**PhD Thesis title:** Assessment of the Dependence of Ventilation Image Calculation from 4D-CT on Deformation and Ventilation Algorithms

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ABSTRACT:

Ventilation imaging using 4D-CT is a convenient and cost effective functional imaging methodology which might be of value in radiotherapy treatment planning to spare functional lung volumes. To calculate ventilation imaging from 4D-CT, deformable image registration (DIR) must be used. This study validates the DIR methods and investigates the dependence of calculated ventilation on DIR methods and ventilation algorithms.

The first hypothesis is if ventilation algorithms are robust then they will be insensitive to the precise DIR provided the DIR is accurate. The second hypothesis is that the change in Houndsfield Unit (HU) method is less dependent on the DIR used and depends more on the CT image quality due to the inherent noise of HUs in normal CT imaging.

DIR of the normal end expiration and inspiration phases of the 4D-CT images was used to correlate the voxels between the two phases. Three different DIR algorithms, Optical Flow (OF), Diffeomorphic Demons (DD) and Diffeomorphic Morphons (DM), were validated using a 4D pixel-based and point-validated breathing thorax model, consisting of a 4D-CT image data set along with associated landmarks. The average target registration errors with one standard

deviation for the DIR algorithms were 1.6 ± 0.7 mm, maximum 3.1 mm for OF, 1.3 ± 0.6 mm, maximum 3.3 mm for DM, 1.3 ± 0.6 mm, maximum 2.8 mm for DD, indicating registration errors were within 2 voxels.

The DIR algorithms were retrospectively applied to the same group of 10 esophagus and 10 lung cancer cases all of which had associated 4D-CT image sets that encompassed the entire lung volume. Three different ventilation calculation algorithms were compared (Jacobian, ΔV, and HU) using the Dice similarity coefficient comparison.

The Dice similarity coefficient for 20% of low ventilation volume for ΔV was 0.33 ± 0.03 between OF and DM, 0.44 ± 0.05 between OF and DD and 0.51 ± 0.04 between DM and DD. The similarity comparisons for Jacobian were 0.32 ± 0.03, 0.44 ± 0.05 and 0.51 ± 0.04 respectively, and for HU 0.53 ± 0.03, 0.56 ± 0.03 and 0.76 ± 0.04 respectively.

Dice similarity coefficient for using OF as DIR was 0.86 ± 0.01 between ΔV and Jacobian, 0.28 ± 0.04 between ΔV and HU and 0.28 ± 0.04 between Jacobian and HU respectively. When using DM or DD as DIR, similar values were obtained when comparing the different ventilation calculation methods. The similarity values for 20% of the high ventilation volume were close to those found for the 20% low ventilation volume.

Mean target registration error for all three DIR methods was within two voxels suggesting that the registration done by any of the methods is quite accurate. Ventilation calculation from 4D-CT demonstrates some degree of dependency on the DIR algorithm

employed. Similarities between ΔV and Jacobian are higher than between ΔV and HU and Jacobian and HU. This shows that ΔV and Jacobian are very similar, but HU is a very different ventilation calculation method.