A Pilot Study of IROC's Proton Head & Neck Phantom

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Purpose: The proton Head & Neck (H&N) phantom is IROC's most complex anthropomorphic phantom design for proton therapy, and closely mirrors the IMRT H&N phantom that is used for clinical trial credentialing. The close configuration of the target and OARs provides a realistic planning challenge for proton TPSs. This work examines the preliminary institutional irradiations of the proton (H&N) phantom used for clinical trial credentialing.

Methods: An anthropomorphic H&N phantom was created with proton-equivalent plastics and an embedded human skull. The phantom contains a horseshoe shaped target, meant to mimic an oropharyngeal tumor, and spinal cord and parotid organs at risk (see **Figure 1**). The insert also contains TLD and radiochromic film for point and planar dosimetric measurements. The phantom is simulated, planned, and irradiated using the institutions' clinical procedures. Ninty-five percent of the target is to receive 6.6 Gy(RBE). The phantom was irradiated 12 times by 11 different proton therapy centers; 15 analyses were performed, as several institutions submitted multiple calculations using different treatment planning algorithms. The criteria for point dose agreement between the TLD and the treatment plan was ±7%, and the criteria for percent of film pixels passing a 7%/4 mm gamma analysis was 85%. The institutions' treatment plans were also assessed for how well they met target and OAR dose constraints.

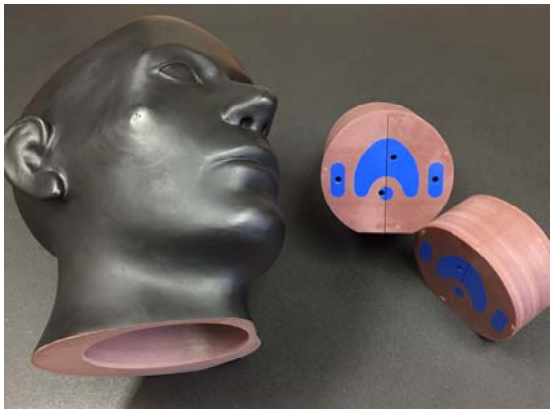

Figure 1. The anthropomorphic proton H&N phantom shown with insert (right). The target, cord, and parotid structures can be seen in blue.

Institution	Modality	% of PTV covered by 6.6 Gy(RBE) Rx dose	Cord volume [cc] receiving >4.5 Gy(RBE)	Mean dose to Parotids [Gy(RBE)]	Film & TLD Pass?
A	PBS	98.8%	5.85	3.3	Pass
B (MC algorithm)	PBS	87.0%	0.00	1.4	Pass
B (PB algorithm)	PBS	87.0%	0.00	1.4	Pass
C	PBS	95.0%	0.21	2.3	Fail
C (2nd irrad MC algorithm)	PBS	95.0%	0.00	3.0	Pass
C (2nd irrad PB algorithm)	PBS	97.0%	0.00	3.0	Pass
D	PBS	90.0%	0.00	3.2	Pass
E	PBS	85.0%	0.00	3.3	Pass
F	PBS	80.0%	0.01	3.6	Pass
G	Scattered	91.0%	0.00	5.3	Fail
H	PBS	90.0%	0.00	3.5	Pass
I	PBS	86.0%	0.00	3.6	Pass
J	PBS	85.0%	0.00	4.1	Pass
K	Scattered	92.0%	0.00	2.0	Pass

Table 1. DVH characteristics for the H&N phantom irradiations. Cells in green pass the criteria for current clinical trial dose constraints; cells in orange are variation acceptable; cells in red fail to meet the dose constraints. MC=Monte Carlo; PB=Pencil Beam algorithm

Planning constraints:
6.6 Gy(RBE) covers ≥95% of the PTV
(*variation acceptable* ≥90%)

Max dose to 0.03 cc ≤4.5 Gy(RBE)
(*variation acceptable* ≤5.0 Gy(RBE))

Mean dose to both parotids ≤2.6 Gy(RBE)
(*variation acceptable* ≤3.3 Gy(RBE))

Results: The phantom pass rate, based on the target dose measurements and gamma comparison, was 87%. The mean ratio of TLD/TPS was 0.97 (σ 0.03), 1.03 (σ 0.11), and 0.97 (σ 0.09) for the target, parotids, and cord, respectively. The large parotid dose σ is a result of the steep dose gradient at the edge of the OAR. The average percent of pixels passing the gamma analysis was 94% (σ 5.7%). Despite this fairly high phantom pass rate, an analysis of clinical dose constraints for the target and OARs showed only 33% of institutions were able to meet all three dose constraint criteria used for clinical trials (see **Table 1**), and even the institutions that did pass were in the "variation acceptable" category for at least one constraint.

Institutions' treatment planning techniques varied widely, with an average of 3.4 beams used to treat the target [range 2-5], and beam angles ranging from AP to lateral, lateral oblique, and PA.

Discussion: Many proton centers are able to deliver what they plan to this phantom, however many struggle to meet typical clinical dose constraints for H&N disease. There is a tradeoff between target coverage and OAR sparing in the phantom, just as there is for real patient cases. It may be that some institutions don't try as hard to meet dose constraints on a phantom study as they would with a patient case (despite instructions to treat the phantom like you would a patient). However, these data may encourage clinical trial PIs to add extra scrutiny of proton therapy H&N plans, or they may request that IROC include planning dose constraints as part of the phantom pass/fail criteria.

There can be a lot of variability among proton institutions when it comes to target coverage and treatment conformality, largely driven by variations in machine delivery capabilities, but also by clinical experience and treatment planning skill. While it has been suggested that only IMPT be allowed for H&N trials, we have seen scattered systems capable of meeting most dose constraints for this phantom. Clinical trial groups should proceed with caution when adding proton therapy as a modality for H&N trials.

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