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Dosimetric comparison of photon and proton treatment techniques for chondrosarcoma of thoracic spine

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ABSTRACT

Chondrosarcomas are relatively radiotherapy resistant, and also delivering high radiation doses is not feasible owing to anatomic constraints. In this study, the feasibility of helical tomotherapy for treatment of chondrosarcoma of thoracic spine is explored and compared with other available photon and proton radiotherapy techniques in the clinical setting. A patient was treated for high-grade chondrosarcoma of the thoracic spine using tomotherapy. Retrospectively, the tomotherapy plan was compared with intensity-modulated radiation therapy, dynamic arc photon therapy, and proton therapy. Two primary comparisons were made: (1) comparison of normal tissue sparing with comparable target volume coverage (plan-1), and (2) comparison of target volume coverage with a constrained maximum dose to the cord center (plan-2). With constrained target volume coverage, proton plans were found to yield lower mean doses for all organs at risk (spinal cord, esophagus, heart, and both lungs). Tomotherapy planning resulted in the lowest mean dose to all organs at risk amongst photon-based methods. For cord dose constrained plans, the static-field intensity-modulated radiation therapy and dynamic arc plans resulted target underdosing in 20% and 12% of planning target volume2 volumes, respectively, whereas both proton and tomotherapy plans provided clinically acceptable target volume coverage with no portion of planning target volume2 receiving less than 90% of the prescribed dose. Tomotherapy plans are comparable to proton plans and produce superior results compared with other photon modalities. This feasibility study suggests that tomotherapy is an attractive alternative to proton radiotherapy for delivering high doses to lesions in the thoracic spine.

Introduction

Chondrosarcomas are a heterogeneous group of malignancies characterized by tumor cell production of cartilage matrix. Chondrosarcomas account for 7% to 20% of all primary malignant bone tumors.[1] Up to 10% of chondrosarcomas involve the mobile spine, and this location presents unique treatment challenges.[2-5] *En bloc* resection remains the mainstay of chondrosarcoma management, and the extent of the surgery has been closely correlated with prognosis. Unfortunately, margin-negative resection of spinal lesions may not be feasible without considerable morbidity. Historically, the anatomic obstacles to extirpation have led to poor outcomes for patients with spine chondrosarcomas. Camins *et al.* found that the 5-year survival rate for chondrosarcomas of the spine was 21%.[2] Based on these outcomes, radiation therapy has been investigated as an adjuvant therapy.

Chondrosarcomas are relatively resistant to radiation therapy. Consequently, high doses are usually advocated for durable local control, particularly in the setting of residual disease.[6] As in the case of surgery, however, anatomic constraints limit the ability to safely deliver high radiation doses. The commonly observed spinal cord radiation tolerance dose of 45 to 55 Gy is well below the radiation dose required to control chondrosarcomas. Consequently, innovative radiation therapy techniques have been explored to permit safe, therapeutic dose escalation. These techniques have included dural plaque brachytherapy, intensity-modulated radiotherapy (IMRT), proton therapy, and carbon ion therapy.[7-10]

In this study, we examine the utility of helical tomotherapy in the adjuvant treatment of chondrosarcoma of the thoracic spine. The delivered tomotherapy plan is compared with a traditional static-field IMRT plan, a dynamic arc plan, and a proton

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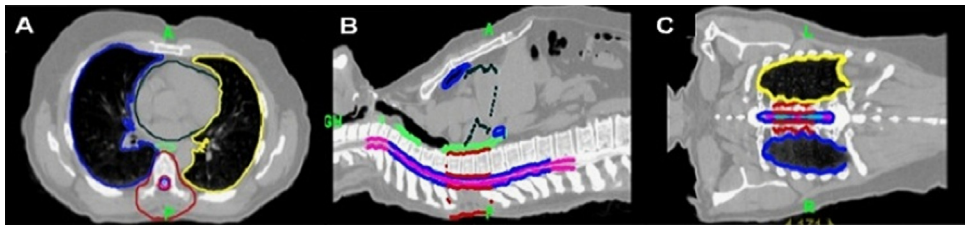

Fig. 1. (A) Transverse, (B) sagittal, and (C) coronal view of the kVCT images obtained from discovery light speed (DLS) scanner with heart (black), lungs (right-blue and left-yellow), esophagus (green), PTV (red), cord-center contours (pink). kVCT = kilovoltage CT. (Color version of figure is available online.)

radiotherapy plan. Both target volume and sensitive normal tissue dosimetries are examined.

Case Description

A 65-year-old male presented with 2 months of progressive bilateral lower extremity weakness and numbness accompanied by back pain. One day prior to presentation, the patient noted complete paraplegia and loss of urinary continence. Magnetic resonance imaging of the spine was performed and the image obtained revealed a peripherally enhancing, extradural spine lesion impinging the cord at T6. Corticosteroids were initiated and the patient was taken emergently for partial laminectomies of T5 and T7, laminectomy of T6, and piecemeal resection of epidural tumor. Intraoperatively, the lesion was found to extensively involve the spinous process of T6. Pathology revealed high-grade chondrosarcoma and margins were not assessable because of the piecemeal resection. Computed tomography (CT) of the chest, abdomen, and pelvis identified no metastatic disease. Postoperative magnetic resonance imaging revealed no gross residual disease and adjuvant radiation therapy was recommended.

CT-guided simulation, with concurrent myelography, was performed on a Discovery Light Speed (DLS) scanner. The kilovoltage CT images were exported to Pinnacle^3 (Philips Medical Systems, Fitchburg, WI) Version 9.0 m treatment planning system. The attending radiation oncologist contoured the clinical target volumes and regions of interest including the spinal cord, spinal cord center, esophagus, heart, and both lungs (Fig. 1). Planning target volumes (PTVs) were generated by uniform expansion of the clinical target volumes by 5 mm. PTV1 was prescribed 50.4 Gy in 28 fractions, followed by a sequential boost

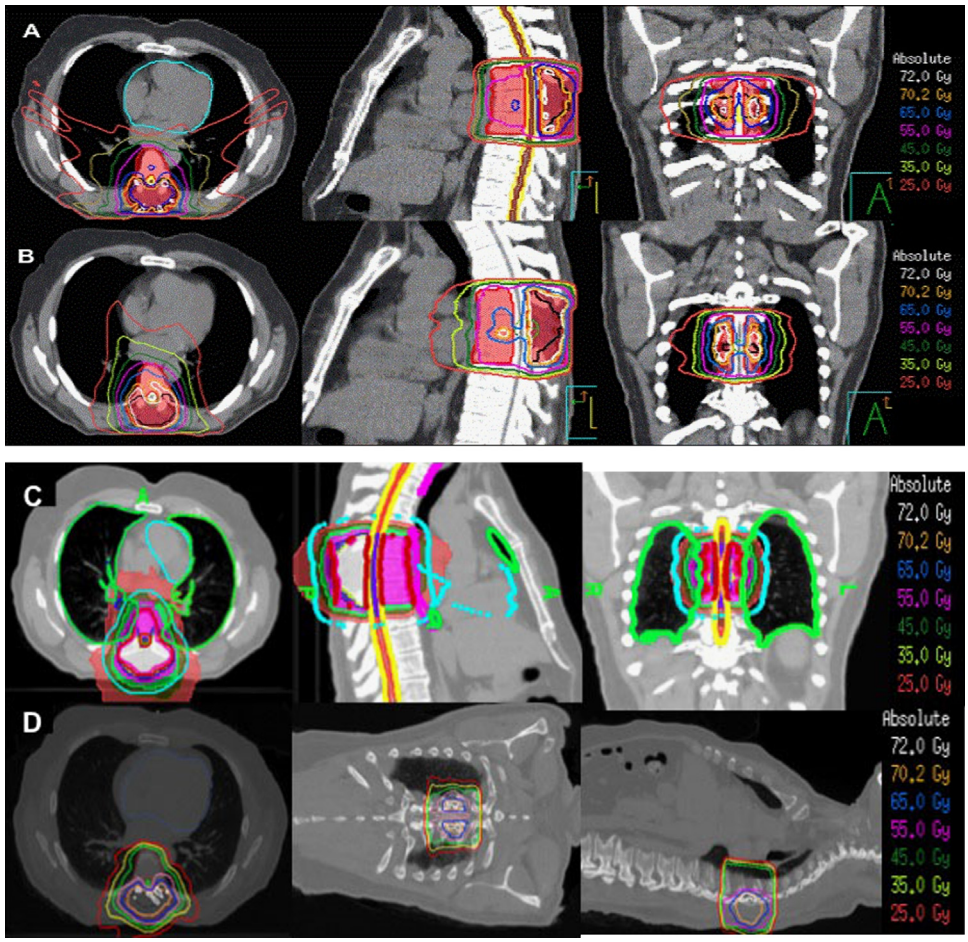

Fig. 2. Adequate delineation of isodose lines in all 3 views transverse, sagittal, and coronal (left to right) for (A) static-field IMRT, (B) dynamic arc therapy, (C) helical tomotherapy and (D) proton radiation therapy plans are represented respectively. Absolute isodose lines for 72, 70.2, 65, 55, 45, 35, and 25 Gy are displayed for all 4 plans.(Color version of figure is available online.)