Purpose: To evaluate the effect of gating and rescanning on dose distributions for scanned proton beam delivery and achievable irradiation time on a patient specific basis.

Methods: We have developed a software tool that simulates scanned proton beam dose delivery to a moving lung tumour by using patient motion and treatment plan data. Based on a 4DCT voxel motion trajectories were calculated along which the dose was accumulated. Using this tool, we investigated rescanning of the ITV for respiration induced organ motion. Furthermore, the effect of gating widow sizes around the exhalation phase (reference phase) as well as gated rescanning was examined. Irradiation time reduction was considered by modeling a high and constant extraction rate of the synchrotron.

Results: Rescanning increased the dose homogeneity, however, ten rescans were not sufficient to mitigate interplay effects completely. Gating was found to alleviate local over- and under-dosages. For a gating window of 20%, the minimal dose to 99% of the CTV differed by 6 Gy from the reference dose distribution whereas doses to 1% and 50% differed by less than 1 Gy. For gated rescanning the dose distribution almost reached the reference dose distribution. Interestingly, the difference in the dose distributions for a gating window size of 20% and of 30% was negligible when additional rescanning was applied. However, for a gating window of 20% the treatment time increased by a factor of 3.5 compared to an irradiation without gating. The additional increase of irradiation time due to rescanning (factor 10) could be significantly reduced by the application of an increased extraction rate.

Conclusions: Gated rescanning was found to mitigate interplay effects significantly at the cost of increased irradiation time. Based on our study time influencing beam parameters should be subject to an investigation to overcome the problem of elongated irradiation times.