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Original Report

Dosimetric feasibility of magnetic resonance imaging-guided tri-cobalt 60 preoperative intensity modulated radiation therapy for soft tissue sarcomas of the extremity

Amar U. Kishan MD*, Minsong Cao PhD, Argin G. Mikaeilian BS, Daniel A. Low PhD, Patrick A. Kupelian MD, Michael L. Steinberg MD, Mitchell Kamrava MD

Department of Radiation Oncology, University of California, Los Angeles, Los Angeles, California

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Abstract

Purpose: The purpose of this study was to investigate the dosimetric differences of delivering preoperative intensity modulated radiation therapy (IMRT) to patients with soft tissue sarcomas of the extremity (ESTS) with a teletherapy system equipped with 3 rotating ^{60}Co sources and a built-in magnetic resonance imaging and with standard linear accelerator (LINAC)-based IMRT.

Methods and materials: The primary study population consisted of 9 patients treated with preoperative radiation for ESTS between 2008 and 2014 with LINAC-based static field IMRT. LINAC plans were designed to deliver 50 Gy in 25 fractions to 95% of the planning target volume (PTV). Tri-^{60}Co system IMRT plans were designed with ViewRay system software.

Results: Tri-^{60}Co-based IMRT plans achieved equivalent target coverage and dosimetry for organs at risk (long bone, skin, and skin corridor) compared with LINAC-based IMRT plans. The maximum and minimum PTV doses, heterogeneity indices, and ratio of the dose to 50% of the volume were equivalent for both planning systems. One LINAC plan violated the maximum bone dose constraint, whereas none of the tri-^{60}Co plans did.

Conclusions: Using a tri-^{60}Co system, we were able to achieve equivalent dosimetry to the PTV and organs at risk for patients with ESTS compared with LINAC-based IMRT plans. The tri-^{60}Co system may be advantageous over current treatment platforms by allowing PTV reduction and by elimination of the additional radiation dose associated with daily image guidance, but this needs to be evaluated prospectively.

Introduction

Radiation therapy is an important modality in the multidisciplinary management of extremity soft tissue sarcomas (ESTS). Although surgery remains the primary treatment, radiation therapy given either preoperatively or

Conflicts of interest: Dr Low and Dr Kupelian are on the Scientific Advisory Board of ViewRay, Inc. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

* Corresponding author. Department of Radiation Oncology, University of California, Los Angeles, 200 UCLA Medical Plaza, B265, Los Angeles, CA 90095.

E-mail address: aukishan@mednet.ucla.edu (A.U. Kishan).

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postoperatively significantly improves local control compared with observation.[1,2] Most centers prefer to deliver preoperative radiation therapy because oncological outcomes are similar to those with postoperative radiation therapy, but the dose is lower and the field size smaller, thereby reducing the risk of long-term complications such as joint stiffness, fibrosis, and edema.[3,4] All of the landmark radiation therapy studies were performed in the era of 3-dimensional conformal radiation therapy; since then, technological improvements have led to widespread capabilities to deliver highly conformal intensity modulated radiation therapy (IMRT). Single-institution data suggest that highly conformal IMRT plans may improve local control and reduce toxicity.[5-7] Contemporaneously, improvements in online imaging technologies have greatly increased the accuracy and availability of image guided radiation therapy (IGRT). These advances allow pretreatment or even intratreatment imaging to be used to verify that radiation is being delivered as intended. Preliminary results from a phase 2 Radiation Therapy Oncology Group trial of IGRT for preoperative radiation therapy of ESTS even suggest a reduction in late complications with the implementation of IGRT.[8]

Although the use of computed tomography (CT)-based IGRT allows reductions in the suggested planning target volume (PTV) margins to 5 mm, these smaller margins require more frequent imaging to verify accurate patient positioning. The cost of accomplishing this is that patients are exposed to additional radiation dose.[9]

Real-time magnetic resonance imaging (MRI)-based image guided IMRT could allow for enhanced confidence in PTV margin reduction by directly accounting for interfractional and intrafractional motion via real-time high-resolution MRI-based imaging. Furthermore, it would achieve this without exposing patients to the additional radiation dose associated with onboard imaging platforms.

Recently, a commercially available MRI-guided tri-^{60}Co teletherapy platform gained clearance from the US Food and Drug Administration for use in radiation therapy (Fig 1).[10] Because ^{60}Co emits gamma rays via radioactive decay, this tri-^{60}Co system obviates any MRI-LINAC (linear accelerator) interactions. Additionally, by using a 0.35-T magnet, this tri-^{60}Co system minimizes Lorentz force-dependent effects.[10-12]

The potential benefits of real-time MRI-based image guided IMRT must be weighed against the fact that ^{60}Co-based devices typically generate beams that have poorer tissue penetration and broader penumbrae. The purpose of this study, therefore, was to compare the dosimetry of preoperative IMRT for ESTS using this MRI-guided tri-^{60}Co system with LINAC-based IMRT.

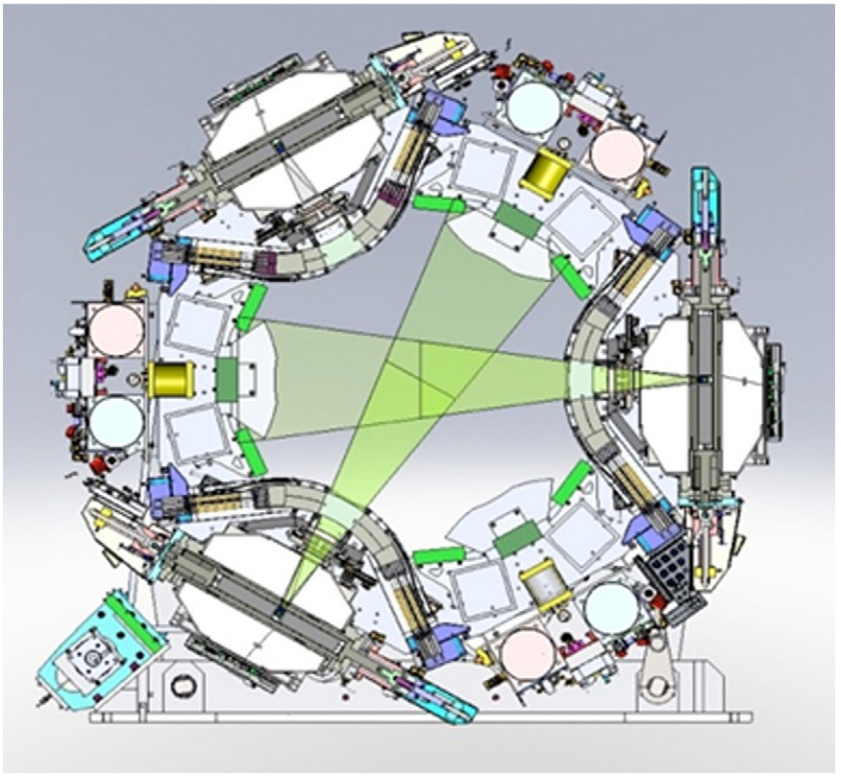

Figure 1 Cutaway view of the ViewRay system exposing the quadrant of the magnetic resonance imaging bore through the 28-cm gap and half of a radiation therapy head at 90°. Adapted from Mutic and Dempsey.[10]