Multi-stage three-dimensional UTE lung imaging by image-based self-gating

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Purpose: To combine image-based self-gating (img-SG)with ultra-short TE (UTE) 3D acquisition for lung imaging to allow effective respiratory gating during free breathing and to compare its efficiency with k-space center self-gating (DC-SG).

Materials and Methods: Since to the golden standard ordering scheme for 3DUTE is not suitable for image-based gating, for which a good coverage of the k-space in short time is necessary, the modified spiral pattern [RS], quasi-random [QR][1]and multidimensional Golden Angle [MGA] scheme were implemented[2] (figure 1). These ordering schemes enabled the reconstruction of time-resolved sliding-window low-resolution three-dimensional images, from which a "navigator-like" signal could be extracted from the intensity profiles calculated along a line crossing the lung-liver interface (Figure 2). The DC-SG signals (magnitude, phase, real and imaginary) were retrieved from the k-space center, derived by principal component analysis of the signal from all 16 elements of the thoracic coil, and band-pass filtered around the respiratory frequency.

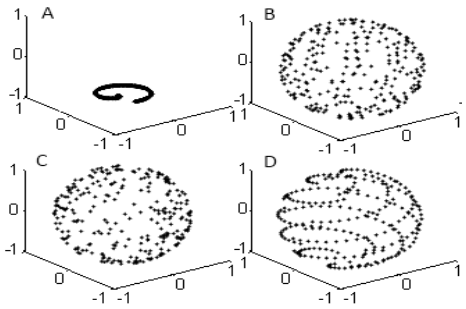

Figure 1: Coverage of the unity sphere by 256 consecutive sample obtained by: a) conventional spiral (CV), b) regularized spiral scheme (RS), c) quasi-random (QR), and d) multidimensional golden angle (MGA).

Six healthy subjects were imaged with the four ordering schemes with the following parameters: TR = 2.3 ms, echo time TE = 0.16 ms, flip angle α = 3°, field-of-view = 400x400x400 mm³, isotropic spatial resolution Δ r = 2 mm³, four-fold angular oversampling. For all gating signals and acquisition methods full inspiration and full expiration images were reconstructed with an acceptance window of 30% of the total number of spokes. Sharpness of the lung-liver interface and apparent diaphragm excursion were calculated.

Results: Navigator-like respiratory signals were successfully extracted from the sliding-window data by monitoring the lung-liver interface displacement (figure 2). Images were reconstructed with a temporal resolution of 588 ms, which was adequate to generate a gating signals. Images reconstructed with the img-SG technique showed significantly better sharpness and apparent diaphragm excursion than any of the DC-SG methods (figure 3). Direct comparison of the three implemented ordering schemes does not demonstrate any clear superiority of one with respect to the others.

Discussion: Image-based respiratory self-gating in UTE 3D lung images allows successful retrospective extraction of respiratory signal. While DC-SG signals requires to be strongly band-pass filtered which results in a sinusoidal shaped signal, Img-SG permits direct visualization of the respiratory movement and therefore provides better outcome.

References: [1]Fischer A, et al, NMR Biomed 2014. [2] Chan RW, et al, Magnetic Resonance in Medicine 2009;61(2):354-63.

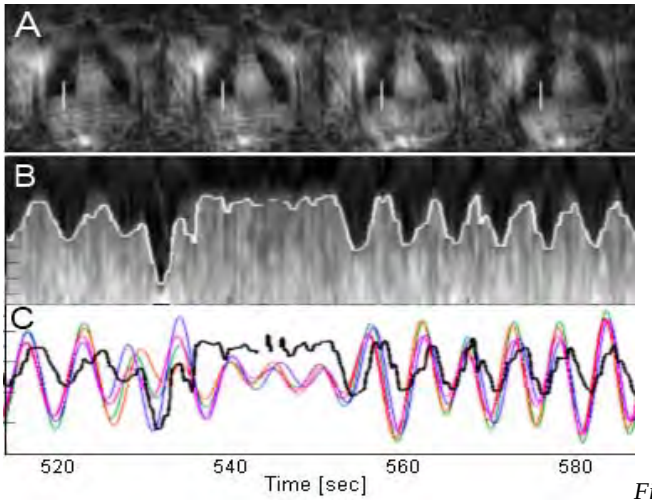

Figure 2:Exemplary image quality of low-definition images (a) from which the "navigator-like" signal is extracted (b). The resulting gating signal (white line in b, black line c) is superimposed to the DC-SG signals (red line: Magnitude; blue line: phase, green line: real; magenta line: imaginary) in direct comparison to the img-SG signal (c).

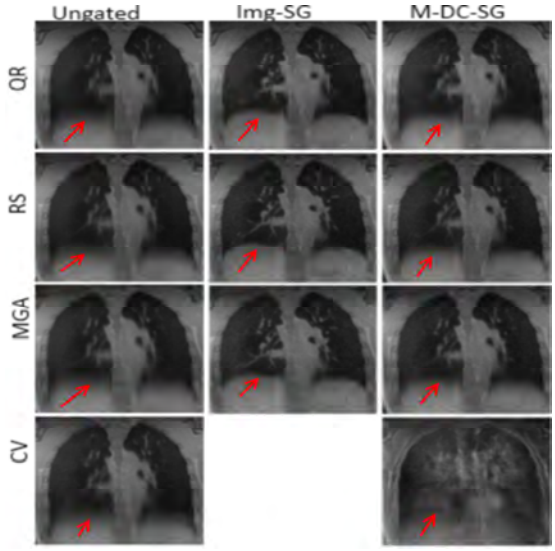

Figure 3:Comparison of image quality for the different gating schemes (columns) and ordering schemes (rows). The CV data cannot be applied to img-SG method. Red arrows indicate the lung-liver interface