Retrospective self-gated 3D UTE lung imaging

Kathrin Hemberger[1], Stefan Weick[2], Felix A Breuer[1], Peter M Jakob[1,2], and Daniel Haddad[1]
[1]*MRB Research Center for Magnetic-Resonance-Bavaria, Wuerzburg, Germany,* [2]*Departement of Experimental Physics 5, Institute of Physics, Wuerzburg, Germany*

Introduction: Proton MRI of the human lung is challenging due to low proton density, short T2* (~1.3ms, @1.5T) and respiratory motion. In order to be able to detect signal from lung parenchyma sequences providing very short echo-times are required. Recently it has been shown that a DC-gated 3D Flash sequence with highly asymmetric echo read-out and a 2D quasi random (QR) phase-encoding ordering allows for retrospectively gated high resolution motion artifact free 3D human lung imaging [1]. 3D radial Ultrashort TE (UTE) sequences allow for even shorter TEs of less than 100µs [2] only limited by the scanner hardware. In [3] standard 3D UTE in combination with prospective respiratory gating has been employed using bellows gating. Prospective gating methods however require stable gating signals and regular breathing for successful motion compensation and only provide images in one breathing state. Therefore, we demonstrate the applicability of the more robust and flexible retrospective approach in self-gated free breathing 3D UTE lung imaging.

Materials and Methods: In standard 3D UTE radial trajectories are acquired on a spiral path along the surface of a sphere in a linear fashion and therefore non-uniform k-space coverage can be expected in the case of retrospective gating. In order to overcome this limitation we employ a QR radial sampling order. 2D QR Niederreiter numbers λ_1 and λ_2 between 0 and 1 were used to determine the projection angles θ=acos(2*mλ_1-1) and ϕ=2π*(mλ_2). In order to demonstrate the applicability of the retrospective gating approach 4000 projections (out of the first 20000) acquired with the QR scheme after gating (using the actual gating data) are displayed (Fig 1a). For comparison the corresponding 4000 projections along the linear spiral path are displayed (F). The smoothed center k-space signal (DC-signal) , shown in Figure 2, which is intrinsically available with each projection serves as gating signal for respiratory motion detection and retrospective gating [4]. All experiments were performed on healthy volunteers during free breathing using a clinical 1.5T scanner. For signal reception a 6 channel body-array in combination with 6 channels from a 12 channel spine array was used. A balanced 3D UTE sequence with 180° alternating rf-pulse phase was implemented. In order to compensate for gradient delays and imperfections of the gradient waveforms especially during ramp sampling, trajectory measurements were performed for each physical gradient axis according to the method proposed by Duyn et al [5]. Images were acquired with following parameters: FoV=400x400x400mm^3; TE=70us, TR=3.6ms; Flip angle=5 degrees; Readout points=192; readout bandwidth = 650 Hz/Pixel; 240000 projections yielding a total scan time of 14 minutes. Image reconstruction was done offline using the Matlab (The Mathworks, R2012a) programming environment and nufft-based gridding [6].

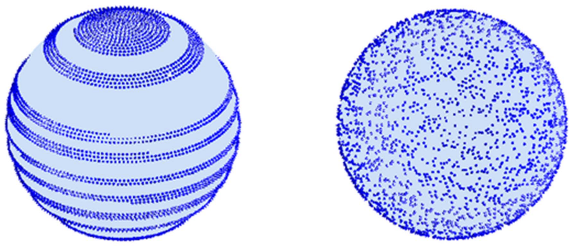

Fig 1: Sampling profiles for 3DUTE after gating: standard spiral path (left), quasi random (right).

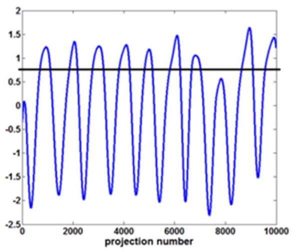

Fig 2: DC gating signal for the first 10000 projections and the gating threshold.

Results: In Figure 2 exemplary coronal and transversal views of a volunteers lung are displayed using all 24000 projections (left) and corresponding reconstructions gated in inspiration (right). While images from all projections show high SNR the reconstruction appears blurred due to respiratory motion. In contrast, the gated images appear sharper at an expense of reduced SNR.

Conclusion: Retrospectively self-gated 3D radial UTE following a QR sampling order allows for successful motion compensation and for the flexibility of reconstructions in arbitrary breathing states.

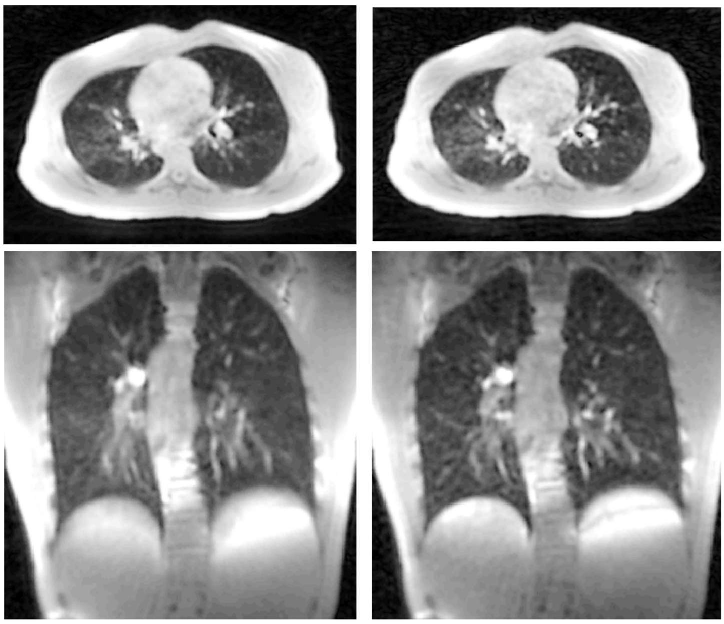

Fig 3: Images from axial and coronal slices reconstructed with all projections (left) and with retrospective motion correction (right)

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References: [1] Weick et al., ISMRM 11' p924 [2] Rahmer et al., MRM 2006; 55:1075-1082; [3] Nackos et al., ISMRM 12' p3966; [4] Brau et al., MRM 2006; 55:263-270 [5] Duyn et al., JMR 1998; 132(1):150-153. [6] Fessler, JMR 2007; 188: 191-195