Arterial Spin Labelling in the Setting of Acute Stroke: Development of an Optimal Imaging Protocol

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Stroke & Arterial Spin Labelling MRI

Stroke:

- Stroke is 3rd leading cause of death in Canada.
- Effective stroke care requires **fast and advanced neuroimaging.**
- Advanced Imaging like non-contrast CT and DWI MRI are widely used, but a significant percentage of patients still present with negative imaging findings.
- **Arterial Spin Labelling MRI has potential to improve diagnosis** due to its ability to detect important and subtle cerebral perfusion changes that are otherwise occult in conventional stroke MRI.

Arterial Spin Labelling (ASL) MRI:

- ASL is a non-invasive, perfusion weighed MRI technique that utilizes blood as endogenous contrast by magnetically inverting inflowing blood to the brain.
- Calculable metrics: **Cerebral blood flow (CBF) and Arterial transit time (ATT)**
- Both metrics are pertinent in stroke

ASL Imaging Technique:

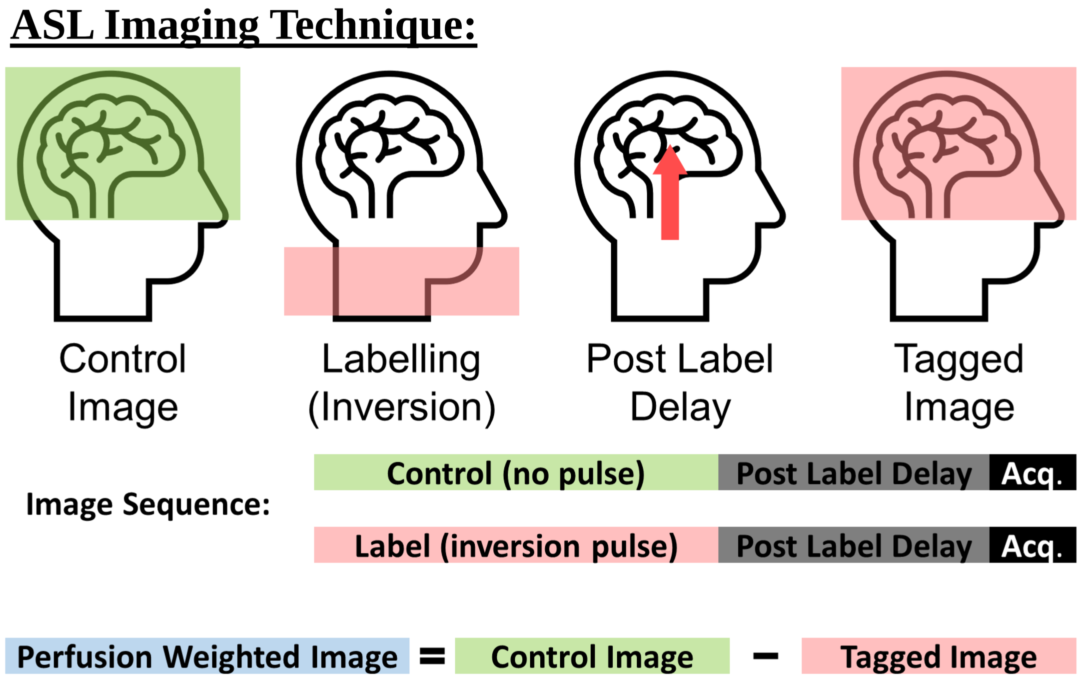

Figure 1: ASL Technique. A control image and tagged image are acquired. A perfusion weighted image is then obtained by subtracting the two images.

Objectives

The aim of the study is to determine whether ASL imaging can improve the diagnosis of acute stroke compared to the conventional stroke MRI utilized at Regina General Hospital. This poster focuses on the initial stages of the volunteer phase of this overall study. Findings will be implemented in the clinical phase.

Volunteer Phase Objectives: The objective of the volunteer phase is to develop an optimal ASL image acquisition protocol and processing pipeline for the clinical phase. Specifically:

1. Develop an advanced image post-processing pipeline to obtain ASL perfusion metrics
2. Develop optimal sequences that improve signal-to-noise ratio (SNR) and minimize long scan times associated with ASL in the clinical setting.

Methods

- One healthy volunteer was scanned using a 3 Tesla MRI scanner (Philips Medical Systems).
- Two clinical Philips ASL sequences were used: A single post label delay (PLD) pseudo-continuous ASL (pCASL) sequence with a 3D acquisition, and a multi-PLD (mPLD) pulsed ASL (pASL) sequence with a 2D multi slice acquisition.
- Two structural images were acquired for registration analysis: a high resolution (1mm x 0.47 mm x 0.47 mm) T1 weighted image with a 3D acquisition (scan time: 4min 24s) and a lower resolution (5 mm x 0.43 mm x 0.43 mm) T1 weighted image with a faster single shot 2D acquisition (scan time: 44s).
- An automated script to process the raw ASL images was developed using FMRIB Software library (FSL) tools to calculate CBF, ATT, and perform image registration and partial volume corrections.

Table 1: ASL pulse sequences obtained with Volunteer #1.

Sequence #	ASL Labelling	# of PLDs	PLD(s), milliseconds	Label Duration, ms	Label Thickness, mm	Resolution (mm)
1	pCASL (control, White paper recommendations)	1	2000	1800	NA	3.75 x 3.75 x 6
2	pCASL (variation)	1	2500	1800	NA	3.75 x 3.75 x 6
3	mPLD pASL (control)	12	225, 520, 834, 1139, 1443, 1747, 2052, 2356, 2661, 2965, 3269, 3574	NA	130	3.75 x 3.75 x 10
4	mPLD pASL (variation)	12	225, 520, 834, 1139, 1443, 1747, 2052, 2356, 2661, 2965, 3269, 3574	NA	300	3.75 x 3.75 x 10

Results

ASL Image processing pipeline

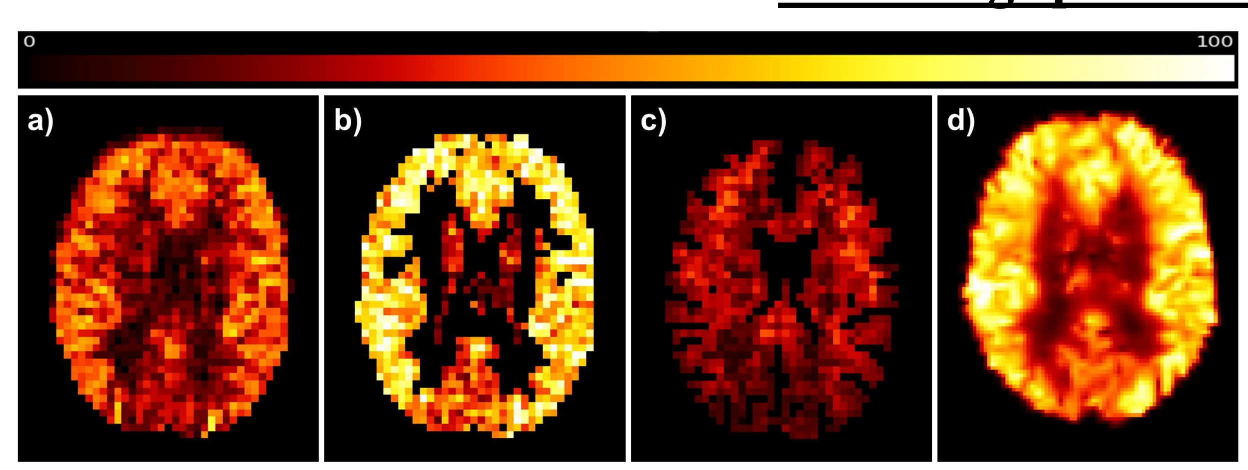

Figure 2: CBF (ml/100g tissue/min) maps from 3D pCASL sequence (#1) for reference. a) CBF map in native space. b) Grey matter and c) White matter perfusion map obtained via partial volume estimates. d) Partial volume corrected perfusion in standard space post registration.

Takeaways:

- Custom code developed to process ASL images
- Metrics obtained (CBF and ATT) and partial volume corrected maps are well-beyond what is available on a clinical scanner
- Processing pipeline is expected to improve stroke diagnosis in the clinical setting.

SNR analysis

pCASL

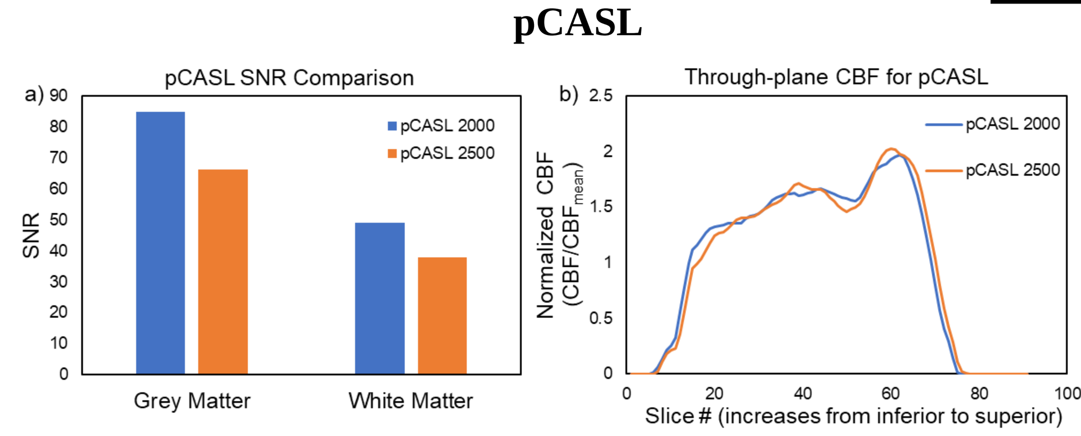

Figure 3: Comparison of pCASL a)SNR and b) through-plane CBF

Takeaways:

- Challenge with pCASL is accounting for long ATT in stroke. Using longer PLD may be useful in minimizing errors but decreases SNR.
- Initial analysis showed that although SNR was reduced (29%) with increased PLD, CBF between Sequence 1 and 2 were similar (Fig 3b) – useful in clinical setting.

pASL

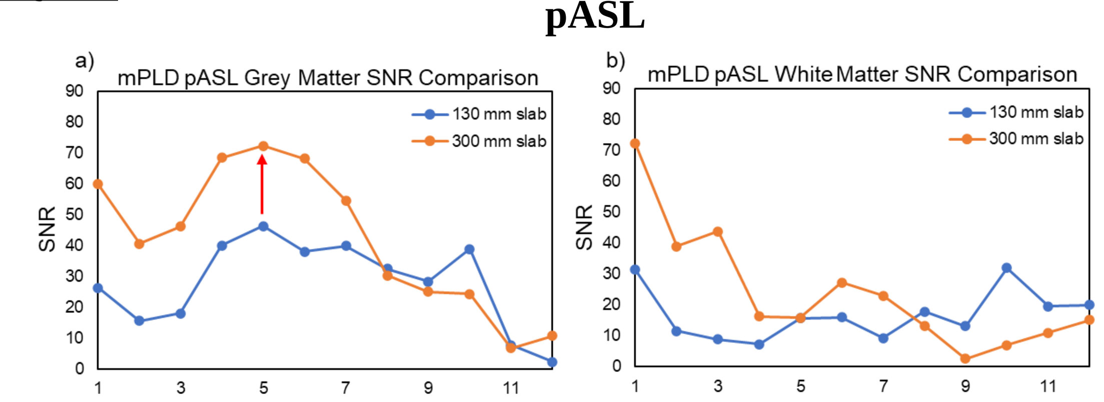

Figure 4: Comparison of mPLD pASL a) GM and b) WM SNR.

Takeaways:

- Challenge with pASL is low SNR.
- Initial analysis showed that increasing labelling slab thickness increased SNR in GM by 80% in PLDs <8. Minimal change in WM due to low perfusion.
- Larger label thicknesses can be useful in clinical setting.

Registration analysis

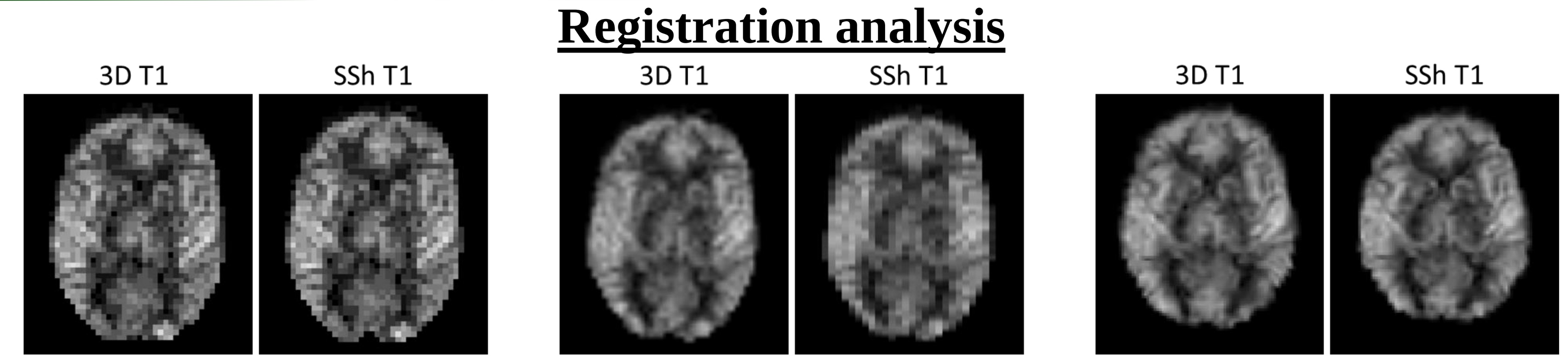

Figure 5: Qualitative Comparison of pCASL (2000 ms PLD) CBF maps registered using 3D T1 and a Single Shot T1 (SShT1) structural images in various image spaces.

Takeaways:

- Qualitative: Minimal differences between CBF in both structural and standard space when using 3D T1 or Single shot T1 (SShT1).
- Quantitive: >60% of all voxels had <20% error between the two images in standard space. Through-plane CBF profiles also similar.
- Low resolution structural images via the Single Shot T1 method may be used to reduce scan times, but further analysis is required.

Conclusions

- ASL imaging has the potential to improve acute stroke diagnosis
- We have developed initial imaging/processing pipelines to assess the clinical utility of ASL in stroke.
- Pipeline produces metrics and maps well beyond what is available on a clinical scanner and is expected to improve stroke diagnosis in the clinical setting.
- To improve pCASL clinical utility – increased label delays may be used.
- To improve pASL clinical utility – increased label thicknesses may be used.
- To reduce scan times, SShT1 structural images may be used for registration, but further analysis is required.

Future Work

- The volunteer phase of the study will image 4 more volunteers. This will enable initial statistical analysis of these potential findings.
- Error for CBF, ATT, and PV estimates need to be quantified
- Resolution of structural images on partial volume effects need to be determined.
- Increased labelling slab thickness with pASL has implications on CBF quantification. Improved estimate for bolus duration in these images is required.

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