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Abstract

Dosimetric Evaluation of Spine Radiosurgery With a Novel Carbon Fiber Spinal Instrumentation System

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Objectives: Traditional titanium alloy and stainless steel implants are used in spinal oncology for stabilization. Surgical tumor removal followed by spinal fixation with metallic screws and rods is used in cases spinal compression and instability. Radiation is given postoperatively to improve local control. Spine radiosurgery (SRS) is increasingly used in this setting because it may give better local tumor control and reduce complications by avoiding radiation dose to normal tissue. However, these metallic implants interfere with SRS by attenuating radiation beams and by limiting beam directions available for irradiation. Furthermore, dose calculation algorithms may not accurately predict the dose around these metallic implants. A novel metal-free spinal instrumentation system is now available for use in spinal oncology. This study was performed to evaluate dosimetric improvements in spine SRS using this new system.

Methods: The CarboClear® Pedicle Screw System is a metal-free carbon-fiber-reinforced polyethil-ether-ether-ketone (CFR-PEEK) spinal instrumentation system. Its biomechanical properties are similar to titanium instrumentation. A series of 10 spine SRS cases from our center with titanium hardware were selected for dosimetric analysis. All SRS cases were replanned, artificially replacing the density of the titanium hardware with the density of the new CFR-PEEK hardware. Dose calculation was performed using the Acuros XB dose calculation algorithm in the Varian Eclipse treatment planning system. Treatment plans with titanium implants were restricted to avoid having beams enter directly through the instrumentation plus a 2 mm margin of uncertainty. Two identical Sawbones models made from rigid polyurethane were used (1 using titanium implants and 1 using CFR-PEEK) with a construct for an L-spine tumor including screws, rods and crosslinks. A series of measurements were taken to confirm the attenuation of the titanium and CFR-PEEK hardware placed in these models as well as the ability of the dose algorithms to correctly predict the dose. EBT3 film dosimetry was used to measure attenuation of radiation through the titanium and CFR-PEEK hardware in the models. LiF TLDs were used to measure dose near the hardware and at the level of the L3 "tumor" placed in a water phantom.

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Results: Treatment plans with titanium hardware showed an average of 8.6% lower target coverage than those with CFR-PEEK hardware (82.7% vs 91.3%). Conformity index for the plans was not significantly different (1.29 vs 1.19), while larger differences were seen for gradient index (1.92 cm vs 2.25 cm). Plans were deliberately prescribed to keep the peak dose to the spinal cord or cauda equina equivalent in the two plans (8.84 Gy vs 8.85 Gy). The EBT3 film dosimetry showed better agreement with the CFR-PEEK than the titanium hardware (Gamma pass rate 99.8% vs 93.1%). The ratio of measured/predicted doses for TLDs near the CFR-PEEK was 1.00 ± 0.01; the TLDs near the titanium was 1.031 ± 0.05.

Conclusions: A metal-free carbon fiber spinal instrumentation system was found to have superior target coverage in SRS plans compared to current titanium implants. Treatment planning system dose calculations near the implants demonstrated superior agreement with measurements for the CFR-PEEK hardware.