Purpose: To explore the potential of beam angle optimization (BAO) for IMPT and compare fixed beamlines with gantries.

Methods: For three patients with challenging intracranial lesions, we generate reference IMPT treatment plans applying three manually selected beam orientations and treatment plans applying three optimized beam orientations considering five scenarios: (1) patients are in supine position and the treatment room features (1.a) a horizontal beamline, (1.b) a horizontal, 45°, and vertical beamline, (1.c) a gantry, (2) patients are in supine or seated position and the treatment room features (2.a) a horizontal beamline, or (2.b) a horizontal, 45°, and vertical beamline. We use a genetic algorithm that considers up to 1,400 non-coplanar candidate beams and evaluates 10,000 beam ensembles for one BAO. Beam orientations that may compromise the robustness of treatment plans are excluded before the optimization based on an objective measure of existing tissue heterogeneities.

Results: The optimized beam ensembles exhibit certain similarities even though the sets of candidate beams differ significantly for the five scenarios. Compared to manually selected beam orientations, they provide improved OAR sparing and equivalent target coverage. Compared to one another, they yield comparable target conformity (deviations of the conformity number <1%), target homogeneity (standard deviations of the target dose <0.8 Gy), and sparing of OARs (deviations of average mean and maximum doses in OARs +/- 1 Gy). Using a gantry, however, the integral dose can be reduced by 5-15% compared to a horizontal beamline with patients in supine position. For the investigated cases comparable reductions can be achieved by also irradiating in seated position with a horizontal, 45°, and vertical beamline.

Conclusions: BAO has the potential to provide beneficial IMPT treatment plans. Compared to fixed beamlines, gantries yield only modest effects regarding OAR sparing but may enable a significant reduction of integral dose for individual patients.