Purpose: To investigate the dosimetric effect of deformable image registration (DIR) inverse consistency and transitivity errors in dose accumulation and to propose a correction strategy to reduce the impact of these errors.
Methods: Given three images, A, B and C, deformation maps are defined as third-order transitive if the deformation A->B->C->A results in the image A. Four tomotherapy MVCT images from a head and neck treatment were selected representing the anatomical change over the duration of the treatment course. A research version of the Pinnacle RTPS (v9.1) was used for all planning, DIR and dose warping. A seven-field IMRT plan was created delivering 69.3Gy, 60 & 56Gy to the high, intermediate and low-dose PTVs respectively. This plan was copied to each of the other three images and the dose calculated on all images. All images were deformed to each other using the fast symmetric Demons algorithm. This algorithm is not inverse-consistent or transitive error-free. The dose from each image was warped to and accumulated on the fourth image to result in 'D_AC1'. The dose from each image was then warped to and accumulated on the third image to result in 'C_AC1'. 'C_AC1' was then warped to the fourth image to result in 'DAC2'. The difference in between 'D_AC1' and 'D_AC2' was measured. This dose accumulation process was then repeated after all deformation maps were made inverse consistent and then transitive.
Results: Inverse consistency and transitivity errors lead to an observable difference between 'D_AC1' and 'D_AC2'. The difference decreased with inverse-consistent DVFs and decreased further with transitive DVFs.
Conclusion: Inverse consistency and transitivity errors lead to discrepancies between doses warped to the same image via different pathways. These discrepancies can be significantly reduced by enforcing inverse consistency and transitivity between all DVFs used in dose accumulation.

Funding Support, Disclosures, and Conflict of Interest:

N Hardcastle is funded by Philips Healthcare