ASL: Comparison of presaturation and RF pulse optimization

D.A Holm[1], K. Sidaros[1]

[1]Danish Research Centre for Magnetic Resonance, Copenhagen University Hospital, Hvidovre, Denmark

Introduction

In arterial spin labelling, the difference between the tag and control image is on the order of 1% of the equilibrium magnetization. A small offset between the images not related to perfusion, can therefore lead to large errors in the measured perfusion. One source of error is non-ideal RF pulses resulting in the inversion pulse affecting the acquired signal from the imaging area. This systematic error can be reduced by increasing the gap between the inversion and imaging regions, by using optimized inversion pulses e.g. FOCI[1] or by saturating the signal from static tissue in the imaging area prior to acquiring the image. In this simulation study, the use of presaturation is compared with using optimized RF pulses. Furthermore the effect of using and optimizing crusher gradients is reported.

Methods

FAIR[2] and PICORE[3] sequences were simulated by numerical solution of the Bloch equation. Different placements of the presaturation pulse were explored. In the following presaturation pulses placed immediately before the inversion pulse will be called presat while presaturation pulses placed immediately after the inversion pulse will be called postsat. Simulations were run with two presats, one presat and postsat and two postsats. A crusher gradient was used after each pulse and the effect of varying the different crusher areas was explored. The simulation did not include perfusion and therefore there should theoretically be no difference between the tag and control images. Optimal as well as suboptimal crusher areas were selected from these simulations and the offset was calculated while stepping the gap between inversion and imaging. All the results were compared with simulations with no presaturation or one presat.

In some simulations a hyperbolic secant inversion pulse was used and in others a FOCI[1] pulse. Both pulses had the following parameters: μ=200, β=800, and pulse duration 15 ms. The presaturation pulses were either Hanning filtered sinc pulses (duration 12.8 ms and BW 1250 Hz) or Hamming filtered SLR[4,5] pulses (max phase, 10.24 ms, 2000 Hz, passband ripple 0.04%, rejection band ripple 0.1%). The imaging pulse was either a Hanning filtered sinc pulse (duration 5.12 ms and BW 2031 Hz) or a Hamming filtered SLR pulse (90 degree refocused, 5.12 ms, 2000 Hz, passband ripple 0.04%, rejection band ripple 0.1%).

Results

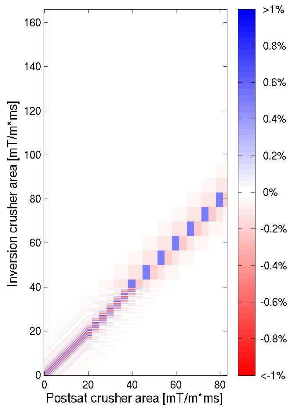

Figure 1. FAIR, two postsat, SLR/HS

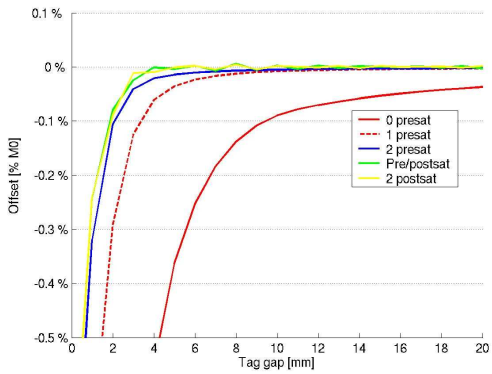

Figure 2, PICORE, SLR/HS

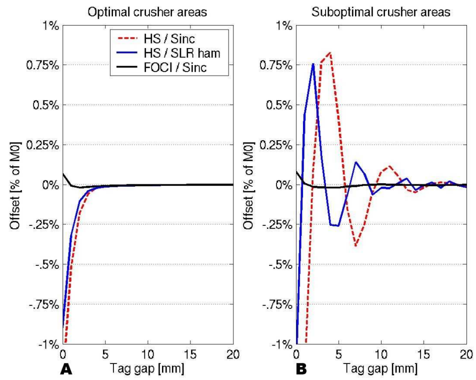

Figure 3, PICORE, 2 presat

As an example, the results from a FAIR simulation using two postsats are shown in figure 1. A large offset, on the order of the expected signal difference due to flowing blood, is seen if the crushers have the same area. This was observed in almost all results, the only exception was when using FOCI inversion pulses while using presat and postsat or two postsats. To avoid this offset the difference between the crusher areas should be ~30% in PICORE experiments and ~50% in FAIR experiments. A crusher gradient should theoretically induce at least one phase roll per slice in order to saturate the slice completely. A large offset was, however, seen in most simulations if the first crusher was reduced below 20 phase rolls per slice.

Optimal as well as suboptimal crusher areas were selected from simulations where stepping two crushers and new simulations were run stepping the tag gap. From this simulation two different series of plots were made. In one plot the effect of changing the presaturation position (before/after inversion or both) was studied (an example is shown in figure 2) and in another the different inversion and imaging pulses (HS, SLR, FOCI, sinc) were compared (an example is shown in figure 3).

In most cases the position of the presaturation pulses had little or no effect but as figure 2 shows, the placement can have an effect when using small gaps between inversion and imaging.

The choice of inversion and imaging pulse can have an impact on the necessary gap between inversion and imaging. An example is shown in figure 3. 3A shows the offset for optimal crusher areas in a PICORE experiment with 2 presat, while 3B shows the offset for suboptimal crushers. From these results it is clear that FOCI inversion is quite insensitive to the choice of crusher areas while other pulses are sensitive. Furthermore the offset for FOCI more quickly reduces to ~0% than for HS/SLR or HS/Sinc.

Conclusion

This study has shown that the use of multiple saturation pulses, each followed by crusher gradients, can result in large offsets between the tag and control image. Although, careful use of saturation pulses can result in efficient static tissue suppression comparable to the results obtained with the FOCI inversion pulse.

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