

Impact of correlation between CT numbers and tissue parameters on Monte Carlo simulations: dosimetric aspects

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Purpose: Monte Carlo (MC) simulation in radiotherapy is well known to be the reference for patient deposit dose estimation. Correlation between CT images and MC tissue parameters is a major step before the estimation of the deposit dose. It requires transforming the CT dicom images in the geometry input of MC code, and depends on the chosen samplings, which modify the CT number. However the CT number determine the density and the chemical composition of each voxel. The purpose of this study is to highlight the dosimetric impact of the density and the chemical composition variation.

Methods: This study was performed with PENELOPE MC code (2011 version). Interactions of monoenergetic (2 MeV) and monodirectional photon beam in a cubic voxel (1cc) in an air environment were simulated with MC. We investigated the absorbed energy in the voxel by changing density and chemical composition. Nine ICRP (publication 110) elements were simulated: air, lung, adipose, breast, water, liver, muscle, spongiosa bone and mineral bone. Because the water is used as reference in the Treatment Planning System (TPS) our results were normalized by energy deposit in water with the same density: $100 \times (\text{Energy deposit in the element} - \text{Energy deposit in water}) / (\text{Energy deposit in water})$. The standard deviation was estimated as the statistical error.

Results: For density in the interval 0.5 to 1.1 g/cm³ the maximum variation between energy deposit in lung, adipose, breast, liver, muscle and energy deposit in water is -1.3%. Concerning the spongiosa bone in a range density of 1 to 1.5 g/cm³ the difference do not exceed -3.2 %. The difference with water for mineral bone in a range density of 1.5 to 2.2 g/cm³ is about -9%. In air medium (density close to 0.001 g/cm³) the variation goes up to -18%. The attached figure illustrates these variations.

Conclusion: Following the energy deposit with MC simulation in different elements for the same density shows the impact of the chemical composition as a crucial point, which strongly influences the accuracy of patient dose calculations in MC treatment planning. It is particularly important to differentiate lung from air (17.5 % for density at 0.3 g/cm³), bone

from soft tissue (3% for density at 1.1 g/cm³) and different bone compositions (6.5 % for density at 1.26 g/cm³).