Voxel-wise analysis of lung parenchymal motion during breathing via a non-rigid registration algorithm in human: Dynamic MRI in different postures.

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Introduction

The lung can be described as an elastic body [1]. Therefore, lung motion is one of the keys to estimating pulmonary function. Grid-tagging techniques have been used to evaluate local mechanical properties of the lung with promising results. However, the efficacy of the technique is limited in the lung by the low spatial resolution of currently feasible grids, rapid fading of the grid secondary to the short T1 of lung tissue, and the challenge of applying tags in 3-D imaging [2]. We previously demonstrated that non-rigid image registration algorithm could be used to compute voxel-by-voxel deformation between successive MR images of the human lung [3]. The purpose of this study was to explore the feasibility of this method to detect differences in regional pulmonary parenchymal motion during free breathing at both supine and prone postures.

Materials and Methods

Eight healthy men (mean 32.3 years; range, 23-42 years) were enrolled in this study. MR imaging was conducted with a 1.5T body MR scanner (Signa[TM,] Twinspeed, General Electric Medical System, Milwaukee, WI) with a torso coil. A dynamic study was performed using multi-slice fast imaging with steady-state acquisition (FIESTA) on a selected sagittal slice of the right lung. Imaging parameters were: TR = 3.2 msec, TE = 1.5 msec, flip angle = 45°, field of view = 35 cm, matrix size = 224x224, slice thickness = 15 mm, NEX = 2. The subjects were instructed to breathe slowly and deeply to complete half of respiration (between maximum inspiration and maximum expiration) during the acquisition of 10 images (14 sec), covering approximately two and a half respiratory cycles. This imaging session were repeated at two different postures (supine and prone). Among the series of MR images, four different phase images over a respiratory cycle (end- and mid-inspiratory, and end- and mid-expiratory phases) were selected. A non-rigid registration algorithm was applied to generate the displacement vector field map between successive images in the sequence. A quantitative analysis was performed to localize motion differences according to standardized anatomic regions (ventral and dorsal) defined manually over the lung (Fig. 1). Within each region, the mean pulmonary displacement magnitude was calculated. To assess the orientation distribution of the voxelwise displacements in each ventral or dorsal region, the motion vectors were binned into 6 groups according to the subdivision shown in Fig. 1. Subsequently, the percentage of the number of vectors in each span of 60 degrees, from I to VI, relative to the total number of vectors in each region were computed. Then, we compared the lung parenchymal motion in the non-dependent and dependent regions of the lung at two different postures, and in four different respiratory phases (early/late inspiratory and expiratory phases).

Results and Discussion

In supine position, the mean magnitude of parenchymal motion was greater in non-dependent regions compared with dependent regions, especially during the late inspiratory phase (Fig. 1a and 2a). In the prone position, however, the magnitude of the lung motion was more uniform throughout the whole lung area at each inspiratory phase (Fig. 1c and 2b). In the supine position, the mean distribution of the angles of the vectors indicates that the predominant movement of the lung was forward and downward (Fig. 1a), especially in the non-dependent regions (II+III = 92 ± 9%). However, in the prone position, the mean distribution of the angles of the vectors was mainly downward in both non-dependent (IV+V = 70 ± 13%) and dependent (IV+V = 66 ± 24%) regions (Fig. 1c and 1d), presumably because of the restriction of the movement of the anterior chest wall. During early expiration, upward (I) movement was predominantly and uniformly distributed throughout the whole lung area in both the supine and prone positions (Fig. 1b and 1d), implying that the mechanisms of expiration (upward movement of the diaphragm due to elastic recoil and increased intra-abdominal pressure) are similar at both postures.

In summary, the present study showed that the regional lung motion during the respiration can be used to quantitatively discriminate between lung motion in different postures. The technique is useful for better understanding of the respiratory function in the patients with pulmonary diseases.

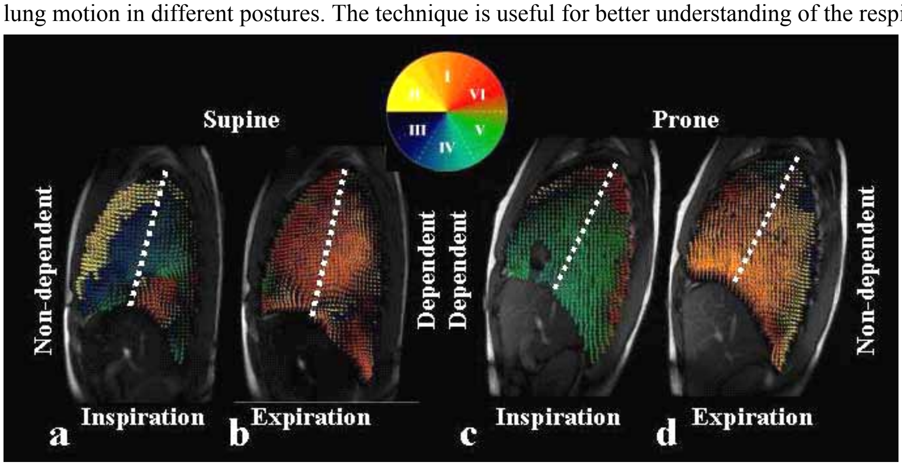

Fig. 1. Representative sagittal MR images superimposed by displacement field vector mapping at inspiratory and expiratory phases in supine (**a**) and prone (**b**) postures. Note each vector shows the magnitude of displacement (length) and is colored depending on its displacement angle as described in the colormap.

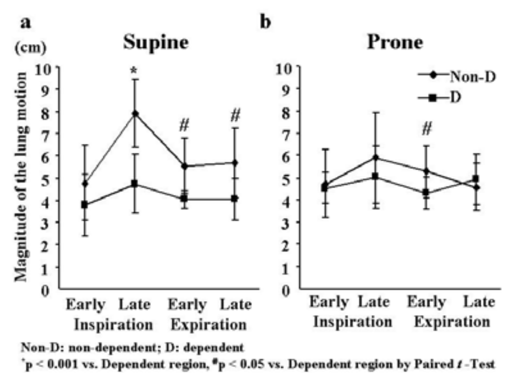

Fig. 2. Comparison of the magnitude of lung motion between non-dependent and dependent regions at four respiratory phases in supine (**a**) and prone (**b**) postures (n = 8).

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Reference

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