Purpose: To investigate the feasibility and impact of a rigidity penalty (RP) on displacement vector field (DVF) for improvement of deformable alignment in the neck region.
Methods: An existing B-spline image registration method was modified to contain a weighted sum of image similarity measure and penalty terms. The penalty term was derived from the orthogonality condition of the deformation gradient tensor. This term was applied to a cervical vertebral body (C3) which was segmented from a reference image. Sum of squared difference (SSD) was used for the image similarity measure. The method was tested on cone-beam CT scans taken for head and neck intensity-modulated radiation therapy. To evaluate the accuracies of the existing and modified methods, the strain components of DVFs were calculated, and the measured versus transformed coordinates of 10 landmarks located on the vertebra were compared.
Results: The RP value was minimized by the penalized image registration method although the SSD was slightly compromised. The strain components of the DVFs were significantly reduced. Moreover, the registration errors of the landmark pairs were decreased (-0.254 ± 2.176, -2.045 ± 3.894, 0.562 ± 3.179) [mm] to (-0.381 ± 0.580, 0.236 ± 1.996, 0.437 ± 1.250) [mm].
Conclusions: Reduction in strain indicates that the RP term successfully discouraged local deformation. In addition, improvement in the registration accuracy of the landmark pairs shows the modified method outperforms unregularized alignment. The results also indicate that image alignment using only intensity metrics may result in nonphysical DVFs. Ongoing work will further explore optimizing the weighting of the penalty for clinical images in the neck region, as well as testing on a finite element modeled representation of the neck anatomy undergoing controlled physical deformations.

Funding Support, Disclosures, and Conflict of Interest:

This work was supported by NIHP01CA59827.