Robust Resolution-adapted 3D Abdominal Breath-hold Water-Fat Imaging with Self-termination

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Purpose: Respiratory motion is a common source of artifacts degrading the image quality, in particular in abdominal imaging. An efficient strategy to minimize the associated artifacts is breath-holding, if the patient can hold his/her breath sufficiently long. To cope with a sudden, premature onset of breathing during scanning, a dedicated sampling pattern recently was proposed[1], which facilitates a continuous temporally changing compromise between undersampling artifacts, SNR, and spatial resolution allowing for scan termination at every point in time during the breath-hold. In this work, dual echo imaging was added to this type of sampling pattern for water-fat separation, and a coil compression[2] technique was included for faster reconstruction. This approach was furthermore complemented with an efficient intrinsic navigator[3] to trigger scan termination.

Methods: The sampling pattern copes with a premature onset of breathing by enabling flexible scan termination. A central area in k-space is fully sampled first, followed by the periphery (see Fig.1). Elliptically shaped nested areas are partially sampled subsequently with samples approximating a variable density Poisson disk distribution for incoherent aliasing enabling a CS reconstruction. The temporally increasing resolution performs a compromise between SNR, undersampling artifacts, and resolution and can be adjusted using a few simple parameters. Imaging on volunteers was performed on a 1.5T scanner (Philips Healthcare, Best, The Netherlands), using a 16-element torso coil with an interleaved (k=0) navigator that uses the imaging sequence to repeatedly measure the k-space centre. This (k=0) navigator is embedded in a T_1-weighted spoiled gradient-echo sequence with a $TE_1/TE_2/TR$ of 1.29/2.34/3.67ms to cover a typical FOV of 380×280×240mm^3 with an actual spatial resolution of 1.5×1.5×3.0mm^3. It is used for triggered automatic scan termination, without disturbing the steady state[3]. The navigator takes only one repetition time (TR), which is faster than a 1D pencil beam navigator (see Fig.2) of approximately 20ms duration. The sum of the single channel signals is taken for further evaluation. Consistency of the navigator data is estimated based on the complex correlation coefficient between the first and subsequent profiles from different time-points to monitor breath-holding. Furthermore, a termination criterion is used based on the deviation from a predefined correlation value. The 16 channel data was compressed[2] into 6 virtual coils for faster reconstruction. A combined PI and CS reconstruction, L1-SPIRiT[4], was used for reconstruction of the individual echo images for each virtual coil from the incomplete k-space data. Using a complex coil combination based on sensitivity of the coils, the 6 virtual coil images of the two echoes are combined into one complex valued image for each echo, which enables subsequently efficient water-fat separation[5] for improved image contrast and high quality fat suppression.

Results: Figure 3 shows a typical breathing curve for illustration derived from the navigator signal from one of the volunteer acquisitions. Real-time detection of the respiration onset is trustworthy with high efficiency allowing for immediate scan termination at onset of breathing. Water-Fat images with reliable and reproducible image quality (Fig. 3) were achieved from PI/CS reconstruction for all volunteers underlining the basic feasibility and robustness of this new sampling approach.

Discussion: Respiration-controlled 3D water/fat resolved breath-hold abdominal imaging with coil compression for faster reconstruction is a promising building stone to pave the way towards clinical robustness in 3D abdominal imaging. The used navigator increases the scan efficiency at no cost in image quality and provides the opportunity to straightforwardly extend this robust sampling approach to other sequences and further applications.

References: 1). Gdaniec N, et al. ISMRM 2012: 600. 2).Zhang T, MRM 2012, doi: 10.1002/mrm.24267. 3). Brau A, et al., MRM 2006,55:263-270. 4). Lustig M, et al. ISMRM 2009: 3345). Eggers H, et al. MRM 2011, 65:96-107.

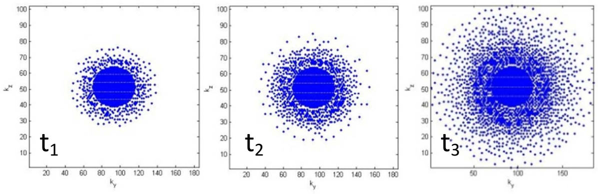

Fig.1: A continuous compromise. A variable density k-space sampling pattern with increasing resolution over time (t_i), producing incoherent aliasing for CS reconstruction for variable breath-hold durations.

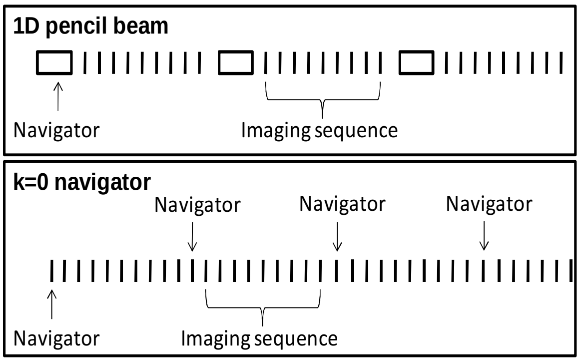

Fig. 2: Temporal arrangement of imaging sequence and navigator. The 1D pencil beam navigator is distinguishable from imaging sequence and has longer duration (factor 4-5) compared with k=0 navigator.

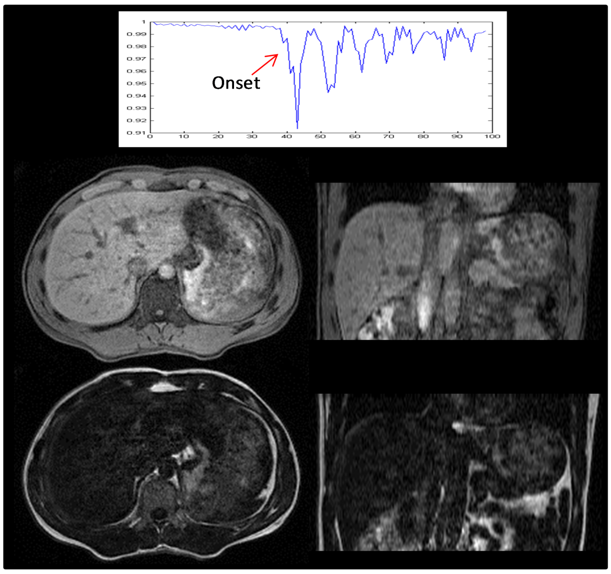

Fig.3: 3D water/fat resolved abdominal data. Typical navigator breathing curve based on correlation terminate scanning at the onset of breathing (example). Volunteer water-fat images and reformats obtained in such a 20 second self-terminated breath-hold.