Off-resonance compensated velocity selective RF pulse design for reducing signal dropout in vessel wall imaging

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Introduction: Velocity-selective (VS) RF pulse designed using Shinnar-Le Roux (SLR) algorithm[1] is able to separate spins at different velocities in a particular direction. So it is potential to be used for black-blood vessel wall imaging by suppressing the signal of flowing blood while leaving the static tissue signal undisturbed[2]. However, the velocity selective profile can be shifted by off-resonance effect, which results in static tissue signal dropout. Here we proposed an improved VS pulse design to compensate the impact of off-resonance effect to the static tissue.

Methods:

<u>*RF pulse design*</u>: SLR algorithm converts the problem of RF pulse design into that of FIR filter design[1]. In black-blood vessel wall imaging, a high pass VS inversion pulse is needed. Traditionally, we can simply add a 90x-180y-90x global inversion pulse in front of a low pass VS inversion pulse designed in previous study[3]. This design results in a narrow velocity pass-band. When the velocity profile is shifted by off-resonance effect, the signal of static tissue is prone to be disturbed due to the limited width of the velocity pass band. So a wider pass-band is needed to compensate the off-resonance effect. An improved design is to directly design a high pass VS inversion pulse with a wider velocity pass-band.

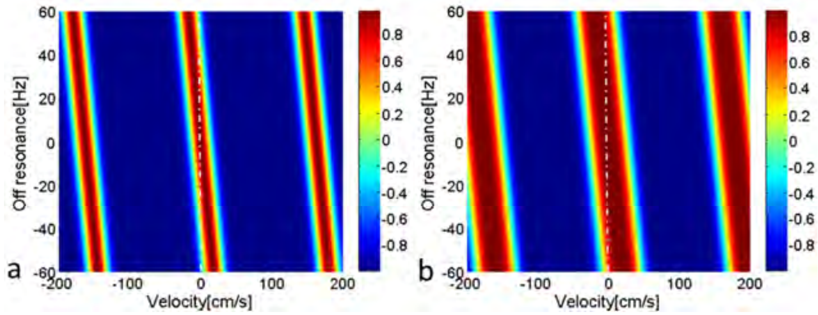

Figure.1 The Bloch simulation of the impact of off-resonance effect to **(a)** low pass VS inversion pulse and **(b)** high pass VS inversion pulse. Velocity selective profile shifting per unit off-resonance is 0.30cm/s/Hz.

<u>*Experiments*</u>: For conventional VS pulse, the parameters included the number of RF subpulses = 9, cut-off velocity = ±12.90cm/s (velocity at full-width-half-maximum) and total pulse duration = 17.54ms. For improved VS RF pulse, the parameters included the number of RF subpulses = 9, cut-off velocity = ±26.90cm/s and total pulse duration = 16.04ms. To evaluate the feasibility of off-resonance compensated VS pulse, in-vivo experiment was conducted on a 3.0 T MR system (Achieva, TX, Philips). Coronal images of carotid artery were obtained using T1-weighted SPGR readout sequence with conventional and improved VS inversion pulse as preparation module, respectively. The main imaging parameters were: TI = 400ms, spatial resolution = 0.7 × 0.7 × 0.7 mm^3, FOV = 250 × 160 × 35 mm^3, TR/TE = 10ms/4.9ms.

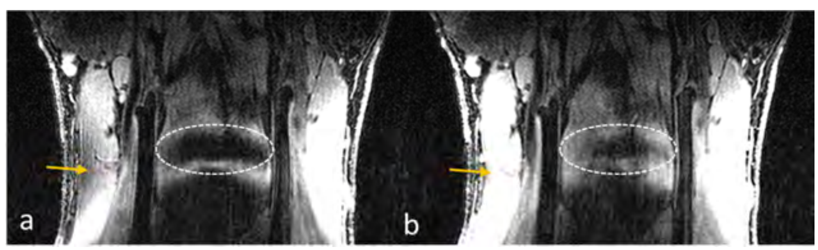

Figure.2 Coronal view of carotid artery vessel wall images using (a) conventional and (b) improved VS inversion pulse.

Results: Simulation results (Fig.1) demonstrate that the improved VS pulse outperforms traditional VS pulse in retaining signal of the static tissue in an off-resonance frequency range of -60 ~ +60Hz. In condition of large frequency offset, there is a signal dropout of static tissue for low pass VS inversion pulse, while for high pass inversion pulse the static tissue remain undisturbed (white dash line). In-vivo studies (Fig.2) indicate that the improved RF pulse partially compensate the signal dropout caused by off-resonance effect, especially in the area of tissue-air interface, such as laryngeal cavity (white circle) and bilateral neck muscle (yellow arrow).

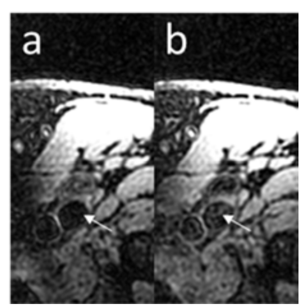

Figure.3 Axial view of right carotid artery bifurcation images using (a) conventional and (b) improved VS inversion pulse. Image artifacts in lumen area (white arrow) shows that the improved VS pulse sacrifices blood suppression efficiency.

Discussion and Conclusion: In this study, we improved the design of velocity selective RF pulse in order to compensate the signal dropout due to off-resonance effect and evaluated its feasibility in carotid vessel wall imaging. Simulation and in-vivo studies showed that the new VS pulse can partially compensate the signal dropout in the static tissue, which results in better image quality and contrast. As the improved VS pulse widened the pass band of VS profile, which sacrificed blood suppression efficiency in case of slow blood flow causing image artifacts (Fig.3). So a trade-off between off-resonance compensation and blood suppression efficiency should be considered in order to relief off-resonance with efficient blood suppression.

References: [1] Pauly J, et al. IEEE TMI 1991; 10(1): 53-65. [2] Yunduo L, et al. ISMRM 2014. [3] Kangrong Z, et al. ISMRM 2010.