Proton beam ocular treatment and intraocular silicone oil: effects on physical beam parameters and clinical relevance of silicone oil in EYEPLAN dose-volume histograms.

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Purpose: Proton beam therapy (PBRT) is an essential tool in the treatment of ocular tumors. Review of clinical cases in our ocular PBRT program identified patients with silicone oil used as an intraocular tamponade following pars plana vitrectomy for repair of retinal detachment. A patient’s eye may be filled with silicone oil prior to PBRT for an ocular tumor. The objective of this study was to extend our knowledge of the physical characteristics of proton beams in silicone oil by measuring dose within a silicone tank itself, hence better representing the surgical eye, as well as applying the range changes to EYEPLAN software to estimate clinical impact.

Methods: The relevant proton beam physical parameters in silicone oil were studied using a 67.5 MeV unmodulated proton beam. The beam parameters being defined included: residual range; peak/plateau ratio; full width at half maximum (FWHM) of the Bragg peak; and distal penumbra. Initially, the dose uniformity of the proton beam was confirmed at 10 mm depth and at the Bragg peak using Gefchromic film. Once the beam was established as expected, three sets of measurements of the beam parameters were taken in (a) water; (b) silicone-1000 oil and water; and (c) silicone-1000 oil only.

Central-axis depth-ionization measurements were performed in a tank with a 0.1cc ionization chamber (Model IC-18, Far west). The tank was 92 mm (length) x 40 mm (height) x 40 mm (width). The tank had a 0.13 mm thick kapton entrance window through which the proton beam was incident. The ionization chamber was always positioned in the center of the circular field of diameter 30 mm with the phantom surface at isocenter. The ionization chamber measurements were taken at defined depths in increments of 2 mm, from 0 to 35 mm. To define the effect of silicone oil on the physical characteristics of proton beam, the above-defined three sets of measurements were made. In the first run, the Bragg-peak measurements were made in the main tank filled with water. In the second run, a second smaller tank filled with 10 mm depth silicone oil was placed in front of the water tank and the measurements were repeated in water. In the third run, the water in the main tank was replaced with silicone oil and the measurements were repeated. Finally, the effect of change in range on dose distribution based on the EYEPLAN\textregistered treatment planning software of patients with lesions in close proximity to the disc/macula as well as ciliary body tumors were studied.

Results: The measured data revealed that the Bragg peak had a penetration at the isocenter of 30 mm in water; 31.5 mm in silicone and water; and 32 mm range in silicone oil. The peak/plateau ratio of the depth dose curve is 3.1:1 in all three set-ups. The FWHM is 9 mm in water; 10 mm in silicone and water; and 11 mm in silicone oil. The distal penumbra was 1.1mm; 1.4 mm; and 2 mm. Clinical relevance of the extended
distal range in silicone was studied. The potential change of range by 2 mm in silicone would impact the dose-volume histograms (DVH) importantly for the posterior structures.

**Conclusion:** The use of silicone oil as a surgical tamponade in the treatment of retinal detachments has important implications for PBRT treatment planning. In patients with intraocular silicone, the physical parameters of the beam should be closely examined and DVHs for posterior structures should be analyzed for potential increased doses to the macula, disc, and length of nerve in the field. The change in beam parameters due to silicone is essential to consider in treatment planning.