Proton Therapy Reduces Normal Tissue Dose Compared to Intensity Modulated Radiation Therapy in Extended Field Pelvic Radiation Therapy for Gynecologic Malignancies

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Purpose/Objective(s): We dosimetrically compared pencil beam scanning proton therapy (PBS) and intensity modulated radiation therapy (IMRT) for pelvic and para-aortic lymph node (PALN) disease in gynecologic malignancies and present acute toxicities associated with extended-field PBS.

Materials/Methods: Eight patients with locally advanced gynecologic malignancies were enrolled on an image guided PBS study. Organs at risk included pelvic bone marrow (PBM), small bowel (SB), large bowel (LB), rectum, kidneys, and bladder. IMRT plans were retrospectively compared and clinical employed PBS plans using Wilcoxon signed-rank tests.

Results: Compared to IMRT, PBS plans appear to result in significantly lower dose-volumes, with a 2.6% to 7.5% reduction in median V20 (PBS 62.0% vs IMRT 78.5%, \(P < 0.05\)) and higher dose-volumes from 34.5 Gy to 50.5 Gy (\(P < 0.01\)). For SB and LB, PBS resulted in significantly lower dose-volumes compared to IMRT (\(P < 0.05\)) from 0 Gy to 37 Gy and 0 Gy to 39.5 Gy, respectively. Two patients had grade 4 hematologic toxicities, and no patients had grade 3+ gastrointestinal toxicities.

Conclusion: Extended-field PBS is clinically feasible, resulting in statistically significant dose reduction to PBM, SB, and LB, and reduced to comparable acute gastrointestinal and hematologic toxicity profiles compared to IMRT.


The Physics of a Novel Compact Linear Accelerator—Based Magnetic Resonance Imaging—Guided Radiation Therapy System

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Purpose/Objective(s): To explain the physics of the enabling technology behind a compact linear accelerator (Linac)—based MRI-guided radiation therapy (MR-IGRT) system.

Materials/Methods: The compact MR-IGRT system integration required overcoming 3 challenges: (1) MRI operate using magnetic fields of thousands to tens of thousands of Gauss. Magnetic fields as small as a few Gauss can negatively affect operation of magneto-rons, port circulators, and electron beam accelerators. The magnetic fields at these components were reduced by placing these systems in nested, coaxial, cylindrical steel sleeves, arranged in 6 locations symmetrically around the isocenter. The RF power in waveguides could be lost due to the Faraday effect, so they were oriented such that the RF wave propagation direction was perpendicular to the local MRI magnetic field, avoiding RF loss. (2) MRI systems use the measurement of weak RF signals that provide the raw data for image acquisition. Linac use strong RF fields to accelerate electrons, potentially leaking RF waves that would degrade MR images. Rather than enclose the RF-generating systems within standard Faraday cages, which would efficiently reflect the RF within the cages and allow it to leak out of small gaps, carbon fiber was used to both reflect and absorb the RF. This made the shielding more mechanically robust and limited the intensity of the RF leaking out of the cages. (3) Most modern Linacs use singly divergent multileaf collimators (MLCs). Such a design for the MR-IGRT system would place the motors and encoders in a very high magnetic field region. The system employed doubly focused MLC leaves, placing the motors and controllers farther from isocenter than would be possible with singly divergent systems.

Results: (1) The magnetic fields at the critical locations were measured to be less than 40 Gauss, significantly below the amount needed for the magnetron and port circulator. Additional mu-metal was employed to reduce the magnetic field at the Linac to less than 1 Gauss. (2) Within a 1.2-MHz band centered on 14.7 MHz (the Larmor frequency for the system), the radiofrequency leakage from the Faraday cages was measured to be -90 dB with no RF on, -40 dB with the RF on and no shield, returning to -90 dB with the RF on and shields in place. (3) With the double focused design, the MLC motors and controllers were positioned at a location with a residual magnetic field of approximately 900 G. A traditional single focused design would have placed them in a field of approximately 3500 G. In addition, doubly focused MLC systems provide sharper beam penumbrae than singly focused systems.

Conclusion: The novel applications of physics principles were able to successfully overcome the 3 major challenges in the compact Linac-based MR-IGRT system development. The system uses a 90-cm SAD, will fit within a standard Linac vault, and can be installed through standard Linac doors and hinges. This will enable most clinics to integrate MR-IGRT into their treatment options.


Using a 3-Dimensional Diode Array System for Synchronicity Test in Helical Tomotherapy

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Purpose/Objective(s): The ArcCHECK device is designed for 3-dimensional dose verification, but there is no standard for testing synchronicity in