Optimization of Normal Tissue Sparing through Ion Selection

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The variable radiobiological effect (RBE) of heavier ions like carbon make it challenging to compare dose distributions across different ions. Comparisons must be made between the isoeffective dose, the product of the dose with the RBE, requiring the use of a model that can predict how RBE changes across different ions. This presentation will discuss Geant4 simulations of parallel opposed beams of protons, helium, lithium, beryllium, carbon, and neon ions incorporating a microdosimetric model of RBE. The beams are constructed to give a homogeneous isoeffective dose to a treatment volume in the center of a water phantom for tissues covering a range of cobalt equivalent alpha/beta ratios from 1 to 20 Gy. Normal tissue isoeffective doses are then compared for different ions across the range of normal tissue and target tissue radiosensitivities. The ion type yielding the optimal normal tissue sparing is found to be highly dependent on the alpha/beta ratio of both the normal and target tissue. For instance, the calculated isoeffective dose to normal tissue at a 5 cm depth varies by almost a factor of 5 for carbon ions, ranging from a factor of 2 less than the isoeffective dose of a similar proton treatment to a factor of 2 greater. The heavier ions such as carbon are superior in cases where the alpha/beta of the target tissue is low and the alpha/beta normal tissue is high. However, lighter ions such as lithium and beryllium appear to offer dose advantages similar to carbon but with considerably less normal tissue dose when the alpha/beta in the target tissue is high and the alpha/beta in the normal tissue is low.

Learning objectives

1) To understand the variation of isoeffective doses to normal tissues across ion types for a simple parallel opposed treatment.

2) To understand the dependency of isoeffective doses to normal tissues on the combination of both normal tissue radiosensitivity and target tissue radiosensitivity.