@gmail.com, Radiocare - Rua dos Timbiras, 3609 - Barro Preto, Belo Horizonte - MG, 30411-052*

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, which the penumbra overlaps the area of the field and that the field is close to the size of the detector [3].

The main objective of the present work was to compare a simulated scenario using the Monte Carlo MCNPX code against a published article [9] A 6MV photon beam of a linear accelerator was reproduced with the mentioned above code in order to calculated the PDD and TPR parameters. The results were compared to the published Fonseca et. al. 2016. After the comparison, several regular small fields were simulated and compared to results published in literature. In addition, the small field simulations were used to estimate the deep dose percentage curves of the 6 MV photon beam.

2. Methodology

When using a Monte Carlo computational code, such as Monte Carlo N-Particle eXtended (MCNPX), the first step is to validate the simulated scenario and code used, thus ensuring that it adequately simulates the proposed models. In a first step a scenario proposed by Fonseca et al. 2016 was simulated and the PDD and TPR results were compared. Secondly, the input file validated was used to calculate the PDD curves for 5 different field sizes.

The geometry used in the simulations consisted of a water phantom, positioned 80 cm from the source that emitted a 6 MeV photon beam, with a 10x10 cm field, as used in the reference paper [4], the spectrum used was taken from the electronic tables provided by Brualla et. al. 2019 [5].

The energy deposited by the beam on the phantom was detected by cylinders with a volume of 0.6 cm^3, such cylinders were positioned with a variation of 1 in 1 mm to the depth of cm, 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 dose$_{20,10}$ ($PDD_{20,10}$).

The detector's geometry was altered in its shape when compared to that used in the reference article [4], to show if there are significant changes when the detector's shape is changed, in this case from sphere to cylinder, but the volume is maintained unchanged.

After the validation, the simulations were also carried out with different field sizes, namely , 5x5cm, 4x4cm, 3x3cm, 2x2cm, and 1x1cm, with the water phantom positioned 100 cm away from the 6 MeV energy photon source, and the detector geometry was the same used in the validation simulation, but it was positioned from 0.5 in 0.5 cm to a depth of 20 cm, and we changed the volume of these detector cells using one tenth of the field diameter as the cylinder radius [6]. For these fields, as well as in the validation simulations $PDD_{20,10.}$ and PDD curves were obtained.

The Tally used in the simulations was the Tally *F8, which estimates the energy deposited in MeV in the cells described in the simulation input, in this case, the energy was estimated in the cells corresponding to the cylindrical detectors [7].

The measurements obtained were normalized using the technique of division by the highest value and then multiplied by 100 to obtain the PDD, because by the definition of PDD we have equation 1 below where D_p is the dose at any depth and D_{max} is the dose at depth of maximum dose, to obtain the PDD20,10 the ratio between the result obtained from the PDD at 20 centimeters and at a depth of 10 centimeters was calculated [8].

$$PDD = \frac{D_p}{D_{max}} \ .100 \qquad (1)$$

The Tissue–phantom ratio in water ($TPR_{20.10}$) was also obtained, where the value of the $PDD_{20.10}$ according to equation 2 below [8].

$$TPR_{20.10} = 1.2661 \, . \, PDD_{20.10} - 0.0595 \qquad (2)$$

3. Results and Discussion

Table I below shows the results of simulations for validation of the Monte Carlo code used, it is observed that the simulated values present a slight difference to the results of the reference paper, which indicates the accuracy of the code used. It is also observed that the geometric alteration of the detector did not bring significant changes to the results, as the differences between the results were not significant. Furthermore, it is important to emphasize that the validation simulations presented a relative error of less than 1%.

Table I: MCNPX validation results

Simulation%		Reference [4] %	Δ%
$PDD_{20.10}$	55.2	55.4	0.47
$TPR_{20.10}$	63.9	64.2	0.42

Figure I shows the PDD curve for the validation simulation with the 6 MeV beam, it is observed that the maximum dose depth obtained about 1.5 cm is in accordance with the literature [9].

Figure I: PDD Curve - 6 MeV photon beam

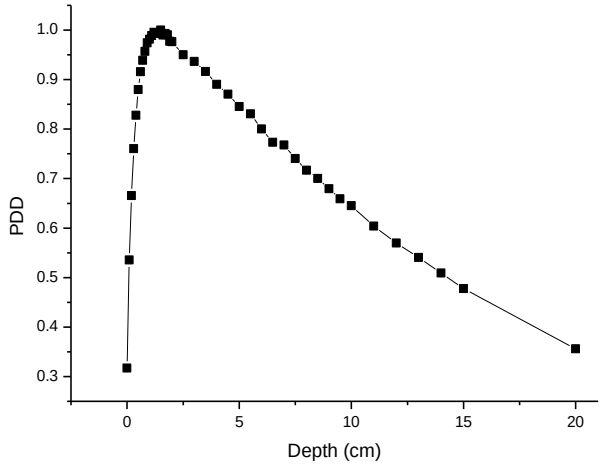
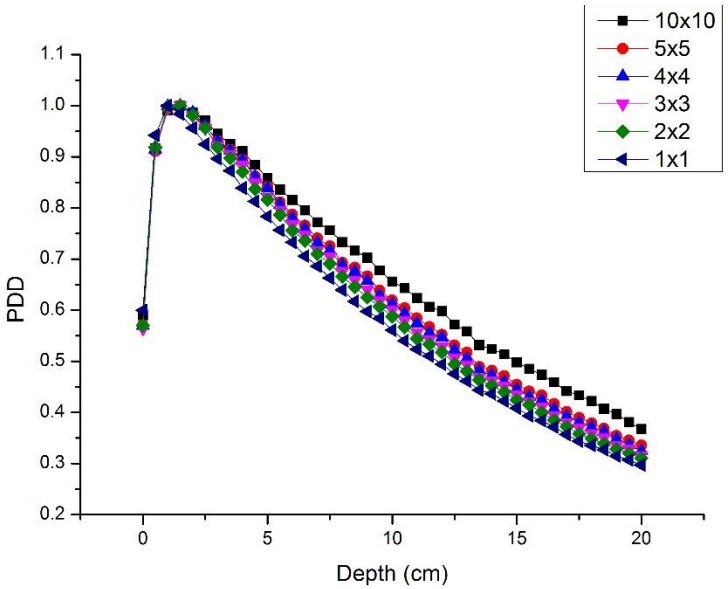


Figure II shows the PDD curves for the simulated fields, there is a certain similarity in all of them, however as can be seen the 1x1cm field curve presented the maximum dose depth a little smaller than the others, it is important to point out that the PDD values obtained between 1 and 2 cm are very close [9], which indicates the need to make measurements with a higher resolution, placing, for example, 0.2 cm in 0.2 cm detectors.

Figure II: PDD curves



4. Conclusions

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 study the influence of the detector volume variation on the measurements and its material, in addition to obtaining the PDD curves with higher resolution.

Acknowledgements

We would like to thank LN/IRD/CNEN for using the ORION cluster, Monte Carlo Expert Group -MCMEG for mediating access to the cluster, CAPES for promoting research.

References

[1] Andreo, P. Monte Carlo simulations in radiotherapy dosimetry. *Radiat Oncol* 13**,** 121 (2018).

[2] D. Rogers, Fifty years of Monte Carlo simulations for medical physics. Physics in Medicine and Biology 51 R287-R301, (2006).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Dosimetry of Small Static Fields Used in External Beam Radiotherapy, Technical Reports Series No. 483, IAEA, Vienna (2017).

[5] L. Brualla, *et al.* PENELOPE/PRIMO-calculated photon and electron spectra from clinical accelerators. *Radiat Oncol* **14,** 6 (2019).

[4] T. Fonseca, et al., "Simulação de um acelerador LINAC 6MV para determinação da dose de profundidade e razão tecido fantoma utilizando MCNPx e EGSnrc". Brazilian Journal of Radiation Sciences. 4. 10.15392/bjrs.v4i2.201, (2016).

[6] A. Mesbahi ,et. al.. "A comparative Monte Carlo study on 6MV photon beam characteristics of Varian 21EX and Elekta SL-25 linacs". J. Radiat. Res. 5. 23-3, (2007)

[7] Pelowitz D, MCNPX User's Manual Version 2.7.0 Los Alamos National Laboratory LA-CP- 11-00438 ed, (2011).

[8] IAEA, TRS. 398. Absorbed dose determination in external beam radiotherapy: An International Code of Practice for Dosimetry based on standards of absorbed dose to water. Vienna International Atomic Energy Agency, 2000.

[9] T. Fonseca, et al., MCMEG: Simulations of both PDD and TPD for 6 MV LINAC photon beam using different MC codes. Radiation Physics and Chemistry 140 386-391, (2017)