Purpose: To present dose uncertainty in composite radiation plans generated through Deformable Image Registration (DIR). We introduce a Fuzzy Composite Dose (FCD) with fuzzified deformation vectors. We compared the Fuzzy method to the statistical approach.
Methods: The accuracy of the DIR is generally verified through visual checks, including confirmation of matching corresponding anatomies. However, most of the soft tissues have few significant image features and therefore greater uncertainty in registration.
We fuzzified the deformation vectors and derived a FCD. We utilized a Gaussian function for uncertainty allocation. A Gaussian variance (two standard deviation; 2sigma) between 2mm to 10mm was assigned, which is based on previous publications analyzing the difference between various DIR methods. The least uncertainty (2sigma=2mm) was assigned to the areas having significant image features. The most uncertainty (2sigma=10mm) was assigned to the areas with few features or a lot of noise. A Fuzzy union operator was utilized to derive the FCD from the Fuzzy deformation vector. The Alpha-cut method was employed to present the uncertainty range of FCD.
A patient example is presented. After radiation treatment to the right lung, they returned to the hospital later to have another radiation treatment to the right rib cage near the liver. B-Spline DIR was utilized to create the composite dose.
Results: In the liver, the statistical analysis shows the uncertainty up to 2sigma=17Gy. With the fuzzy approach, the alpha-cut showed the uncertainty range up to 35Gy. The dose uncertainty range using the alpha-cut is shown to be asymmetric, a representation not possible using the standard statistical approach.
Conclusions: FCD showed the better presentation including the range and direction of uncertainty in the composite dose. This will enable the clinician to deliver effective dose to a recurrent tumor or new tumor near the previously treated site while minimizing complications.