Comparison of Physiological Trigger Modes for DWI in the Abdomen

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Introduction: Diffusion-weighted imaging (DWI) is a promising functional method for the diagnostic work-up of the kidney [1-3]. One major problem in abdominal imaging is related to physiological motion artifacts caused by respiration and cardiac pulsation leading to image artifacts, blurring and signal voids. While the necessity to perform DWI in abdominal organs either during a breath-hold period or employing respiratory triggering is generally accepted, the requirement to perform additional pulse triggering has been disputed [4-6]. Chow et al. [5] concluded that by acquiring multiple signal averages pulsation effects may cancel out. It is well known that in DWI measurements of the abdomen in addition to diffusion, microperfusion may contribute (intravoxel incoherent motion, IVIM-model [1]). Previously we have separated diffusion and micro-perfusion contributions in DWI scans of the kidney [7]. However, it is expected that reliable determination of the perfusion contribution is more susceptible to pulsation effects than the generally performed apparent diffusion coefficient (ADC_{tot}) estimation. On the other hand, its estimation requires the acquisition of multiple b-values with several averages which may lead to cancelation of artifacts. The aim of this study was therefore to compare different physiological triggering modes, i.e. respiratory versus combined respiratory-cardiac gating in DWI of the kidney.

Methods: Nineteen healthy volunteers (age=24y±3y) were examined on a 3T MR scanner (Siemens Trio Tim, Erlangen, Germany). A DW single shot echo-planar imaging sequence was applied employing one out of three triggering methods under otherwise identical conditions: I) respiratory triggering alone (RTA), II) combined respiratory-cardiac triggering (RCT), and III) combined respiratory-cardiac triggering with a prospective slice position correction (RCTc). In all cases the Siemens' prospective acquisition correction (PACE) technology based on a navigator scan was used. For pulse triggering a finger tip sensor was employed. Each triggering method was repeated up to six times to determine reproducibility resulting in up to 6×3=18 DWI scans for each subject. Five coronal slices (7mm thickness, 1mm gap) were acquired with one average applying parallel imaging (GRAPPA, acceleration factor=3). Diffusion weighting was performed in 3 orthogonal directions with up to 12 different b-values. Because the main interest was on testing the signal stability in a b-value range with perfusion contributions, predominantly low b-values (0-200s/mm^2) were applied. However to compare in addition the stability of the diffusion-perfusion separation between the trigger modes, b-values ranging from 0-700s/mm^2 were applied for a subgroup of 5 subjects. Other parameters were FOV=40×40cm^2, BW=2300Hz/Px, matrix=128×128, TR_{min}=3000ms and TE=52ms. The total examination lasted for approximately 1 hour.
Six regions of interest (ROI) were placed in homogeneous areas in both kidneys of each subject. The ROIs were placed for every subject at identical positions for all repetitions and gating methods. For each ROI the coefficient of variation (CV) of the signal intensity was calculated for the identical repetitions. These CVs were then averaged over all 6 ROIs resulting thus in 1 CV for each gating method, each b-value, and each subject and used as a measure of DWI scan stability and reproducibility. The CVs were then A) averaged over all b-values for each subject, yielding one CV for each subject and trigger method; B) averaged over all subjects for each b-value. Method A) allows for comparing the overall variability between the three gating methods, while method B) allows for investigating the CVs at different b-values. For a subgroup consisting of 5 subjects a complete DWI analysis as in [7] was additionally done. Processing of the data was performed I) by monoexponential fitting employing all b-values, yielding ADC_{tot}, and II) separating diffusion and perfusion contributions by biexponential fitting of all b-values, yielding ADC_D (mostly determined by diffusion) and the contribution of the fast decaying component characterized by the perfusion fraction F_P.

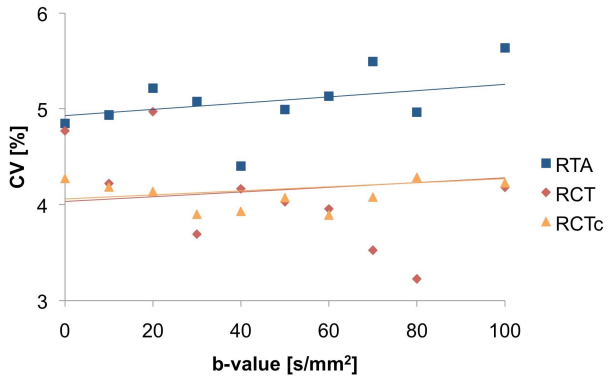

Fig. 1: Coefficient of variation (CV) calculated from multiple DWI scan repetitions versus b-value for respiratory triggering alone (RTA), combined respiratory-cardiac triggering (RCT) and combined respiratory-cardiac triggering with prospective acquisition correction (RCTc). The CV for RCT and RCTc is lower than for RTA independent of the b-value applied.

	Medulla			Cortex		
	RTA	**RCT**	**RCTc**	**RTA**	**RCT**	**RCTc**
ADC_{tot}	190±10	186±10	185±11	208±6	200±6	200±6
ADC_D	169±15	168±12	167±8	192±9	186±8	182±5
F_P	14±6	12±4	13±3	12±4	11±3	13±2

Tab. 1: Mean values (± standard deviation) of the different diffusion coefficients [10^{-5}mm^2/s] and the perfusion fraction F_P [%] in medulla and cortex for respiratory triggering alone (RTA), combined respiratory-cardiac triggering (RCT) and combined respiratory-cardiac triggering with prospective acquisition correction (RCTc).

Results: Visual inspection of the signal decay with increasing b-values demonstrated high signal stability for all 3 trigger modes. Quantitative data evaluation yielded significantly lower overall CVs for RCT and RCTc compared to RTA (4.4% and 4.4% compared to 5.3%, $p<0.001$, paired *t*-test). Between RCT and RCTc no significant difference was observed. For all b-values the CVs of RCT and RCTc are lower than of RTA (Fig. 1). The diffusion indices determined from the subgroup of 5 subjects were not different between the different trigger modes. However, the corresponding standard deviations were lower for RCT and RCTc versus RTA (Tab. 1).

Discussion & Conclusions: Combined respiratory-cardiac triggering in DWI leads to better signal stability and thus lower CVs than single respiratory gating. The mean values of the calculated diffusion indices remain unchanged independent of the trigger mode applied, whereas the standard deviations of the parameters like F_P are reduced for both combined respiratory-cardiac triggering methods RCT and RCTc. Furthermore it should be noted that double triggering methods like RCT and RCTc do almost not prolong the total acquisition time due to efficient pulse triggering.

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