MOTSA TOF-MRA using multi-oblique-stacks acquisition (MOSA)

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Introduction

In TOF-MRA, the signal from blood is maximized when the blood vessel is orthogonal to the imaging plane [1]. However, when blood vessel is parallel to the imaging plane (Slice 1 in Fig. 1a) or makes a turn (Fig. 1a) within the imaging plane, the signal from blood would be more saturated and thus result in hypointense signal or discontinuity in the MRA due to reduced inflow effect [1]. Such signal saturation is becoming more prominent when the slice is not sufficiently thin or the blood vessel size is small, it could be circumvented by adjusting the imaging slice plane to be orthogonal to the vessel direction and hence maximizes the inflow effect in that vessel, yet there will always be vessels which are still parallel to a single stack. To overcome this intrinsic problem of TOF-MRA, we propose the multi-angle TOF-MRA approach to acquire multi-angle image stacks (which, for example in the case of brain MRA, are tilted at different angles with respect to the AP axis), and to better visualize all vessels via combining the MIP-reconstructed TOF data.

Methods

To test the proposed technique, intracranial MRA study was carried out in a 3.0T scanner (Achieva, Philips Medical Systems, Netherlands B.V.) using 3D MOTSA TOF T_1 FFE sequence with four chunks. TOF images were obtained by conventional axial acquisition, and by MOSA. With MOSA, the final MRA is obtained pixel-by-pixel by taking the maximum intensity among multiple MRAs that are MIP-reconstructed from multi-angle TOF image sets. By maximum-intensity-combination of all MRAs, the resultant MRA should provide an improved visualization of all the blood vessels within the volume of interest.

In our study, we used two oblique stacks (Fig. 1b). With the two stacks being inclined, slices in one of the stack (Stack 2 in Fig. 1b) would be traversed across by a portion of vessel marked by the yellow curly bracket. As a result, this part of the vessel should be clearly seen in the MRA obtained from Stack 2, but not in Stack 1 due to the fact that the vessel is traversing within the imaging plane in Stack 1. Imaging parameters: FOV = 220 x 220mm, 132-slice stack with 3mm slice thickness and -1.5mm slice gap, in-plane matrix = 400 x 229, TR/TE/α = 25/3.5ms/20°, NEX = 2 for conventional axial acquisition and NEX = 1 for MOSA, with both acquisition techniques taking the same amount of time, 11 minutes. The reconstructed resolution was 0.43 x 0.43 x 1.5 mm. For MOSA, one of the stacks was tilted 25° clockwise from the AP axis, and the other was tilted 27° anti-clockwise. Prior to MRA reconstruction, the two sets of MOSA TOF images were coregistered by using SPM2 (Wellcome Dept of Cognitive Neurology, London, UK). Two set of MRAs were then reconstructed from the TOF data using etdips v2.00 (NIH Clinical Centre). The two MRAs were then combined by taking the larger intensity value, pixel by pixel, among the two MRAs to form a new MRA matrix using MATLAB 7.1 (The MathWorks, Inc.).

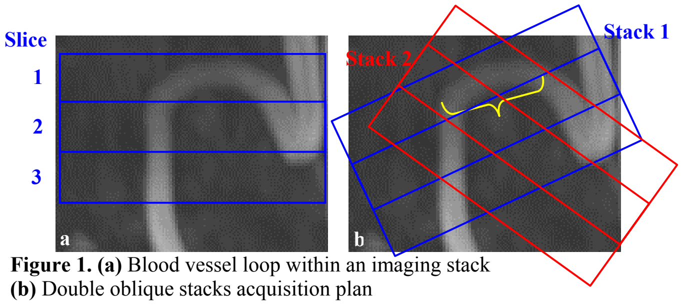

Figure 1. (a) Blood vessel loop within an imaging stack **(b)** Double oblique stacks acquisition plan

Results

The MOSA approach generally demonstrated better MRA quality. Fig. 2 shows the TOF-MRA obtained from conventional MOTSA (Fig. 2a) and that obtained from MOSA (Fig. 2b). With MOSA, the signal intensity from the large blood vessel indicated by yellow arrow in Fig. 2b is clearly stronger than that in Fig. 2a. In addition, small vessels, indicated by red and blue arrows, are also better visualized by MOSA. Those vessels in Fig. 2 are shown in Fig. 3. For comparison, Fig. 3a and 3b show the large blood vessel indicated by the yellow arrow, Fig. 3c and Fig. 3d show the blood vessel indicated by the red arrow, and Fig.3e and Fig. 3f show the blood vessel indicated by the blue arrow. Note that these vessels that were enhanced in Fig. 2b are mostly parallel to the axial plane, i.e. the blood within these vessels was more saturated by RF pulses for the case of conventional axial slice acquisition. Therefore, they resulted in hypointense signal.

Discussion

The results proved that the MRA quality can be substantially improved by using MOSA approach. Given the same total scan time, MOSA-MOTSA image quality is clearly superior to that of conventional MOTSA technique because MOSA overcomes the hypointense signal problem associated with in-plane blood flow in the conventional or single-angle TOF acquisition. In this study, only two oblique stacks were used to illustrate the MOSA concept. In fact, MOSA MRA can incorporate multiple angles instead of two and further improve the visualization of various vessels, especially those vessels that twist and turn, or are small. MOSA approach is highly applicable to MRA of the brain, organs, especially the liver which is traversed by blood vessels from all directions. Our preliminary data suggests that MOSA can improve MRA without scan time penalty. More studies will be conducted to further evaluate the robustness of this MOSA approach, and results will be reported.

References

[1] Lenz G.W. Radiology 1988;166:875-882

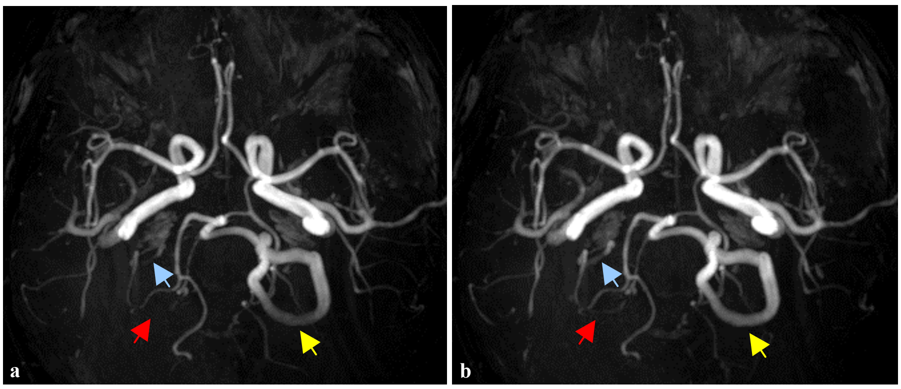

Figure 2. (a) TOF-MRA obtained from MOTSA, scan time = 11mins. **(b)** TOF-MRA obtained from MOSA, scan time = 11mins

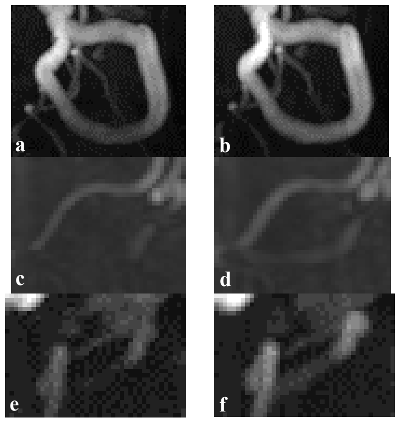

Figure 3. (a), (c), (e) are blood vessels from Fig. 2a. **(b), (d), (f)** are from Fig. 2b