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Spine SBRT using VMAT

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Abstract. Metastases of the spinal column are common amongst cancer patients with approximately 18,000 new cases in North America each year that require urgent treatment. Historically radiation therapy doses have been limited due to the proximity of the spinal cord. However as image guidance and localization techniques have improved it has become possible to deliver higher radiation doses to the tumour whilst sparing the spinal cord. This paper presents some of the techniques undertaken at our center.

1. Introduction

Metastases of the spinal column are common amongst cancer patients with approximately 18,000 new cases in North America each year that require urgent treatment [1]. Metastases are the most common group of spinal column tumours, with post mortem examination of terminal cancer patients revealing spinal metastasis in more than 70% of patients [2]. Approximately 10% of cancer patients develop symptomatic lesions, with the primary presenting symptom being pain. As such the primary goal of treatment is pain relief.

A single fraction of 8Gy has been shown to have similar efficacy to a conventional fractionated regimen of 30Gy in 10 fractions, whilst maintaining a low rate of adverse affects [3]. A single fraction treatment presents an advantage to the patient in ease of treatment, and reduced machine time required at the treatment facility. Approximately 61% of patients treated in this study experienced pain relief at 1 month post treatment. The rate of pain control may be improved by treating to higher radiation doses, however, the close proximity to the spinal cord has been the limiting factor in previous studies.

Stereotactic Body Radiation Therapy (SBRT) techniques allow the delivery of high doses of radiation precisely and accurately to the target [4, 5]. The clinical feasibility of SBRT for treating spinal column metastases was first demonstrated in 2003 [6], with targeting accuracy reported as less than 1.5mm. Dose escalation studies have shown rapid improved pain relief when treated up to 16Gy in a single fraction [7]. However only a small number of patients were treated on these studies. RTOG 0631 is a multi-institutional study, began in 2009, designed to show the clinical feasibility of SBRT for the treatment of spine metastases. RTOG 0631 also aims to investigate the efficacy of 16Gy vs. 8Gy single fraction radiation therapy for the relief of pain.

This paper presents our clinical experience using VMAT for SBRT delivery and steps taken to improve it.



2. Methods

2.1 Optimization Objectives

Montefiore Medical Center (MMC) began treating spine metastases using SBRT in January 2008, planning goals at this time were simply to achieve the best possible coverage whilst meeting cord dose constraints. Since Sept 2011 additional constraints were added according to the RTOG 0631 [8] (Spine SBRT), 0813 [9] & 0915 [10] (Lung SBRT) protocols.

0631 established detailed requirements for treatment planning, which included prescription isodose surface coverage, target dose heterogeneity, high dose spillage, spinal cord dose, low dose spillage, and critical organ dose-volume limits. Regarding the low dose spillage, 0631 only indicated, “The falloff gradient beyond the target volume extending into normal tissue structures must be rapid in all directions” without quantitative definition of the dose falloff gradient. However, both RTOG 0813 & 0915 clearly specified intermediate dose spillage criteria based on the size of planning target volumes (PTVs). Dosimetric comparison of 31 lesions treated before and 35 lesions treated after these constraints were added shows improvement in almost all aspects of treatment planning [11].

2.2 Beam Arrangement

In early 2013 a standard beam arrangement utilizing Volumetric Arc Therapy (VMAT) was introduced to simplify treatment delivery and plan QA workflows. Initially treatments used a single arc with collimator set to 45°. Two coplanar 360° arcs are now used with collimators set to 0° and 90° respectively. This minimizes collimator opening size and reduces low dose spillage as shown in figure 1. Avoidance sectors are used to skip patient shoulders and/or arms as necessary.

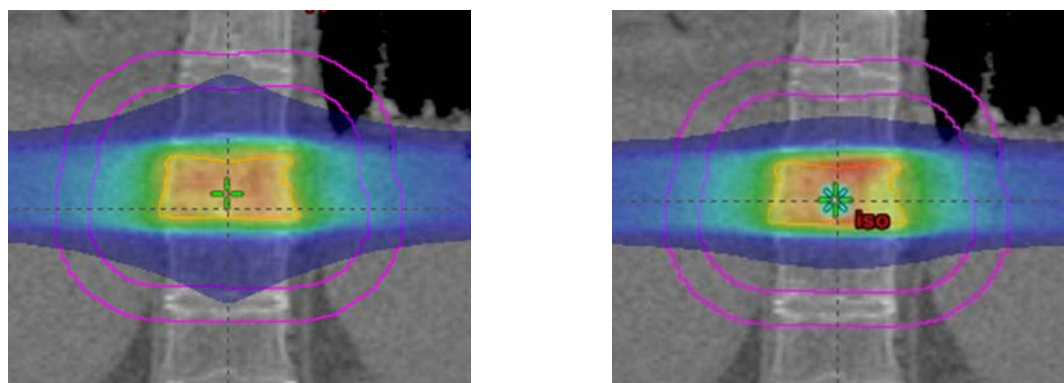


Figure 1. >5% dose colourwash for a single (left) and dual arc (right) configuration.

To show the advantages of this technique, 19 patients initially treated using Static IMRT fields were first replanned using current planning guidelines. These patients were then replanned using our standard VMAT beam arrangement. Dosimetric comparison of these plans showed a reduced maximum dose 2cm from the target (D2cm), ratio of the volume receiving 50% of prescription dose to target volume (R50) and maximum skin dose for VMAT plans, whilst maintaining target coverage and maximum dose to the spinal cord.

Additional treatment plans were also created using a 3 field Intensity Modulated Proton Therapy (IMPT) technique. As shown in Figure 2, similar cord maximum doses are achievable using IMPT, however dose conformity index (CI) for smaller targets is worse. Figure 3 shows IMPT has higher D2cm values, however, this is due to the limited number of fields used. R50 values are better for IMPT plans for larger targets.

2.3 Patient Positioning

Patient planning CT scans are performed in a head first supine position with the patient arms raised for disease of the lower thoracic spine and lumbar spine, and arms down for disease of the upper thoracic spine and cervical spine. Patients are immobilized using the Elekta BlueBAG BodyFIX vacuum cushion, to allow for comfortable stable positioning. CBCT positioning verification is performed before each treatment.

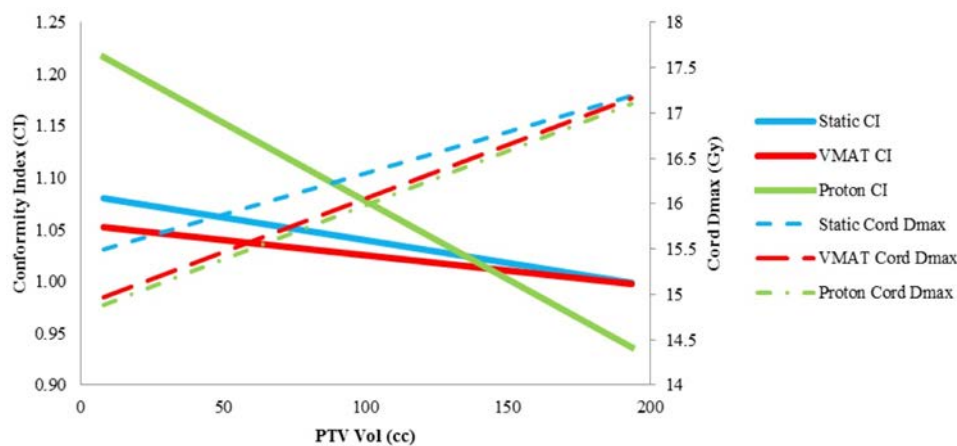


Figure 2. Conformity Index and maximum cord dose for static IMRT photon therapy, VMAT and IMPT.

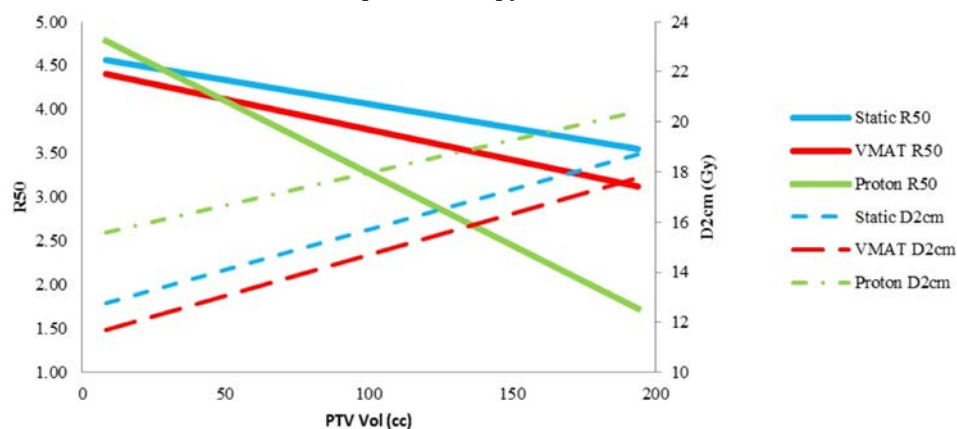


Figure 3. R50 and D2cm for static IMRT photon therapy, VMAT and IMPT.

2.4 Cord Compression

Metastatic epidural spinal cord compression (MESCC) occurs in approximately 5% of diagnosed patients [12]. If not addressed this can lead to permanent neurologic defects, including paraplegia. Conventional treatment techniques include surgery followed by radiation therapy. However for patients who are not surgical candidates definitive radiation therapy is required.

SBRT dose constraints have previously used the thecal sac as a surrogate for the spinal cord, however, RTOG 0631 recommends the true cord be delineated using an MRI registered to the planning CT. Another option for true cord delineation is CT Myelogram (CTM). Comparison of the true cord as contoured using CTM vs. MRI shows excellent agreement between the two modalities as shown in Figure 4. The use of CTM removes any uncertainties caused by image registration, and for this reason is the preferred method used at MMC.

When the true cord is within 3mm of the PTV, underdose of the PTV in this margin is acceptable to ensure Cord dose constraints are met. This is common in cases of MESCC, however, leads to sub

optimal PTV coverage and the possibility of disease progression [13]. An adaptive planning study is currently underway at MMC in which patients with MESCC receive an initial SBRT treatment of 8 Gy, with the hopes of increasing the patency of the spinal canal. Patients then receive a second SBRT treatment 14-21 days later, based upon the radiographic response of the disease.

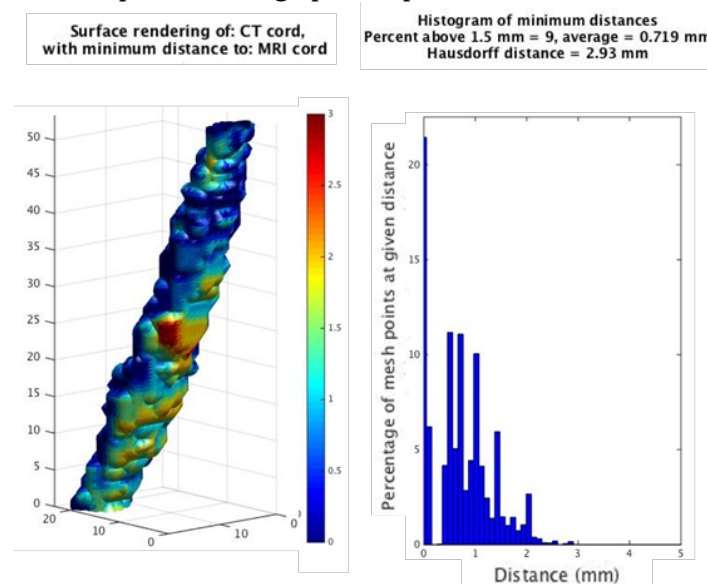


Figure 4. Distance between true cord as contoured using CTM and MRI imaging.

3. Conclusions

Using intermediate dose spillage criteria based on PTV size VMAT Spine SBRT plans can be improved regarding dose coverage, conformity, and dose falloff. In order to achieve this clearly established planning objectives are necessary to ensure quality of spine SBRT treatment plans [11].

VMAT treatment techniques offer improved dose falloff and sparing of normal tissues, whilst reducing overall treatment time compared to static field IMRT. Moreover, IMPT may offer an improved treatment in some cases and could be an important tool in the delivery of SBRT for metastatic epidural spinal cord compression. However, IMPT does not necessarily represent the optimal treatment modality unless range uncertainties can be minimized to guarantee that the dose gradient between PTV and Spinal Cord can indeed be achieved and the treatment can be safely and accurately delivered.

4. References

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