Time-Resolved 3D MR Angiography by Interleaved Biplane Projections

Y. Huang[1,2], D. Gurr[3], G. Wright[1,2]

[1]Department of Medical Biophysics, University of Toronto, Toronto, ON, Canada, [2]Imaging Research, Sunnybrook & Women's College Health Sciences Centre, Toronto, ON, Canada, [3]GE Healthcare, Waukesha, WI, United States

Introduction

Time-resolved MR angiography has been the subject of great interest recently. Undersampled PR-TRICKS (1) and interleaved spiral sampling (2) are able to produce 3D data sets at a high temporal rate (2-4 s/3D). Therefore, difficulties associated with contrast timing are avoided, and pathological information can potentially be observed. However, these techniques are not without limitations. Due to the sliding window reconstructions, temporal information is smoothed. Therefore, rapid signal changes are not expected to be captured well. Furthermore, the undersampling of high-resolution data both spatially and temporally introduces concerns about the accuracy of the dynamic signals in small vessels. Alternatively, 2D thick-slab projection (3) provides high in-plane spatial resolution at high temporal resolution. It has been proved that 3D data can be reconstructed from a limited number of projections if the data is sufficiently sparse (4). However, assumptions about signal uniformity and/or structure connectivity are required as constraints to resolve the ambiguity problems of the reconstruction. This restricts application of limited-view projections in clinical practice. Here we propose a new method in which projections are interleaved to form a full 3D data set as a priori knowledge of the vascular map; therefore no further assumption is needed. Phantom data suggests that 3D data can be reconstructed from biplane projections based on a correlation analysis with the a priori data. By this technique, temporal resolution of 1s per 3D data set can be achieved without sacrificing spatial resolution.

Methods

The data acquisition scheme is illustrated in Fig.1. Pairs of orthogonal projections are acquired in an interleaved manner to create a full 3D k-space data set, which is reconstructed to produce an a priori vascular map. Each pair of the projections is then reconstructed to an individual 3D data set based on an expansion of the Assignment and Update method (5). This algorithm assigns a step-value to the crossover-pixel of two projection rays if both projections have values, until all the values in the projections are fully assigned. To reduce the ambiguity in the assignment process, the a priori data is used to identify the best positions to assign the values by correlation analysis.

The algorithm was tested by a simulation based on in-vivo MRA data. Two projections were formed from a cross-sectional image. The image was used as the a priori data during the reconstruction. To investigate the feasibility to reconstruct 3D data sets in the presence of temporal information, a flow-phantom study was performed. A 3mm-diameter plastic tube was wound to form a 3D structure. Contrast agent (Omniscan, Nycomed) was injected at a flow rate about 2 cm/s. 32 pairs of projections were acquired during the injection to cover the full k-space. Projections were acquired by a modified 2D fast SPGR sequence (GE 1.5T Excite), head coil, FOV=20x20cm, 256x128 matrix, slice thickness 200mm, TR=3.5ms, flip angle=20°, BW 62.5KHz, ~0.5 s/frame. Therefore in total 64 projections were collected over about 30 s. After the complex subtraction of mask data, the 64 projections were combined to reconstruct the a priori 3D data set. Pairs of projections were then reconstructed to produce 32 3D data sets resolved in time.

Results

The algorithm works well as demonstrated by the simulation results shown in Fig.2, where the cross-sectional image was successfully reconstructed from the two projection curves. This demonstrates in the absence of temporal difference between the projection data and the a priori data, the algorithm is able to fully reconstruct cross-sectional data. The phantom result in Fig.3 demonstrates the feasibility of reconstructing 3D data in the presence of dynamic information. The temporal MIPs from the reconstructed 3D data sets are shown at 1s intervals. The dynamic 3D structure was reconstructed successfully with limited artifacts.

Discussion and Conclusion

A previous work on 3D reconstruction from limited-view projections was developed to reduce streak artifacts based on a blurred a priori data (6). Because the a priori data contributes to the signals in the reconstructed image, the result is also blurred. In our method, the a priori data is only used as a reference to help determine the positions to assign the projection values. It itself does not contribute to any signal in the reconstructed image. Therefore, some artifacts in the a priori data are tolerable. In conclusion, 3D reconstruction from interleaved biplane projections provides a new way for performing time-resolved MRA with simultaneous high spatial and temporal resolution.

References

1. Du, J. et al, MRM 48:516-522, 2002
2. Zhu, H. et al, MRM 52:14-18, 2004
3. Wang, Y. et al. MRM 36:551-556, 1996
4. Smith, PR. et al, J.Phys.A: Math.,Nucl.Gen. 6:361-382, 1973
5. Chang S. et al. IEEE Trans. Comp C-22, 18-28, 1973
6. Garden KL. et al. IEEE Trans. Med. Imaging MI-5, 233-239, 1986

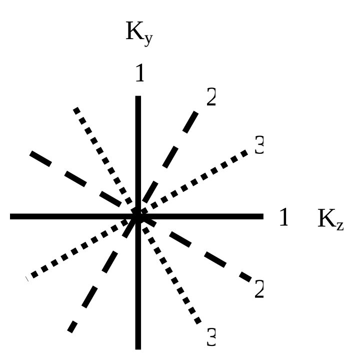

Figure 1. Illustration of the k-space scheme of the interleaved biplane-projection imaging. K_y and K_z are the phase-encoding dimensions, K_x is the frequency-encoding dimension. Pairs of orthogonal biplane projections are interleaved to cover the entire k-space for the reconstruction of the a priori data, while each pair will be reconstructed into an individual 3D data.

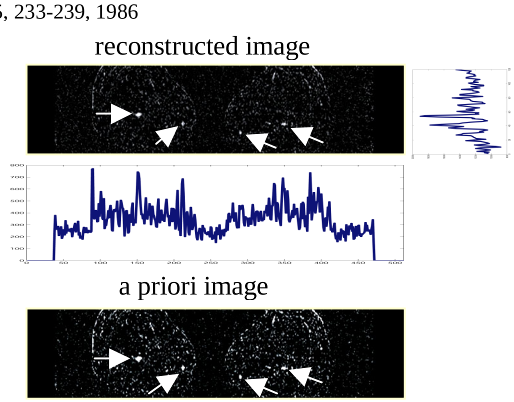

Figure 2. Simulation of the cross-sectional reconstruction from biplane projections. Two sum-projections were formed from a cross-sectional peripheral MRA image. The image is used as a priori knowledge to guide the reconstruction. All the four arteries (arrows) were successfully reconstructed despite the relatively low SNR of the projection data.

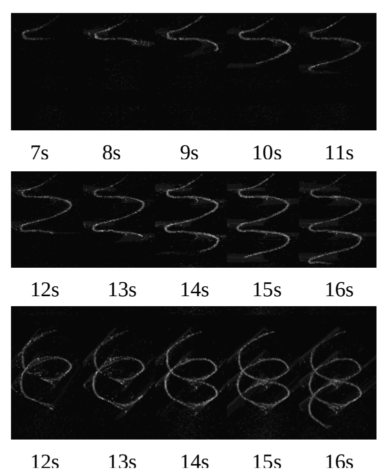

Figure 3. MIPs of reconstructed temporal 3D data sets of a flow phantom. Each 3D data set is reconstructed from two orthogonal projections. The temporal resolution is 1s/3D. The distribution of the contrast agent is clearly visualized. The 3rd row is a top-side view of the temporal 3D data sets corresponding to the 2nd row, by which the dynamic 3D structure can be better conceived.