High-resolution zero echo time lung imaging

Fabio Gibiino[1,2], Laura Sacolick[3], Anne Menini[4], Luigi Landini[1], and Florian Wiesinger[4]

[1]University of Pisa, Pisa, PI, Italy, [2]GE Global Research, Munich, Bavaria, Germany, [3]GE Heathcare, Munich, Germany, [4]GE Global Research, Munich, Germany

Target Audience: All scientists interested in the imaging of the lungs or tissues with short T_2^*.

Purpose: MR imaging of the lungs is challenging because of i) strong microscopic B_0 gradients resulting in short signal lifetimes and blurring and ii) respiratory motion. Pulse sequences providing (ultra) short echo times (TE) have been demonstrated to be suitable for that purpose[1,2]. In this work a respiratory-triggered zero echo time (ZTE) sequence was optimized for the high-resolution structural imaging of the lungs.

Methods: 3D radial ZTE imaging was implemented similar to the Rotating-Ultrafast-Imaging-Sequence[3] (RUFIS). The sequence uses non-selective hard pulse excitation in combination with 3D center-out radial data acquisition. Because the readout gradients are kept active during the excitation, the nominal TE equals 0. In order to keep the gradient ramping minimal, the spokes are sequentially arranged along a 3D spiral trajectory. The sequence produces 3D isotropic datasets with proton density contrast weighting. The receive bandwidth (RBW) was optimized to find the best trade-off between resolution, scan time and SNR. Respiratory motion was addressed via prospective triggering[4] on the signal from a respiratory belt. The acquisition was synchronized with end-expiratory phase. *In-vivo* volunteer experiments were conducted on a MR750w 3T scanner using GEM array coils (GE Healthcare, Waukesha, WI).

Results: Figure1 shows a simulation comparison between ZTE and ultra-short TE (UTE) image encoding. The avoidance of gradient ramping allows ZTE to achieve the same spatial resolution as UTE with shorter readouts. For high values of the RBW the spatial resolution (characterized by the FWHM of the PSF) improves at the expense of the SNR. Similar results were obtained with the *in-vivo* scans using RBW=±31.25 kHz, ±62.5 kHz and ±125 kHz (Fig. 2). With increasing RBW, the images show less off-resonance blurring, but the SNR worsens accordingly. A RBW=±62.5 kHz was identified as the best compromise between resolution, scan time and SNR. Figure 3 shows three orthogonal slices (top row) and corresponding maximum intensity projections (MIP) over a18mm thin slab (bottom) of a prospectively triggered ZTE scan acquired at a nominal resolution of π/k_{max}=0.9mm (FOV=28 cm, FA=1.2°, RBW=±62.5 kHz, 204800 radial spokes, 2x radial oversampling, scan time ~9min). Respiratory motion was successfully rejected, as demonstrated by sharp vessel structures and the lung diaphragm interface.

Discussion and Conclusion: A 3D radial ZTE sequence was implemented similar to RUFIS[3] and was demonstrated to be efficient for high-resolution structural MR imaging of the lungs. Zero TE imaging at high imaging bandwidth allows efficient sampling of the low density and rapidly decaying lung signals. The 3D center-out radial acquisition provides motion robustness, facilitated by the prospective triggered acquisition. Prospective gating using pencil beam navigators was implemented as well, providing similar quality results. The minimal gradient switching provides TR~1ms and practically eliminates eddy current artifacts. Unlike UTE, no dedicated calibration scans are required for RUFIS. The simulation demonstrates that for similar 3D radial sampling, ZTE is more time efficient than UTE. The present sequence provided highly detailed structural lung images down to ~0.9mm nominal resolution in a scan time of ~9min.

References: **1.** Wild *et al*. Insights Imaging. 2012. **2.** Johnson *et al*. Magn Reson Med. 2012. **3.** Madio *et al*. Magn Reson Med. 1995. **4.** Lewis *et al*. Radiology. 1986.

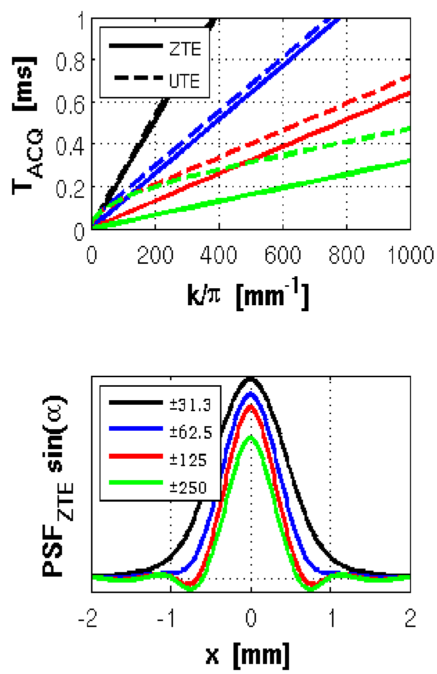

Fig. 1: Simulations comparing ZTE and UTE imaging performance for different RBW. Avoidance of gradient ramping results in faster sampling and hence shorter effective TE in case of ZTE (top). With increasing RBW the PSF narrows but the SNR efficiency slightly worsens. (Simulation parameters: S_{max}=120T/m/s, T_2^*=0.5ms)

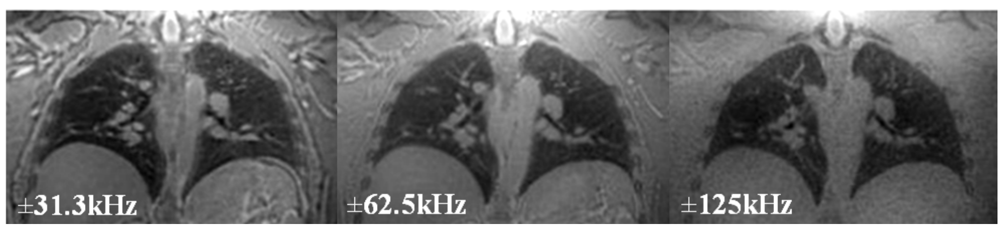

Fig. 2: In-vivo volunteer RBW comparison. With increasing RBW the images appear sharper but SNR worsens. Off-resonance contrast at tissue interfaces increases with decreasing RBW (i.e. longer imaging readouts).

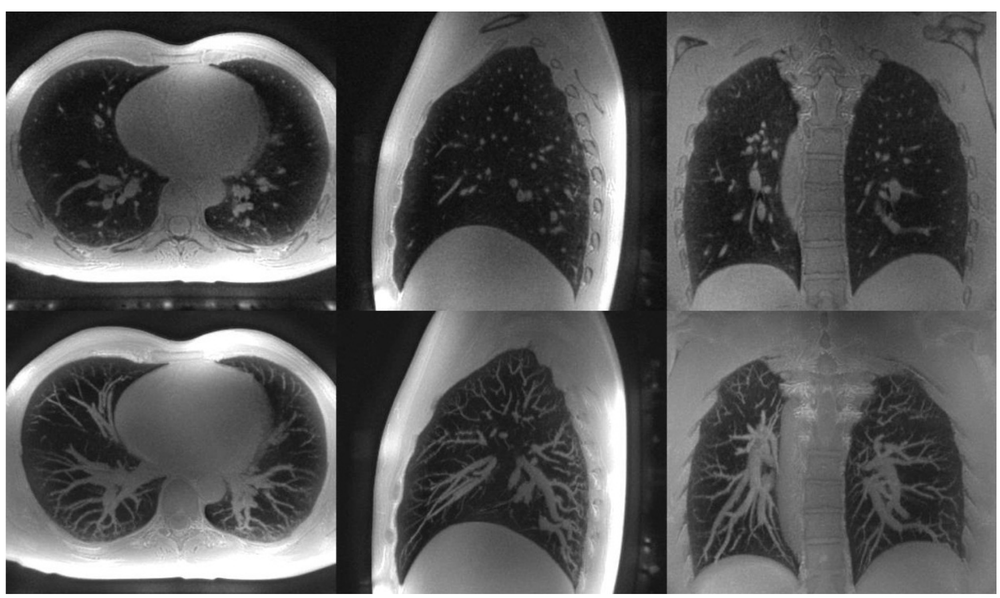

Fig. 3: Single orthogonal slices (top) and corresponding MIPs (bottom) of a prospectively-triggered ZTE acquisition acquired at a nominal resolution of π/k_{max}~0.9mm in ~9min scan time.