Direct Virtual Coil (DVC) with HighlY Constrained Cartesian Reconstruction (HYCR)

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INTRODUCTION

Recently, a HighlY constrained Cartesian Reconstruction has been proposed for dynamic contrast-enhanced (DCE) MR angiography (MRA) [1] and DCE perfusion applications [2,3]. This technique has shown improved temporal fidelity over conventional view-sharing techniques. However, the reconstruction time for HYCR is approximately 3× longer than view-sharing, making implementation challenging in a clinical setting, especially when combined with the increased reconstruction times associated with auto-calibrated parallel imaging (*e.g.* GRAPPA [4], ARC [5]) and high channel count coil arrays. A novel technique called Direct Virtual Coil (DVC) [6] has been developed to reduce the reconstruction time and computer memory demand for auto-calibrated parallel imaging methods by combining multi-channel MR data into a single virtual channel prior to any Fourier transform and post processing. The purpose of this work is to demonstrate the feasibility of combining this new DVC method with the HYCR reconstruction to reduce the reconstruction time without a loss in image quality. The method is demonstrated in the challenging application of pulmonary perfusion, where high frame rates (*i.e.* large data sets and reconstruction demands) are critical for accurate determination of the true arterial input function and the subsequent calculation of quantitative pulmonary perfusion parameters such as mean transit time, pulmonary blood flow, and pulmonary blood volume.

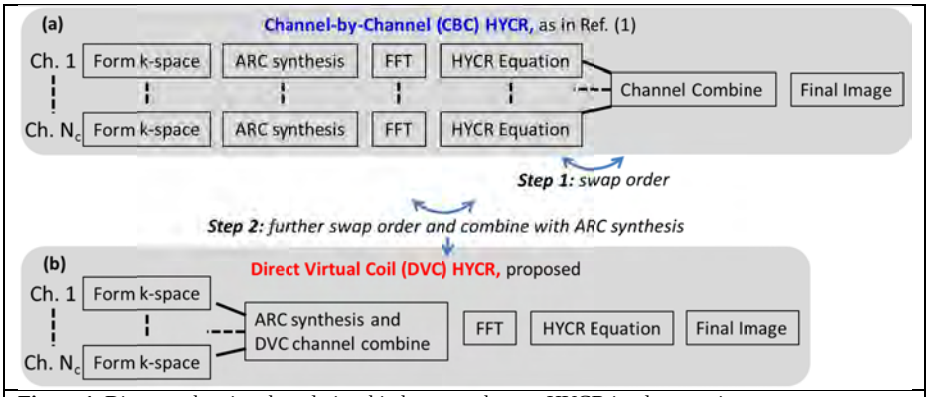

Figure 1. Diagram showing the relationship between the two HYCR implementations.

THEORY

The conventional HYCR implementation is shown in Fig. 1(a), where the ARC synthesis, FFT and multiplicative operation are all performed on a channel-by-channel (CBC) basis, followed by channel combination. The proposed DVC HYCR implementation, shown in Fig. 1(b), is achieved by moving the channel combination step ahead of the FFT and merging it with ARC synthesis. In the DVC HYCR implementation, all synthesis, FFT and multiplicative constrained reconstruction need only be performed once on the channel-combined image, which significantly reduces the computational demands of reconstruction.

MATERIALS AND METHODS

Pulmonary perfusion data sets obtained from eight (8) healthy subjects were used to demonstrate the feasibility of the DVC HYCR technique in this HIPAA-compliant, IRB-approved protocol. Informed consent was obtained prior to all scanning. An Interleaved Variable Density (IVD) sampling strategy [1] was used with an 8-channel cardiac coil, parallel imaging factor of R = 4 (2 × 2), and a matrix size of 100 × 70 × 100. Each data set was reconstructed twice: once with CBC HYCR and once with DVC HYCR. The peak parenchymal enhancement phase was selected and images reconstructed using the two methods were randomized and compared in both coronal and axial orientation by a cardiothoracic radiologist with MRI expertise, using a 5-point Likert scale: left image much better (clinically significant); left image slightly better (not clinically significant); equivalent; right image slightly better (not clinically significant); right image much better (clinically significant). Line profiles and waveform comparisons were also performed.

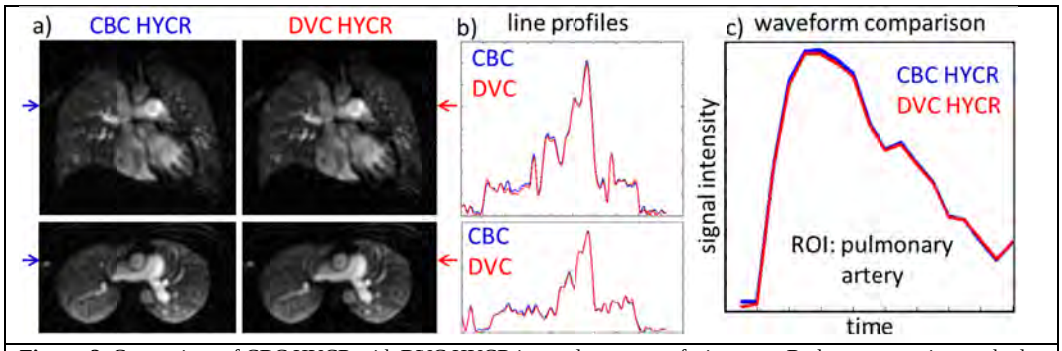

Figure. 2: Comparison of CBC HYCR with DVC HYCR in a pulmonary perfusion scan. Both reconstruction methods show very similar image quality in terms of parenchymal enhancement. Line profiles (indicated by arrows) comparisons demonstrate good agreement between the two methods. DVC HYCR was about 3.5× faster in reconstruction time than DVC HYCR (200sec vs. 700sec). 8-channel cardiac coil, with 256 × 256 × 100 matrix size.

RESULTS: Fig. 2 shows the comparison from a pulmonary perfusion exam. Image quality in coronal and axial views in Fig. 2(a) is similar for both reconstruction methods. A line profile (Fig. 2(b)) was measured at the same location (arrows) for both CBC HYCR (blue) and DVC HYCR (red), and good agreement was found. Fig. 2(c) shows the waveform comparison of a ROI placed on the pulmonary artery, with good agreement between both methods. CBC HYCR and DVC HYCR were judged equivalent in 2/8 (25%) of the data sets. In the other 6/8 (75%) of the data sets, CBC HYCR was judged slightly better, although the difference was not considered clinically significant. An example of the difference is shown in Fig. 3. For this 8-channel, 256 × 256 × 100 matrix data set, reconstruction time for DVC HYCR was about 3.5× faster than CBC HYCR.

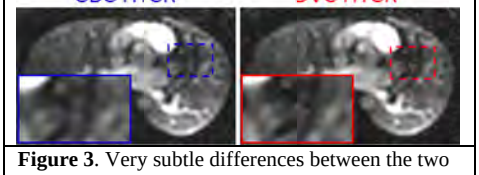

Figure 3. Very subtle differences between the two HYCR implementations.

DISCUSSION: Good agreement between CBC HYCR and DVC HYCR was found, both in qualitative scoring and by inspection of both the line profiles and temporal enhancement curves. The very subtle differences observed in the comparison are mostly in the low signal intensity regions, and may due to suboptimal regularization factors in the division operation in the HYCR algorithm [1]. These differences were not considered clinically significant.

CONCLUSIONS: In this work, we proposed a direct virtual coil implementation of the HYCR algorithm (DVC HYCR), which significantly reduces the reconstruction demand of the original channel-by-channel HYCR (CBC HYCR) implementation. This computational advantage of DVC HYCR is expected to become even more significant when using a higher channel count array, such as a 32-channel coil, because the computation time for conventional auto-calibrating parallel imaging reconstruction methods is scaled by the square of number of channels [5].

REFERENCES: [1] Wang et al., MRM 2011; 66:428 [2] Wang et al., ISMRM 2011, p3034 [3] Wang et al., ISMRM 2011, p3459 [4] Griswold et al., MRM 2002; 47:1202-1210 [5] Brau et al., MRM 2008; 59:382-395 [6] Beatty et al., ISMRM 2008, p8.