BASIC DOSIMETRY OF RADIOSURGERY NARROW BEAMS USING MONTE CARLO SIMULATIONS – A DETAILED STUDY OF DEPTH OF DOSE MAXIMUM

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Dose measurements of narrow photon beams used in radiosurgery are complicated by the lack of lateral electron equilibrium which is a requirement namely for ionometric methods. The details of basic dosimetry for these narrow beams are still quite unknown. To overcome this difficulty Monte Carlo simulation is a privileged tool to assess the processes of the energy deposition phenomena in such narrow photon beams. Some simulations had already been performed to calculate percent depth doses in a water phantom of the narrows beams used in our hospital (Centro Regional de Oncologia de Coimbra-Portugal) and the agreement with experimental data was good [1]. A more specific analysis of the calculated and experimental dose measurements in the build-up region revealed that the depth of the dose maximum d_{max} increases with the size of the additional collimators (Figure 1) which is the opposed behavior presented by radiotherapy conventional radiation fields [2]. To fully understand this phenomenon, Monte Carlo simulations are performed in order to verify if it is due to processes occurring in the generation of the narrow photon beams or in processes occurring in the water phantom. The Monte Carlo code used in these studies is MCNP-4c [3], the accelerator is a Siemens Mevatron KD2 in 6MV photon mode and the size of the additional collimators goes from 5mm to 23mm (geometrical dimension).

For the analysis in air, various scoring planes were placed just after the collimators (one for each collimator). Phase space data from the scoring planes is characterized in terms of: type of particles, energy and spatial distributions. Contributions of the various elements of the accelerator head are scored. The photons that reach the scoring plane have two different origins: photons coming from the elements of the accelerator head and photons that had suffered interactions inside the additional collimators. Regarding the photons coming directly from the head structures, most of them were generated by Bremsstrahlung process in the target; the contributions of the other head elements become more important as the size of the collimator increases. The ratio between photons coming from the accelerator head and photons originated in the additional collimator also increases as the size of the collimator increases. The analysis of the various scoring planes shows also that the electron contamination of the additional collimators is quite negligible. Finally, the average energy of the incident photons upon the water phantom decreases as the size of the collimator increases. These results seem to contradict the behavior of d_{max}.

The in-water analysis includes a scoring cell array along the central axis in the buildup region. As the radius of the additional collimators increases, the number of electrons that contributes to the energy deposition increases for each scoring cell as it was expected. The spatial distribution analysis of these electrons shows that some electrons are generated in the scoring cells or very close to them due to primary photons that reach them and other electrons, equally generated by primary photons, are created relatively far away from those cells. The energy analysis shows that as the collimator radius increases for each electron spatial distribution, the electron average energy increases in the same scoring cells and also increases as the depth of the scoring cells increases for a given collimator. In fact, as the size of the collimators increases, the electrons of these two spatial distributions will contribute to the energy deposition deeper in the buildup region increasing the depth of the dose maximum d_{max}.

Through this detailed analysis, we have concluded that characterizing the photon and electron spectra in air is not sufficient to explain the increase of d_{max} with the increase of the size of the additional collimator. Only the processes occurring in water explain this behavior.

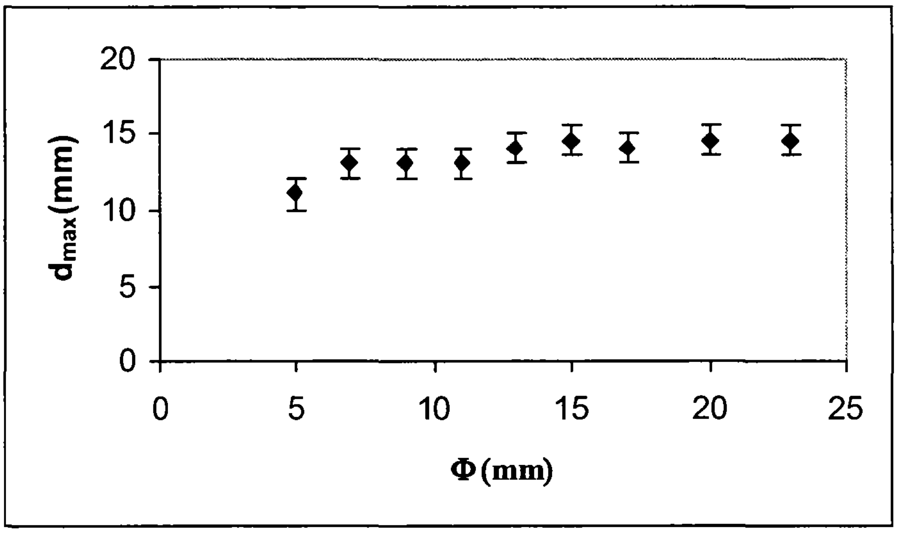

Figure 1. Measured depth of maximum dose in central axis versus diameter of the collimators.

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