Lung Volume and Motion measured by Dynamic 3D MRI using a 128-channel Receiver Coil

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Introduction Recent developments in dynamic 3D MRI have enabled the physiological study of the lung in a dynamic state. Physiological studies are possible by post-processing images with image segmentation and registration, and measuring the volume and motion of the lung over a breathing cycle [1-2]. However, automated segmentation and registration of lung MRI remains a challenge due in large part to the lack of image quality in today's dynamic MRI. The objective of this paper is to present the physiological study of the lung using state-of-the-art 3T MRI with a 128-channel coil [3]. Our original hypothesis is that the increased quality of images acquired from a 128-channel coil enables automatic processing of lung MRI, thus leading us to perform volume and motion analysis of the free-breathing lung.

Materials and Methods The first subject, a healthy male (age: 35) and the second subject, a female (age: 22) were scanned with the Prototype Siemens Tim TRIO 3T whole body scanner extended to accommodate 128 independent receive channels (Siemens, Erlangen, Germany) [3]. Dynamic MR imaging was performed using a 3D FLASH sequence with GRAPPA. An imaging time of 1.3-1.6 seconds per 3D frame was achieved with imaging parameters of TR/TE: 1.66/0.72 ms; flip angle: 9 degree; receiver bandwidth: 1560 Hz/pixel; GRAPPA acceleration factor: 4; field of view: 400×400 mm; acquisition matrix: 128×128; slab thickness: 150 mm; 24-30 slice encodings; voxel size: $3.1\times3.1\times5$ mm. During the scan, the first subject was instructed to continue shallow / deep breathing; the second subject was asked to continue shallow / normal / deep breathing. Twenty frames of 3D images were obtained for each examination. The lung area in each 3D frame was segmented on the Linux-based workstation (Dell Precision 470, Dell Inc., TX), based on the confidence connected algorithm, which was implemented by the Insight Segmentation and Registration Toolkit (ITK) (Kitware Inc., Clifton Park, NY). To gain reasonable segmentations, the multiplier parameter for the confidence connected method and the threshold parameter for the fuzzy connected method were manually adjusted for each 3D frame. The marching cubes algorithm was applied to the segmented data to extract the surface of the lung area and therefore visualize its surface using the Visualization Toolkit (VTK) (Kitware Inc., Clifton Park, NY). The number of voxels in the segmented lung area was counted for each 3D frame to measure the volume of the lung.

Results Images were successfully acquired. The images show whole lung motion with sufficient contrast, including the lifting of the chest wall and the displacement of the diaphragm. The images, surface renderings, and volume measurements are presented in Figs. 1 and 2. The volume of the lung varied from 2000 to 2500 cc and from 1300 to 1800 cc for the first and second subject respectively in the case of shallow breathing. In the case of deep breathing, the volume of the lung varied from 2300 to 3200 cc for the first subject and from 1200 to 3500 cc for the second subject. The volume measurements presented a reasonable volume change for deep breathing, but the temporal resolution was not enough to observe shallow and medium breathing.

Discussion and Conclusion Our initial experience analyzing the volume and motion of the free-breathing lung using a 128-channel coil shows that the scanner and imaging protocol provide dynamic 3D images with enough spatial and temporal resolution to analyze the lung motion with automated post-processing. The coil has the potential to be used with larger acceleration factors for higher temporal resolution, therefore enabling volume measurement during shallow breathing, thus leading to the analysis of natural breathing.

References:

[1] Blackall JM et al. Phys Med Biol 2006; 51:4147-4169; [2] Plathow C et al. Invest Radiol 2005; 40:173-179; [3] M. Schmitt et al; ISMRM 15th Scientific Meeting, Berlin, 2007, p. 245

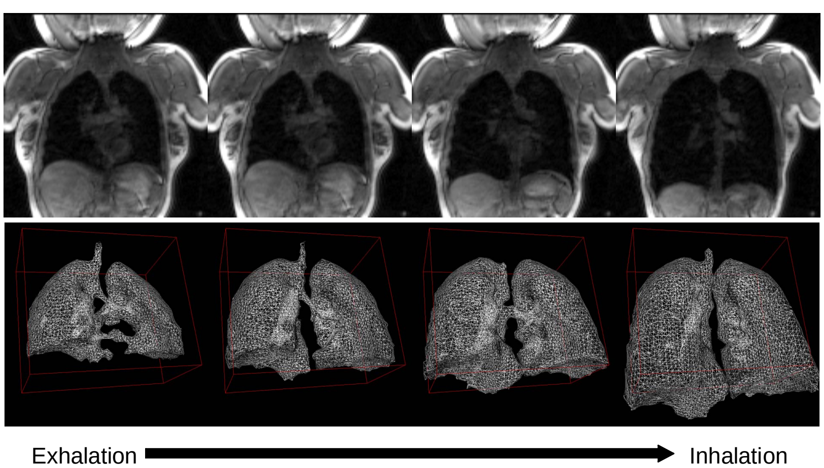

Fig. 1: Coronal slices (above) and triangular representation of the lung surface (below) of consecutive frames of free-breathing dynamic 3D images of the lung of the second subject. The images were acquired every 1.6 seconds from exhalation to inhalation during deep breathing.

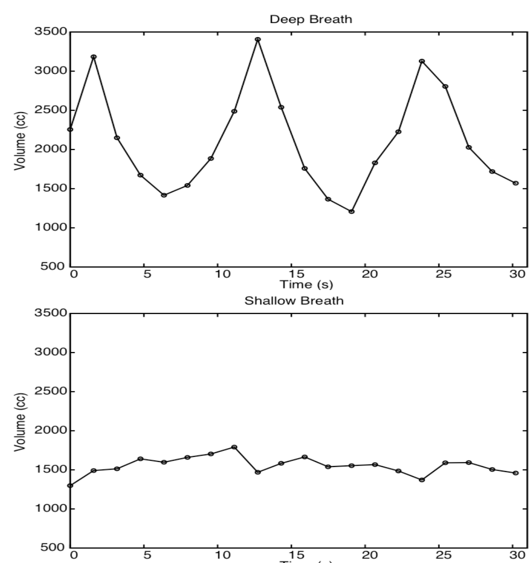

Fig. 2: The changes of the lung volume for the second subject during shallow and deep breathing were measured by counting the number of voxels belonging to the lung area on the segmented images.