MRC at 3 Tesla with SPACE

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Introduction: MR cholangiography (MRC) is an important, non-invasive imaging modality of the biliary ductal system. It has become even more clinically useful and desired since the recent development of respiratory-triggered 3D T2w turbo spin echo techniques (TSE) during the past few years. These sequences allow for nearly isotropic voxel datasets with spatial resolution in the range of 1.5mm^3 or below. Respiratory-triggered TSE sequences are particularly well suited for MRI at 3.0 Tesla with its inherent gain in signal-to-noise-ratio (SNR) over 1.5 Tesla [1, 2]. However, a number of artifacts are commonly seen in MRC studies performed at 3.0 T such as N/2 ghosting artifacts. In addition, the temporal resolution of the 'standard' respiratory triggered 3D TSE T2w sequence is poor and may benefit from the implementation of parallel imaging techniques. The purpose of the study was to evaluate whether MRC using a SPACE sequence (Sampling Perfection with Application optimized Contrasts using different flip angle Evolutions) will increase image quality and temporal resolution while maintaining sufficient contrast-to-noise ratio (CNR).

Methods: The study was approved by our institutional review board and written informed consent was waived. The study population consisted of 15 men and 14 women (mean age 46.2 years) referred for MRC. MR imaging was performed on a 3 T Siemens Magnetom Trio (Erlangen, Germany) with a dedicated 8-channel torso array coil (USA Instruments, Aurora, OH) used for signal reception. MRC sequence protocol consisted of a 3D TSE T2w sequence and a SPACE sequence. Respiratory triggering was performed using the PACE (Prospective Acquisition CorrEction) technique in both sequences. Detailed sequence parameters were as follows:

3D TSE T2w: TR/TE/FA/NSA/BW/IPAT 1xrespiratory cycle/645/180°/1/257/1

SPACE: TR/TE/FA/NSA/BW/IPAT 1xrespiratory cycle/746/120°/2/751/3

Image matrix for each sequence was identical at 240 x 256, and the FOV ranged from (30cm)^2 to (35 cm)^2 depending on the patient's size. A total of 60 slices per slab were acquired for each sequence with an effective slice thickness of 1 mm each.

Quantitative data analysis: Signal amplitudes of the common bile duct (CBD), of the right hepatic duct (RHD), of the left hepatic duct (LHD) and of the periductal tissue were measured three times each for both MRC sequences. Standard deviation of the noise was also measured in an artifact-free background region. CNR was calculated as the difference between the ductal and periductal signal amplitude divided by the noise standard deviation. In addition, the acquisition time (TA) for each sequence was recorded. Statistical analysis was performed using the two-tailed paired student's t-test.

Qualitative data analysis: Two independent readers assessed the image quality in a side-by-side comparison with a 5-point DROC (differential receiver operating characteristics curve; 1 = TSE T2w much better, 2 = TSE T2w slightly better, 3 = both sequences equal, 4 = SPACE slightly better, 5 = SPACE much better). In addition, inter-observer agreement was assessed by calculating the Pearson's correlation coefficient.

Results and Discussion: Mean TA for the 3D TSE T2w sequence and the SPACE sequence was 4 min 57 sec (range 3 min 14 sec – 8 min 10 sec) and 3 min 53 sec (range 2 min 12 sec – 6 min 32 sec), respectively. These differences were statistically significant ($p < 0.01$) and are due to the parallel imaging acceleration factor of 3 in the SPACE sequence which outweighs the two signals averaged in the SPACE sequence. CNR calculations for the CBD, RHD, and LHD revealed statistically significant differences in all locations with the CNR values measured in the SPACE sequence being lower ($p < 0.05$ for each location) (Table 1). These differences can be attributed to the decreased refocusing flip angle, the increased receiver bandwidth, and the use of parallel imaging techniques in the SPACE sequence. All these factors outweigh the increased number of signals averaged in the SPACE sequence.

	3D TSE T2w	SPACE
Mean CNR_{CBD} ± StdDev	172 ± 86	96 ± 42
Mean CNR_{RHD} ± StdDev	161 ± 90	119 ± 80
Mean CNR_{LHD} ± StdDev	172 ± 88	107 ± 82

Table 1: Contrast-to-noise ratios between various biliary ductal components (common bile duct, right hepatic duct, left hepatic duct) and periductal tissue measured in two different MRC sequences. All differences are statistically significant.

Both readers independently assessed the image quality of the SPACE sequence as superior (mean qualitative rank of 3.50 for reader 1 and 3.48 for reader 2). Inter-observer correlation was excellent with $\rho = 0.82$. The area under the DROC curve was .764 which indicates a statistically significant preference for the SPACE sequence. In particular, N/2 ghost artifacts were completely eliminated by the SPACE sequence (Figure 1). This artifact is commonly seen on 'standard' 3D TSE T2w and results from the filling of k-space during two consecutive respiration cycles if the patient's breathing pattern is irregular. Dielectric artifacts on the other hand were slightly more pronounced on the SPACE sequence. This is most likely due to the longer echo train which makes T2w sequences more susceptible to dielectric artifacts.

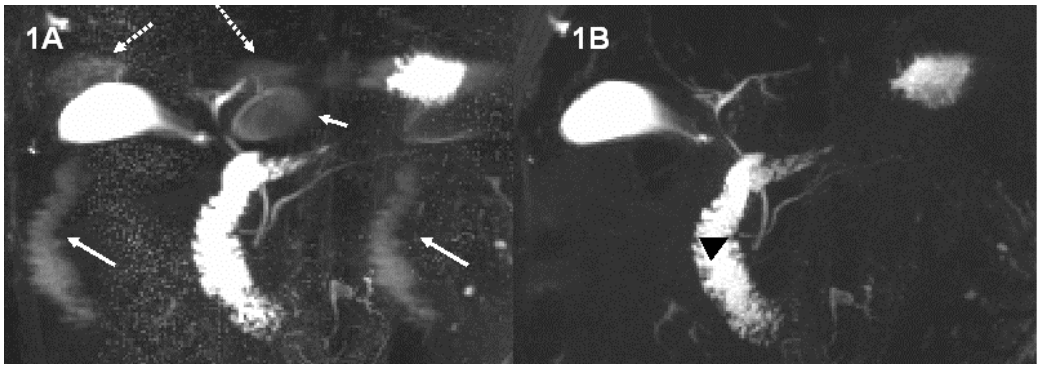

Figure 1: 42-year old male with pancreas divisum. (A) Standard TSE T2w sequence shows severe N/2 ghost artifacts of the fluid-filled duodenum (long arrows), the gallbladder (short arrow), and the fluid-filled gastric fundus (dashed arrows). (B) SPACE sequence eliminates N/2 ghost artifacts and also provides better background signal suppression. Note black arrowhead in (B) which marks minor pancreatic papilla.

Conclusion: MRC at 3 tesla using SPACE offers improved temporal resolution while maintaining sufficient CNR. In addition, image quality is substantially improved, particularly through the elimination of N/2 ghost artifacts and the reduction of parenchymal background signal.

References: [1] O'Regan DP et al.: Br J Radiol; 2005 [2] Merkle EM et al.: AJR; 2006