# Improving Look & Locker readout for pCASL using a variable Flip Angle sweep

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**TARGET AUDIENCE –** Scientists and clinicians with interest in perfusion MRI

**PURPOSE** –Arterial spin labelling (ASL) is a technique that permits to estimate perfusion non-invasively. The readout phase of ASL sequence can follow several schemes. In particular, to sample the entire kinetic curve of the inflowing blood the use of a Look&Locker (LL) read-out[1] combined with 2D multi slice Echo Planar Imaging (EPI) has been proposed. The LL approach suffers, however, from a progressively lower Signal-to-Noise Ratio (SNR) for later post-labeling delays (PLDs) due to $T_1$-relaxation and the fact that the label experienced multiple excitation pulses. This work presents an approach to optimize the SNR over all PLDs of a LL read-out scheme by introducing a variable flip-angle (FA) sweep.

**METHODS** –The SNR at a certain PLD can be modelled by assuming that the label experienced each excitation pulse and by calculating the resulting transverse magnetization ($M_i$) available with the used FAs modulated by the $T_1$ decay of blood.

$$SNR = e^{-\frac{t}{T_{1b}}} \cdot \sin(FA_i) \cdot M_i \qquad M_i = \begin{cases} M_{i-1}(i-1) \cdot \cos(FA_{i-1}) & i > 1 \\ 1 & i = 1 \end{cases}, i = 1 \dots N$$

A variable sweep of FAs (vFA) (Fig. 1) is proposed. The aim of this variable sweep is to obtain the maximum possible SNR correcting for the multiple and variable LL excitation. These new version was implemented and evaluated in vivo. Furthermore, a constant FA of 35° was included as example of a traditional LL-readout. Ten healthy subjects (age 30.6±5.7 F/M=4/6) have been scanned using a Philips Achieva 3T scanner with a 32-channels head coil. For each FA-sweep two pCASL-scans were acquired (one with and the other without bipolar crushing gradients ($v_{enc}$=4cm/s), labelling duration of 1.65s, 2D EPI readout, Look & Locker readout with 10 PLDs ranging from 50 ms to 3100ms, TE=23ms, 11 slices, resolution 3x3x7mm$^3$, 45 averages). The estimation of perfusion (CBF), Arterial Arrival Time (AAT) and $T_1$ was performed for each dataset using a modified version of Buxton model[2] incorporating the effect of a variable FA excitation in the magnetization relaxation function. Temporal SNR (tSNR) were calculated for each voxel as $mean(\Delta M)/std(\Delta M)$ where $\Delta M$ is the mean ASL signal and std(ΔM) the standard deviation of the ASL-signal, i.e. the difference between control and label images. tSNR in gray (GM) and white matter (WM) were extracted and averaged over all subjects to evaluate the performance of the different version of FA-sweep. Finally, coefficients of variation (CV) were calculated based on the inverse of the Fisher information matrix divided by the parameter estimate (i.e. CV=SD(p)/p with SD = standard deviation).

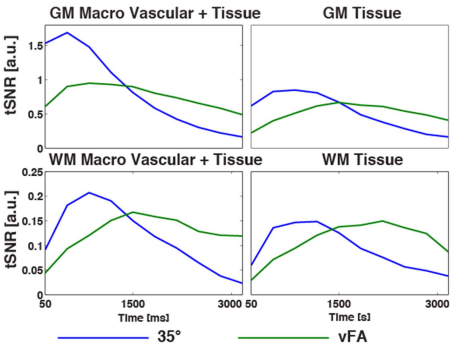


**Fig.2** Mean temporal SNR (tSNR) obtained for the evaluated flip-angle sweeps: optimized to correct for T1 decay of blood and the look locker read out (vFA) and the reference constant 35° sweep.

**RESULTS** – Fig. 2 shows that the new vFA-sweep results in higher tSNR for the later PLDs (i.e. PLD>1700ms) as compared to a constant 35° FA sweep. The distribution of CBF in GM obtained shows a physiological CBF range for both the sweep used (Fig. 3) when only the tissue signal is considered. Without vascular crushing macrovascular artefacts can be observed. The AAT–maps (Fig. 4) show for both sweeps a significant ($p < 0.001$) higher ATT-value in WM compared to GM. The CV of both CBF and AAT in both GM and WM (both for the crushed and non-crushed data) are comparable and acceptable for both the sweeps (< 50%). Nevertheless, the variability of the precision of estimates (estimated as the sd of the CV) is lower for vFA than for the constant FA sweep for both CBF and AAT.

**DISCUSSION** – Both FA sweeps provided a reasonable estimation of both CBF and AAT. Nevertheless, when the sweep is optimized, the variability of the precision of estimates is narrower, suggesting that the precision of estimates is more uniform than when a constant FA sweep is employed. Moreover, also the highest tSNR was obtained by using vFA. The performance of the sweeps in case of late arrival caused by pathological situations has still to be tested, but the higher tSNR at later PLDs seems to be promising in this regard.

**CONCLUSION** –Variable FA sweep for a LL read-out could be employed successfully and outperforms a constant FA approach when measuring CBF by means of multiple PLD-ASL.

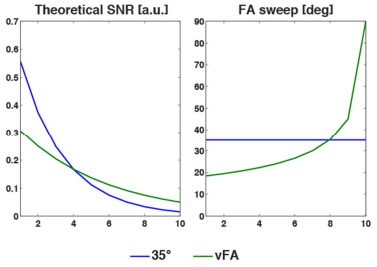


**Fig. 1** The predicted SNR obtained with the constant FA of 35° and the variable sweep (vFA).

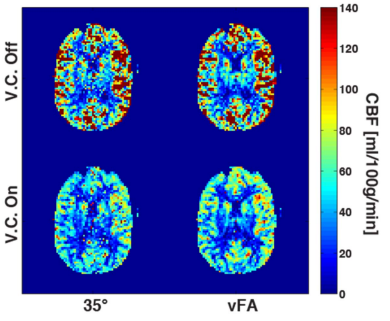


**Fig. 3** CBF maps of a representative subject obtained using the constant FA sweep of 35° and the variable sweeps optimized to correct for LL excitation and for T1 decay of blood. Top/Bottom row reports CBF when vascular crushing gradients were used or not.

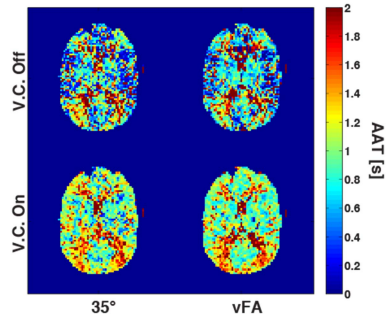


**Fig. 4** AAT maps of a representative subject obtained using the constant FA sweep of 35° and the variable sweeps optimized to correct for LL excitation and for T1 decay of blood. Top/Bottom row reports AAT when vascular crushing gradients were used or not.

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