Highly Constrained Backprojection: A Method for High Spatial and Temporal Resolution in DCE-MRI of Breast Cancer

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Introduction: The sensitivity of dynamic contrast-enhanced MRI (DCE-MRI) for diagnosis of breast cancer depends on high spatial and temporal resolution during contrast uptake to distinguish differences in tumor structures (1). Projection acquisition has been shown to be a robust method for trading off temporal and spatial resolution in DCE MRI of breast cancer (2). Nonetheless, there remains a largely unmet clinical need for robust temporal-spatial resolution that includes bilateral 3D coverage to detect multi-focal and bilateral disease (3). Undersampled projection acquisition (PR-TRICKS) has been applied to breast MRI (2, 4), but streak artifact and signal to noise is not always sufficient to depict tumor uptake at full spatial resolution (2). Several recent techniques have been proposed to improve temporal resolution of contrast kinetics for applications using sparse training sets (5, 6). The present work applies similar features of sparse data to HighlY constrain the location of signal in a back PRojection reconstruction (HYPR). It is hypothesized that a 10-20 fold improvement in time resolution for 3D DCE MRI of breast tumors can be achieved without compromise in spatial resolution.

Methods: The HYPR reconstruction's ability to increase SNR and reduce streak artifact in undersampled PR applications stems from its use of a composite image consisting of a much wider temporal aperture of projections than the desired temporal resolution (Fig. 1). This composite image is then used to spatially constrain the location of the signal contained in a far smaller subset of projection data used to construct the high temporal resolution frames. To maintain consistent contrast levels, each projection in the time-resolved frame is normalized to the signal in a Radon transform of the composite image at the equivalent projection angle (Fig. 2). In the simulations for this study, the composite image was made up of 120 projections of a 2D image corresponding to a temporal aperture of 3 times the reconstructed resolution. The HYPR reconstruction was applied in phantom studies and retrospectively to clinical DCE-MRI data acquired in an invasive ductal carcinoma (IDC). The phantom study consisted of a PR-TRICKS acquisition (7) of a constant flow phantom in which a small 4 cc dose of Gd contrast agent was injected at ~4 cc/sec. The conventional PR-TRICKS recon was compared to the HYPR recon with respect to temporal dynamics and streak artifact. The retrospective reconstruction of the IDC lesion was performed in 2D, using 256 × 256 matrix images through the center of the tumor. Synthesized HYPR time frames were reconstructed at two temporal resolutions corresponding to 20 and 40 projection angles – corresponding to azimuthal undersampling factor of 20 and 10 respectively. Images were compared for level of streak artifact and fidelity of contrast dynamics.

Fig 1:

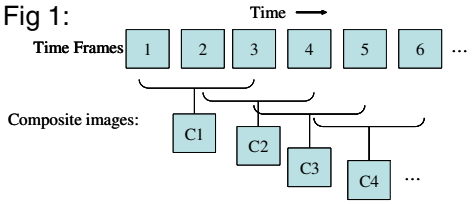
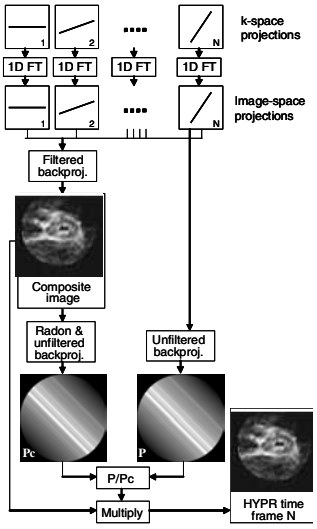


Fig 2:



Results: The results of the flow phantom study demonstrated improved streak artifact suppression of the HYPR recon relative to the conventional PR-TRICKS acquisition (not shown). Similar artifact suppression was observed in the HYPR recon of the IDC lesion using 40 projection angles (Fig. 3a, row 1). The conventional filtered back projection reconstruction for 40 projections is shown for reference in row 1, while the HYPR recon using the same 40 projections is shown in row 3. The enhancement within the heterogeneous structures of the lesion for the HYPR recon is seen to match well with the fully sampled time frames shown in Fig 3a, row 2. The contrast uptake curves measured in the body of the tumor were nearly identical when comparing the HYPR and fully sampled reconstructions (Fig. 3b; grn = HYPR, blue = Original).

Discussion: The HYPR recon is a promising approach to high temporal and spatial resolution acquisition with reduced streak artifact and high SNR. It is well suited to data sets in which the object is relatively static, such as in DCE MRI of breast cancer. Moreover, contrast kinetics appear to be preserved for the 40 projection simulation tested, further supporting the technique for quantitative evaluation of breast lesions. Finally, assuming a 3 msec TR, the case studied would correspond to a nominal 60-120 msec temporal resolution for 2D acquisition, approximately 1.5-3 sec temporal resolution for a 3D volume with full breast coverage. This temporal resolution is nearly sufficient to sample the arterial input function of the tumor. This information could significantly improve the accuracy for kinetic analysis of angiogenesis and more accurately depict tumor regional uptake. However, the technique depends on the data being sparse and works best in cases where all structures have similar contrast kinetics. By definition, this is not the case for most breast lesions which may put a lower limit on the attainable temporal resolution that is sufficient to maintain the fidelity of the contrast kinetics in complex structures like the spiculated tumor studied in Fig. 3.

Fig 3 a

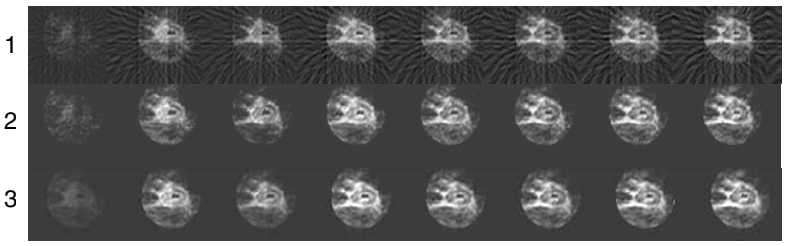
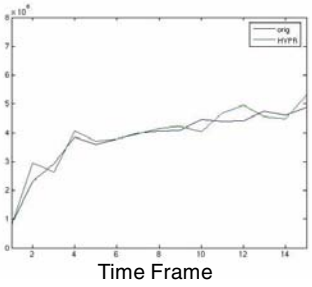


Fig 3 b



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