Purpose: 4D-CT ventilation imaging is a novel promising technique for lung functional imaging and has potential as a biomarker for radiation pneumonitis, but has not been validated in human subjects. The current 4D-CT technique with phase-based sorting results in artifacts at an alarmingly high frequency (90%), which may introduce variations into ventilation calculations. The purpose of this study was to quantify the variability of 4D-CT ventilation imaging to 4D-CT sorting techniques.

Methods: Two 4D-CT images were generated from the same data set by: (1) phase-based; (2) anatomic similarity- and abdominal displacement-based sorting for five patients. Two ventilation image sets (V_phase and V_anat) were then calculated by deformable image registration of peak-exhale and peak-inhale 4D-CT images and quantification of regional volume change based on Hounsfield unit change. The variability of 4D-CT ventilation imaging was quantified using the voxel-based Spearman rank correlation coefficients and Dice similarity coefficients (DSC) for the spatial overlap of segmented low-functional lung regions. The relationship between the abdominal motion range variation and ventilation variation was also assessed using linear regression. Furthermore, the correlations between V_phase or V_anat and SPECT ventilation images (assumed ground-truth) were compared.

Results: In general, displacement- and anatomic similarity-based sorting reduced 4D-CT artifacts compared to phase-based sorting. The voxel-based correlations between V_phase and V_anat were only moderate (range, 0.57-0.77). The DSCs for the low-functional lung regions were moderate to substantial (0.58-0.70). The relationship between the motion range variation and ventilation variation was strong on average (R2=0.79±0.25), suggesting that ventilation variations are related to 4D-CT artifacts. V_anat was found to improve correlations with SPECT ventilation images compared to V_phase.

Conclusions: 4D-CT ventilation images vary markedly with 4D-CT sorting techniques. 4D-CT artifacts should be considered as a significant source of variation in 4D-CT ventilation imaging during its validation.

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