Validation of 4D Computed Tomography (4D-CT) to evaluate fractional regional ventilation against the clinical gold-standard scintigraphy V/Q.

Introduction: The potential benefit of 4D-CT extends beyond characterization of tumor motion, and could include functional imaging of regional lung ventilation as postulated by Guerrero et al. While these works have been proposed on the basis of regional density changes over the course of the respiratory cycle, it is necessary to benchmark the results against proven metrics of lung ventilation. This work aims at validating the use of a 4D-CT based technique for evaluation of lung ventilation against the current “gold-standard” of scintigraphy V/Q studies. Furthermore, 4D-CT based estimation of global aeration is compared to Pulmonary Function Testing.

Methods: Scintigraphy V/Q, Pulmonary Function Tests and 4D-CT images were collected for lung cancer patients (N=4). 4D-CT images were used to extract fractional regional ventilation maps defined as \((V_{in} - V_{ex})/V_{ex}\) per voxel, where \(V_{in}\) is the volume of air at end-inhale and \(V_{ex}\) is the volume of air at end-exhale. The maps were condensed into 2D coronal projections and analyzed using signal intensity counts. Standard clinical protocols were utilized for the acquisition and analysis of scintigraphy V/Q data, which was then compared to 4D-CT data using Kendall’s tau correlation coefficients. Density based Hounsfield unit calculations were performed to measure functional residual capacities (FRC) and tidal volumes (TV). FRC was also measured in the standard PFTs. Mean fractional regional ventilation was calculated across the 3D volume and compared to the global estimate of TV/FRC to provide internal validation. Statistical analysis was performed using a Student’s T-test.

Results: Fig1 shows the corresponding scintigraphy (V) and 4D-CT based fractional regional ventilation maps for each patient. It is important to note that subject 1 (Fig1.a and Fig1.1) was the recipient of a lung transplant and thus had extenuating anatomical factors that might explain the relative difference in the tau value. Correspondence with other external metrics is demonstrated by the calculated versus measured FRC. Calculated FRC values were within 20% of the PFT measurements. The mean of fractional regional ventilation, measured on a voxel-by-voxel basis, correlated well with the global estimates of TV/FRC.

Innovation/Impact: While 4D-CT has been shown to provide exquisite spatial resolution, attempts to validate the technique against nuclear studies have not been conclusive. By demonstrating a correlation between 4D-CT data and scintigraphy analysis, this work will provide the basis for further incorporating spatial information in future developments and testing. This high-resolution functional information has the potential to provide current treatment planning methods with a new dimension that extends beyond anatomical boundaries and could help reduce the adverse effects of radiation therapy.