Cureus

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Abstract
Published 03/06/2024

Dose Painting with the Gamma Knife Lightning Dose Optimizer: A Technique for Delivering a Simultaneous Integrated Boost to Areas of Recurrent or Residual Tumor in Brain Metastasis Resection Cavities

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Categories: Medical Physics, Radiation Oncology
Keywords: gamma knife

How to cite this abstract
Barbour A B, Gates E, Ford E, et al. (March 06, 2024) Dose Painting with the Gamma Knife Lightning Dose Optimizer: A Technique for Delivering a Simultaneous Integrated Boost to Areas of Recurrent or Residual Tumor in Brain Metastasis Resection Cavities. Cureus 16(3): a1106

Abstract

Objectives:

Following brain metastasis resection, approximately 10% of patients have radiographic evidence of recurrent or residual disease at the resection cavity. During adjuvant radiotherapy, such patients may benefit from a simultaneous integrated boost (SIB) to areas of gross disease in an attempt to improve local control. Historically, the Gamma Knife (GK) treatment platform has not provided an explicit method for creating a SIB. The recently introduced GK Lightning optimizer allows simultaneous automated optimization of multiple intracranial radiotherapy targets, but the use of this optimizer for a SIB has neither been described nor validated. Here, we describe the use of the GK Lightning optimizer to create a SIB plan and validate this method by measuring dose-delivery accuracy on radiochromic film in an anthropomorphic phantom.

Methods:

Radiochromic film was positioned in the cranium of an anthropomorphic phantom and simulation scan performed. A 15.7cc irregular contour was drawn to represent a brain metastasis resection cavity, a uniform 2mm radial-expansion contour created, and a 1.6cc contour drawn representing a nodule of gross tumor within the resection cavity. In GammaPlan v11.3.1, three targets were created with overlapping dose matrices. Targets were prescribed 3Gy (2mm expansion), 4Gy (resection cavity), and 5Gy (residual disease) in one fraction. Prescription doses were selected to match the radiochromic film's optimal dose range. Within the GammaPlan Lightning optimizer, full coverage was selected, no maximum dose was specified, and 'beam-on time' and 'low-dose' settings were iteratively adjusted to create a clinically acceptable plan. On the GK Icon system, an occipital mold was made, an unexposed film placed in the phantom's cranium, cone-beam co-registration conducted, and treatment delivered. The film was scanned and calibrated for absolute dosimetry using a calibration curve generated from a 6MV linear accelerator. To evaluate dose-painting accuracy, global gamma index (GI) analyses were performed at various dose and distance tolerances, excluding points below 30% of the maximum dose. The passing rate was defined as the percentage of points with GI < 1.

Results:

An 18-minute treatment plan with 40 shots was created and delivered. There were 7 shots to the 2mm margin (2.01 minutes of beam-on time), 27 to the resection cavity (12.63 min), and 6 to residual disease (3.14 min). Prescription isodose lines were 3Gy at 55% (2mm expansion, mean 4.8Gy), 4Gy at 69% (resection cavity, mean 5.2Gy), and 5Gy at 75% (residual disease, mean 6.1Gy). All target volumes had ⩾ 99% prescription dose coverage and the maximum dose was 6.9Gy. Paddick Conformality Indices were 0.79 (2mm expansion), 0.74 (resection cavity), and 0.15 (residual disease). Gamma index pass rate/mean GI/median GI were 77%/0.68/0.54 at 1%/1mm tolerance, 85%/0.58/0.49 at 2%/1mm tolerance, and 97%/0.34/0.28 at 2%/2mm tolerance. An average of 17,883 points were evaluated per analysis.

Conclusion(s):

We successfully created a SIB plan with the GK Lightning optimizer, verifying dose delivery within clinically acceptable tolerances. Future work is needed to determine optimal dose levels for use in clinical practice and to determine what disease entities may benefit from an intracranial SIB.