3D HYPR in CE MRA of the Lower Extremeties

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Introduction

In recent work, we used the 3D HYPR method to greatly improve the temporal resolution of contrast-enhanced MR angiograms of the lower extremities [1-6]. The stack of stars acquisition method [7] was applied with a quasi-random projection acquisition order [8]. Temporal behavior was evaluated by comparing time curves obtained from HYPR images with true time curves obtained from a fast, multiphase, 2D Cartesian acquisition. In addition, image quality was evaluated by measuring SNR.

Methods

In the stack of stars acquisition, radial sampling is applied in plane, and conventional partition encoding is applied in the third dimension. For the HYPR contrast-enhanced MRA method, a full mask data set was acquired before the contrast agent arrived. During the reconstruction, the mask data were used for subtraction of unsuppressed signals from stationary tissues. Subsequent to acquisition of the mask data, time frame data were acquired. Projections were acquired with a quasi-random acquisition order so that projections were uniformly distributed at different angles. Thus, any number of projections could be formed into one time frame, and projections in the composite images were statistically evenly distributed.

For image reconstruction, high temporal (low spatial) resolution ‘weighting’ images were produced from the highly-undersampled time frame data by backprojecting unfiltered and normalized profiles (obtained by Fourier transforming the radial k-space lines) and high spatial (low temporal) resolution ‘composite’ images were formed using standard filtered backprojection of the profiles of more densely populated data sets formed by combining data from multiple time frames. The final high temporal, high spatial resolution HYPR images were formed by multiplying the weighting images by the composite images.

Results and Discussion

We have obtained contrast-enhanced 3D HYPR MR angiograms of the lower extremeties in 7 volunteers. Figure 1 shows every fifth frame of a series of CE MRA images obtained from the calves of one volunteer. Relevant acquisition parameters were: 312 samples/projection (partial echo for 512 resolution), 24 slices (zero-filled to 48) with a slice thickness of 1.5mm, a TR of 3.4ms, a TE of 1.1ms, and a FOV of 44cm. Because the data were acquired using a quasi-random acquisition order, HYPR images could be reconstructed using any number of projections per time frame from the same data set. It was found that the image quality and temporal characteristics were well represented using as few as 8 projections per time frame with a moderate sliding composite window width of 16 time frames. The frame time of the HYPR images was 1.04 seconds, whereas each composite image spanned 16.6 seconds.

Figure 2 and Figure 3 show the rescaled signal intensity curves within an ROI placed in an artery. The red curve in both plots is the true curve obtained using a fast, multiphase, 2D sequence. The blue curve in Figure 2 was determined using HYPR images. It closely tracks the true curve. The green curve in Figure 3 was obtained from composite images. As expected, it demonstrates the poorer temporal resolution of the composite images. A frame time of 1.04 seconds was achieved using 8 projections per frame, representing a speedup factor of 100 relative to fully sampled radial imaging (804 projections for full sampling/8 projections for the HYPR frame), and a speedup factor of 64 relative to conventional Cartesian imaging (512 phase encoding values/8 projections for the HYPR frame). The number of projections per frame was decreased to 8 without much loss in temporal accuracy and SNR compared with 12, 16, and 20 projections.

Figure 4 shows the rescaled signal intensity curves from another data set. The green, blue and pink lines correspond to time curves obtained from TRICKS and HYPR images reconstructed using 8 and 16 projections per time frame, respectively. With similar image quality obtained, HYPR (reconstructed using 8 projects per time frame) achieved a speedup factor of 8 compared with TRICKS (96 frames vs 12 frames). In addition, the HYPR images contain temporal information from only a single time frame, whereas, for the TRICKs images, different spatial frequency information comes from different time frames. The improvements in temporal resolution afforded by HYPR can also be exchanged for improvements in coverage or spatial resolution.

Figure 5 shows HYPR time curves from a foot exam. The red curve demonstrates the signal intensity within an artery and the green curve demonstrates the signal intensity within a vein. It can be seen that the contrast curves of the artery and vein were well separated.

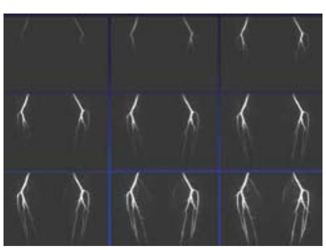

Figure 1

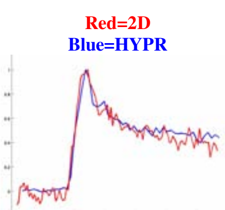

Figure 2

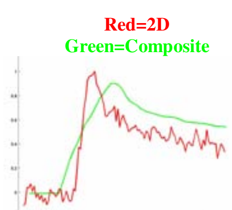

Figure 3

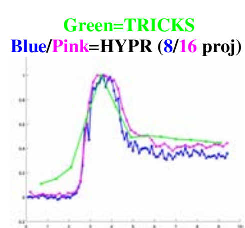

Figure 4

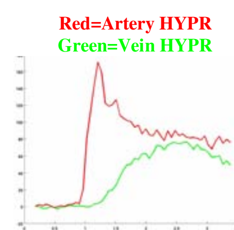

Figure 5

Conclusion

In a small number of volunteers, 3D HYPR (stack of stars) has provided high temporal and spatial resolution while maintaining temporal accuracy and more SNR than previously provided by other methods at the speedup factors used here.

References

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