A Technique for High Spatial and High Temporal Resolution Dynamic MRI: Temporal KWIC

H. K. Song[1], M. D. Schnall[1], L. Dougherty[1]
[1]Department of Radiology, University of Pennsylvania, Philadelphia, PA, United States

Introduction

A novel technique is proposed for dynamic MRI that enables reconstruction of images at both high spatial and high temporal resolutions. The method is based on an angle interleaved acquisition of projection reconstruction (PR) data, and temporally selective data filtering. The effective temporal resolution is equivalent to that of a highly undersampled PR acquisition, but the image quality, including the SNR and the level of streaking artifacts, is equivalent to that of a high spatial resolution image acquired with a "full data set". The technique is demonstrated in a 3D dynamic contrast-enhanced exam of the breast.

Methods

The technique described in this work is based on the combination of two recently described PR data acquisition/reconstruction methods: an interleaved acquisition scheme for allowing reconstruction of multiple temporal/spatial resolution images [1] and a method termed KWIC (K-space Weighted Image Contrast) that allows for the manipulation of image contrast by judicial filtering of the acquired views [2]. In the former technique, PR data are acquired in a multiple angle-interleaved fashion. Each interleave (or subaperture) consists of a highly undersampled PR data set in which the views are equally spaced between 0^o and 180^o (e.g., 512 sampled points and 48 views). Subsequent subapertures are selected such that the view angles of previous interleaves are bisected [1] (**Fig. 1**). During reconstruction, either high spatial / low temporal resolution images are formed using multiple subapertures, or high temporal / low spatial resolution images are formed using only a single subaperture. Since the data set of each subaperture is highly undersampled, fewer sampled points must be used to create low spatial resolution images to avoid streaking artifacts. The KWIC technique makes use of the fact that the central region of k-space in PR imaging is over-sampled, affording a choice of different data weighting schemes to enhance or reduce the amount that each view contributes to the central k-space region, which dominates image contrast. The technique was originally used to reconstruct multiple T_2-weighted images from a single data set. The application of the KWIC technique for dynamic imaging had been proposed [2] but not implemented, and the method is different from that of Lethmate, et al. [3], in which only the inner core of k-space is dynamically replaced and which does not employ the angle bisection strategy that allows smooth transition of subaperture data between the inner and outer k-space regions.

In the new method termed "temporal KWIC", all subapertures of a full data set acquired in an interleaved fashion are used to reconstruct each image. However, the data are weighted similar to the KWIC filtering scheme in order to increase the effective temporal resolution to that of a single subaperture (**Fig. 1**). A "sliding window" scheme [4] is used to dynamically update the subapertures for the most accurate time series reconstruction. Temporal KWIC was used in a dynamic contrast enhancement study of the breast to demonstrate its feasibility. The following parameters were used: 3D gradient echo PR sequence (slice was phase encoded), 512 xres, 8 subapertures (48 views/subaperture for a total of 384 views for a full data set), 32 slices, FOV = 24 cm, TE/TR = 4.0/9.6 ms. Four such data sets were acquired in succession - one baseline and three during and following the injection of Gd contrast agent.

Results and Discussion

A 512x512x32 data set with a voxel dimension of 0.47x0.47x3 mm^3 had an effective temporal resolution of 14 seconds, the time required for 32 slice encodings of one subaperture. **Figure 2** shows images reconstructed with (a) temporal KWIC processing; (b) standard "full resolution" reconstruction using all 384 views; (c) high temporal resolution image using only one subaperture (48 views). Eight subapertures, centered at the time where maximum enhancement occurs, were used in **Fig. 2a** and **b**. The inset figures show that image detail is preserved with the temporal KWIC technique, and it can easily be seen that the SNR is close to that of the standard full resolution image. SNR is expected to be somewhat lower due to the reduced effective averaging near the central k-space regions, but is expected to be considerably higher than the 48-view image due to the use of greater number of views. **Figure 3** shows the time-intensity curve of one of the lesions (arrow in **Fig. 2b**), demonstrating that the temporal KWIC method can accurately follow the intensity curve of a rapidly enhancing lesion.

Conclusion

This work demonstrates that by utilizing an angle interleaved PR acquisition scheme and a temporally selective data filtering scheme, both high temporal and high spatial resolution image set can be obtained. The technique was demonstrated in an in vivo dynamic contrast-enhanced breast MR study.

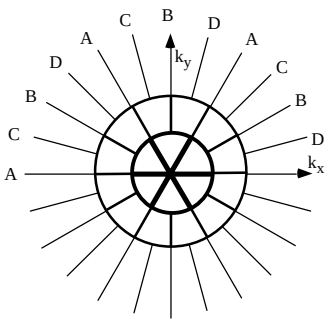

Fig. 1 Four subapertures (in acquisition order: A,B,C,D), and the KWIC weighting scheme. Acquisition B bisects A; C and D bisect A and B. For 8 subapertures, A-D are subsequently bisected.

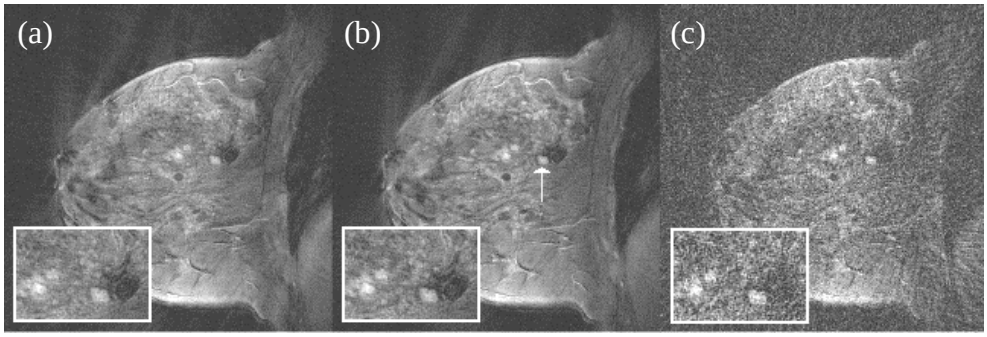

Fig. 2 (a) Temporal KWIC-processed image. (b) Full resolution image (512x384 views). (c) 512x48 view image. The images demonstrate that high spatial resolution is preserved in temporal KWIC. Due to the intrinsic averaging effect as more views are used, temporal KWIC-processed images have higher SNR than the 48-view image (c). Image SNR and level of streaking are similar to that of the full resolution image (b).

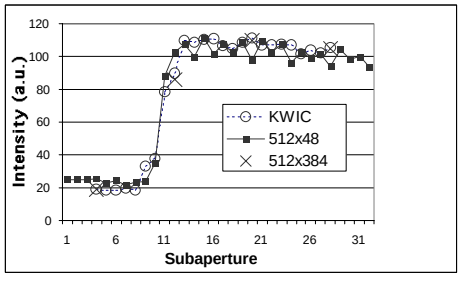

Fig. 3 Plot of the enhancement curve for a lesion in **Fig. 2b** (arrow). The plot shows that the high temporal resolution (14 sec/subaperture) is achieved with the temporal KWIC technique, similar to the result achieved with the high temporal resolution (but lower image quality) 512x48 view image series. Only 4 points can be plotted if the full data set (512x384) is used.

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References

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