Reducing View-sharing artifacts in dynamic Contrast-Enhanced Magnetic Resonance Angiography using Compressed Sensing

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Target Audience: Clinicians and researchers working with dynamic Contrast Enhanced MRA (CE-MRA).

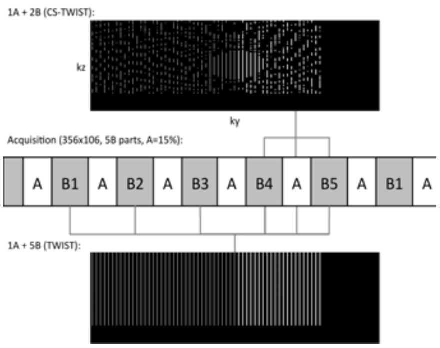

Figure 1: View-sharing is reduced from full k-space (TWIST) to its minimum using adjacent acquired parts of k-space only (CS-TWIST). Compressed Sensing allows for the reconstruction of images for CS-TWIST.

Purpose: Dynamic Magnetic Resonance Angiography (MRA) has become a widely accepted tool for clinical evaluation of complex vascular hemodynamics. To allow for high spatial and temporal resolution, view-sharing techniques [1,2] are commonly used whereby the k-space center is updated more frequently than the periphery. However view-sharing elongates the long temporal footprint of images, which can lead to temporal and spatial blurring. In this work, we aim to study the temporal and spatial blurring effect of view-sharing on dynamic CE-MRA using phantom and in vivo data and its impact on the assessment of blood vessels. Furthermore we propose to reduce artifacts and improve the accuracy of dynamic CE-MRA by limiting the use of view-sharing and reconstruct under-sampled k-spaces with compressed sensing [3–5] (CS).

Methods: As shown in Figure 1, the widely used TWIST [2] dynamic CE-MRA sequence uses view-sharing where the k-space center region (A=15%) is sampled more frequently than peripheral k-space (B_1-B_5, each 17%). Each under-sampled trajectory B_i covers the whole peripheral k-space region B differently. The full view-sharing scheme (TWIST) is used to combine different segments of k-space, resulting in a much longer temporal footprint (~6s in neck MRA) than the nominal temporal resolution (~1.2s in neck MRA). In our work, we combine only 2 adjacent peripheral k-space trajectories (CS-TWIST) to significantly reduce the temporal footprint. Then we applied a recently proposed CS algorithm[3], enhanced with parallel imaging to reconstruct the MRA frames. The CS reconstruction benefits from the high sparsity of the magnitude subtraction of 2 consecutive time frames as well as the Total Variation of individual volumes. Parallel imaging was implemented using SPIRiT[6] coil-to-coil iterative reconstruction. The optimization is performed with a split-Bregman algorithm that guarantees fast convergence. To evaluate qualitatively and quantitatively the artifacts from view-sharing in a phantom experiment, we followed the trajectory of a 2-3cm-long air bubble through a convoluted plastic tube perfused with doped saline. Transit of the bubble signal void was clearly seen against the bright fluid in the tube and mean transit time (MTT) was measured in regions-of-interest (ROIs). The same parameters were then confirmed in routine clinical datasets.

Results: Similar temporal blurring was observed in the phantom and in clinical experiments (Fig.2). However because the view-sharing is performed in higher spatial frequencies, smaller vessels (carotids) are more affected than larger ones (veins) (Fig.2b&c) and because TWIST view-sharing reconstruction uses data from earlier timepoints, signal enhancement appears delayed and elongated when compared with CS reconstruction. In practice, mean transit time is then overestimated using TWIST compared to CS-TWIST (0.7 ± 0.1s, $p<0.01$ in carotids and 0.04 ± 0.1s in jugular veins). The CS-TWIST reconstruction resulted also in higher peak signal and much different signal enhancement pattern over time for the carotid artery shown in Fig. 2c, although the signal enhancement of the veins were similar. Thus CS-TWIST provided an improved separation of the early venous phase from the late arterial phase (Fig.2c).

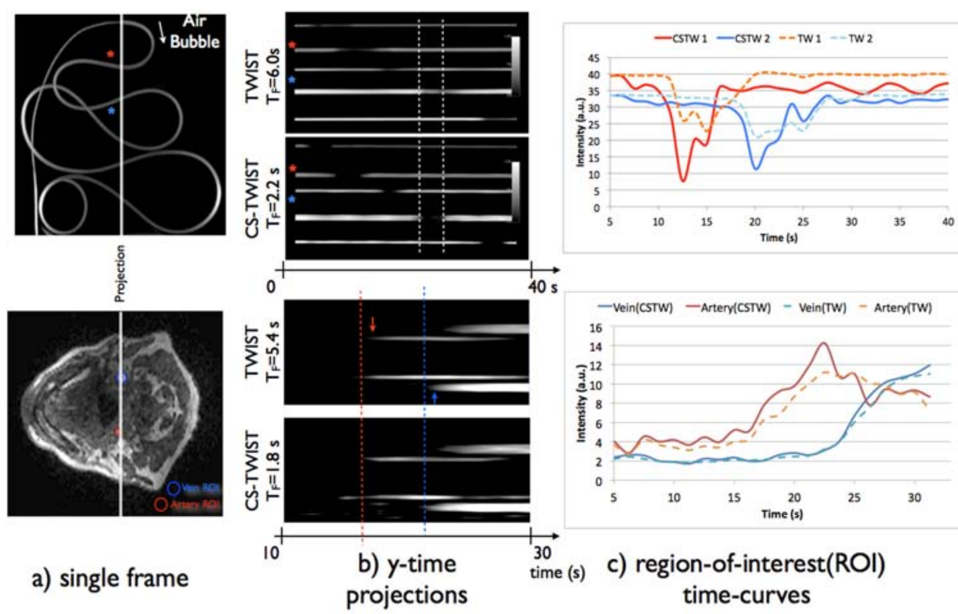

Figure 2: The projection of a single frame (a) along a line shows differences in enhancement timing due to reconstruction (b) in both phantom and clinical experiment (temporal resolution was 1.25s for both experiments, temporal footprints T_F are provided for each reconstruction). The temporal blurring is confirmed (c) using 2 regions of interest (ROI). Clinically, the temporal blurring is more severe in the smaller vessel (carotid, red) then in the larger one (vein, blue). Peak enhancement is also improved using CS-TWIST compared to TWIST.

Conclusion and Discussion: The reduction of view-sharing using Compressed Sensing allows accurate visualization of fast flow in smaller vessels, limits the likelihood of arterial-to-venous contamination artifacts, and improves the assessment of arterial to venous transit time by mitigating the non-uniform temporal blurring. The temporal and spatial blurring caused by view-sharing is a potential source of error for quantitative imaging such as dynamic contrast-enhanced perfusion imaging.

References: **1**. Turski PA, et al. *MRI.* 2001;12(3):175–181; **2**. Lim RP, et al. *AJNR.* 2008;29(10):1847–1854.; **3.** Rapacchi S, et al. *MRM.* 2013; **4**. Trzasko JD, et al. *MRM.* 2011;66(4):1019–1032; **5.** Lee GR, et al. *MRM* 2011; **6.** Lustig M, et al. *MRM.* 2010;64:457–471.