Unraveling the Mysteries of Arterial Spin Labeling in Pediatric Neuroimaging

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Objective/Learning Points

- To improve understanding of how arterial spin labeling (ASL) images are acquired
- To highlight tips for high quality ASL acquisition and pitfalls to avoid.
- To illustrate the clinical applications of ASL in pediatric patients.

How are ALS images generated and acquired?

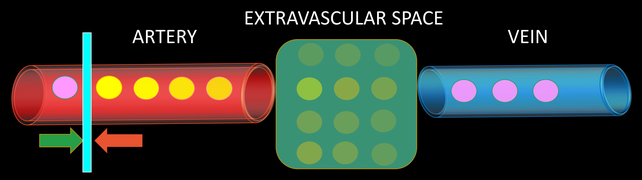

Fig 1: T1 magnetization of untagged water protons in blood is inverted by an RF pulse generating T1 signal. The tagged arterial protons diffuse into extravascular space in the capillary beds with T1 signal in each voxel proportional to perfusion of the cerebral tissue. T1 signal time is shorter than transit time through capillary bed, thus protons untagged when by the time they reach venous circulation.

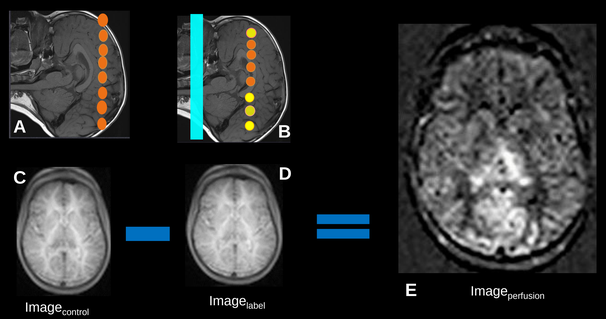

Fig 2: Each ASL "image" is acquired as a pair acquired at the same location before labeling (control, A,C)) and after labeling (B,D), and then subtracted from one another to generate the perfusion image (E). Note that the RF pulse is always generated at the skull base (carotid arteries), while perfusion images are acquired throughout the brain following a post-labeling delay/inversion time.

ASL Method	Technique	Pros	Cons
Continuous (CASL)	Uses long RF pulses (2-4 sec) and constant gradient	• Well defined image plain • Great signal to noise ratio (SNR)	• High specific absorption rate (SAR) • Sensitive to magnetization transfer • Requires RF transmit coil often not available on clinical scanners
Pseudo-continuous (pCASL)	Uses short train of short RF and gradient pulses	• Great SNR with lower SAR • Available on clinical scanners • Less susceptible to delay artifacts between label and image	• Optimizing label plane can be challenging • 4-5 minute acquisition time • Can be difficult to reliably reproduce
Pulsed (PASL)	Uses short RF pulse applied over large slab (dependent on slab size rather than pulse length)	• Good SNR with low SAR • Reproducible • Available on clinical scanners • Faster (3-4 min acquisition)	• Prone to problems with delay between label and scan (ie. Moyamoya, neonate) • Labeling of systemic blood can alter cerebral data in setting of cardiac L-R shunt
Velocity Selective (vsASL)	Labels all blood below a target velocity.	• Eliminates erroneous intravascular signal • More uniform transit delay • Can be used quantitatively	• Lower SNR • Optimizing cut-off velocity can be difficult

Clinical Applications in Pediatric Neuroradiology

Hypoperfusion
- Infarct/penumbra
- Diffuse cerebral edema
- Hemiplegic migraine
- Tuberous sclerosis
- Seizure (interictal)
- Tumor
- Vasospasm
- Medication

Hyperperfusion
- Reperfusion phase of hypoxic injury
- Inflammation/infection
- Hemiplegic migraine
- Seizure (ictal/peri-ictal)
- PRES
- MELAS
- Tumor

Intravascular
- Artifact from timing of acquisition
- Diffuse cerebral edema
- Moyamoya
- A-V shunting
- Sickle cell crisis

Clinical Cases

Case 1

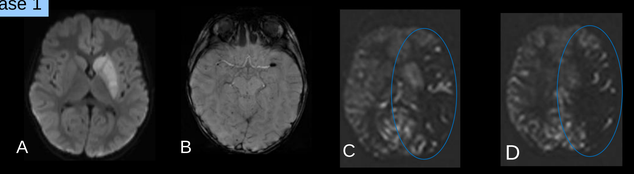

Fig 3: 3-year-old boy with history of prior cardiac surgery. DWI (A) shows an acute infarct in the left basal ganglia and SWI (B) demonstrates a clot in the distal left M1 branch. PASL images (C,D) demonstrate large penumbra (hypoperfusion) through the left MCA territory, much larger than infarct on DWI. Hyperperfusion noted in left basal ganglia (C,D).

Case 2

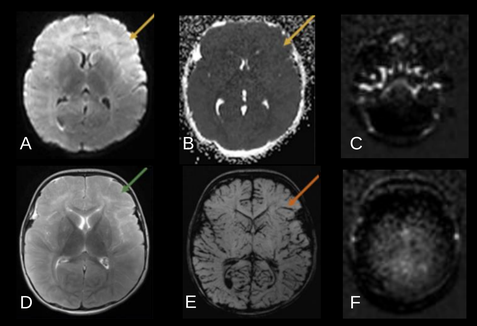

Fig 4: Unresponsive 6-month-old female with suspected non-accidental trauma. There is global cerebral restricted diffusion (A,B), T2 hyperintensity with gyral swelling (D), and distended cerebral veins (E) in keeping with diffuse cerebral edema. 3D-PASL shows intravascular flow at the skull base (C) and reduced flow throughout the cerebral hemispheres. Brain death was determined clinically.

Case 3

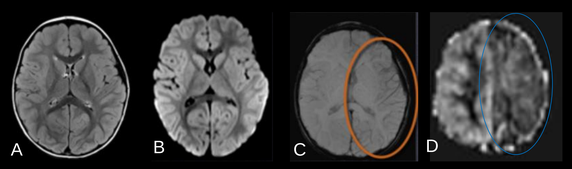

Fig 5: 2-year-old boy with headache found to be neglecting one half of a page while coloring. Axial FLAIR (A) and DWI (B) images were normal and SWI demonstrated subtle asymmetric increase oxygen extraction in left cerebral hemisphere (C). PASL image (D) demonstrated reduced perfusion throughout the left cerebral hemisphere. Imaging and clinical diagnosis consistent with hemiplegic migraine.

Case 4

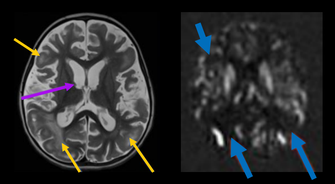

Fig 6: Surveillance imaging in 17-month-old girl with tuberous sclerosis shows multiple T2 hyperintense cortical tubers and subependymal nodules. PASL images reveal hypoperfusion to the cortical tubers.

Case 5

13 year-old-boy unresponsive after cardiac arrest — 11 days later

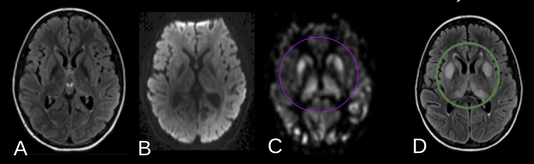

Fig 7: Hypoxic ischemic injury. Initial FLAIR (A) and DWI (B) images are unremarkable, but PASL shows hyperperfusion in the basal ganglia and thalami (C). FLAIR image 11 days later reveals evolving ischemic injury in the basal ganglia and thalami (D).

Case 6

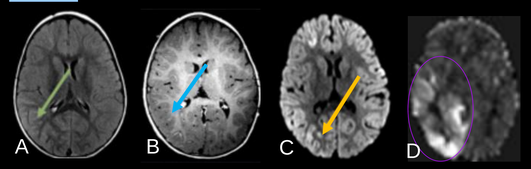

Fig 8: 18-month-old male with altered mental status, fever, and lethargy diagnosed with meningoencephalitis of unknown etiology. Traditional images demonstrate subtle sulcal FLAIR hyperintensity (A), minimal leptomeningeal enhancement (B), and faint patchy restricted diffusion (C). PASL reveals marked hyperperfusion (D) related to active infection/inflammation.

Case 7

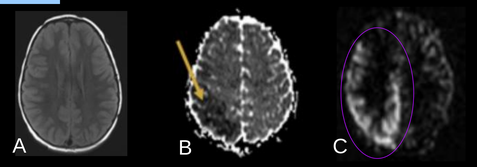

Fig 9: 7-year-old male presenting in status epilepticus. No FLAIR abnormality observed (A). ADC map shows restricted cortical diffusion (B) and corresponding hyperperfusion is appreciated on PASL (C).

Case 8

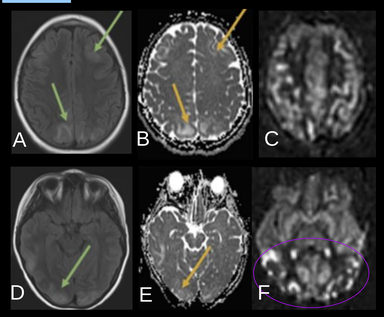

Fig 10: 10-year-old female with hypertension and encephalopathy diagnosed with posterior reversible encephalopathy syndrome (PRES). Mildly expansile posterior predominant FLAIR hyperintensity (A,D) and facilitated diffusion (B,E). Hyperperfusion in the occipital lobes bilaterally (C,F).

Case 9

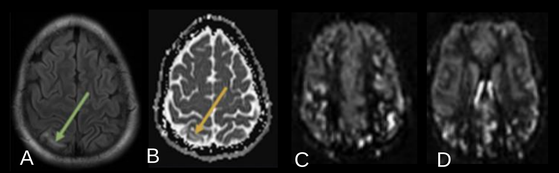

Fig 11: 16-year-old girl with known Mitochondrial Encephalopathy, Lactic acidosis, and Stroke-like episodes (MELAS). FLAIR hyperintensity (A) with facilitated diffusion (B) in the right parietal lobe consistent with gliosis. Scattered areas of cortical hyperperfusion in the frontal and parietal lobes represents "at risk" tissue (C,D). Note sites of old injury/gliosis demonstrate iso/hypoperfusion.

Case 10

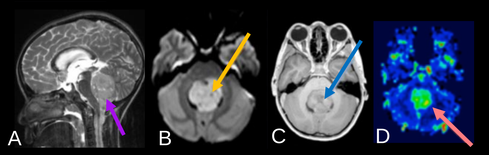

Fig 12: 7-year-boy presenting with headache found to have a large T2 hyperintense posterior fossa mass (A) with restricted diffusion (B) and heterogenous enhancement (C) subsequently diagnosed with medulloblastoma. PASL demonstrates hyperperfusion (D).

Case 11

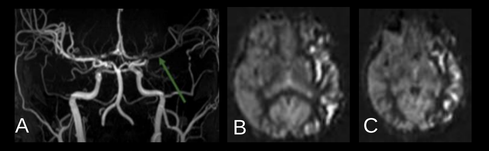

Fig 13: 11-year-old female with history of moyamoya status post left pial synangiosis. Time-of-flight MRA image shows severe steno-occlusive narrowing of the left MCA (A). PASL images (B,C) show expected intravascular enhancement due to delayed flow through synangiosis relative to native vessels.

Case 12

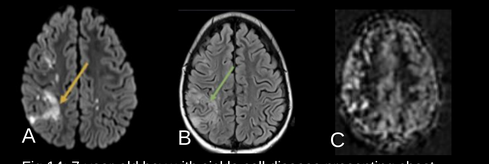

Fig 14: 7-year-old boy with sickle cell disease presenting chest pain and headache found to have multiple foci of developing infarct on DWI (A) and FLAIR (B). PASL revealed hypoperfusion in areas of infarct, but also patchy foci of intravascular enhancement in the right MCA territory likely secondary to narrowing of proximal vessel.

Discussion

ASL offers several advantages in pediatric patients:
- Lack of ionizing radiation
- Does not require exogenous contrast administration
- Can be repeated multiple times in same study/day

Perfusion alterations can precede abnormalities on routine sequences, thereby allowing early detection

Familiarity with ASL can improve diagnostic confidence in identifying and refining diagnoses frequently encountered in pediatric neuroimaging.

References

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