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Abstract
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Stereotactic Treatment of 40 Brain Metastases Over 5 Treatments: A Software Model Comparing Temporal versus Spatial Fractionation

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Abstract

Objectives:

Spatial fractionation involves partitioning a group of multiple metastases into subgroups, which are then treated on different days. This can result in fractionation of radiation dose to intervening normal tissue between metastases, yet the dose to targets will remain relatively unfractionated. A software model was created to test whether spatial fractionation of multiple brain metastases could reduce radiation dose to normal brain compared with traditional temporal fractionation.

Methods:

Using Python 3.6, a simplified matrix model of a human brain was created with forty tumors randomly generated throughout the brain, measuring 0.25 to 1.00 cc in size . The set of tumors was partitioned into 5 groups to minimize the sum of vol1 * vol2 * 1/d^2 for every possible pair of tumors within the same group. Tumors that were close together were assorted into different treatment groups with this formula. With simplified and idealized dosimetry, 6Gy x 5 was prescribed to all 40 tumors in a single plan, and compared with 17.5Gy x 1# prescribed to each group in its own plan, treated on its own day. These dosages equal the same BED for a tumor alpha/beta ratio of 10.0Gy. Spatial temporal IMRT (STIMRT) was used to account for bystander dose contributions to tumors occurring from treatments to other groups on other days. Next, the BED to intervening normal tissue voxels was calculated and summed for all 5 treatments, using an alpha/beta ratio of 2.5Gy for brain. A therapeutic ratio was calculated which was the mean tumor BED divided by the mean brain BED.

Results:

By using 5 temporal fractions, the mean brain BED was 32.0Gy, but by using spatial fractionation with 5 groups the mean brain BED dropped to 24.2Gy. Therapeutic ratio improved by 58%. As well the summed volume of brain tissue receiving over 70Gy BED (equivalent to 12 Gy x 1#) dropped from 21cc to 14cc in favor of spatial fractionation.

Conclusion(s):

Spatial fractionation was superior to temporal fractionation in this computer model for 40 small tumors, and resulted in reduced mean BED to the healthy brain, a reduced V12 equivalent (V70Gy BED), and an improved therapeutic ratio. This strategy was first reported by the author in 2014 in "Treatment of multiple brain metastases with a divide-and-conquer spatial fractionation radiosurgery approach". Similar scenarios could be modeled for existing treatment platforms, although planning software requires new tools such as polymetastases partitioning, BED-Volume Histograms (BVH), summed BED distributions and spatial temporal IMRT.