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, D_m, or dose to water, D_w, 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 D_m or D_w 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 D_w and D_m in spongiosa. Dose uncertainties of ~1% (BSC, RBM) or ~0.5% (D_m, D_w) are obtained after up to 5 days of simulations on 88 CPUs. Clinically significant differences (>5%) between D_m and D_w 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 D_m and D_w, comparisons of differential dose volume histograms (DVHs) and average doses show that D_w provides a better overall estimate of dose to RBM and BSC. For example, in cranial spongiosa the average D_m underestimates the average dose to sensitive tissue by at least 5%, while average D_w is within ~1% of the average dose to sensitive tissue. Thus, it is better to specify D_w than D_m in Monte Carlo treatment plans, since D_w 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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