HYPR PR-TRICKS: Highly Undersampled hybrid radial/Cartesian acquisition with HighlY constrained backPRojection reconstruction for time resolved MRI

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INTRODUCTION

In time-resolved MRI, there is a trade-off between spatial and temporal resolution due to requirement of the Nyquist theorem. Previously, we described a time-resolved hybrid radial/Cartesian acquisition, PR-TRICKS [1], which combines in-plane radially undersampled acquisition with through-plane Cartesian TRICKS acquisition to provide large undersampling factors. We have recently developed a method called HighlY constrained back PRojection (HYPR), which allows us to greatly reduce the sampling requirement in each time frame [2,3,4]. Combination of these two techniques, HYPR-PR-TRICKS, provides relatively artifact-free images with overall Nyquist undersampling factors of 200 or more. This provides the opportunity for substantial increases in temporal resolution, spatial resolution or volume coverage. The unique SNR properties of HYPR result in individual time frames having SNR determined by a running average of all or a substantial subset of the acquired data rather than the acquired data for each time frame.

METHODS

A series of interleaved undersampled radial acquisitions are obtained during the passage of contrast. For each radial acquisition in the kx, ky plane, a series of TRICKS-encoded kz acquisitions are acquired. A composite image, I_{cmp}, is formed from all or a substantial subset of the acquired projection sets. This composite image has relatively less streak artifacts and good SNR. Individual time frame projection information is backprojected using the constraint that information is non-iteratively deposited only in the vessel locations defined by the composite images and with weighting provided by the composite images, expressed as: $I_t = \sum_{i=1}^{n} \frac{P_t^i}{P_{cmp}^i} \cdot I_{cmp}$, where I_t is the image at time frame t, P_t^i is the ith projection at time frame t in the image space, which is the 1D FFT of the ith projection at time frame t in the k-space; P_{cmp}^i is the corresponding radon transform of the composite image at the same angle as the ith projection, and n is the number of projections collected at each time frame. Such constraint reduces both extravascular and intravascular streak artifacts. In the limit in which temporal behavior is spatially homogeneous, a single projection provides an exact reconstruction [5]. As temporal behavior becomes more heterogeneous, more projections per time frame are required to isolate spatially distinct temporal behavior. For HYPR PR-TRICKS, as few as 10 projections per time frame have been obtained to produce a 512 x 512 in-plane matrix, which requires 800 projections to satisfy the Nyquist criterion, giving the Nyquist undersampling factors of 80x3=240 for the 3D acquisition.

RESULTS AND DISCUSSION

HYPR PR-TRICKS has been applied to angiography of the head and legs. Figure 1 shows results from a head study. Ten projections were acquired for each time frame, 50 different sets of interleaves were applied through the whole time series, providing 0.5x0.5x1.5 mm^3 spatial resolution and 0.5sec/frame. Images were reconstructed using the traditional regridding technique (Fig.1a) and the HYPR method (Fig 1b). Three of 126 acquired time frames were shown. Arterial and venous phases are well separated with high spatial resolution and substantial spatial coverage. HYPR images have fewer streak artifact and higher SNR than the images produced using only the regridding technique. Corresponding contrast enhancement curves from a voxel randomly picked from the artery are shown in Fig1c and d. Although the average effect from the composite image smoothes the contrast washout phase, HYPR images caught most of the dynamic information characterized by the images reconstructed using the regridding technique. Due to the use of integrated projection information in the composite image that constrains the reconstruction, relatively smoothed temporal response and motion blurring are potential limitations of this method. In some instances it is advantageous to use less than the complete set of projections in a series of composite images that advance in time. For example, composite images may be retrospectively formed from temporal averages sliding along with the time frames. SNR gain, artifact reduction and temporal response depend on how large a temporal aperture is used for the composite images.

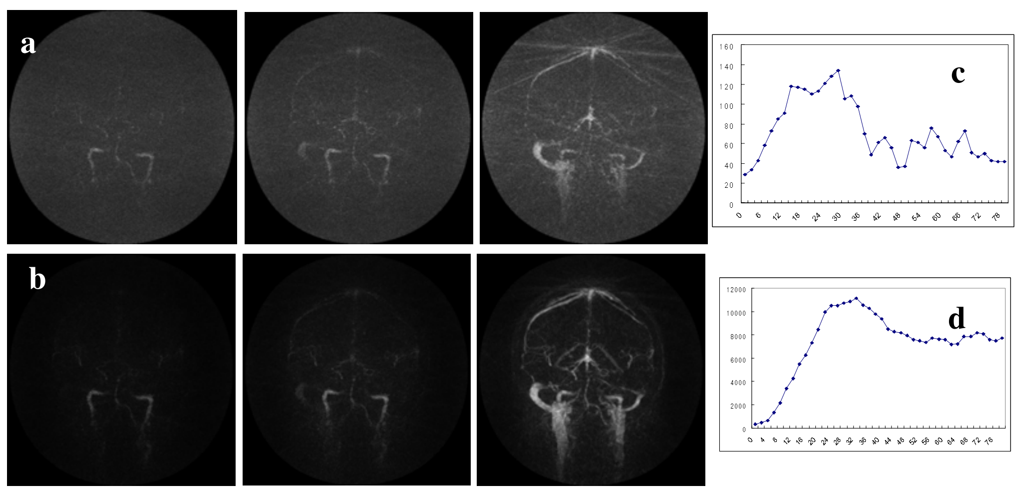

Figure1. Comparison of traditional PR-TRICKS reconstruction (a and c) with HYPR reconstruction (b and d) shows the improvement of the streak artifacts and SNR due to the highly undersampling and reservation of the temporal resolution.

CONCLUSIONS

HYPR PR-TRICKS provides both high spatial and temporal resolution using a large undersampling factor of more than 200. The unusual properties of HYPR result in far less decrease in SNR than would normally be associated with such large acceleration factors. This technique can be generalized to other applications such as cardiac and perfusion imaging.

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