Comparison of Monte Carlo and Pinnacle Algorithms in Palliative Radiation to the Spine in the Presence of Titanium Hardware

Charlotte Dai Kubicky, MD PhD, Tony He PhD, Paul H. Cooper CMD, Tenzin Stelljes, BS
Brian T. Ragel MD, Wolfram U. Laub PhD
Departments of Radiation Medicine and Neurosurgery, Oregon Health & Science University

OREGON HEALTH & SCIENCE UNIVERSITY

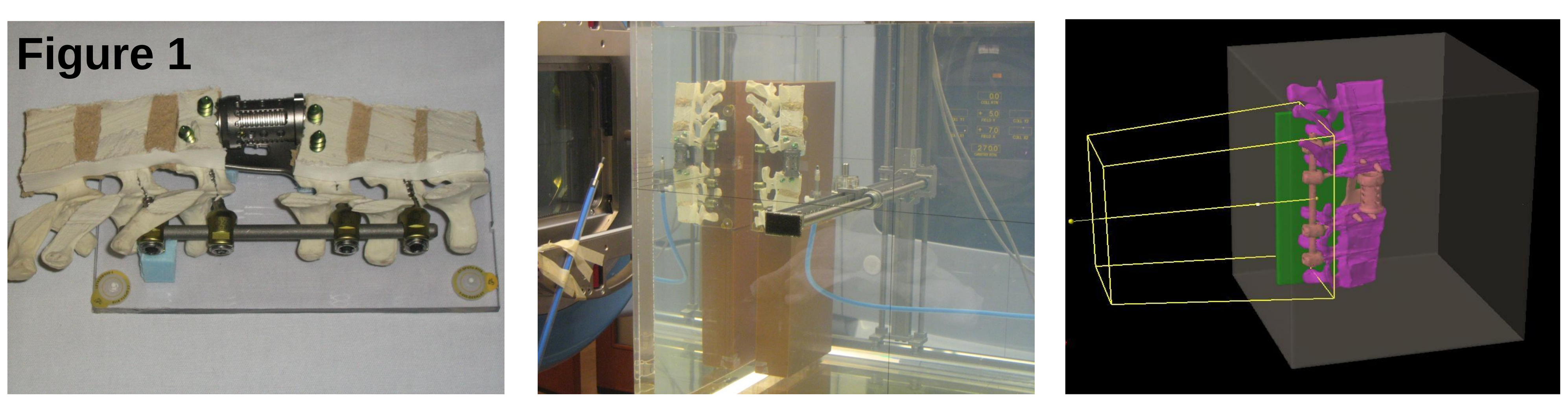
Background

Metallic hardware is often required in the surgical management of spine tumors. Previous studies have shown dose perturbations caused by spine fixation hardware in a phantom. In this study, we sought to determine whether treatment planning algorithms can accurately predict radiation doses in the presence of titanium hardware.

Methods

A spine model was instrumented to replicate a typical setup consisting of pedicle screws, rod, expandable vertebral body cage, and lateral mass Plate (Figure 1) The spine model was placed in a PTW water tank with 0o and 270o gantry irradiation. Doses were measured using a 0.125cc ion chamber. CT images of the above setup were transferred to Pinnacle and the XVMC Monte Carlo based planning system Hyperion with the correct densities assigned. Doses were calculated using the collapsed cone algorithm in Pinnacle and XVMC and compared with ion chamber measurements.

Figure 1



We selected 9 patients with spine hardware who received post-operative radiotherapy using standard AP/PA fields. In all patients, the titanium hardware and CT artifacts were contoured and were overridden with a density value of 4.5 and 1.0, respectively. Treatment planning was first performed in Pinnacle with heterogeneity correction. 30 Gy in 10 fractions was prescribed to cover 90% of the vertebral bodies (VB). All plans were re-calculated using the fast Monte Carlo code XVMC with the same beam settings and monitor units (MUs). We compared the Pinnacle and Monte Carle plans using the following endpoints: VB V30Gy, spinal cord D0.1cc, D1cc, D5cc.

Results

In the phantom study, both Pinnacle and Monte Carlo dose calculations agreed reasonably well with ion chamber measurements at 6 points along the spine. Dose differences were within 2% for Pinnacle and 3% for Monte Carlo simulations calculated with a standard deviation of 1%. Pinnacle and Monte Carlo calculations agreed well for open field calculations in solid water phantoms and for in-patient calculations where the density inside the entire patient was set to 1.0.

In the clinical study, using the same MUs, Monte Carlo calculations resulted in 17.4% lower target coverage (P= 0.004, paired t –test). Mean VB V30Gy was 90% ± 0% for Pinnacle, and 72.6% ± 13.2% for Monte Carlo. Monte Carlo calculations also predicted higher D0.1cc (3.6%), D1cc (3.6%), and D5cc (5.8%) to the spinal cord (P=0.002, paired t–test).

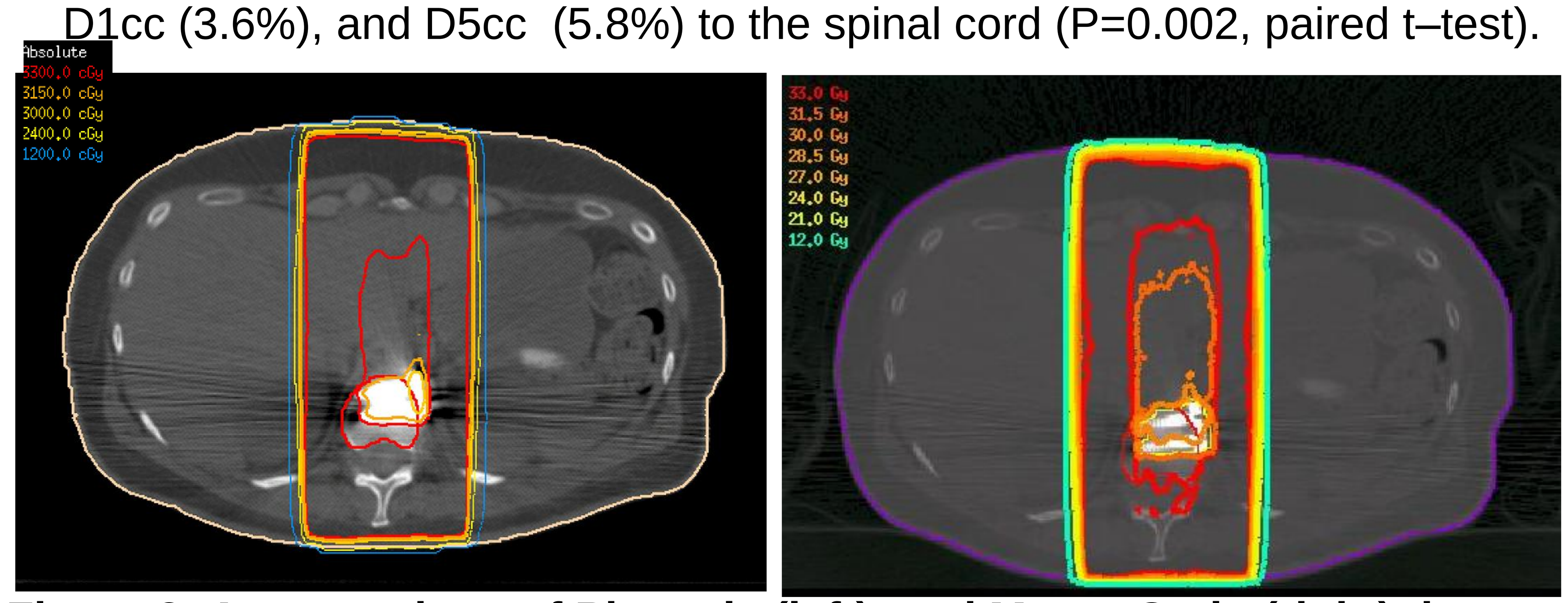


Figure 2: A comparison of Pinnacle (left) and Monte Carlo (right) dose distributions.Pinnacle calculations showed lower doses within the hardware, whereas Monte Carlo calculations showed a dose lowering effect extending beyond the hardware, leading to a decrease in coverage of vertebral bodies.

Conclusions

Both Monte Carlo and collapsed Pinnacle cone algorithms had reasonably good agreement with dose measurements in a phantom at the dose points selected. However, our preliminary clinical study showed that Monte Carlo predicted significantly lower target coverage (17.4%). This is due to a dose lowering effect extending beyond the hardware, extending into the vertebral bodies and adjacent soft tissue. This finding warrants further investigation.

Knight Cancer Institute at Oregon Health & Science University