

Perfusion: ASL Basics and Analysis

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WHO: Newcomers to the Arterial Spin Labeling (ASL) perfusion field.

WHAT: The basic ASL acquisition sequences will be introduced and it will be explained how to subsequently process the data.

OUTLINE:

1. The acquisition
 - a. Spatial labeling (PASL) versus
 - b. Temporal labeling (CASL, pCASL)
 - c. Background suppression
2. Basic blood flow kinetics
 - a. Blood and tissue compartments
 - b. Scaling parameters
 - i. Blood's equilibrium-magnetization
 - ii. Inversion efficiency
 - c. Bolus characteristics
 - i. Bolus transit time, duration and dispersion
 - ii. Single versus multiple inversion times (TI)
 - iii. Quantitative imaging of perfusion using a single subtraction (QUIPSSI-II)
 - iv. Model free approach
 - d. Relaxation parameters
 - i. Tissue and blood (T1/T2)
 - ii. Multi compartment
3. Protocol suggestions

OVERVIEW: Although ASL was invented in the early nineties [1] then it is primarily during the last 10 years that the application of ASL really gained popularity. The main application is still within the research field, but popularity is rising in the clinic as well. There are multiple reasons; the fact that hardware improved (3T, parallel imaging etc.), the introduction of new sequences such as pseudo Continuous ASL, but also just the fact that ASL sequences has become available as clinical packages by the scanner vendors. Therefore it is a field with growing activity and this teaching session aims at being an introduction to ASL for people interested in

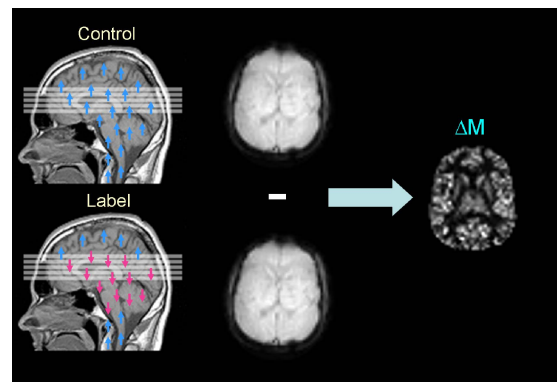


Figure 1. Schematic description of a perfusion weighted image (ΔM) obtained by subtraction of the labeled images from the control images.

joining the enthusiasm of having access to non-invasive perfusion measurements. Today the main ASL workhorse is pseudo Continuous ASL (pCASL) followed by pulsed ASL (PASL with QUIPSS bolus saturation). The basic of these sequences will be explained in addition to an often used feature called background suppression which improves the SNR in the perfusion estimate.

Having acquired the arterial spin labeling data using either of the techniques (PASL, CASL or pCASL), the subtracted control-label images will be perfusion weighted (Fig. 1). The

relationship between the ΔM signal and the actual quantitative cerebral blood flow (CBF) depends mainly on proton density and T1 relaxation rates of tissue and inflowing blood and their respective differences. In addition, bolus transit time from the inversion slab to the observed region, within the images, is also an important factor affecting the conversion of ΔM into CBF. Therefore, obtaining quantitative CBF using ASL techniques is challenging due to uncertainties in inversion efficiency, bolus arrival time, arterial-input-function, underlying kinetics and static tissue parameters like blood's equilibrium-magnetization [2]. Blood's equilibrium-magnetization is of special importance in longitudinal ASL studies, because it is a direct scaling factor in the CBF quantification process and therefore any error in this parameter will propagate directly to the uncertainty in the perfusion estimate. Many solutions have been suggested to account for or make the quantification less sensitive to parameters such as: bolus arrival time, bolus dispersion, restricted water exchange and so fort. Most of these approaches are referenced in the following review [3], but what one need to keep in mind, is that, no model is perfect! There are always assumptions and compromises to be made; it will always be an estimate of CBF. How to weight these compromises, for an optimum flow estimate, all depend on the questions to be answered and how much scan time one can afford in the given study population. This lecture aims at highlighting the priority of parameter needed for CBF estimation and which options are available to control them, while considering scan time, sequence used and coverage needed.

SUMMARY:

The accuracy of CBF estimation depends on many parameters and with ASL we are so fortunate that we can deal with the majority of the challenges realized to date. Nonetheless, we rarely account for everything possible, simply because it would be too time consuming. In addition, our signal to noise does not always allow for highly detailed model fitting. Therefore the target accuracy of the CBF estimate is different in a dementia study as compared to a basic neuroscience experiment of healthy volunteers or in animal studies. Physiological quantification is all about a qualified (and justified) prioritization of parameters affecting the estimate, here CBF.

REFERENCES:

- [1] Detre JA et al. Magn Reson Med, 23, 37-45, 1992
- [2] Buxton RB et al. Magn Reson Med, 40, 383-396, 1998
- [3] Petersen ET et al. The British Journal of Radiology, 79, 688-701, 2006