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Original Report

Efficiency gains for spinal radiosurgery using multicriteria optimization intensity modulated radiation therapy guided volumetric modulated arc therapy planning

Huixiao Chen PhD [a,1], Brian A. Winey PhD [a,1], Juliane Daartz PhD [a], Kevin S. Oh MD [a], John H. Shin MD [b], David P. Gierga PhD [a,*]

[a]*Department of Radiation Oncology, Massachusetts General Hospital, Harvard Medical School, Boston, Massachusetts*
[b]*Department of Neurosurgery, Massachusetts General Hospital, Harvard Medical School, Boston, Massachusetts*

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Abstract

Purpose: To evaluate plan quality and delivery efficiency gains of volumetric modulated arc therapy (VMAT) versus a multicriteria optimization-based intensity modulated radiation therapy (MCO-IMRT) for stereotactic radiosurgery of spinal metastases.

Methods and materials: MCO-IMRT plans (RayStation V2.5; RaySearch Laboratories, Stockholm, Sweden) of 10 spinal radiosurgery cases using 7-9 beams were developed for clinical delivery, and patients were replanned using VMAT with partial arcs. The prescribed dose was 18 Gy, and target coverage was maximized such that the maximum dose to the planning organ-at-risk volume (PRV) of the spinal cord was 10 or 12 Gy. Dose-volume histogram (DVH) constraints from the clinically acceptable MCO-IMRT plans were utilized for VMAT optimization. Plan quality and delivery efficiency with and without collimator rotation for MCO-IMRT and VMAT were compared and analyzed based upon DVH, planning target volume coverage, homogeneity index, conformity number, cord PRV sparing, total monitor units (MU), and delivery time.

Results: The VMAT plans were capable of matching most DVH constraints from the MCO-IMRT plans. The ranges of MU were 4808-7193 for MCO-IMRT without collimator rotation, 3509-5907 for MCO-IMRT with collimator rotation, 4444-7309 for VMAT without collimator rotation, and 3277-5643 for VMAT with collimator of 90 degrees. The MU for the VMAT plans were similar to their corresponding MCO-IMRT plans, depending upon the complexity of the target and PRV geometries, but had a larger range. The delivery times of the MCO-IMRT and VMAT plans, both with collimator rotation, were 18.3 ± 2.5 minutes and 14.2 ± 2.0 minutes, respectively ($P < .05$).

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* Corresponding author. Massachusetts General Hospital, Radiation Oncology, 55 Fruit St, Cox 8, Boston, MA 01890.
E-mail address: dgierga@partners.org (D.P. Gierga).
[1] Co-first authors.

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Conclusions: The MCO-IMRT and VMAT can create clinically acceptable plans for spinal radiosurgery. The MU for MCO-IMRT and VMAT can be reduced significantly by utilizing a collimator rotation following the orientation of the spinal cord. Plan quality for VMAT is similar to MCO-IMRT, with similar MU for both modalities. Delivery times can be reduced by nominally 25% with VMAT.

Introduction

Stereotactic radiosurgery (SRS) has gained increasing importance in the treatment of patients with spine metastases.[1-3] Many studies have been presented using intensity modulated radiation therapy (IMRT) for spine SRS and established this technique as a treatment option for rapid pain relief and safe and effective tumor control.[3-5] However, IMRT treatments for spine SRS often require 30-60 minutes including imaging verification time in our clinic, which can be challenging for patients with substantial pain from tumor involvement or recent spine surgery.

Volumetric modulated arc therapy (VMAT) is an alternative technique to IMRT with the beam modulated by variable gantry speed, dose rate, and multileaf collimator motion. Earlier studies have shown that VMAT provides comparable dose distributions and improved delivery efficiency when compared with IMRT for a variety of treatment sites,[6-11] but very few data exist on spine SRS cases.

All IMRT and VMAT SRS cases in our department are planned on the RayStation treatment planning system (Version 2.5, RaySearch Laboratories, Stockholm, Sweden). The IMRT plans are generated using the multicriteria optimization (MCO) approach, which has been demonstrated to be beneficial for a variety of treatment sites.[12,13] The MCO approach is based on Pareto-surface techniques to generate a database of optimal plans that satisfy different objectives and criteria. The planner can navigate interactively through this database by exploring convex combinations of the database to achieve an optimal plan with the desired tradeoff between different planning objectives.[14,15] MCO has only recently become clinically available for VMAT. We utilize an approach termed MCO-IMRT guided VMAT optimization, where output dose-volume histogram (DVH) point values of MCO-IMRT from a clinically acceptable MCO-IMRT plan are utilized as a starting point for VMAT optimization.[16]

The presented study compares plan quality and delivery efficiency between VMAT and MCO-IMRT plans for spine metastases treated with spine SRS. Furthermore, the influence of collimator rotation was also evaluated for both treatment methods because rotating the collimator may provide benefits given the relative geometry of the spinal cord and target.

Methods and materials

Patients, volume definition, and SRS dose prescription

Ten patients were randomly selected from a clinical set of spinal radiosurgery cases treated in our department. The treatment sites range from T1 to L4. Figure 1 shows the patient anatomy for an L3-4 spine case; all patients were immobilized in a vacuum cushion. For site T4 and above, a head and shoulder mask was also used. The target volume was defined per guidelines of Radiation Therapy Oncology Group 0631, with a clinical target volume (CTV) defined for radiation planning purposes. For gross disease limited to the vertebral body, the CTV included the vertebral body and both pedicles. For gross disease that extended into a pedicle, the CTV was extended to include

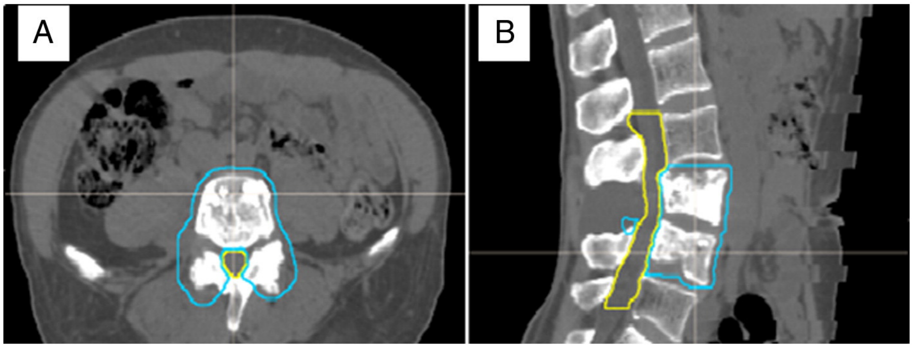

Figure 1 Patient anatomy on (A) transversal computed tomographic slice and (B) sagittal computed tomographic slice. (Blue contour, planning target volume; yellow contour, spinal cord planning organ-at-risk volume.