CODE (COncurrent Dephasing and Excitation) MRI of human lung at 3T

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Target Audience: Radiologist, clinicians, radiographers, and physicists interested in lung imaging

Purpose: Lung MRI has been limited mainly due to innate characteristics of lung such as a paucity of protons in air, large field inhomogeneity (or short T_2^*) at the interface between airspace and bronchovascular structure, and cardiopulmonary motions. Such difficulties can significantly be overcome by ultrashort echo-time (UTE) MRI techniques with radial data acquisition (1-3). However it may be challenging to standardize conventional UTE imaging on commercial MRI scanners due to demanding hardware requirements, gradient-ramp sampling, and difficulty in preserving k=0 data point (4). In contrast, CODE(Concurrent Dephasing and Excitation) imaging, which was recently developed, is based on a 3D radial gradient-echo sequence and avoids most of the challenges of conventional UTE, acquiring an asymmetric gradient-echo and still offering TE≥ ~0.14ms on a clinical scanner (5). The aim of our study was to investigate the technical feasibility of CODE sequence for lung MRI in human.

Materials and Methods: CODE imaging was performed with three healthy adult volunteers on a 3.0 T MR system (Siemens Magnetom Trio, Erlangen, Germany). MR parameters were as follows: TE/TR = 0.14ms/4.0ms, FA = 5°, FOV = 396mm^3, 1.3 mm^3 isotropic resolution, number of projections =160 k, scan time =8 min, a sinc pulse of 0.05 ms, and free breathing. The image quality, noise, and artifacts of CODE images were rated on a scale of 1to 5 (Table 1) by a consensus of two radiologists and compared with images of other MRI techniques such as free-breathing T_2*HASTE*, multi-breathhold T_2 TSE, TrueFISP, T_1breathhold *VIBE*, and breathholdT_1radial *VIBE*, though only CODE images are presented here.

Results: An overall image quality of CODE was graded good to excellent. Pulmonary vessels were consistently traceable from central to subpleural area in whole lung. Thin bronchial walls were also traceable from main bronchus to segmental bronchi with mild motion and streak artifacts on CODE (Fig.1). Lobar fissures were also identifiable (Fig.1).In regard to image quality, CODE was consistently superior to other techniques in all items. When noise and artifacts were compared, CODE showed similar or less noise and motion artifacts than other sequences except for streak artifact which may be inevitable for 3D radial sampling in a limited scan time (Fig 2).

Table 1. Qualitative grading for image quality, noise and artifacts

Overall image quality [1 = undiagnostic, 2= poor, 3 = fair, 4 = good, and 5 = excellent]
Depiction of the intrapulmonary vessels and lobar fissure, mediastinal, and bronchial structures [1 = unacceptable (indistinguishible central pulmonary, great vessel, lobar and bronchus with blurred margin), 2 = poor (only central pulmonary vessels, great vessels, and lobar bronchus visible with clear margin;), 3 = fair peripheral pulmonary vessels visible with blurred margin; azygos vein and esophagus partially visible with blurred margin; most segmental bronchial walls visible with blurred margin), 4 = good (peripheral pulmonary vessels visible with clear margin; azygos vein and esophagus partially visible with clear margin; most segmental bronchial walls visible with clear margin), 5 = excellent (peripheral pulmonary vessels, lobar fissure, azygos vein, esophagus, and some subsegmental bronchial wall visible with clear margin)]
Image noise [1 = unacceptable, 2 = above-average increase, 3 = average and acceptable, 4 = less-than average, 5 = minimum or nothing]
Respiratory, cardiovascular motion, and streak artifacts [1 = unreadable because of severe artifacts, 2 = substantial artifacts, 3 = moderate artifacts, 4 = minor artifacts,5 = no artifacts]

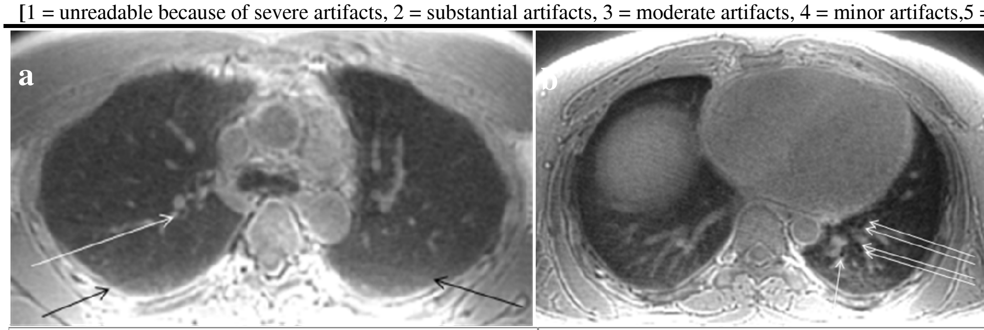

Fig. 1. (a) Bilateral major fissures in both lungs (black arrow) and segmental bronchial wall in the right upper lobe (white arrow) are clearly visible on CODE MR. (b) Divisions of subsegmental bronchi (white arrows) are identifiable in the left lower lobe with mild overlying streak artifacts.

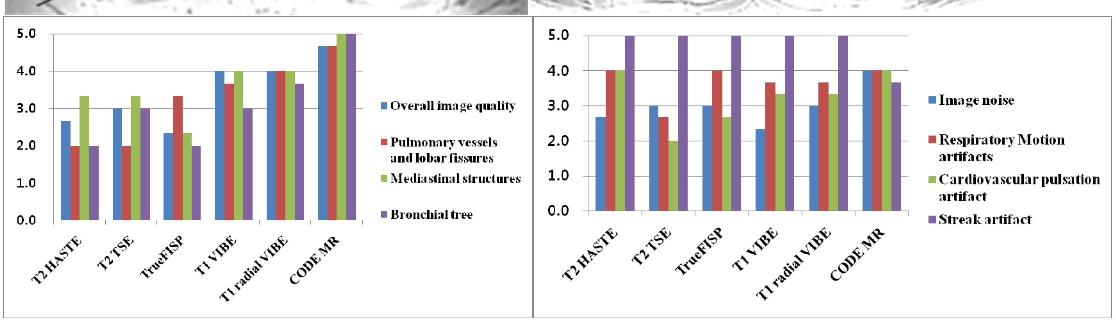

Fig. 2 (a,b). Result of qualitative evaluation of CODE compared to other sequences in terms of image quality, noise, and artifacts.

Discussion and Conclusion :A new UTE 3D radial gradient-echo based CODE imaging was implemented on a 3T clinical scanner and its technical feasibility was evaluated for free-breathing pulmonary imaging in human volunteers in comparison with other pulmonary imaging techniques. The grading of overall image quality was good to excellent and important anatomical structures of human lung were consistently identifiable with mild motion and streak artifacts. Compared to conventional UTE having some challenges, CODE seems to be a good and easy alternative for standardized lung MRI on a clinical scanner.

References: (1) Bergin CB, Pauly JM, Macovski A. Lung Parenchyma: Projection Reconstruction MR Imaging. Radiology 1991;179:777-781. (2) Yu J, Xue Y, Song HK. Comparison of Lung T2* During Free-Breathing at 1.5 T and 3.0 T with Ultrashort Echo Time Imaging. Magn Reson Med. 2011;66:248-254. (3) Johnson KM, Fain SB, Schiebler ML, et al. Optimized 3D Ultrashort Echo Time Pulmonary MRI. Magn Reson Med. 2013;70:1241–1250. (4) Robson MD, Gatehouse PD, Bydder M, et al. Magnetic Resonance: An Introduction to Ultrashort TE (UTE) Imaging. J Comput Assist Tomogr. 2003;27:825-846. (5) Park JY, Moeller S, Goerke U, et al. Short Echo-Time 3D Radial Gradient-Echo MRI Using Concurrent Dephasing and Excitation. Mag Reson Med. 2012;67:428-436.