A Novel 3D Time-of-Flight MRA With Optimized Partial Saturation Recovery 3D-FLASH

Y. Natsuaki[1], R. Kroeker[2], and G. Laub[3]
[1]Siemens Medical Solutions, Los Angeles, CA, United States, [2]Siemens Medical Solutions, Winnipeg, Manitoba, Canada, [3]Siemens Medical Solutions, San Francisco, CA, United States

Introduction

3D time-of-flight (3DTOF) is a non-contrast MR angiography (MRA) technique to image arterial and venous blood vessels [1]. The 3DTOF generates contrast from the flow-related enhancement [2]. One of the major drawbacks with 3DTOF is the inplane flow saturation, where the fresh inflow enters the imaging volume and gets saturated by imaging RF pulses. The inplane flow saturation is particularly problematic when inflow vessels are perpendicular to the slice direction (e.g. vertebral arteries), and this may result in signal loss of the blood vessels.

To compensate the inplane flow saturation effects, numerous magnetization preparation strategies have been proposed (e.g. [1],[3]). The magnetization preparation is utilized for the background suppression, while extra inflow time is allowed for more fresh spin inflows. To avoid further complications with spin dynamics and to retain robustness of the conventional 3DTOF, we've opted to remain simple with non-gated, a single traveling saturation, a saturation recovery time (Tsr), and a 3D FLASH acquisition.

The current work proposes a novel approach to the magnetization prepared 3DTOF MRA with a partial saturation recovery (SR) 3D-FLASH. The optimization strategies and the results from a volunteer scanning of vertebral arteries are presented.

Methods

The proposed technique consists of 2 parts: the preparation and the acquisition (Figure 1). The sequence is repeated until the entire data set is acquired. The preparation part has (in chronological order) Saturation pulse, spoilers, and Tsr (i.e. inflow time). A slice-selective saturation pulse covers the imaging slab and a region above for the venous suppression. Note that the sequence acquires multiple overlapped slabs, and the saturation pulse is traveling with the imaging slab (Travelling Sat). Based on a conservative estimate of the arterial flow at 10cm/sec. and maximum arterial length within the imaging volume at 4cm, we determined that Tsr needs to be at 400ms. With Tsr = 400ms, the saturation pulse's flip angle is optimized to partially saturate background (T1=250ms(fat), 800ms(WM)) and blood (T1=1200ms). A computer simulation (Figure 2) shows the optimal flip angle for the partial saturation at 120°. Fat cannot be saturated enough with given Tsr, so the opposed-phase TE will be utilized to further suppress fat signals.

The data acquisition part is a multiple readout lines per shot (LPS) 3D-FLASH sequence. Every readout line acquisition is performed with a constant flip angle α. LPS is set at 20 to minimize magnetization decay. To take full advantage of high contrast at the beginning of the LPS, the radial centric phase encode k-space reodering is implemented.

Results, Discussion and Conclusion

The sequence was implemented at 3.0T (Siemens Healthcare, Erlangen, Germany) and tested in a series of 10 healthy volunteers under IRB regulations. The conventional TOF (denoted "conv") and the new partial SR 3DTOF (denoted "new") have the following imaging parameters: TE/TR = 3.69ms/25ms(conv.) or 9.51ms(new), FOV=210mm, voxel size =$0.6 \times 0.4 \times 0.6 \text{mm}^3$, BW=238Hz/pixel, α=18°, base RO res=512matrix, 32 slices per slab, 5 slabs with 18.75% overlap, iPAT=2, Travelling Sat = gap10mm with 40mm width FA90° (conv) or gap -23mm with 150mm width FA120° (new), and total scan time = 6:31 min. The parameters are closely matched for the comparison purpose.

Figure 3 shows the sagittal and coronal MIP comparisons of the multi-slab axial 3DTOF MRAs on the vertebral arteries. The conventional 3DTOF shows signal loss in the vertebral arteries (yellow box) due to the inflow saturation effect. The proposed TOF, on the other hand, clearly demonstrates the vertebral arteries in addition to the quality and details of the conventional 3DTOF. Further testing and the clinical validation of the proposed partial SR 3DTOF MRA are warranted.

Figure 1: The sequence diagram of the proposed partialSR 3DTOF.

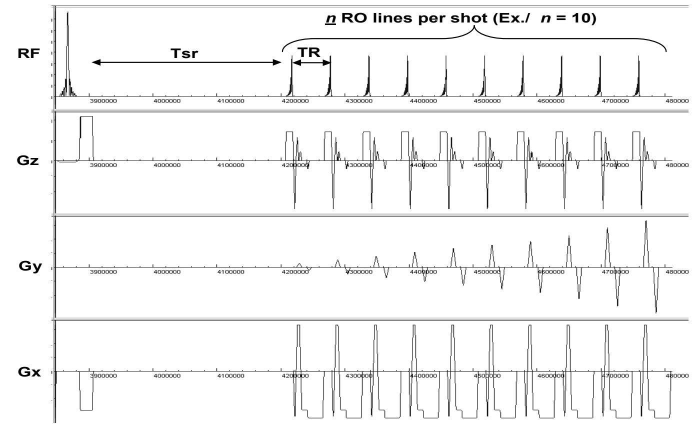


Figure 2: Simulation of Mz vs Saturation Flip Angle, with Tsr=400ms

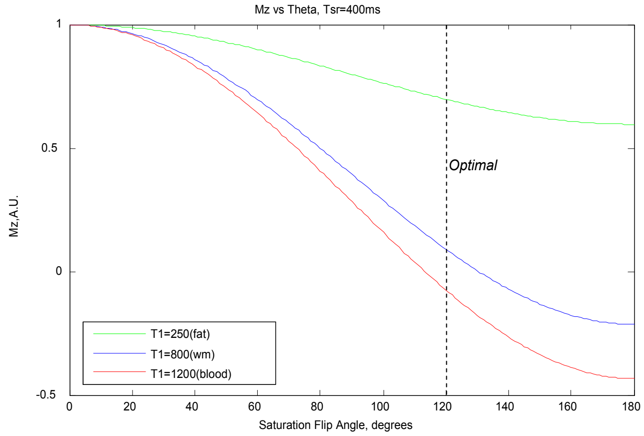
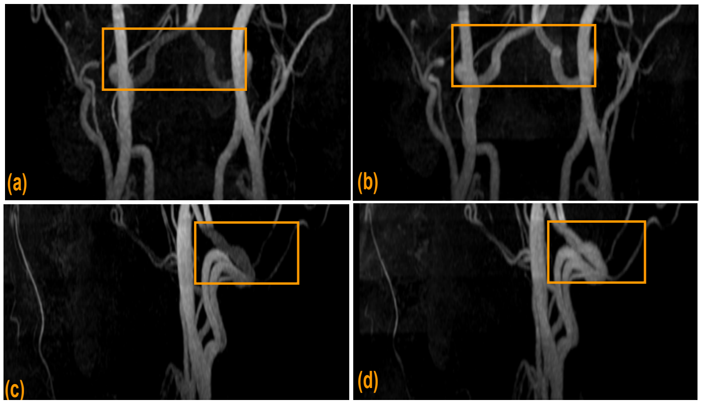


Figure 3: MIP comparisons of the representative 3DTOF MRAs on the vertebral arteries. (a)(c) Coronal and Sagittal MIPs of the conventional 3DTOF, and (b)(d) Coronal and Sagittal MIPs of the proposed partial SR 3DTOF.



References

[1] Leupold J, Hennig J, Scheffler HK. Proc.ISMRM,2002. [2]Axel L. Am.J.Roentgenol.143:1157-1166,1987. [3] Wilman AH, Huston J, Riederer SJ. MRM 37-252-259,1997.