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Towards Robust Breath-held 3D Abdominal DCE Imaging

Nadine Gdaniec[1], Andrea J. Wiethoff[2,3], Qing Yuan[4], Peter Börnert[5], Holger Eggers[5], Daniella Pinho[4], Ivan Pedrosa[3,4], and Alfred Mertins[1]
[1]Institute for Signal Processing, University of Luebeck, Luebeck, Luebeck, Germany, [2]Philips Research North America, Briarcliff Manor, New York, United States, [3]Advanced Imaging Research Center, UT Southwestern Medical Center, Dallas, Texas, United States, [4]Department of Radiology, UT Southwestern Medical Center, Dallas, Texas, United States, [5]Philips Research Laboratories, Hamburg, Hamburg, Germany

Purpose: Image quality in clinical dynamic contrast enhanced (DCE) MRI of the abdomen is often challenged by respiratory motion artifacts. DCE studies are commonly acquired at the end of the MRI examination, after the patient has gone through several breath-holds and the average breath-hold capability is known. However, patients may have trouble holding their breath after contrast injection and this is often unpredictable as many of them may have been able to do so earlier in the exam. To overcome this problem, DCE imaging with flexible scan termination[1] is proposed in this work, to automatically adapt to the breath-hold capabilities of the patient. Shorter breath-holds are compromised with lower but adapted spatial resolution.

Methods: The sampling pattern copes with premature breathing onset by enabling flexible scan termination. A central area in k-space is fully sampled first, followed by the periphery. Elliptically shaped, nested areas are partially sampled subsequently with samples approximating a variable density Poisson Disk distribution for incoherent aliasing enabling a compressed sensing (CS) reconstruction at any point in time. Reconstruction of pre- and post-contrast images can be performed for different breath-hold durations indicating robustness against premature breathing onset. Furthermore, signal difference maps are calculated for distinct breath-hold duration of pre- and post-contrast images to evaluate the influence of the breath-hold duration on quantitative enhancement characteristics.

Abdominal imaging was performed on 1 healthy volunteer and 4 patients on a 3T scanner (Achieva, Philips Healthcare, Best, The Netherlands) using a 16-element torso coil. Embedded in a clinical DCE series, two additional 19-sec breath-hold acquisitions were obtained: one before contrast injection and one after the clinical DCE acquisitions in order to avoid interference with the existing clinical procedure. The early image is comparable to the first pre-contrast dataset of the clinical series, while the late image is comparable to the last post-contrast acquisition. A T_1-weighted spoiled dual-gradient-echo sequence with a $TE_1/TE_2/TR$ of 1.13/2.0/3.7ms (mDIXON) was employed to cover a typical FOV of 340×262×300 mm^3 with an actual acquired spatial resolution of 1.5×1.5×3.0 mm^3. A combined parallel imaging (PI) and CS reconstruction (L1-SPIRiT[2]) was used for reconstruction of the two echo images, and two-point water fat separation[3] with flexible echo times was performed as a final step. The reconstruction ensures the same final voxel size of pre- and post-contrast acquisitions to enable subtraction. Because relative enhancement is a crucial criterion for lesion characterization in clinical practice, one needs to be sure that the signal amplitude is not influenced by the breath-hold duration. This is evaluated in this work with an additional control volume within the FOV.

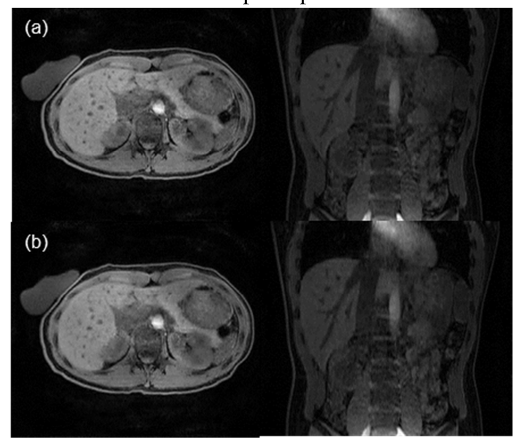

Fig.1: Pre contrast images. (a) reconstructed from a scan with 19s breath-hold, while (b) reconstructed from shorter breath-hold of 13s.

Results: The data shown are from the fully acquired 19s breath-hold acquisitions. In addition, a shorter 13-sec breath-hold was also simulated by truncating the acquired data. Pre-contrast images were successfully reconstructed from various simulated breath-hold durations with preservation of image quality (Fig.1). Post-contrast images were also reconstructed with shorter (i.e. 13s and 10s) simulated breath-holds (Fig.2). The difference between the pre- and post-contrast images as well as the ratio of the difference and the pre-contrast images is calculated for different breath-hold durations of the post-contrast images. For Fig.3, the pre-contrast images are taken from the first 19s, while the post-contrast images are from 19s, 13s and 10s breath-hold durations. Fig.3 indicates expected enhancement characteristics within the body and no significant change of the mean value within the control volume for the two acquisitions and breath-hold durations. The breath-hold duration influences the resolution of the motion artifact-free final images, but leaves the quantitative information unaffected. The pre- and post-contrast water images in Fig.4 are reconstructed from 3D patient data.

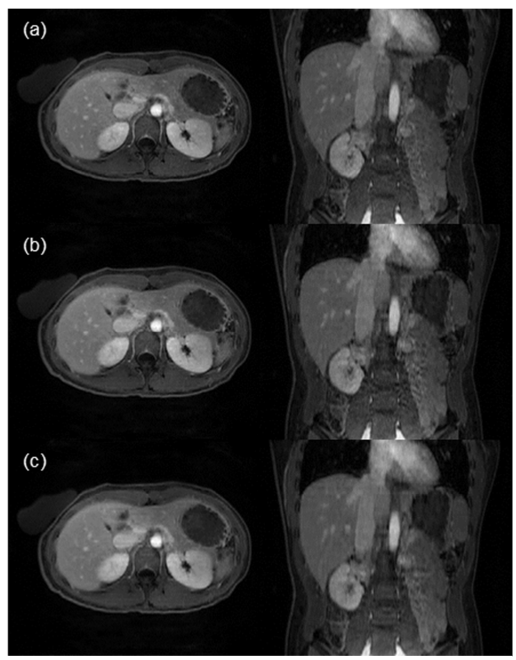

Fig. 2: Post contrast images. (a) reconstructed from a scan with 19s breath-hold, while (b,c) are from shorter breath-holds of 13s (b), and 10s (c).

Discussion: The concept of flexible scan termination based on the individual breath-hold duration of a patient can be applied to dynamic contrast enhanced imaging of the abdomen. Different breath-hold durations have no influence on the mean signal value which enables an evaluation of spatially restricted absolute and relative enhancement for diagnosis on the water/fat images as well as difference images.

References: 1. Gdaniec N, et al. ISMRM 2012: 600. 2. Lustig M, et al. ISMRM 2009: 334. 3. Eggers H, et al. MRM 2011, 65:96-107.

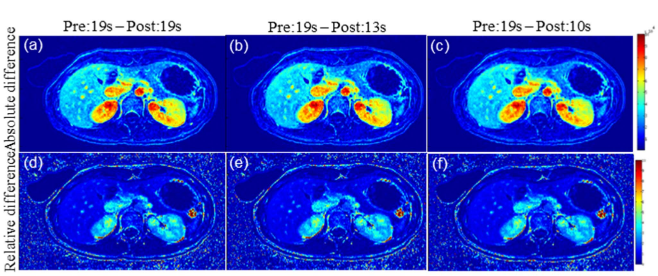

Fig. 3: Difference of pre- and post-contrast images. (a-c) is the absolute difference between the water images of the two phases (S_{post}-S_{pre}), while (d-f) is the ratio between difference and the pre-contrast image (S_{post}-S_{pre})/S_{pre}.

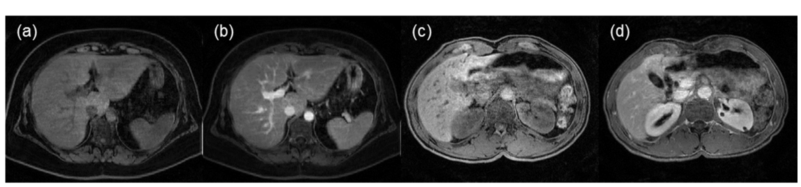

Fig.4: Data from two patients. Left: patient I (a) pre-, (b) post-contrast. Right: patient II (c) pre-, (d) post-contrast, acquired with the adaptive sampling pattern.