Time of arrival enhanced 4D MRA

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INTRODUCTION

High resolution time-resolved contrast-enhanced MRA using hybrid HYPR reconstruction (4D Hybrid HYPR MRA) is able to provide sub-second temporal resolution and sub-millimeter isotropic spatial resolution with whole brain coverage. However, due to the significant dispersion of the contrast bolus resulting from the circulation through the heart and lungs after the venous injection contrast, it is very challenge to achieve similar temporal effects provided by x-ray DSA. A time-of-arrival (TOA) map can be estimated from the 4D MRA dataset and provide quantitative description of contrast material arrival time in each voxel. In this project, we propose to combine the TOA map with the Hybrid HYPR MRA to further enhance the visualization of contrast kinetics and display "DSA" like bolus tracing with intravenous injection.

METHODS

4D Hybrid HYPR MRA involves two acquisitions, a fast acquired dynamic series during the first pass of the contrast and a high spatial resolution high SNR static image. The final 4D MRA (3D spatial plus time) images are reconstructed using the HYPR algorithm. The TOA map is estimated based on signal intensity changes over time for each voxel. For this implementation, the TOA of a voxel was defined as the time point when the signal intensity of this voxel first reaches 20% of its maximum intensity. Linear interpolation was used for more accurate estimation. A 3D TOA map was generated, colored encoded and then multiplied with the time-resolved contrast enhanced MRA images at each time frame to form a new 4D MRA images (TOA enhanced 4D MRA) which not only represent the contrast enhancement of vessels at different time frames, but also contain the contrast arrival times with defined color encoding. The static 3D TOA map can also be weighted by a Gaussian distribution in time domain to form a virtual 4D bolus map. This 4D bolus map was then color coded and multiplied with the 4D MRA images to form a DSA-like display (virtual bolus), where at each time frame, only vessels with certain TOA values within the defined bolus length appear. These two new visualization methods have been applied to 4D Hybrid HYPR MRA exams of five patients with brain AVM and compared with the clinical x-ray DSA images.

RESULTS AND DISCUSSION

TOA enhanced 4D MRA and virtual bolus tracing have been generated for each dataset. The figure on the right shows an example of the TOA color enhanced visualizations of a patient with a brain AVM. Compared to the traditional 4D Hybrid HYPR MRA (top row), the TOA enhanced 4D MRA (second row) significantly enhanced the contrast pathways. Feeding arteries and different draining veins can be identified easily (as shown with white arrows) and are confirmed with the DSA images (yellow arrows on the third row). Nidus structure is also better visualized with color coding. The virtual bolus visualization (bottom row) reduces the vessel overlaps and may be potentially benefit for cases with extreme complex vascular structure.

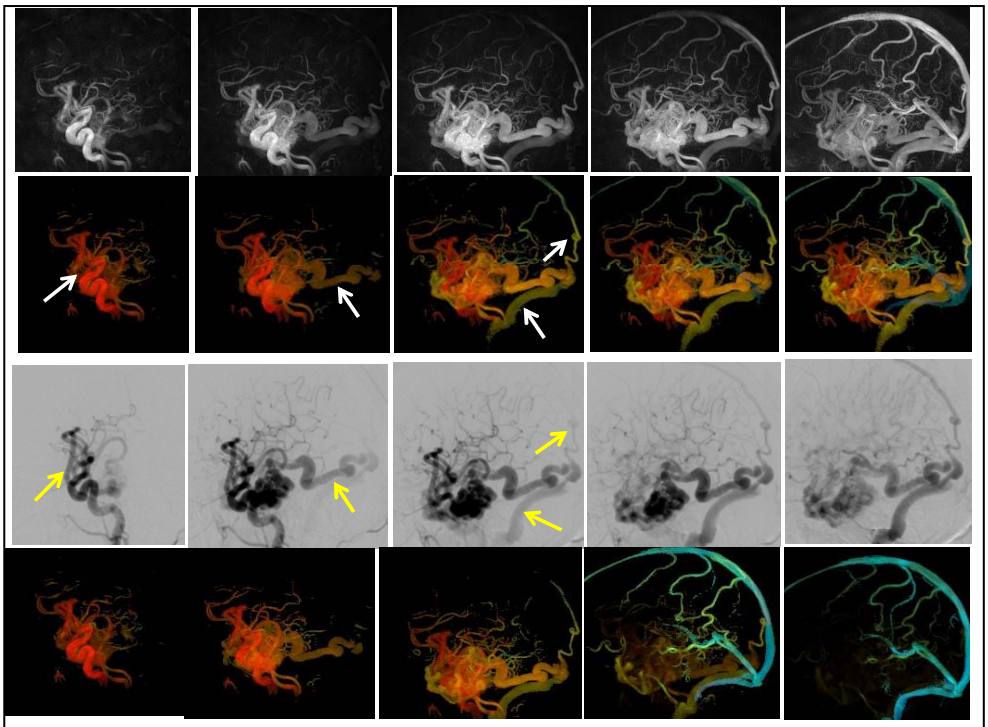

Figure Comparison of the TOA enhanced 4D MRA (second row) and 4D vitual bolus tracking (bottom) to the traditional 4D Hybrid HYPR MRA (top) and x-ray DSA (third row).

TOA color-coding has been proved to enhance the conspicurity of findings on DSA images [1] and recently been used on 4D MRA images [2-3]. However, the color-coded TOA map of intracranial vasculature is challenging due to the limited temporal and spatial resolution and SNR of current MRA techniques. 4D Hybrid HYPR MRA with sub-second temporal resolution and sub-millimeter spatial resolution and high SNR improves the accuracy of TOA mapping, by combining the TOA map with the 4D MRA images, the TOA enhanced 4D MRA is able to demonstrate not only the qualitative contrast dynamics but also the parametric time of arrival information in one simple display.

CONCLUSIONS

TOA enhanced 4D MRA significantly improves the visualization of the time resolved contrast enhanced MR angiography. 4D MR virtual bolus mapping provides "DSA" like bolus tracking with intravenous injection.

REFERENCES

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