Influence of statistical fluctuations in Monte-Carlo dose calculations on radiobiological modelling and dose volume histograms.

Monte-Carlo (M-C) dose calculations in radiotherapy can potentially yield highly accurate values for the delivered dose.

Unlike analytical algorithms for dose calculations, M-C provides a mean dose (d) and a statistical variance (σ_d^2) for each scoring region, i.e. the phantom voxel.

The aim of this work is to analyze the statistical nature of M-C dose distributions by investigating the influence of the statistical fluctuations of d on the dose volume histograms (DVH) and radiobiological models outcome. Whilst the quantities d and σ_d depend on many statistical and physical parameters; it is assumed here that they only depend on the phantom voxel size and the number of histories.

We have analyzed high-energy photon and electron beams. We have found that when considering nominally uniform dose distributions the M-C statistical fluctuations do not affect so heavily the outcome of radiobiological models and DVH; in fact even up to values of σ_d of about 5-6% the model answers were varying less than 10%. In contrast when dealing with non-uniform dose distributions the outcomes could be strongly dependent on σ_d.

To give an example, we consider here the tumor control probability model when the dose to the target is not homogeneous and contains cold spots. The outcome of the model varies by approximately 10% when running 10^7 and 10^8 histories respectively; this variation reaches values of about 40% when decreasing the voxel size from 0.5x0.5x0.5 to 0.25x0.25x0.25 cm^3.