Results of IROC Anthropomorphic Liver Phantom Irradiations with Protons and Photons

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Introduction: The purpose of this study was to evaluate the pass rate for irradiations of the anthropomorphic liver phantom using proton and photon beams. The IROC liver phantom has a poor pass rate for both photon and proton therapy, and while IROC provides feedback to failing institutions about possible reasons for their specific failure, this is the first comprehensive analysis of results across both modalities looking at thematic reasons for failure. This data can be used by institutions to improve liver phantom irradiations.

Methods: The anthropomorphic liver phantom has one insert that represents the liver and two targets mimicking non-coplanar liver metastases. The insert is made of polystyrene for photon beams and Blue Water (Standard Imaging, Middleton, WI) for proton beams. PTV1 is an ovoid 2 cm in diameter and 2.5 cm long. PTV2 is a 3 cm diameter sphere. There is one TLD and 2 planes of radiochromic film in each PTV. The phantom includes a motion table to simulate 1 cm respiratory motion in the superior-inferior direction. Institutions were instructed to design and deliver a plan that delivers 6 Gy / 6 Gy(RBE) to ≥95% of each PTV.

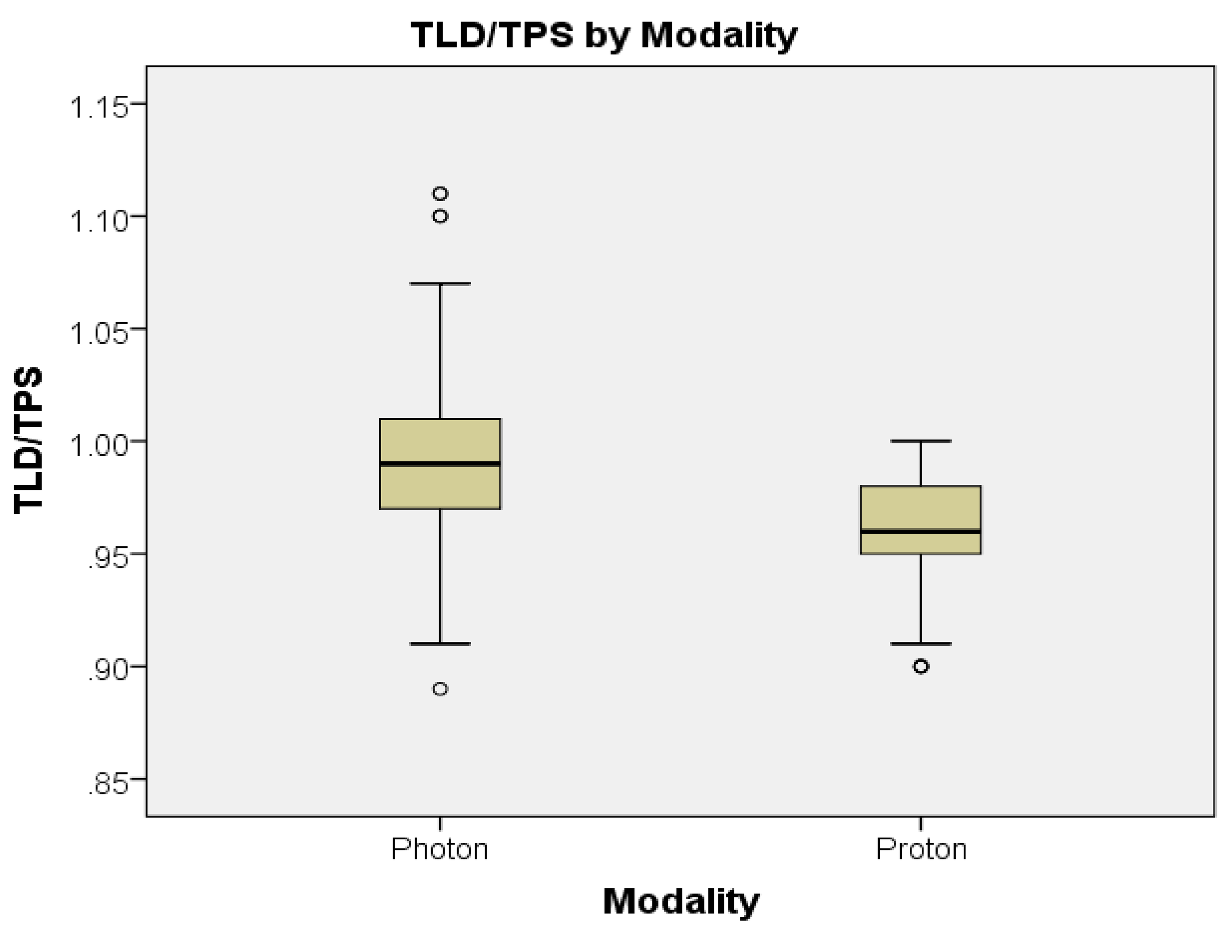

Figure 1: TLD/TPS values for photon and proton beams.

Results: The mean TLD/TPS values were 0.99 (±0.03) and 0.96 (±0.02) for photons and protons, respectively, which were statistically different (ANOVA, $p<<0.05$). The proton TLD/TPS values were statistically different from unity (t-test: $p<<0.05$), which was a key component of the poor performance of proton centers on this phantom (Figure 1). While the photon TLD values were statistically different by TPS algorithm (ANOVA, $p<0.05$), the pass rates were not different by algorithm. Proton irradiations showed no statistical difference between TPS algorithm. The mean percent of pixels passing the 7%/4mm gamma analysis were 91% (±9%) and 82% (±14%) for photons and protons, respectively, which were statistically different (Kruskal-Wallis, $p<<0.05$). The pass rate was 72.8% and 37.5% for photons and protons, respectively.

For photon irradiations, the pass rate was statistically worse for phantom irradiations using an ITV technique (Chi-square, $p=0.05$), as seen in Figure 2; breath hold, gating, and tracking performed better. Proton data was not analyzed by motion technique as most irradiations were performed using the ITV technique. Currently, very few proton centers use breath hold, gating, or tracking, so this might be one area where proton treatment could evolve and improve.

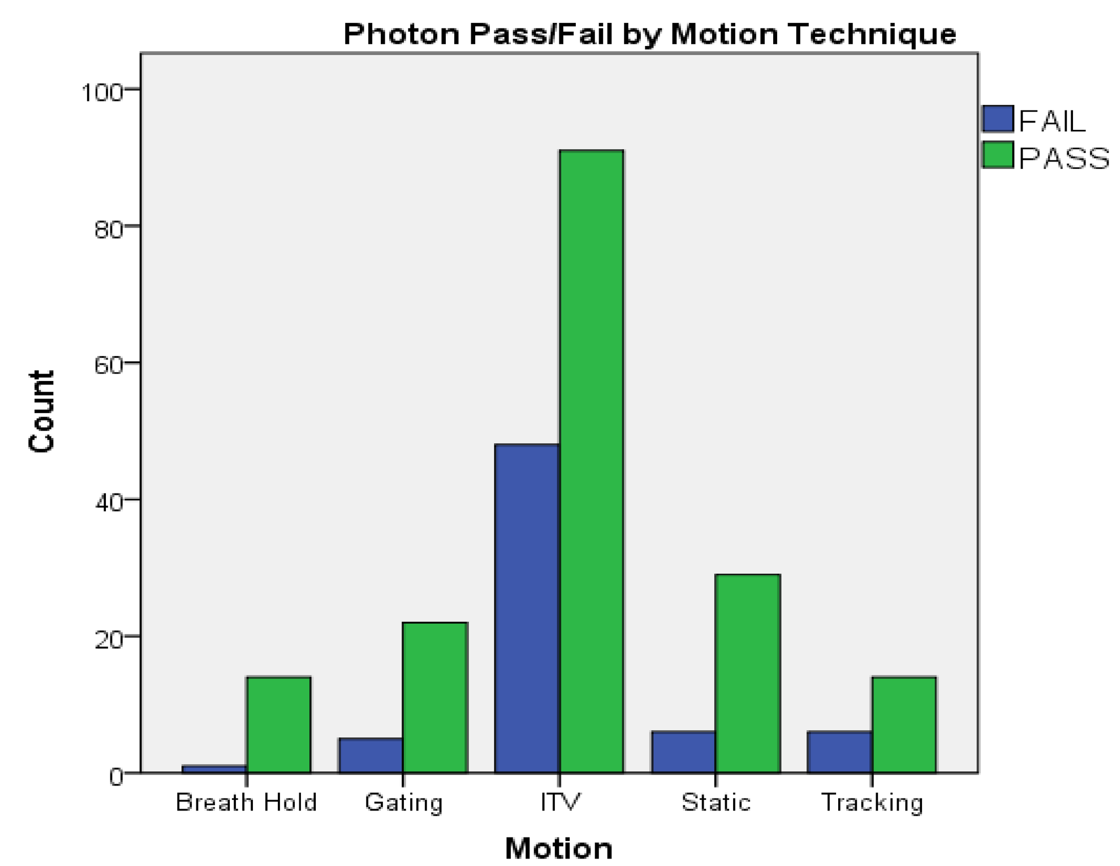

Figure 2. Pass/Fail by motion technique for photons.

Results: Both photons and protons had numerous failures due to alignment errors, particularly in direction of target motion (Figure 3). This is another indicator that current motion-management practices could be improved.

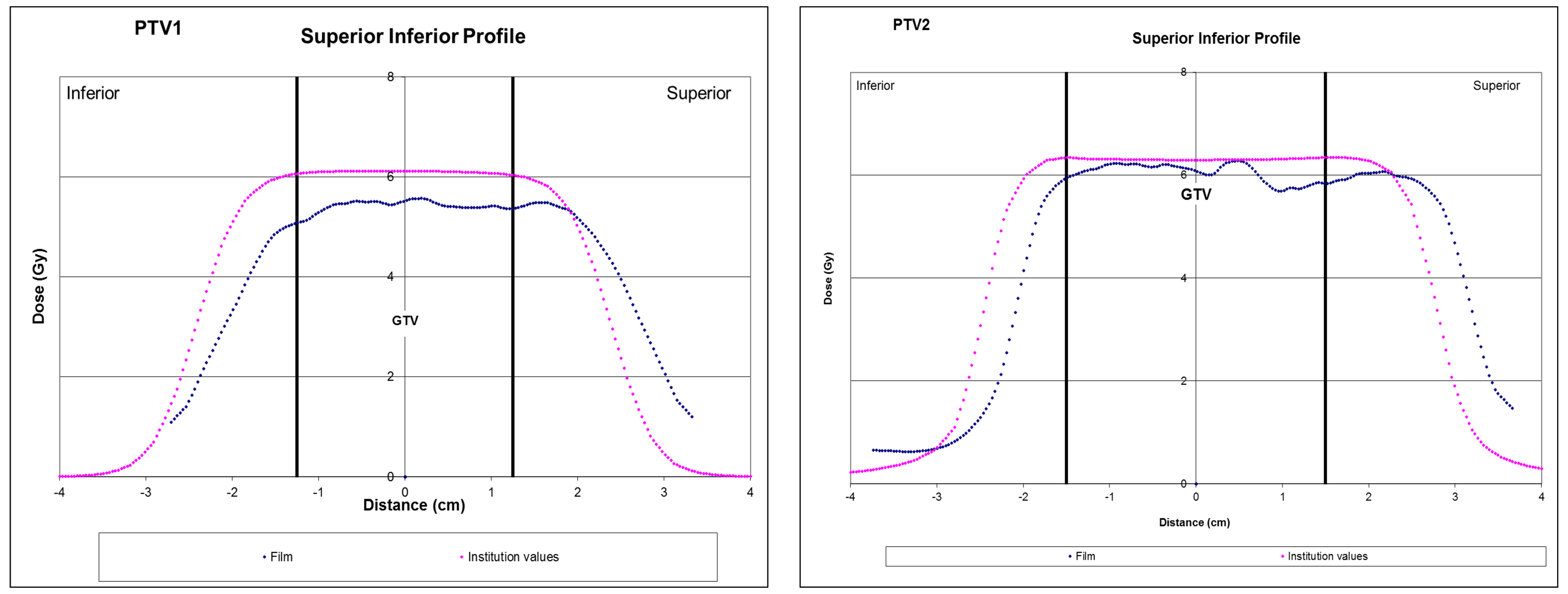

Figure 3. Phantom profiles of the film (blue) and TPS (pink) demonstrating offsets in the direction of target motion.

Conclusion: While both modalities have low pass rates, photon centers perform better irradiating the liver phantom. The ITV technique of motion management performs worse than other motion-mitigation techniques. All centers could potentially improve their pass rate with implementation of tracking, gating, or breath-hold techniques. Proton centers should strive to improve their planning system dose calculations.

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