

# **A comparison of intensity modulated x-ray therapy to intensity modulated proton therapy for the delivery of non-uniform dose distributions**

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The distribution of biological characteristics such as clonogen density, proliferation, and hypoxia throughout tumors is generally non-uniform, therefore it follows that the optimal dose prescriptions should also be non-uniform and tumor-specific. Advances in intensity modulated x-ray therapy (IMXT) technology have made the delivery of custom-made non-uniform dose distributions possible in practice. Intensity modulated proton therapy (IMPT) has the potential to deliver non-uniform dose distributions as well, while significantly reducing normal tissue and organ at risk dose relative to IMXT.

In this work, a specialized treatment planning system was developed for the purpose of optimizing and comparing biologically based IMXT and IMPT plans. The IMXT systems of step-and-shoot (IMXT-SAS) and helical tomotherapy (IMXT-HT) and the IMPT systems of intensity modulated spot scanning (IMPT-SS) and distal gradient tracking (IMPT-DGT), were simulated.

A thorough phantom study was conducted in which several subvolumes, which were contained within a base tumor region, were boosted or avoided with IMXT and IMPT. Different boosting situations were simulated by varying the size, proximity, and the doses prescribed to the subvolumes, and the size of the phantom. IMXT and IMPT were also compared for a whole brain radiation therapy (WBRT) case, in which a brain metastasis was simultaneously boosted and the hippocampus was avoided. Finally, IMXT and IMPT dose distributions were compared for the case of non-uniform dose prescription in a head and neck cancer patient that was based on PET imaging with the Cu(II)-diacetyl-bis(N4-methylthiosemicarbazone (Cu-ATSM) hypoxia marker.

The non-uniform dose distributions within the tumor region were comparable for IMXT and IMPT. IMPT, however, was capable of delivering the same non-uniform dose distributions within a tumor using a 180° arc as for a full 360° rotation, which resulted in the reduction of normal tissue integral dose by a factor of up to three relative to IMXT, and the complete sparing of organs at risk distal to the tumor region.