Isotropic 3D MR Cholangiopancreatography (MRCP) imaging in breath-hold using SPARSE-SENSE acceleration

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Target Audience: Scientists and clinicians who are interested in advanced abdominal MRI techniques

Purpose: Magnetic resonance cholangiopancreatography (MRCP) is an established non-invasive imaging method to assess biliary and pancreatic duct anatomy, which is a common component of abdominal MR imaging[1, 2]. MRCP is routinely performed using a respiratory-triggered isotropic 3D heavily T2-weighted pulse sequence such as SPACE (Sampling Perfection with Application optimized Contrast using different flip angle Evolutions)[3]. This conventional approach provides high-spatial-resolution volumetric images with excellent background suppression for patients who have a steady respiratory rhythm. However, in patients with shallow or irregular respiratory rhythms, respiratory-gated acquisitions may fail to trigger correctly, prolonging scan times, which can further degrade image quality[4]. Compressed sensing techniques can be used to accelerate data acquisition by enabling accurate reconstructions from undersampled k-space data if the underlying images are compressible. As MRCP images are inherently sparse, due to the heavy T2-weighting, it may be possible to prospectively acquire only a small portion of the k-space data in a breath-hold and reconstruct images with a compressed sensing approach. SPARSE-SENSE combines compressed sensing and parallel imaging in a joint reconstruction algorithm to enable higher acceleration rates[5]. The aim of this study was to perform a breath-hold 3D volumetric MRCP imaging by prospectively acquiring only 5% of k-space data and reconstructing with SPARSE-SENSE (BH-SPARSE-SPACE). BH-SPARSE-SPACE was compared to conventional respiratory-navigated 3D SPACE (Nav-SPACE) in patients undergoing clinically indicated MRCP.

Methods: In this prospective HIPAA compliant IRB approved study, 13 patients underwent clinically indicated MRCP at 3T (MAGNETOM Skyra, Siemens Healthcare) with conventional respiratory triggered 3D SPACE sequence and a breath-hold prototype SPARSE-SPACE acquisition.10 patients (3 male, 7 female; mean age 61.7 years) with breath-hold capacity over 10 seconds were included in the study. BH-SPARSE-SPACE and Nav-SPACE had matching voxel size (1 x 1 x 1.1 mm³), base resolution of 384, fat saturation (SPAIR), echo time (TE 812 msec), and flip angle of 100^0. For BH-SPARSE-SPACE, TR was 2000 msec, and 64 coronal partitions were acquired with 100% oversampling in the partition direction. Conventional Nav-SPACE had variable TR (set at 2400 msec) due to respiratory triggering, and 96 partitions were acquired with 8.2% oversampling. Parallel imaging factor of 3 was employed. .

BH-SPARSE-SPACE Acquisition: An accelerated SPACE sequence prototype was developed using a variable-density Poisson-disk undersampling pattern of the two phase-encoding dimensions. This sampling pattern is suitable for SPARSE-SPACE since it contains sufficient incoherence and avoids gaps in k-space. A technique for trajectory-optimization was used to prevent strong echo train fluctuations in the highly undersampled data[6].

BH-SPARSE-SPACE Reconstruction: Image reconstruction was performed by enforcing joint multicoil sparsity in the wavelet space of the 3D MRCP images. The wavelet transform is a common compression transform that produces sparser representations of the MRCP images by exploiting spatial correlations between edges. The iterative reconstruction algorithm uses soft-thresholding in the wavelet space of the image resulting from the contribution from all coils to enforce sparsity (keep the high-value coefficients, knock-out the low-value coefficients) followed by coil-by-coil data consistency to ensure that the reconstructed image is compatible with the acquired data. This algorithm was implemented in Matlab (prototype version) using a fast version of the iterative soft-thresholding algorithm (ISTA).

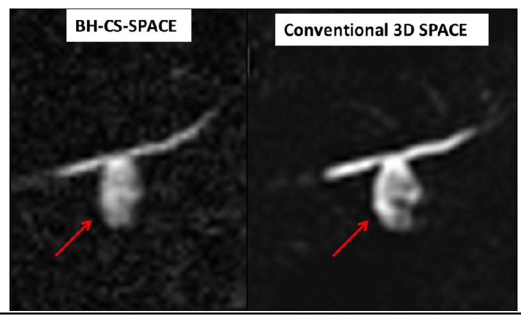

Figure 1: Cystic pancreatic lesion is equally well seen with BH-SPARSE-SPACE and Nav-SPACE.

Image Analysis: BH-SPARSE-SPACE MRCP data (in DICOM format) as well as conventional-Nav-SPACE MRCP acquisitions were anonymized and presented in random order to a board-certified radiologist. The reader evaluated clarity and sharpness of the proximal, mid and distal pancreatic duct (PD) as well as that of proximal and distal common bile duct (CBD) on a 5-point scale (1-5), with higher score indicating better exam. Lesions if detected were noted. Image quality was compared between BH-SPARSE-SPACE and Nav-SPACE with Student's t-test.

Results: Acquisition time for BH-SPARSE-SPACE was 20 seconds versus 301 sec (range 258-398 sec) for Nav-SPACE. There were no significant differences (all $p > 0.1$) in image quality scores for pancreatic duct (PD) as shown in the table. Similarly BH-SPARSE-SPACE and Nav-SPACE had similar scores for proximal and distal CBD clarity (4.1±1.2 versus 3.9 ± 1.7) and sharpness (4.1±1.2 versus 3.9 ± 1.7).

	PD Prox		PD Mid		PD Distal	
	Clarity	Sharpness	Clarity	Sharpness	Clarity	Sharpness
BH-SPARSE-SPACE	3.9 ± 1.2	3.9 ± 1.2	3.8 ± 1.4	3.8 ± 1.4	3.5 ± 1.5	3.7 ± 1.3
Nav-SPACE	4.1 ± 1.3	4.1 ± 1.3	3.9 ± 1.4	3.9 ± 1.4	3.4 ± 1.6	3.4 ± 1.6

Table: Image quality scores for PD were nearly identical for BH-SPARSE-SPACE and Nav-SPACE

Conclusion: 3D isotoropic MRCP imaging in a single breath-hold is feasible with SPARSE-SENSE acceleration. The proposed technique exploits the inherent sparsity in the MRCP images to reconstruct highly undersampled data and present similar image quality to the conventional respiratory-triggered navigated acquisition but with approximately 15-fold acceleration, which represents a significant boost in data acquisition efficiency.

References: **1**. Ringe KI, et al. BMC Medical Imaging 2014. **2**. Glockner, JF, et al. Magn Reson Imaging 2013 **3**. Arizono S, et al. J Magn Reson Imag 2008. **4**. Taylor AM, et al.J Magn Reson Imaging 1997. **5**. Otazo R et al. MRM 2010. **6.** Li et al., Proc Intl Soc Mag Reson Med 2013. #3711