Interleaved carbon minibeams: An experimental radiosurgery method with clinical potential

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Abstract
Radiation therapy and radiosurgery for the CNS tumors, head-and-neck tumors, and benign neurological targets have well known limitations. Interleaved carbon minibeams is a novel experimental radiosurgery method that uses arrays of parallel, thin planes of carbon ion beams (minibeams). These minibeam arrays (300 µm or thicker), as their synchrotron-generated x-ray minibeam counterparts, are tolerated by normal tissues, including the CNS, at extraordinary high doses. The effect was first established with 25-37 µm x-ray beams (microbeams, <300 µm). Single-dose-fraction exposures of about 250 Gy in-beam in-depth doses produced no short- or long-term histological effects to the rat brain. Subsequently, x-ray minibeams as thick as 0.68 mm retained much of this tissue-sparing effect, and two arrays of such thick horizontal minibeams aimed at 90º to each other could be interleaved (or “interlaced”) to produce a solid beam at the target. In the present study four arrays of 0.3 mm carbon minibeams administered from 90º angles interleaved to ablate a 6.5-mm target in the rabbit brain. A single-fraction of 46.3 Gy physical target dose, relating to 139 photon-equivalent Gy (GyE) was produced, using an average 3.0 relative biological effectiveness (RBE). Contrast MRI at 65 days and 6 months, and H&E histology at 6 months, showed little to no damage in surrounding brain. These results indicate the method’s potential for clinical use. Advantages over conventional techniques include carbon therapy’s Bragg-peak dose deposition, high RBE culminating at the target, and sharp dose falloff, together with the minibeams’ sparing of non-targeted tissues and single-dose-fraction feature.

Key words: carbon therapy, minibeams, tissue sparing, tissue repair, high RBE radiation, single dose-fraction therapy, radioresistant tumors, sharp dose falloff, radiosurgery
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