Feasibility Study of Combining CS with SENSE for Catheter Visualization in MR Endovascular Intervention

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Introduction: MR imaging is a promising alternative to the x-ray fluoroscopy gold standard for guiding/monitoring catheters in endovascular intervention due to its absence of ionizing radiation and/or iodinated contrast agents, superior soft tissue image contrast, and the ability to provide functional/physiological information. Conventional MR imaging has insufficient temporal resolution, but accelerated approaches such as sensitivity encoding[1] (SENSE) and compressed sensing[2] (CS) may prove favorable via accurate reconstruction of undersampled k-space datasets. Since SENSE relies on coil sensitivity whereas CS depends on sparsity to recover the missing information, it may be advantageous to combine these two different methodologies.[3] Previously, we demonstrated that CS alone accurately reconstructs catheter images.[4] Here, we extend our catheter image reconstruction approaches and investigate the potential of sequentially combining CS with SENSE.

Method: Following a protocol approved by the local Animal Care Committee, we placed a 1-mm diameter (4 F) catheter into a common carotid artery of a dog under x-ray guidance. The catheter was filled with a 20-mM Gd-DTPA solution to maximize catheter MR signal. We acquired fully sampled k-space data using the multi-cycle projection dephaser[5] (mcPD) method on a 3.0 T scanner (Signa VH/*i*; General Electric Healthcare, Waukesha, WI). From these data, we simulated a 2x undersampled SENSE acquisition with 4 channels, coupled with 4x undersampling with CS (for a total acceleration factor of 8). Thereafter, CS-SENSE reconstruction was performed sequentially, as per Liang.[3] For the CS reconstruction, we used both the wavelet and image domains as sparse domains and adjusted the regularization parameters accordingly.

Results: Figure 1 shows the sequential CS-SENSE reconstruction paradigm. Adequate and judicious selection of the CS regularization parameters not only preserved high spatial resolution but also removed most of the background noise in the aliased images (Figures 1c/1d). Unfolding these aliased images via SENSE reconstruction (Figure 1e) resulted in a final catheter image with superior conspicuity when compared to the fully sampled mcPD catheter image (Figure 1f), albeit with some remnant undesirable noise-like artifacts (arrow in Figure 1e).

Conclusions: Combining CS with SENSE can produce catheter images with moderate-to-high accuracy from fewer *k*-space samples than suggested by the Nyquist-Shannon sampling theorem. This makes it possible to significantly reduce acquisition time and may potentially allow for real-time MR catheter tracking: the CS-SENSE reconstructed catheter image could likely be overlaid onto a vascular roadmap without any need for further post processing.

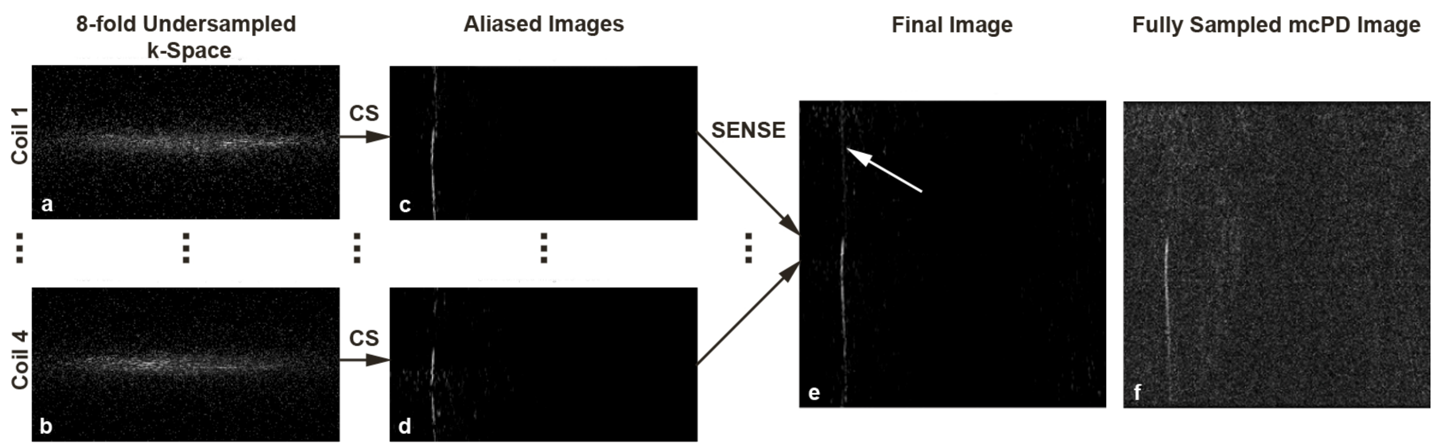

Figure 1. The CS-SENSE reconstruction paradigm. Two of the 4 undersampled k-space datasets are shown in (a) and (b), with the respective CS-reconstructed aliased catheter images given in (c) and (d). The final SENSE-reconstructed catheter image is presented in (e), with the fully sampled mcPD image displayed in (f) for reference. The arrow in (e) shows some undesired noise-like artifacts in the final CS-SENSE catheter image.

References:
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