Purpose: To explore the feasibility of using daily volumetric imaging for optimizing beam-by-beam alignment for proton therapy based on dosimetric factors instead of simple anatomical alignment.

Methods: Eight weekly 4DCT images for a lung patient who was previously treated with two-beam passively scattered proton therapy were analyzed for dosimetric alignment. Only the time-averaged CT was used for this inter-fractional alignment study. An anatomy-based registration was first obtained using rigid registration software. Each weekly CT was retrospectively evaluated by calculating the dose distribution for various potential shifts for each beam using a fast dose approximation method based on range mapping of water-equivalent thickness. Deformable image registration was used to deform contours from the original planning CT to each successive CT image for dose evaluation of the target and organs-at-risk for each shift. Various dosimetric metrics, which include target coverage (V95), maximum dose to the spinal cord, and mean doses to the esophagus, heart, and total lung, were evaluated for the best alignment.

Results: We found that, on average, the relative difference for all beams from the best anatomical alignment to the best dosimetric alignment was 5.8 mm anteriorly, 1.7 mm laterally, and 4.7 mm superiorly. The maximum relative beam displacement between two beams was 12.3 mm.

Conclusions: Proton dose distribution changes with the change in patient's anatomy. The best alignment based on anatomical alignment may not represent the best dosimetric alignment. Instead of replanning from scratch prior to each treatment, we demonstrated that a slight adjustment to the daily isocenter from the best anatomical alignment could improve target dose coverage and/or spare normal structures. Additionally, beam-by-beam alignment may be necessary because the best alignment for each beam may be different.

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