Breathing maneuvers result in regional changes in ventilation as assessed by 4D-CT

**Introduction:** Changes in CT characteristics of the pulmonary parenchyma were used to reflect the changes in the fractional regional ventilation in each voxel as proposed by several groups\(^1, 2\). Factors that affect fractional regional ventilation include: 1) the actual technique used to extract ventilation i.e.: HU-based methods\(^1, 2\) and Jacobian methods\(^3\), and 2) the different registration algorithms\(^4\). One factor that is often overlooked is the breathing maneuver used during the acquisition of the 4D-CT. In this work we study the effect of different breathing maneuvers such as free-breathing (FB), audio-visual guidance (AV), and active breathing control (ABC).

**Methods:** Data from 5 subjects was acquired using 4D-CT while the subjects were made to breathe using the 3 respiration maneuvers (FB, AV, and ABC). Fractional regional ventilation was estimated by using a “mass corrected” density change from 4D-CT images\(^2\). The density change on a voxel-by-voxel basis was calculated after the CT images acquired over different phases of respiration were spatially matched using a "Demons" deformable image registration algorithm\(^5\).

**Results:** Figure 1 shows the fractional regional ventilation extracted using FB, AV, and ABC breathing maneuvers in a single slice (top-panel: a, b, c), and a coronal projection created from the 3D volume (lower-panel: d, e, f). Arrows indicate areas of increased fractional regional ventilation due to changes in breathing patterns as a result of what could be increased alveolar recruitment. Similar changes are also visible in a coronal projection image. Ovals shown in d) FB, e) AV, and f) ABC, point to an area in the right upper lobe that shows additional recruitment due to changing breathing patterns. These regional changes are also reflected in the global measures of change in tidal volume as measured by the mean of the distribution of fractional regional ventilation as shown in Figure 2. We see consistently higher tidal volumes in a group of 5 subjects when they breathe using the ABC as opposed to FB or AV.

**Innovation and Impact:** This is one of the first studies to analyze the effect of various breathing maneuvers on fractional regional ventilation extracted using 4D-CT. The results suggest that it is just as important to pay attention to different breathing maneuvers, as it is to pay attention to the different algorithms, as these may result in significant variability in regional ventilation. The results suggest the need to use repeatable breathing maneuvers when performing longitudinal studies over the duration of treatment. When using these maps for treatment planning, one needs to be mindful that lower fractional regional ventilation might represent un-recruited instead of non-functioning lung regions.

**References:**

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Figure 1: Fractional regional ventilation shown in an axial slice for 3 different breathing maneuvers: a) FB, b) AV, and c) ABC. Changes in fractional regional ventilation shown in projection images for 3 different breathing maneuvers: d) FB, e) AV, and f) ABC.

Figure 2: Mean of distributions from 3 different breathing patterns analyzed for 5 subjects, shows much larger tidal volume when the patients breathe using ABC.