Cureus

Kernel-Based Step-and-Shoot Beam Delivery via Hundreds of Isocenters for Hypofractionated Brain Radiosurgery

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Abstract
Published 03/06/2024

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Categories: Medical Physics, Radiation Oncology
Keywords: hypofractionated brain radiosurgery

How to cite this abstract
Ma L, Braunstein S, McDermott M, et al. (March 06, 2024) Kernel-Based Step-and-Shoot Beam Delivery via Hundreds of Isocenters for Hypofractionated Brain Radiosurgery. Cureus 16(3): a1136

Abstract

Objectives:

Hypofractionated radiosurgery is widely used for treating various brain tumors. In this study, we have developed a novel dose kernel-based step-and-shoot (DKS) approach by using hundreds of isocenters for hypofractionated brain radiosurgery and have implemented clinically for actual patient treatments.

Methods:

DKS was developed to mimic the concept of dynamic dose painting (DDP) with unlimited number of beams and isocenters for the Gamma Knife system as described in our previous publication. To clinically implement DKS, algorithms were developed to sequentially optimize a limited number (e.g., 100-200) of isocenters and their associated dose kernels of variable sizes and relative beam weights within a 3D target volume. These dose kernels were mostly placed in a layer-by-layer fashion reminiscent of the radioactive prostate seed implants. Clinical treatment plans of DKS were created and their deliverability and dosimetric parameters were always investigated and compared against the conventional treatment plans prior to its actual treatment delivery.

Results:

Most notably, DKS drastically (70% or more) improved the target dose homogeneity compared to the conventional Gamma Knife treatments, a result was found to rival that of ideal DDP delivery. In addition to the improved dose uniformity, DKS also produced identical or better dose coverage, dose conformity compared to the conventional treatments. For the first patient treated with DKS in clinical settings, a large diffusive brain tumor with a GTV-to-PTV margin of 5 mm was prescribed. For the case, DKS produced conformal target dose distribution (Paddick Conformity Index = 0.84) with reduced dose hot spots (Maximum Dose/Prescribed Dose = 117.6%) that aimed to alleviate radionecrosis concerns associated with excessive dose hot spots irradiating a significant amount of normal brain tissue that falls within the GTV-to-PTV margin, A result was found unachievable with the conventional treatment plans. The total treatment time for the DKS delivery was also encouragingly similar to that of conventional treatment despite of deploying hundreds of isocenters. Technical caveats of overcoming machine hardware constraints with such a high number of isocenters for actual clinical implementations will be presented at the meeting.

Conclusion(s):

DKS is technically feasible and clinically advantageous for hypofractionated radiosurgery of certain brain tumors that cannot be safely and effectively treated with the conventional treatment approaches using only handful of isocenters. Further studies are underway toward translating DKS on other treatment modalities as well as other disease sites.