The Study of Temporal Behavior and Image Quality of HYPR Using Computer Simulations

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Introduction

HYPR is an innovative acquisition and reconstruction method that increases the undersampling factor in time resolved radial acquisitions [1]. The permitted degree of improvement in temporal resolution is determined by the sparsity and spatial-temporal correlation of imaged objects [2][3]. With computer simulations, we investigated the temporal behavior and image quality of the HYPR algorithm using different imaging parameters under various conditions of sparsity and spatial-temporal correlation [4]. This will aid in the proper selection of parameters for different clinical applications with different degrees of sparsity and spatial-temporal correlation.

Methods

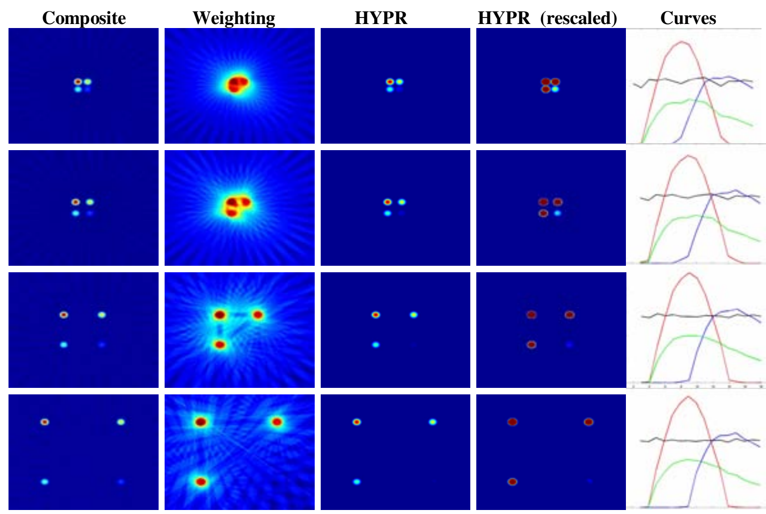
With computer simulations, a series of input images of multiple objects was generated. The signal intensity of the objects changed with time. Each of the input images was sampled using only few projections and the HYPR algorithm was applied to reconstruct the sampled data. The HYPR image can be viewed as the multiplication of a composite image and a weighting image. The spatial configuration and image quality are dictated by the composite image, whereas the temporal information is dominated by the weighting image.

The maximum undersampling factor (determined by the reduction in the number of projections per time frame) is determined by the sparsity and spatial-temporal correlation of the imaged objects. Fewer projections per frame are needed for sparse or highly spatial-temporally correlated objects. The size of objects and the distance between the objects were changed to simulate different extents of sparsity, and the signal intensity of each object was varied individually to simulate various spatial-temporal correlations.

Results and Discussion

Numerous simulations were performed under various conditions. In one example, shown in Figure 1, the signal intensity of one object remained constant, whereas the signal intensities of three other objects changed as a sinusoid or Gamma-variate curves that enhanced at different times, and to different amplitudes. The performance of HYPR was evaluated as the distance between the objects was changed. At a particular time frame, 9, three objects were enhanced whereas the fourth object was just about to enhance. Some of the results of this simulation are shown in Figure 1.

In this figure, the first column demonstrates composite images used to construct time frame 9 for objects spaced at four different distances (different columns). For this time frame, there should be no signal in the lower right object in the HYPR time frame image. A sliding window composite was used where information before and after the current frame was incorporated. Due to the temporal averaging effect of the composite images, there is some signal in the lower right object in the composite images.



Curves of different colors correspond to the signal intensity change of different objects.

Figure 1

The second column shows weighting images that reflect the correct temporal information but have poor spatial discrimination. The third column demonstrates HYPR images that were produced by multiplying the composite images (column 1) by the weighting images (column 2). In the HYPR images (column 3), the temporal information was dominated by the weighting images and the image quality was dominated from the composite images. The fourth column shows HYPR images rescaled to better demonstrate the low signal intensity in the lower right object. The fifth column shows the signal intensity curves obtained by placing ROIs in the four objects in the time series of HYPR images. Overall, the time curves obtained from the HYPR images tracked the true time curves well for all of the objects. However, as the distance between the objects was reduced, the correlation between the HYPR curves and true curves was slightly decreased due to the inability of the weighting images to accurately place the temporal weighting coefficients in the proper spatial location.

This and additional simulations demonstrate that the constrained backprojection of a single profile can provide accurate temporal results only when no objects overlap in the projection direction. When objects get closer, overlap occurs in more projections, and the inaccuracy accumulates in the HYPR images. In these situations, accuracy could be improved by increasing the number of projections per time frame.

Other simulations demonstrated that the amount of inaccuracy in the HYPR time curves was typically very small and it depended not only on the spacing of the objects, but also the relative size of the objects, the temporal frequencies of the enhancement curves, the number of projections per time frame, the number of time frames per composite image, as well as a number of other parameters.

It was also found that the background noise of HYPR images is lower than that of composite images, since weighting images have low signal intensity in the background and suppress the background noise in HYPR images after multiplying with composite images. Both denoising effects and reduction of streak artifacts were very obvious in HYPR images compared with composite images.

Conclusions

Computer simulations clearly demonstrated the benefits and robustness of the HYPR algorithm. HYPR provides very high temporal resolution, which is determined by the weighting image. HYPR has very good image quality in terms of high SNR and few streak artifacts, which are determined by the composite image. The temporal behavior of HYPR is substantially accurate under various conditions of sparsity and spatial-temporal correlation.

References 1. Mistretta C, *et al.* MRM 55:30-40, 2006. 2. Mistretta C, ISMRM 2006, plenary talk. 3. Korosec F, ISMRM 2006, plenary talk. 4. Korosec, F *et al.* Procs. of MRA workshop 2006, p.108.