Alignment of Ventilation and Perfusion Images at Acquisition: Validation in a Porcine Model

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Introduction: Quantitative and comprehensive assessment of lung function has proven to be very demanding in that it requires regional information about both alveolar V and Q. One of several recently developed noninvasive methods for MR imaging of V [1] utilizes exogenous airway contrast agents such as hyperpolarized (HP) ^{3}He. Similarly, one method used to obtain quantitative images of Q is that of a dynamic gadolinium study [3]. Though previously shown applicable to several physiological conditions, the methods show difficulty in calculating regional V/Q because simultaneous values for each parameter of lung function are required. Furthermore, regional V/Q computation requires spatial matching of V and Q images, and to our knowledge no validation method has been reported on registration of lung MR V/Q images even when acquired in a controlled situation. In this work, we use a post image processing technique to quantify the degree of misregistration between MR V/Q images at the time of acquisition and confirm that it is possible to acquire data that are co-registered within an acceptable range of a few degrees in rotation and a fraction of a millimeter in translation.

Methods: Experiments were conducted on 25-35 kg Yorkshire pigs (N=5) under ketamine/isoflurane anesthesia. The pigs were ventilated and transferred supine to a 1.5T imaging system configured for broadband acquisition and double tuned bird-cage coil used for signal reception was double tuned to ^{3}He and proton frequencies. V and Q images were obtained using HP ^{3}He and gadolinium, respectively, as was described in [1, 2]. Absolute translations and rotations around different axes needed to register the images were computed as a measure of initial misregistration. Because V and Q images were acquired with the same amount of gas inhalation, the task was considered to be a rigid body registration. The mutual information (MI) based method of rigid body registration has been proven superior when intensity characteristics are dissimilar [4]. The method maximizes the information that one volumetric image provides about the other and seeks for an optimum transformation T that registers the reference image C_1 with the test image C_2 by maximizing their mutual information as follows:

$$T = \max_T I(C_1, T(C_2)), \quad (1)$$

where,

$$I(C_1, T(C_2)) = h(C_1) + h(T(C_2)) - h(C_1, T(C_2)) \quad (2)$$

In (2), $h(\cdot)$ is the entropy of the histogram of an image and $h(\cdot, \cdot)$ is the entropy of the joint histogram of two images. For each pair of images rotational and translational components of T were computed to quantify the initial misregistration.

Figure 1:

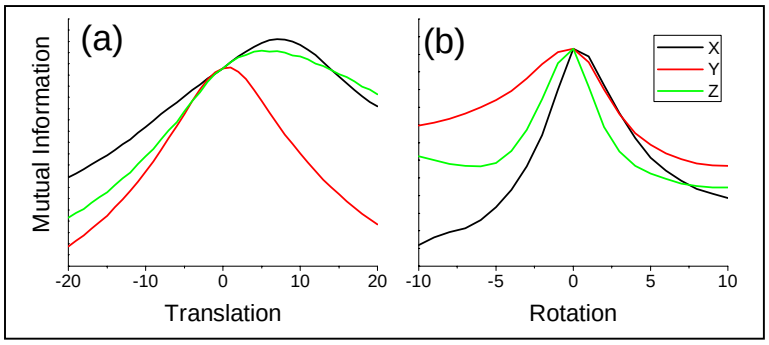

Table 1	Mean	Std Dev
Trn. x-axis	5.6 mm	5.3 mm
Trn. y-axis	2.6 mm	0.68 mm
Trn. z-axis	6.8 mm	7.2 mm
Rotation x	0.34°	0.17°
Rotation y	0.31°	0.25°
Rotation z	0.17°	0.19°

Figure 2:

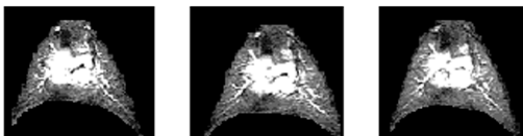

Figure 3:

Results and Discussion: Means and standard deviations for the 5 studies in terms of absolute translation and rotation around three axes are shown in Table 1. Figures 1A and B are two partial plots of MI values for translation and rotation around each of the three axes, respectively. Figures 2 and 3 illustrate 2-D gradient-echo images, one (3) of which shows ^{3}He distribution obtained in one pig, suggesting normal V, while the other (2) shows the Q image of the same subject. Though limitations of co-registration technology range from physiological variations to co-registration characteristics, the results of our preliminary study demonstrate that, under a controlled situation and proper imaging protocol, it is possible to achieve approximately co-registered images of V and Q (within 1-2 voxels of perfect alignment). This preliminary work is crucial because it allows reliable quantitative measurements of regional V and Q to be obtained in both normal and diseased lungs. In this manner 'responders' versus 'nonresponders' to clinical therapies could be identified, and the lung's subsequent response to acute therapy could be monitored.

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