Dose to medium versus dose to water as an estimator of dose to sensitive skeletal tissue

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Abstract

The purpose of this study is to determine whether dose to medium, Dₘ, or dose to water, Dₘₚ, provides a better estimate of the dose to the radiosensitive red bone marrow (RBM) and bone surface cells (BSC) in spongiosa, or cancellous bone. This is addressed in the larger context of the ongoing debate over whether Dₘ or Dₘₚ should be specified in Monte Carlo calculated radiotherapy treatment plans. The study uses voxelized, virtual human phantoms, FAX06/MAX06 (female/male), incorporated into an EGSnrc Monte Carlo code to perform Monte Carlo dose calculations during simulated irradiation by a 6 MV photon beam from an Elekta SL25 accelerator. Head and neck, chest and pelvis irradiations are studied. FAX06/MAX06 include precise modelling of spongiosa based on μCT images, allowing dose to RBM and BSC to be resolved from the dose to bone. Modifications to the FAX06/MAX06 user codes are required to score Dₘₚ and Dₘ in spongiosa. Dose uncertainties of ~1% (BSC, RBM) or ~0.5% (Dₘ, Dₘₚ) are obtained after up to 5 days of simulations on 88 CPUs. Clinically significant differences (>5%) between Dₘ and Dₘₚ are found only in cranial spongiosa, where the volume fraction of trabecular bone (TBVF) is high (55%). However, for spongiosa locations where there is any significant difference between Dₘ and Dₘₚ, comparisons of differential dose volume histograms (DVHs) and average doses show that Dₘₚ provides a better overall estimate of dose to RBM and BSC. For example, in cranial spongiosa the average Dₘₚ underestimates the average dose to sensitive tissue by at least 5%, while average Dₘ is within ~1% of the average dose to sensitive tissue. Thus, it is better to specify Dₘₚ than Dₘ in Monte Carlo treatment plans, since Dₘₚ provides a better estimate of dose to sensitive tissue in bone, the only location where the difference is likely to be clinically significant.

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