Repeated ASL Measurements as a Method for Detection of Altered Cerebral Blood Flow in Patients in the Neurointensive Care Unit

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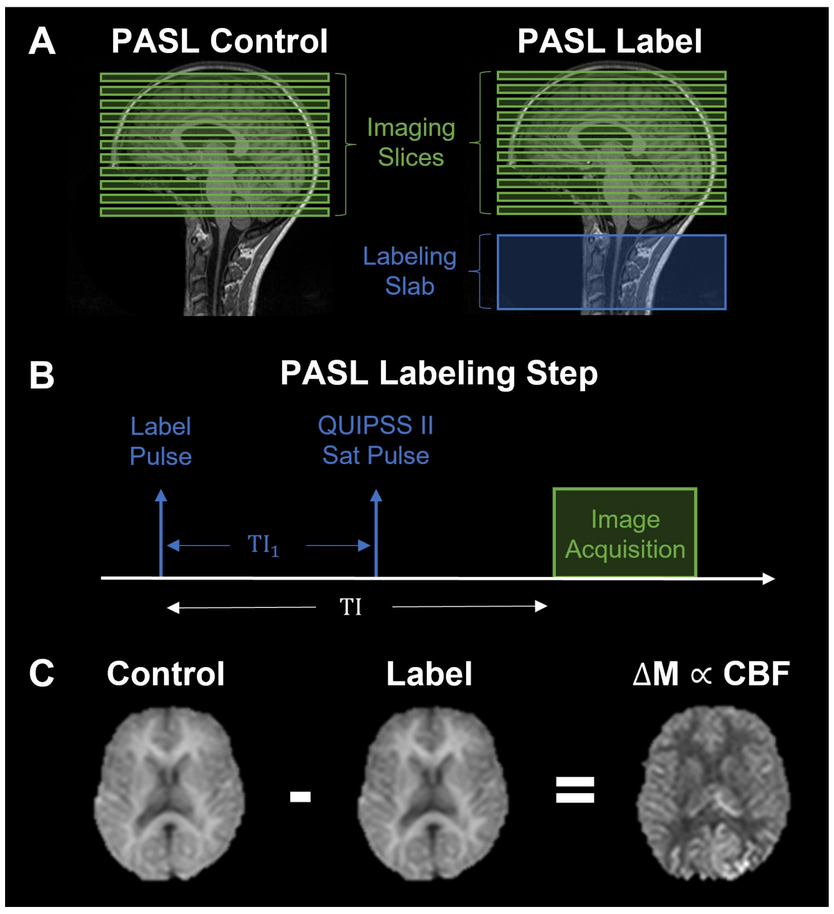
Background

Patients in the Neurointensive Care Unit (NICU) who have suffered from severe brain damage need to be monitored carefully to prevent secondary brain injury. A reduced cerebral blood flow (CBF) can indicate that secondary brain injury may occur [1]. Arterial Spin Labeling (ASL) is a non-invasive subtraction-based MRI technique not requiring any contrast agent and instead relies on magnetically labeling of arterial blood water [2], which makes it suitable for daily repeated measurements of CBF.

Aim

To implement an analysis workflow for detecting altered CBF in the NICU patient using daily repeated ASL measurements.



Arterial Spin Labeling

The ASL measurement is divided into two main experiments, the control and the label, performed repeatedly in an interleaved fashion, where the control images are acquired without any labeling. In Pulsed ASL (PASL, Fig. 1) the labeling is performed using a labeling slab that is inverting the blood passing through the arteries in the neck. The labeled image is then subtracted from the control to generate a map with a signal proportional to the CBF.

Fig. 1. A. Illustration of PASL control and label. **B.** In the PASL labeling step, the label pulse creates a bolus of labeled blood with a duration (TI_1) that is controlled by the QUIPSS II saturation (Sat) pulse. The inversion time (TI) describes the time between the label pulse and the image acquisition. **C.** The labeled image is subtracted from the control generating a map showing the difference in magnetization ΔM, which is proportional to the CBF.

Analysis Workflow

MRI Acquisitions

- One healthy volunteer (EPN, 2018/143-32)
- 3T MR system (Skyra, Siemens)
- PASL (5 min), T1w and PDw imaging

Processing & Calibration

Fig. 2 illustrates the processing steps and calibration procedure to generate a quantitative CBF map. Processing steps for the generation of the qualitative CBF map are mainly built upon FSL [3]. The calibration step is performed using a voxelwise approach based on partial volume estimates, where the fraction of cerebrospinal fluid, grey matter, and white matter, is calculated for each voxel. PDw images are used for scaling the quantitative perfusion maps to absolute units [ml/100g/min], which is essential for enabling day-to-day comparison.

Registration & Quantification

The daily repeated calibrated CBF maps are registered to the same space (Fig. 3). The quantification is performed using a template with 6 regions representing the approximate regions supplied by a specific artery. The perfusion (mean ± SD) in each region is then calculated for each day.

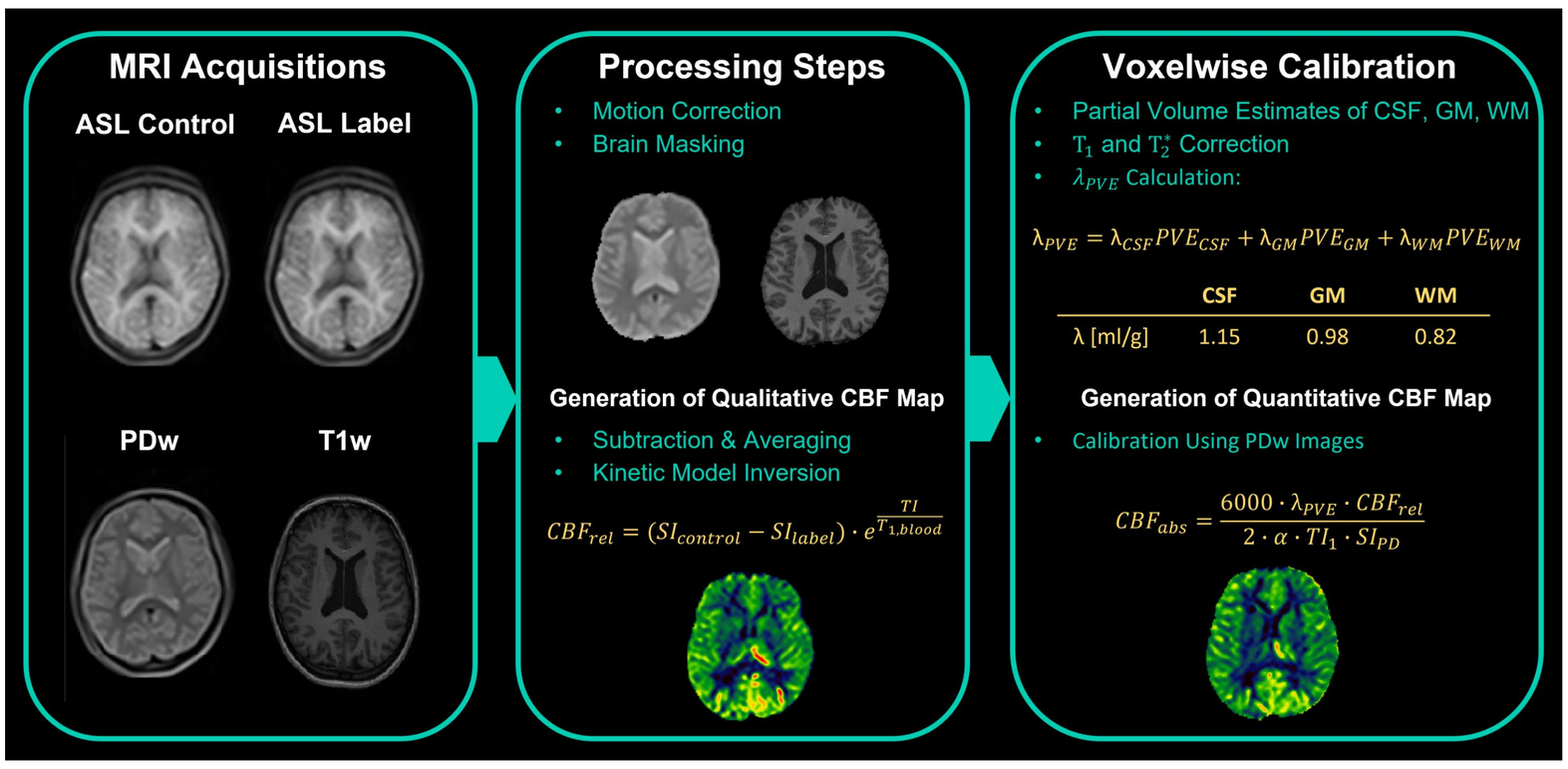


Fig. 2. PASL, T1w, and PDw images are acquired. The processing steps are performed to generate the qualitative CBF map (CBF_{rel}). The calibration is performed using a voxelwise approach to generate the quantitative CBF map (CBF_{abs}). λ = brain/blood partition coefficient [ml/g], SI = signal intensity, $T_{1,blood}$= longitudinal relaxation time of blood [s], α = labeling efficiency.

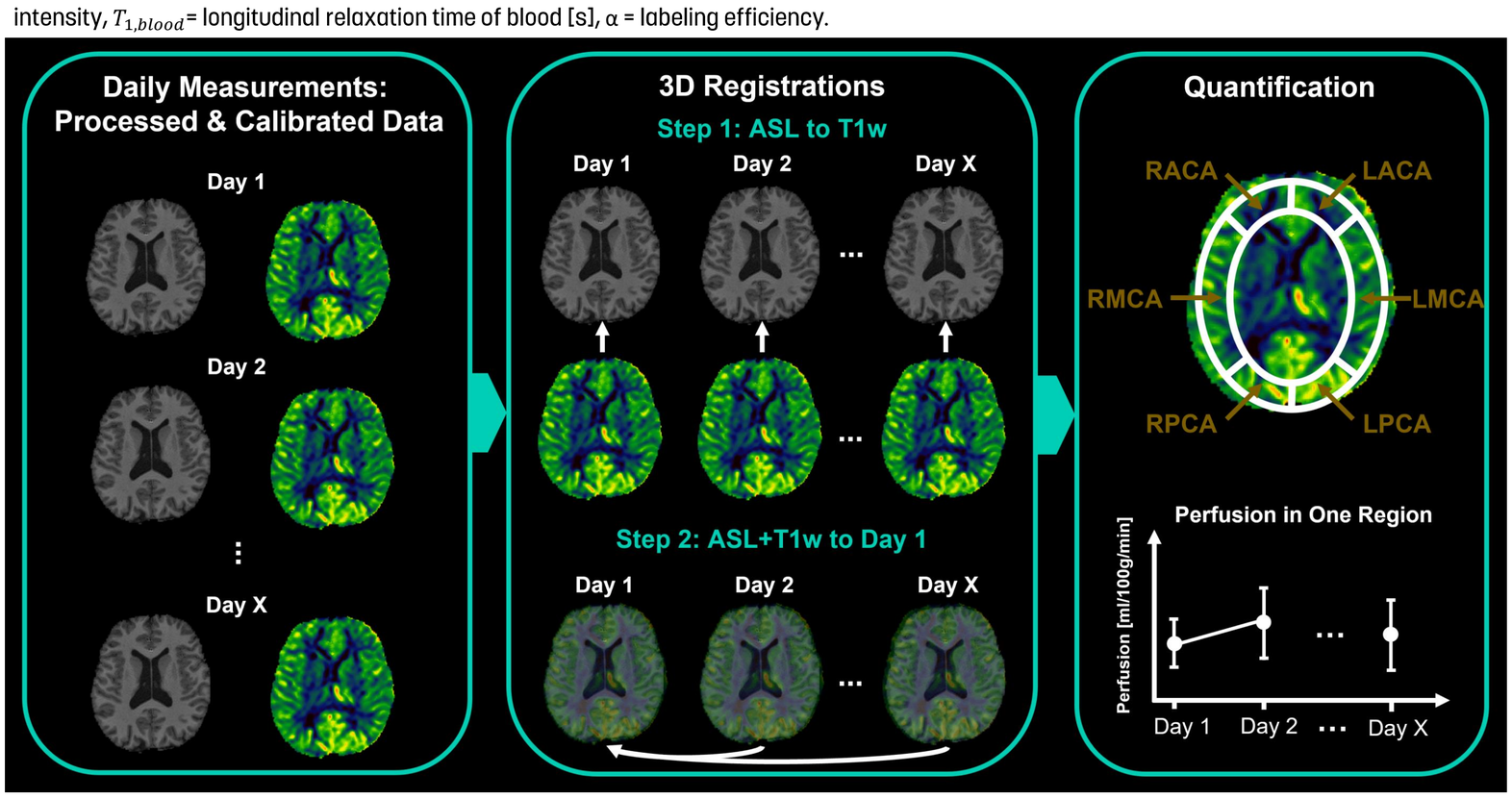


Fig. 3. Illustration of the registration and quantification of the daily repeated ALS measurements. The quantification is performed using a template and the perfusion (mean ± SD) in each region is then calculated for each day. RACA/LACA = Right/Left Anterior Cerebral Artery, RMCA/LMCA = Right/Left Middle Cerebral Artery, RPCA/LPCA = Right/Left Posterior Cerebral Artery.

Future Perspectives

- Continue data collection and evaluate the workflow
- Combine with MR flow measurements in the larger arteries entering the brain -> Investigate CBF from a macro- to a micro perspective
- Compare with local microcirculation recording using laser Doppler flowmetry

References

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