



56th Annual Meeting &
42nd Post Graduate Course

JUNE 06-10 2022
MARSEILLE, FRANCE

Palais du Pharo

Arterial spin labeling: your best friend in pediatric emergencies



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Palais du Pharo

- **No Conflicts of interests**



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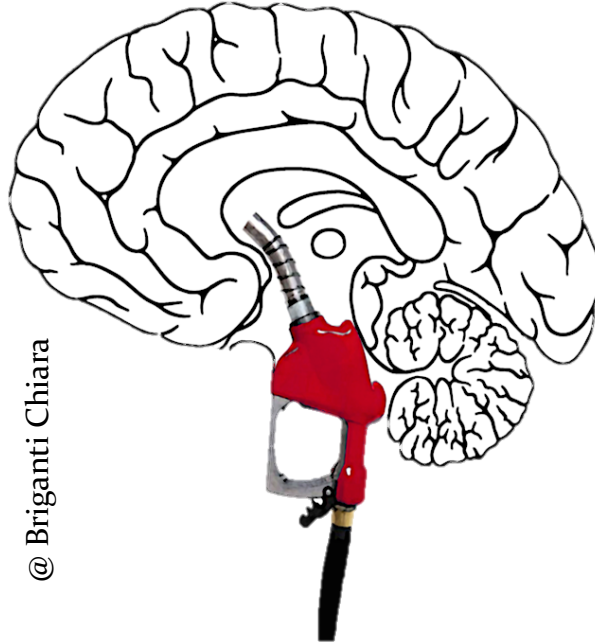
Palais du Pharo

Overview

- 1 – Arterial Spin Labeling: perfusion technique**
- 2 – Perfusion changes in neurologic emergencies**
 - 2.1 Mechanisms**
 - 2.2 Clinical scenarios**

BRAIN PERFUSION-IMAGING TECHNIQUES

Exogenous tracer



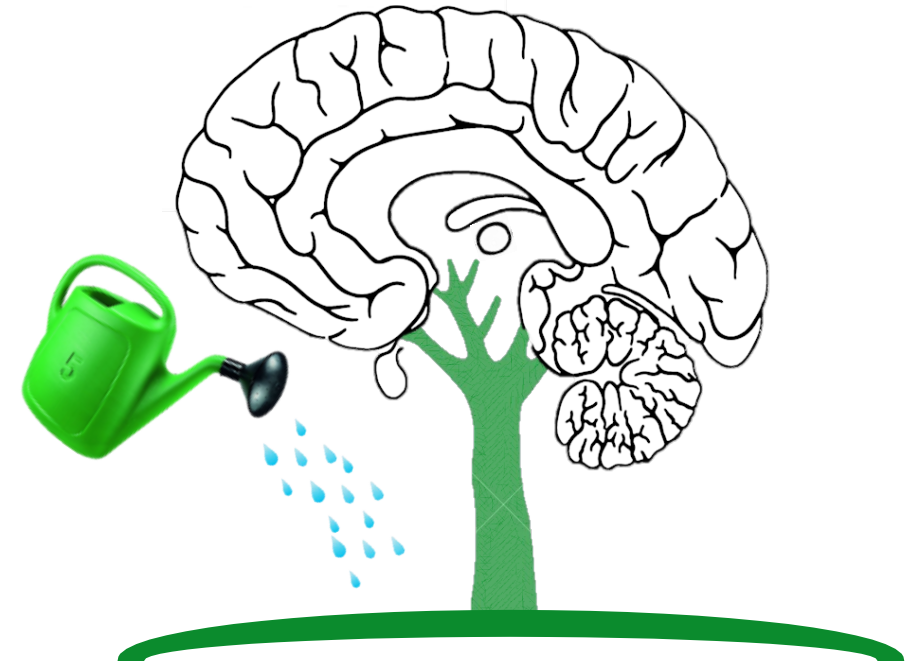
DSC and DCE MR-P

XENON-CT

$[^{15}\text{O}]\text{H}_2\text{O}$ PET

^{123}I -IMP SPECT

Endogenous tracer



ARTERIAL SPIN LABELING

NEAR-INFRARED SPECTROSCOPY

SONOGRAPHY + CEUS

PERFUSION with Exogenous tracer



14G



16G



18G



20G



22G



LIMITATIONS

INJECTOR

HIGH FLOW BOLUS

HIGHER NEEDLS Gauge

IONIZING RADIATIONS

ARTERIAL SPIN LABELING

ADVANTAGES

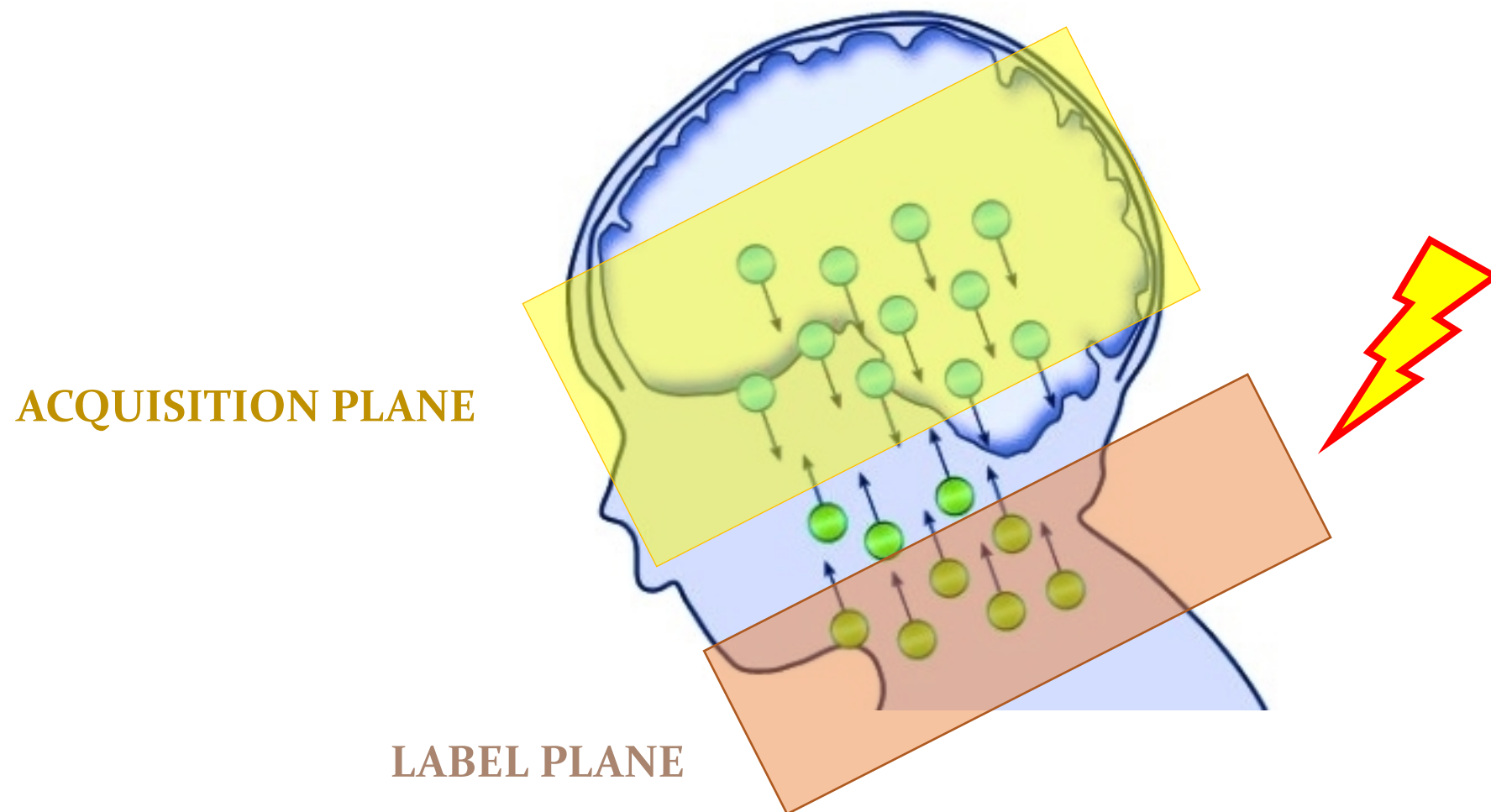
Does not require contrast (NFS, children....)

Can be **repeated** (while Gd is dose-limited)

Provide **absolute quantification of CBF**

Has a **better temporal resolution**

ARTERIAL SPIN LABELING



ARTERIAL SPIN LABELING

TAG IMAGE
ACQUISITION



POST-LABEL
DELAY



CONTROL IMAGE
ACQUISITION

SPIN LABEL OF
ARTERIAL
VESSELS (NECK)

TAG-CONTROL
SUBTRACTION

MULTIPLE
REPETITIONS

ARTERIAL SPIN LABELING

Table 1
Recommended Labeling Parameters

Parameter	Value
PCASL labeling duration	1800 ms
PCASL PLD: neonates	2000 ms
PCASL PLD: children	1500 ms
PCASL PLD: healthy subjects <70 y	1800 ms
PCASL PLD: healthy subjects >70 y	2000 ms
PCASL PLD: adult clinical patients	2000 ms
PCASL: average labeling gradient	1 mT/m
PCASL: slice-selective labeling gradient	10 mT/m
PCASL: average B ₁	1.5 μ T
PASL TI ₁	800 ms
PASL TI	Use PCASL PLD (from above)
PASL labeling slab thickness	15–20 cm



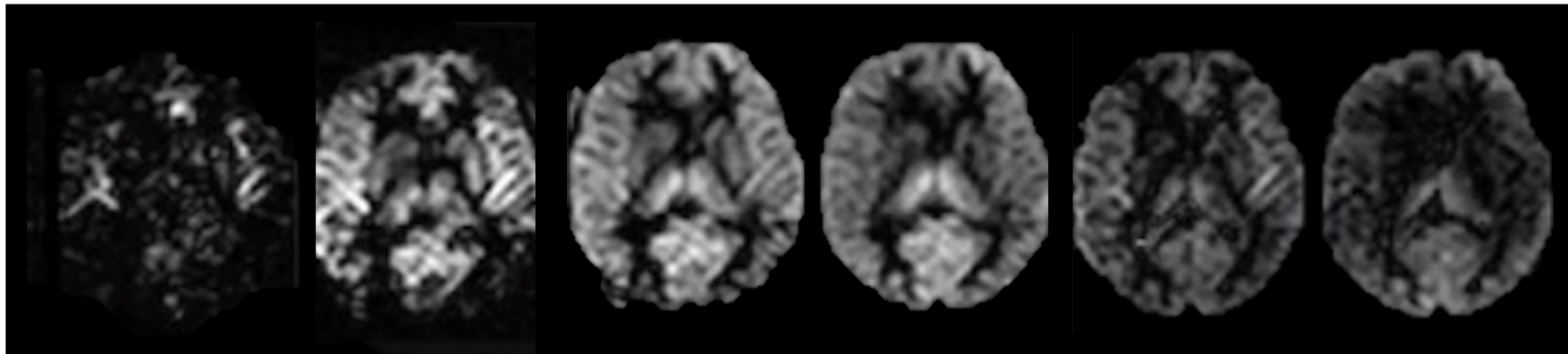
**POST-LABEL
DELAY**



Too short

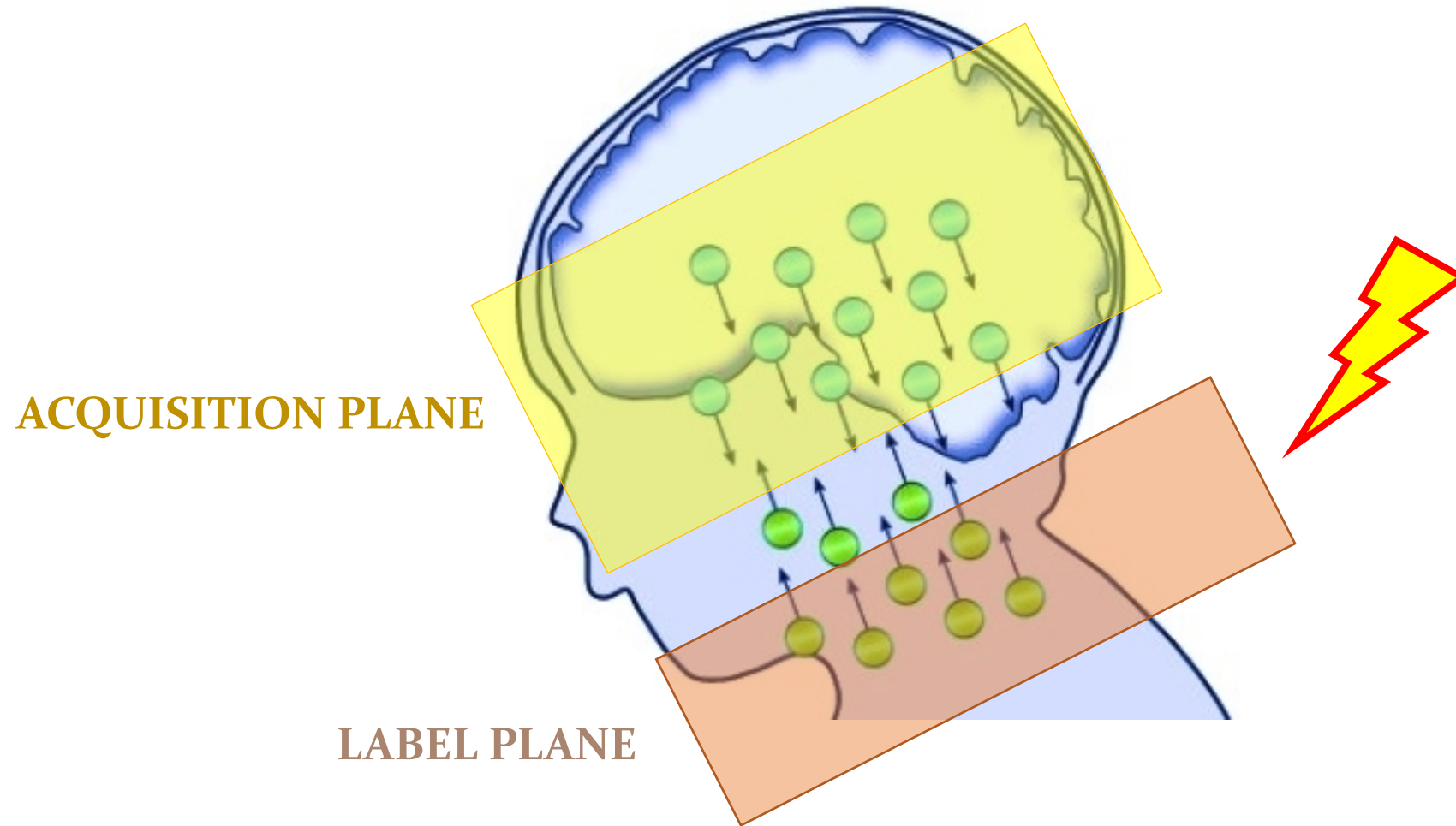
Right PLD

Too long



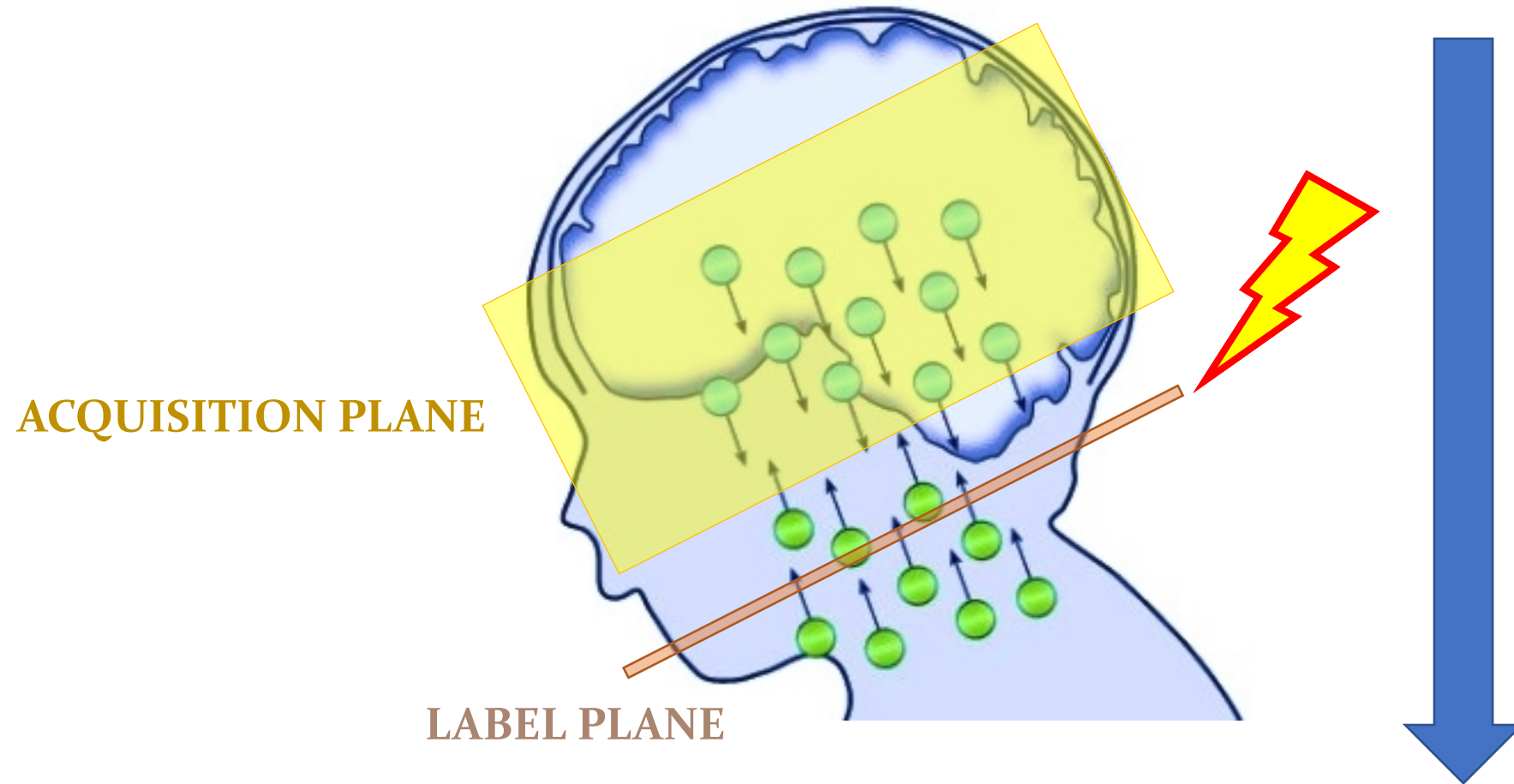
ARTERIAL SPIN LABELING
Labeling methods

Pulsed ARTERIAL SPIN LABELING - PASL



ARTERIAL SPIN LABELING

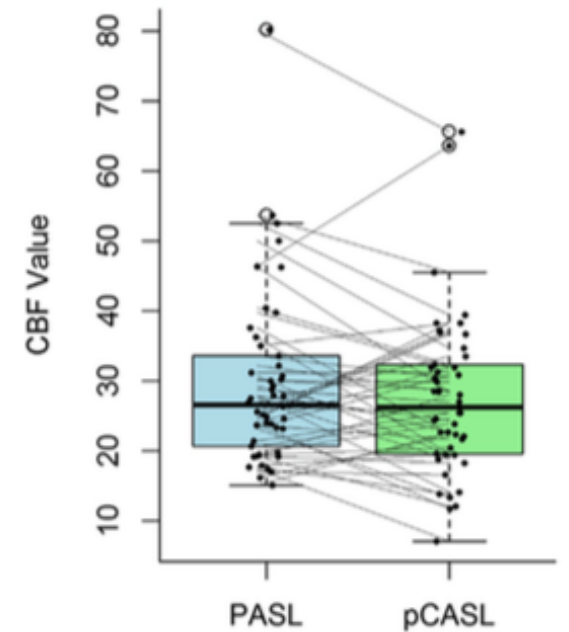
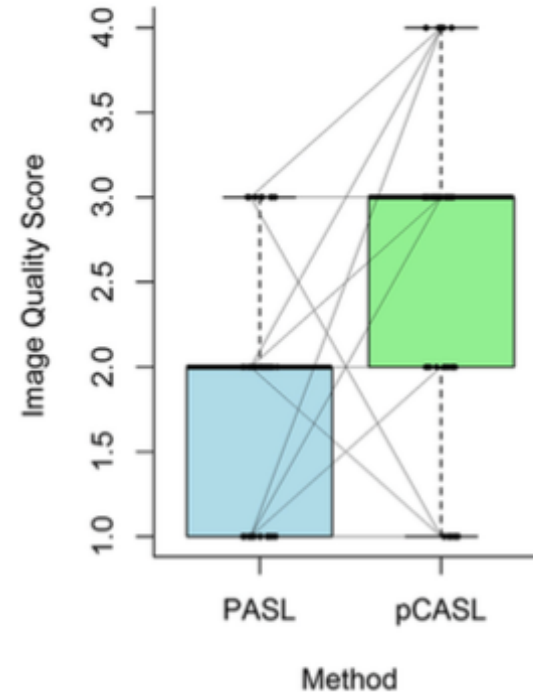
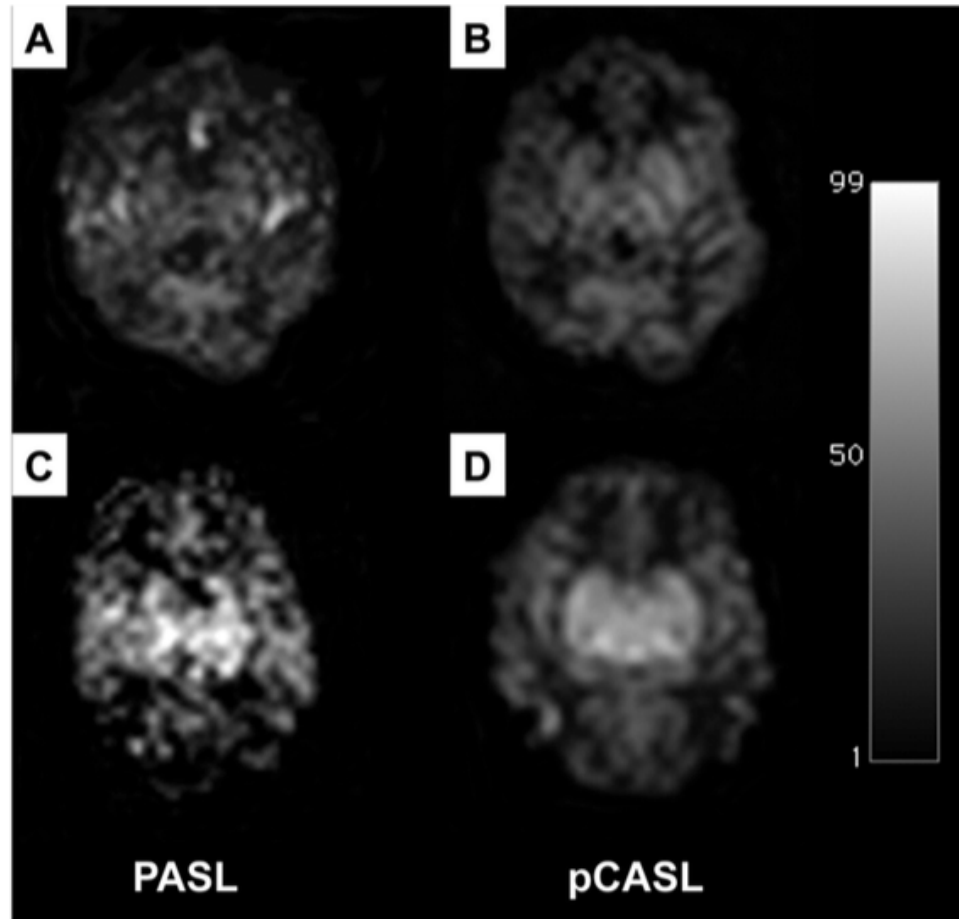
Continuous ARTERIAL SPIN LABELING - CASL



PseudoContinuous ARTERIAL SPIN LABELING pCASL

Short radiofrequency pulses mimic the effects of CASL

ARTERIAL SPIN LABELING BEST TECHNIQUE?



ARTERIAL SPIN LABELING
BEST TECHNIQUE?

3Tesla may help?



$3T/1.5T \approx$ **2x more signal**

T_1 of blood is longer: **STRONGER ASL label**

STRONGER label = more ASL perfusion signal

Brain perfusion changes in neurological emergency

ABNORMAL VASCULAR SUPPLY

- Stroke
- HIE

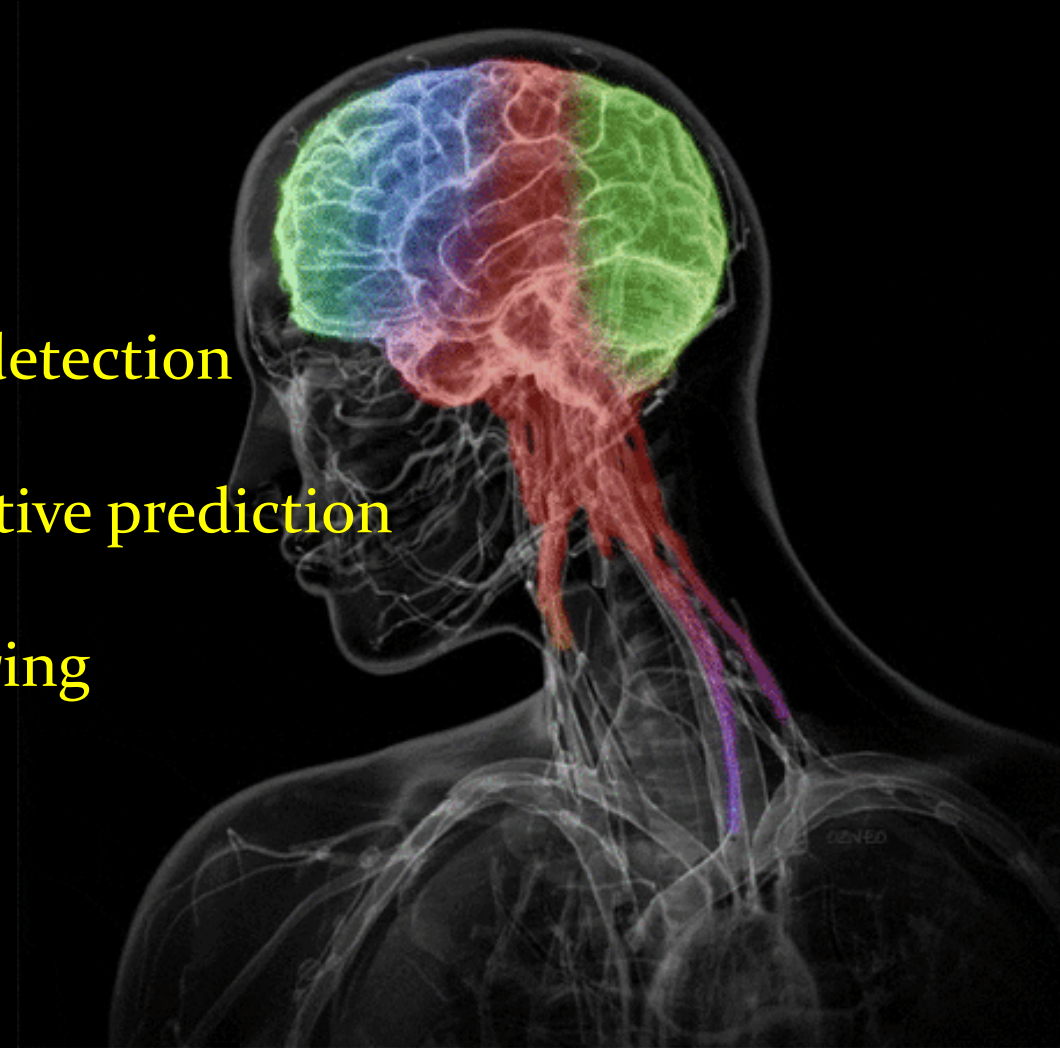
ABNORMAL VASCULAR REACTIVITY

- Migraine
- Infections
- Inflammation

ABNORMAL NEURONAL ACTIVITY

- Seizure
- Metabolic diseases
- Infections

- Lesion detection
- Prospective prediction
- Monitoring



Hypoxic-ischemic encephalopathy

HIE is a major cause of death and disability during the first months of life in full term neonates

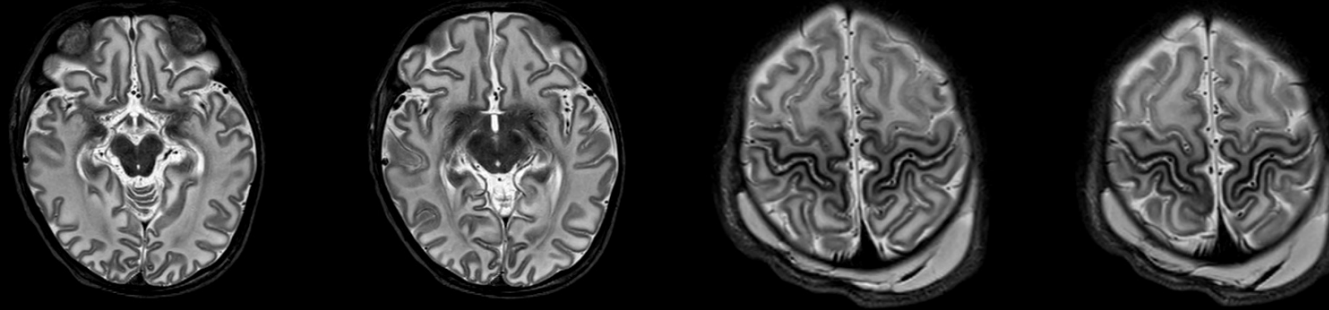
The pathogenesis of brain damage is complex and related to impaired perfusion and oxygen delivery



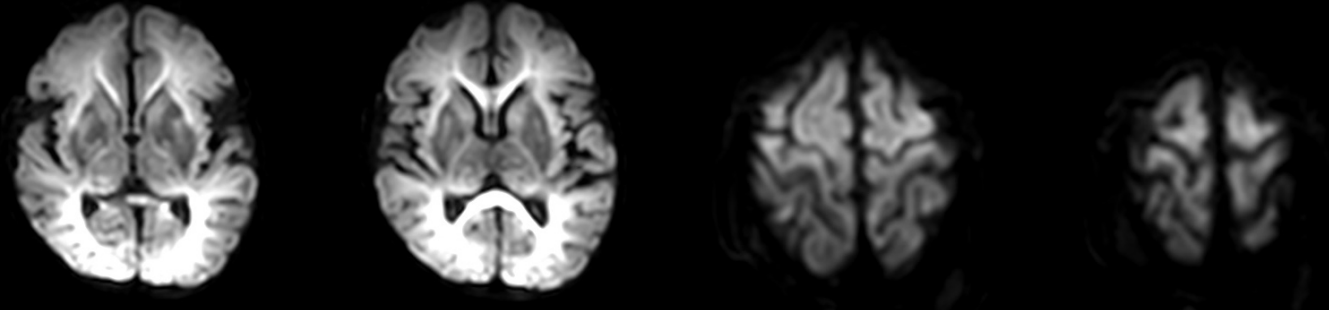
SEVERE HIE

40 weeks, male, APGAR 3 – 5, MRI 5 days after birth

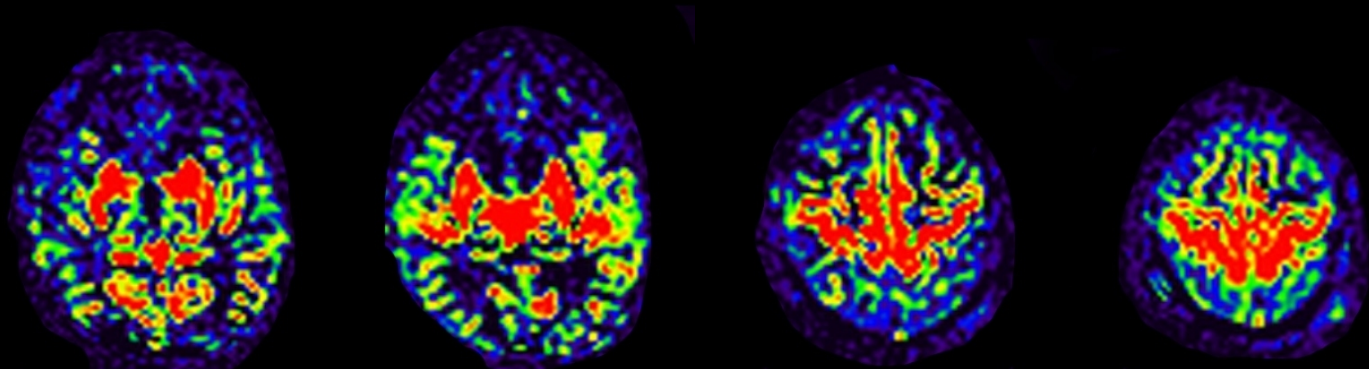
T2-w



DWI



3D-PCASL



MILD HIE

38 weeks, female, APGAR 5 – 7

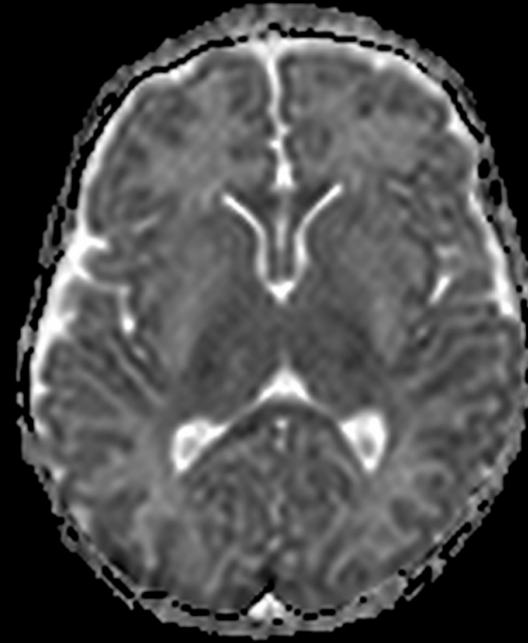
MRI performed at 10 days



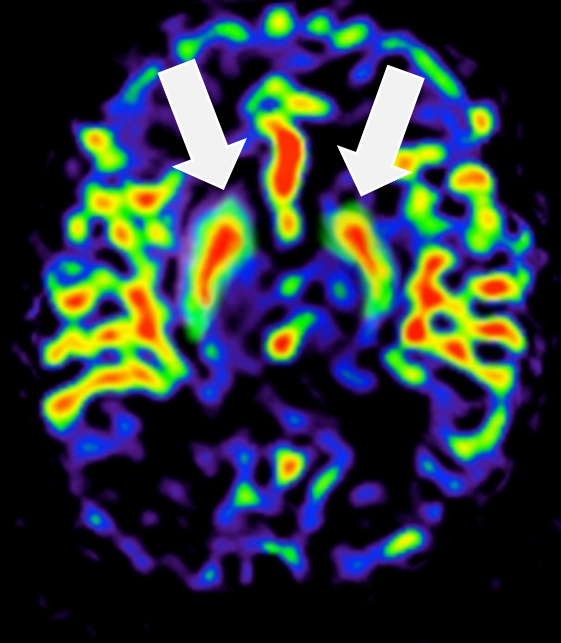
T2-w



T1-w



ADC



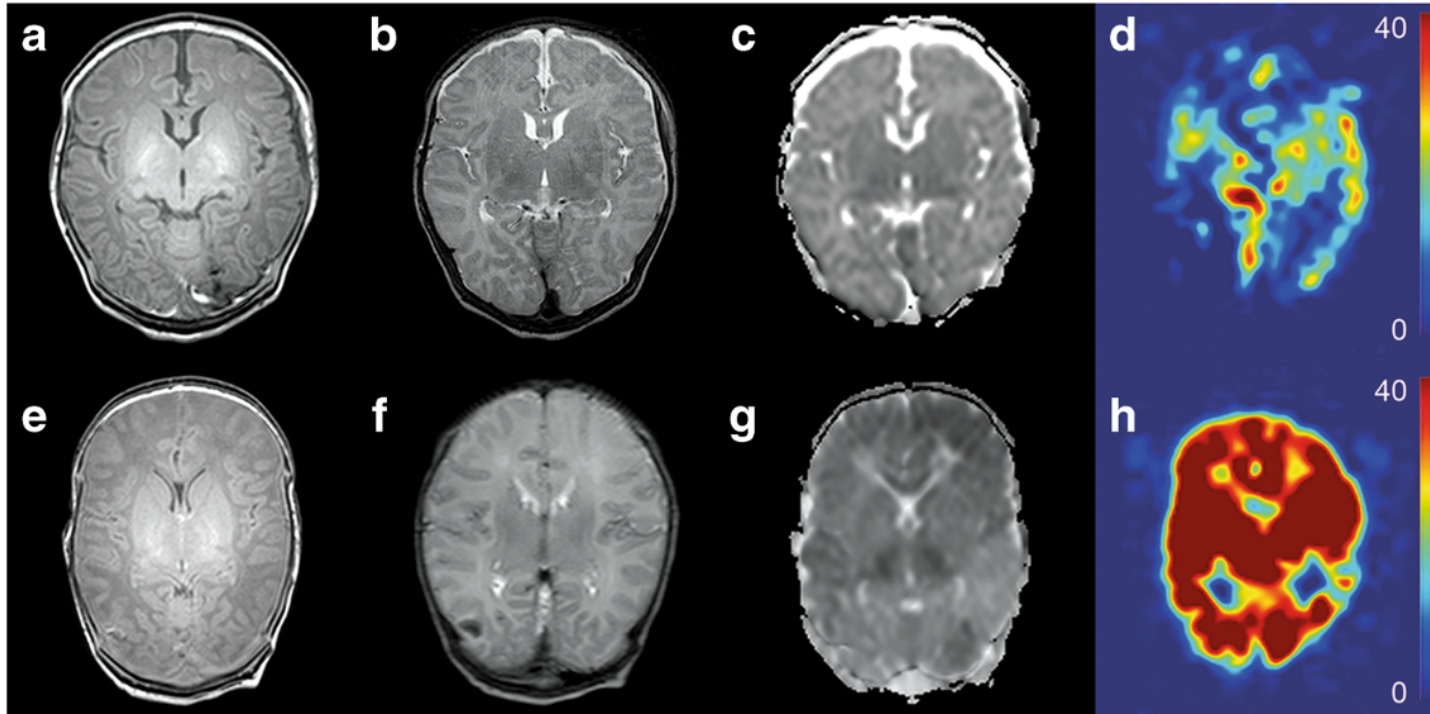
3D-pCASL

PERINATAL ASPHYXIA



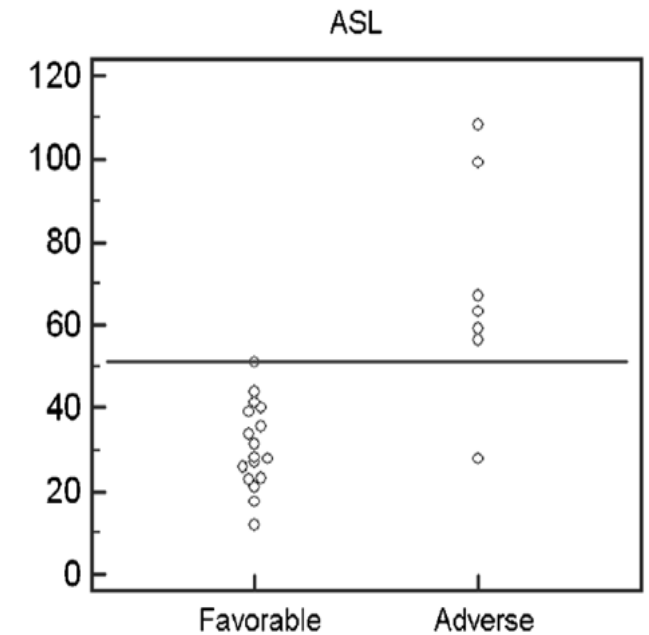
Hyperperfusion predicts worst outcome in HIE

HIE favorable
outcome



HIE adverse
outcome

AUC 0.924 (.74-.99)
Sensitivity 85.7% Specificity 100%





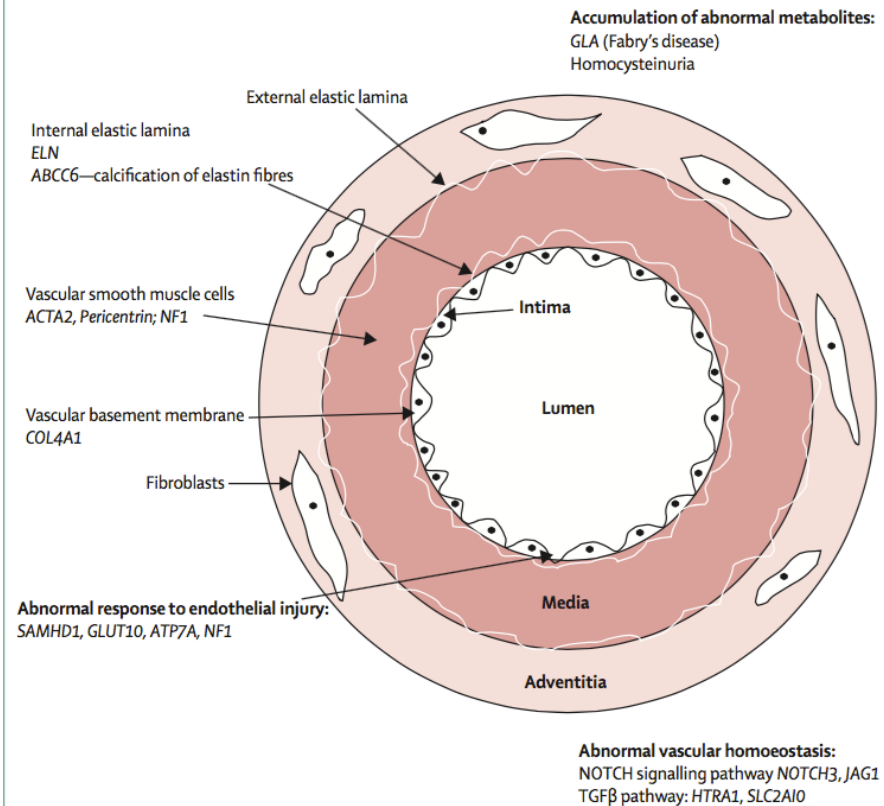
Pediatric arterial ischemic stroke

Relatively rare in children but can lead to significant morbidity and mortality rates ranging between 4% and 14%

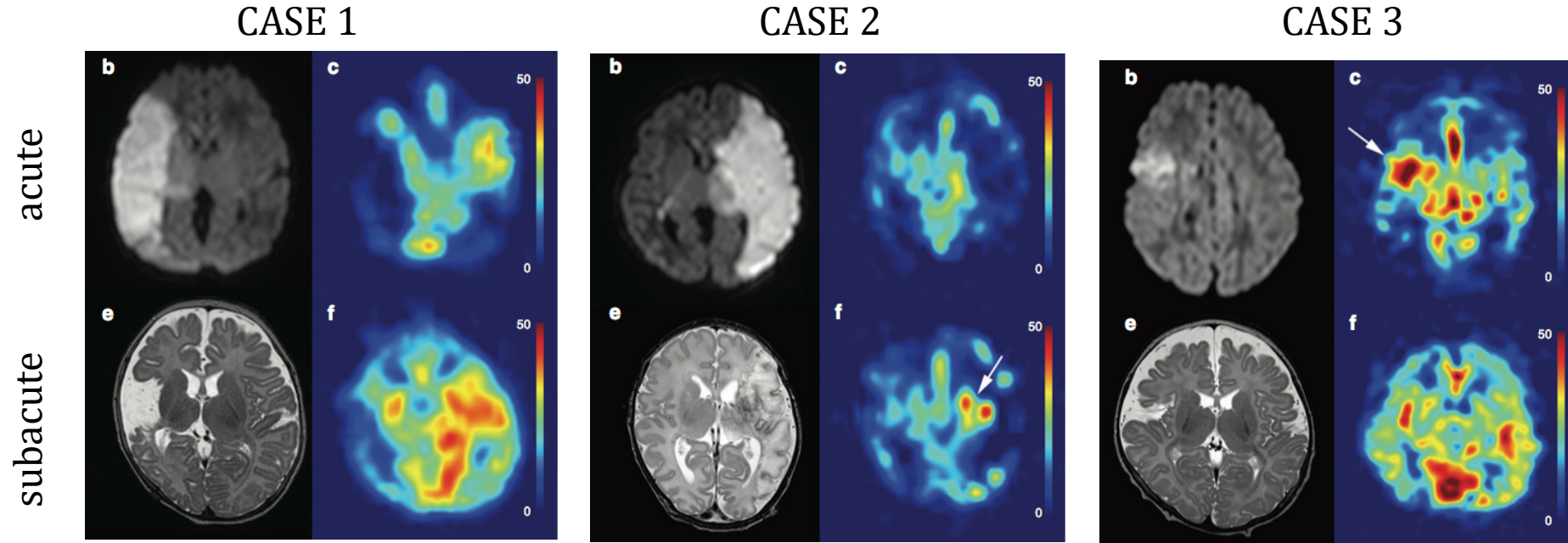
CHILDHOOD ARTERIAL ISCHEMIC STROKE

Risk factors for stroke are different in children and adults!

- **Focal cerebral arteriopathy – *infections***
- **Moyamoya disease / syndrome**
- **Sickle cell disease**
- **Cardiac disease**
- **Arterial dissection – *trauma***
- **Thrombophilia**



PEDIATRIC ARTERIAL ISCHEMIC STROKE



HYPOPERFUSION



CORE

**TRANSIT
ARTIFACTS**



**DELAYED TRANSIT
&
COLLATERAL
PERFUSION**

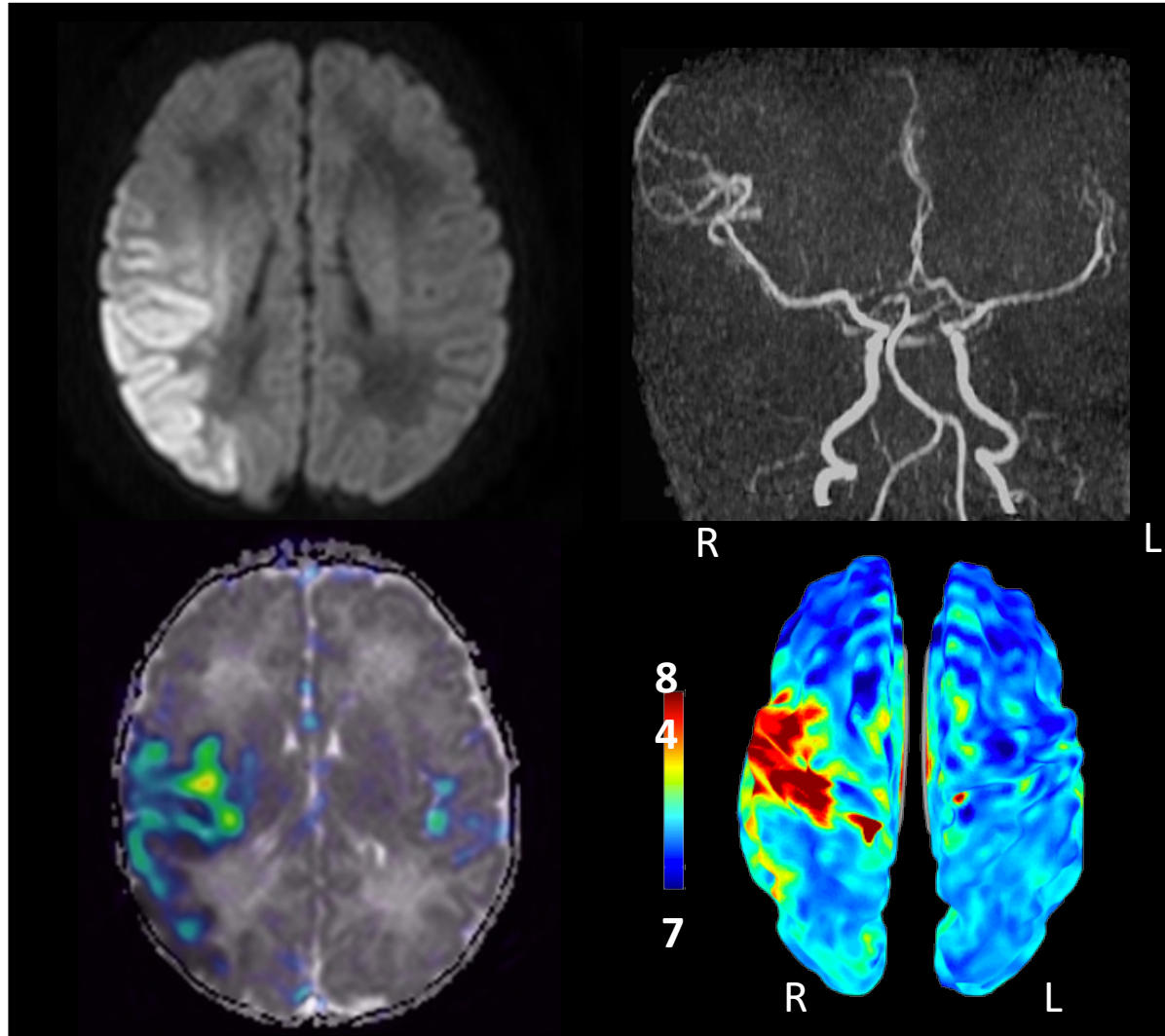
LUXURY PERFUSION



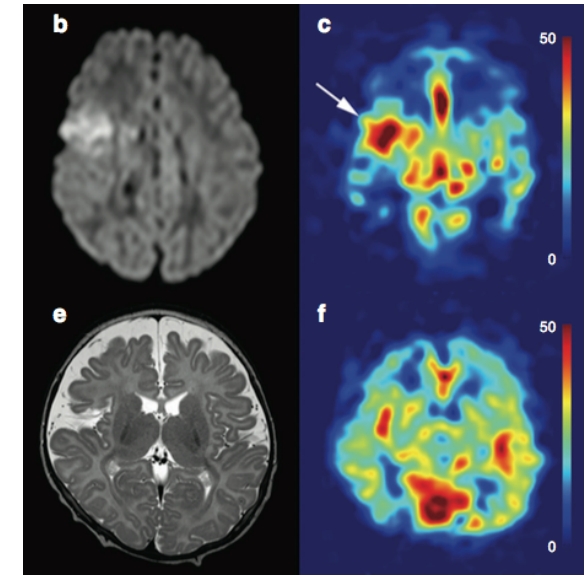
**IPSI LATERAL
HYPERPERFUSION**

PERINATAL ARTERIAL ISCHEMIC STROKE

Flow Increase



CASE 3



LUXURY PERFUSION

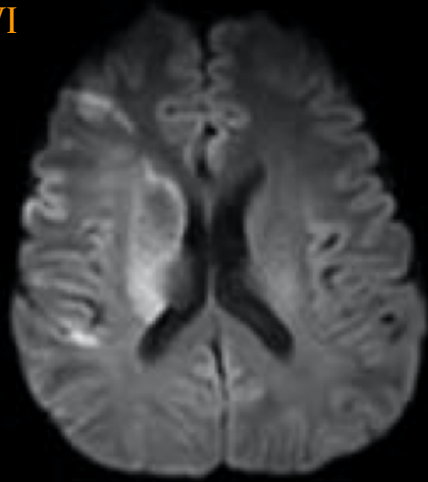


IPSILATERAL
HYPERPERFUSION

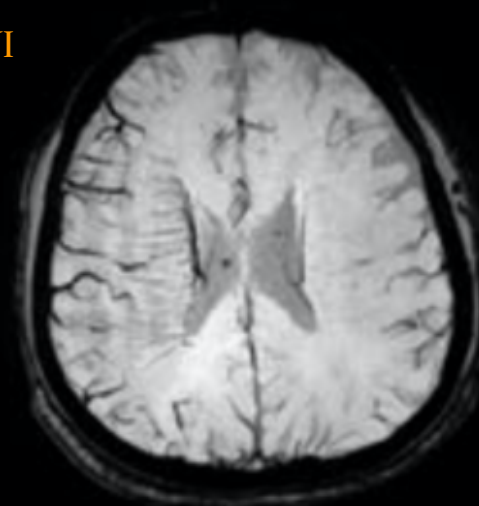
Ischemic penumbra can be evaluated with ASL

SWI-DWI mismatch ratio and ASL PWI-DWI mismatch approach perform equivalently for the penumbra assessment in AIS

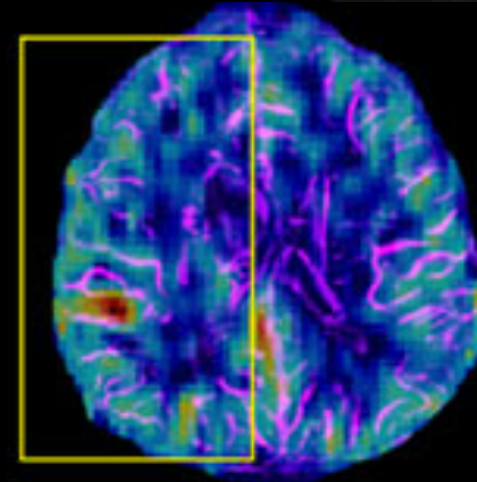
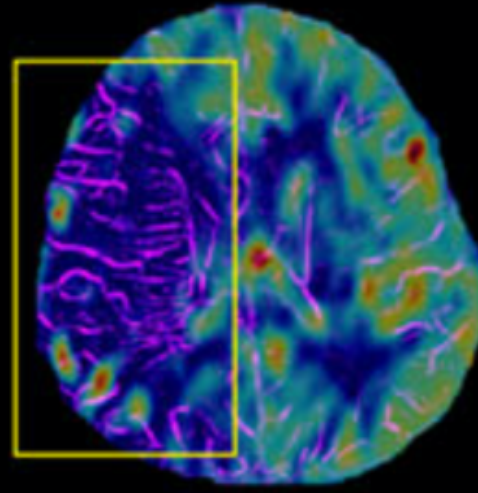
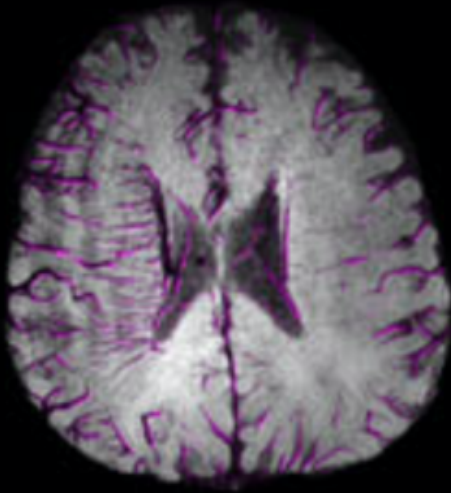
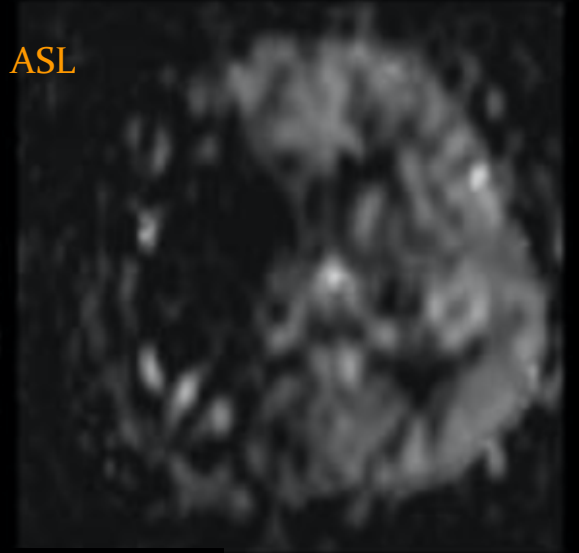
DWI



SWI



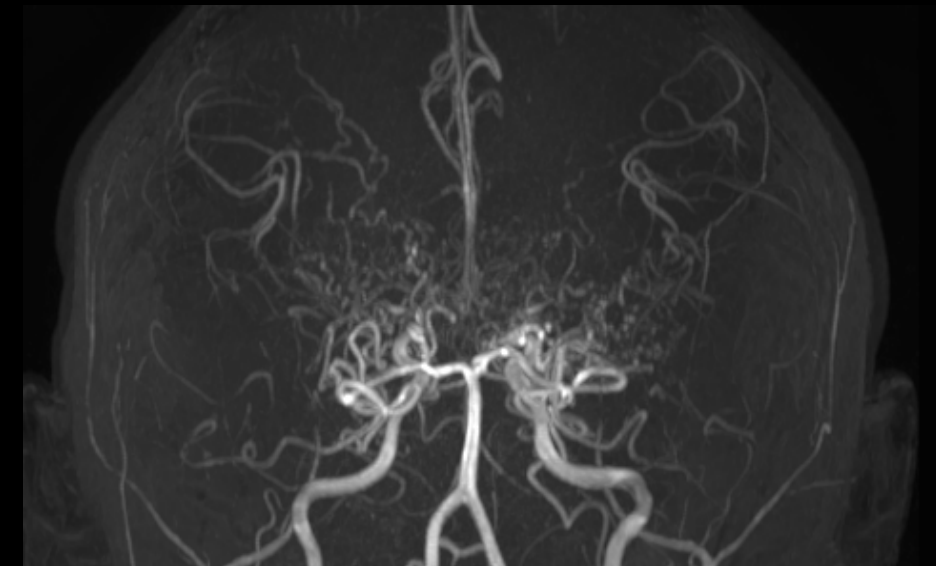
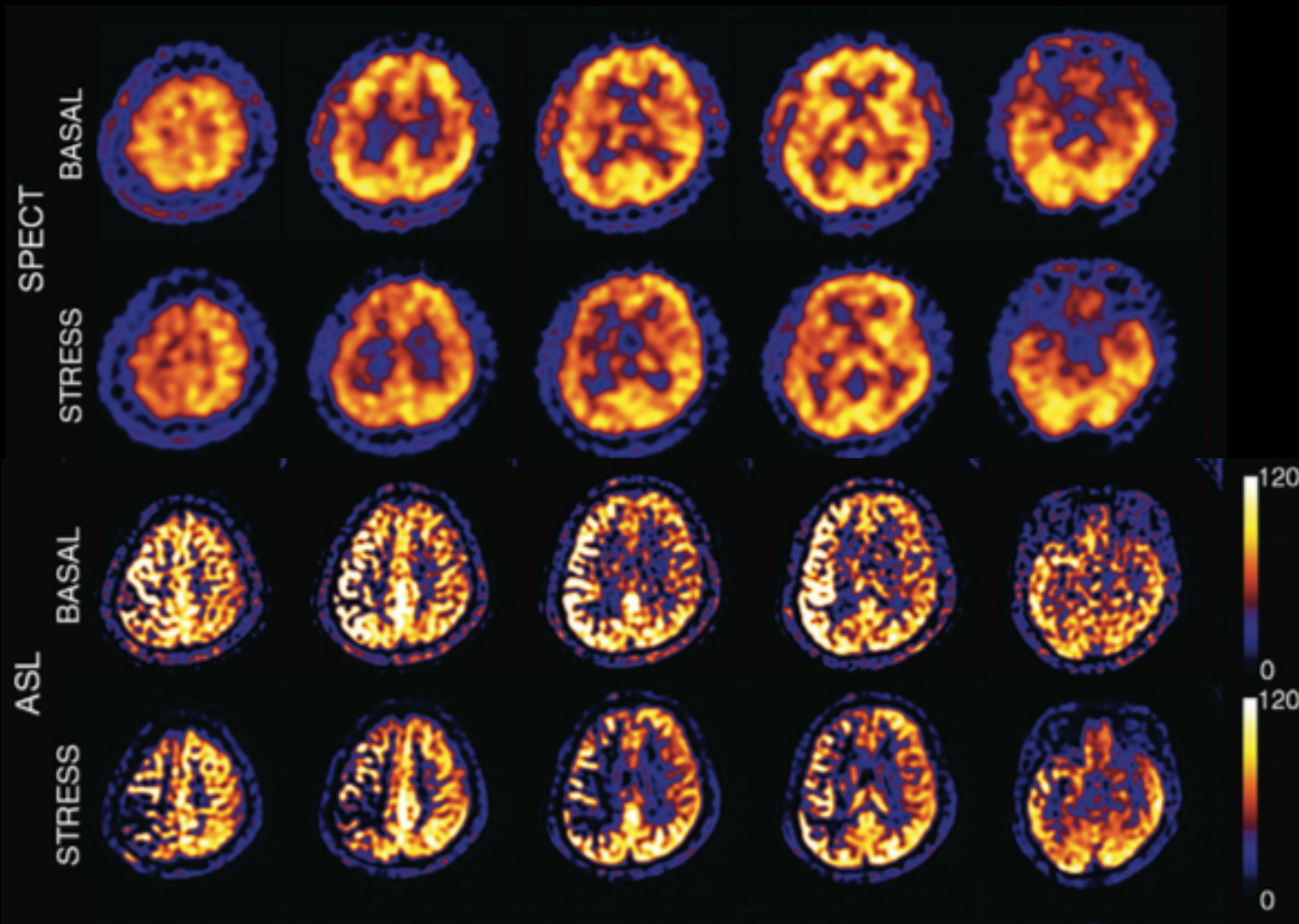
ASL



after mechanical thrombectomy

Cerebrovascular reserve can be evaluated with ASL

How far cerebral perfusion can increase from a baseline value
after stimulation (acetazolamide)



Accuracy of ASL for detecting an acute neurologic disorder

All cases (526)		All cases with DWI volume ≥ 2 cc (110)		All cases with NIHSS ≥ 3 (151)	
Sensitivity	0.85	Sensitivity	0.94	Sensitivity	0.88
Specificity	0.99	Specificity	0.99	Specificity	0.99
PPV	0.98	PPV	0.98	PPV	0.97
NPV	0.94	NPV	0.98	NPV	0.94

Table 2 Comparison of ASL with clinical parameters

Frequency of clinical/imaging findings	Normal-ASL ($n = 388$)	Abnormal-ASL ($n = 138$)	Statistical measure (P -value)
NIHSS–median (IQR)	2 (1)	4 (5.2)	0.0001
Length of hospital stay, median days (IQR)	0 (0)	3 (3)	0.0001
mRS, %	98% (mRS = 0) 1.7% (mRS = 1) < 1% (mRS = 2) 0% (mRS = 3)	37% (mRS = 0) 33% (mRS = 1) 20% (mRS = 2) 10% (mRS = 3)	0.0001
Future neurologic event (%)	12%	66%	0.0001

mRS, modified Rankin Scale; *NIHSS*, NIH stroke scale; *SD*, standard deviation

STROKE-MIMICS

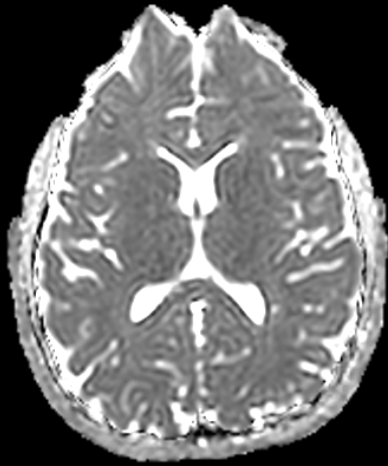
21% of Stroke-like events in children are Stroke-mimics

Shellhaas et al. Pediatrics 2006

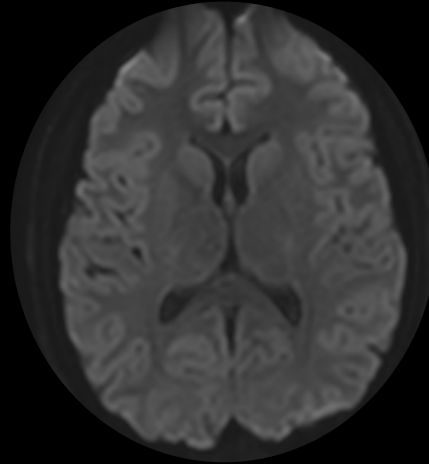


Stroke-like events – TIA vs Migraine

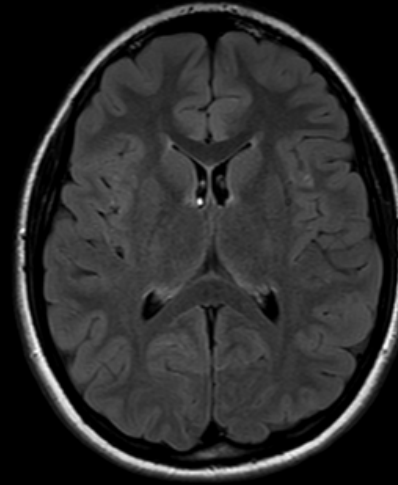
F, 14y, acute confusional state, disturbance of speech and left visual loss



ADC



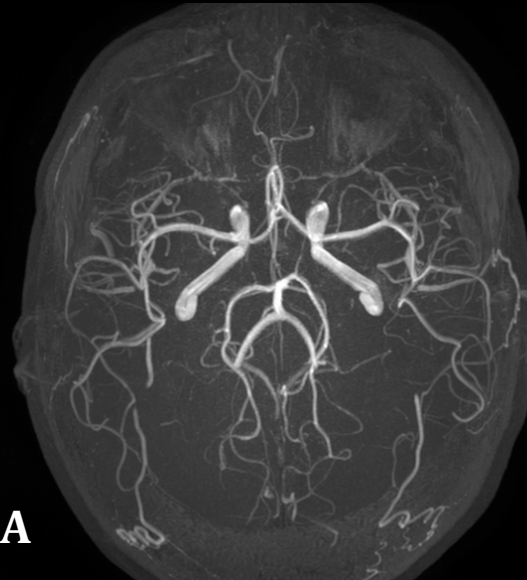
DWI



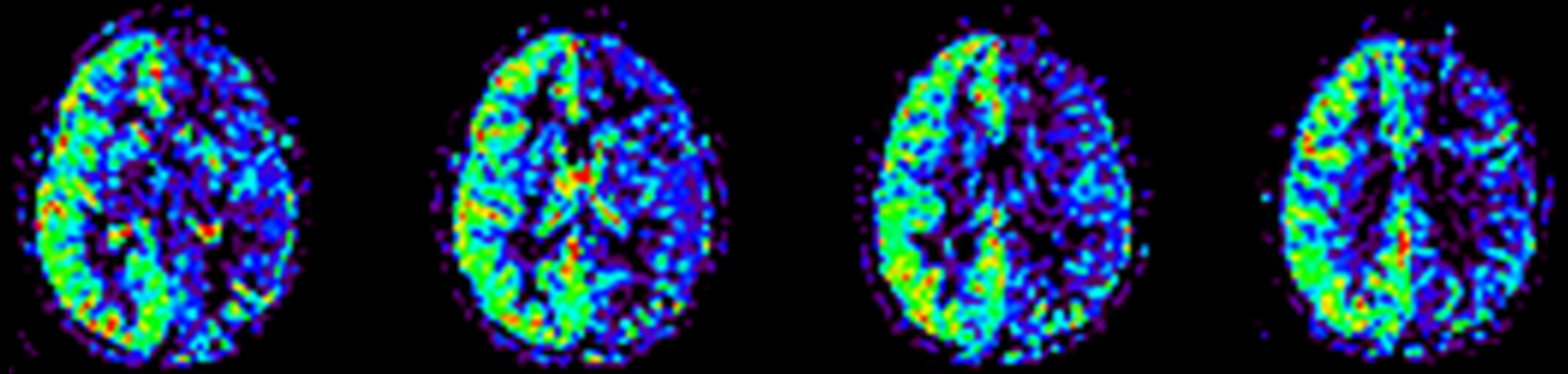
FLAIR



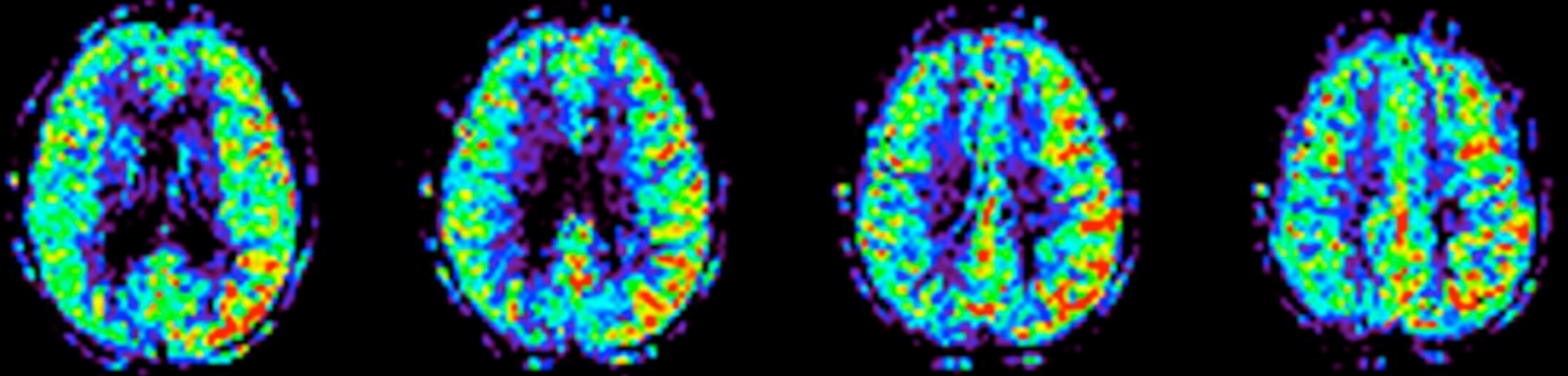
TOF-MRA



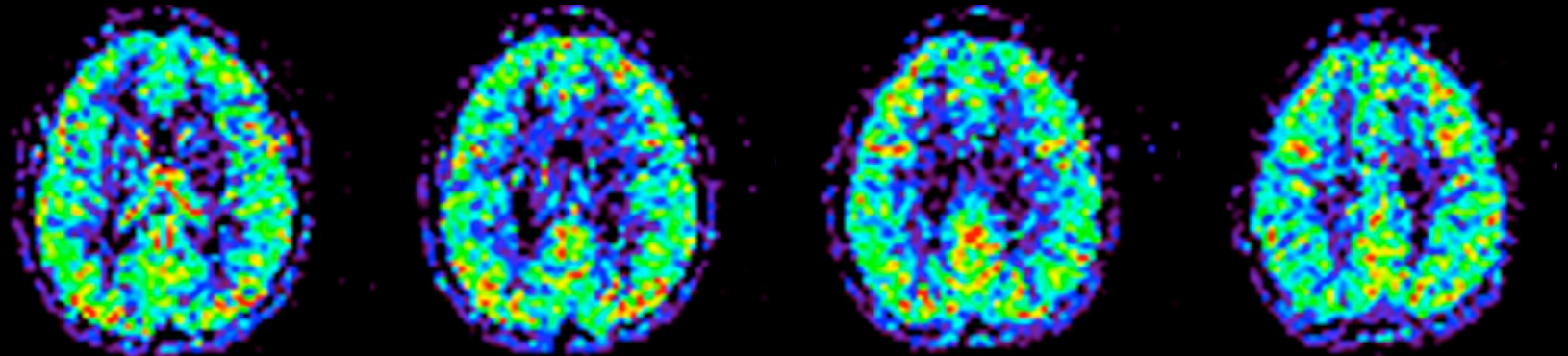
Clinical onset



1 day later...headache onset!!



5 days later... headache resolution!!



Migraine

- MR imaging in children with migraine & aura **could not reveal abnormalities in conventional sequences**
- **Migraine Aura (*stroke-like event*)** is more frequently associated with **hypoperfusion**
- MR studies performed **during the early stages of headache** reveal **hyperperfusion**
- **Perfusion changes did not match the boundaries of major cerebral vascular territories**
(*dd Arterial Ischemic Stroke*)

Wolf et al. 2018 Journal of Cerebrovascular disease

- **Painful phase of migraine without aura attacks** could not be associated with brain perfusion abnormalities

Gil-Gouveia et al. 2017 Front Neurol

Stroke-like events

M, 14y, cardiomegaly, acute visual loss, headache

MELAS

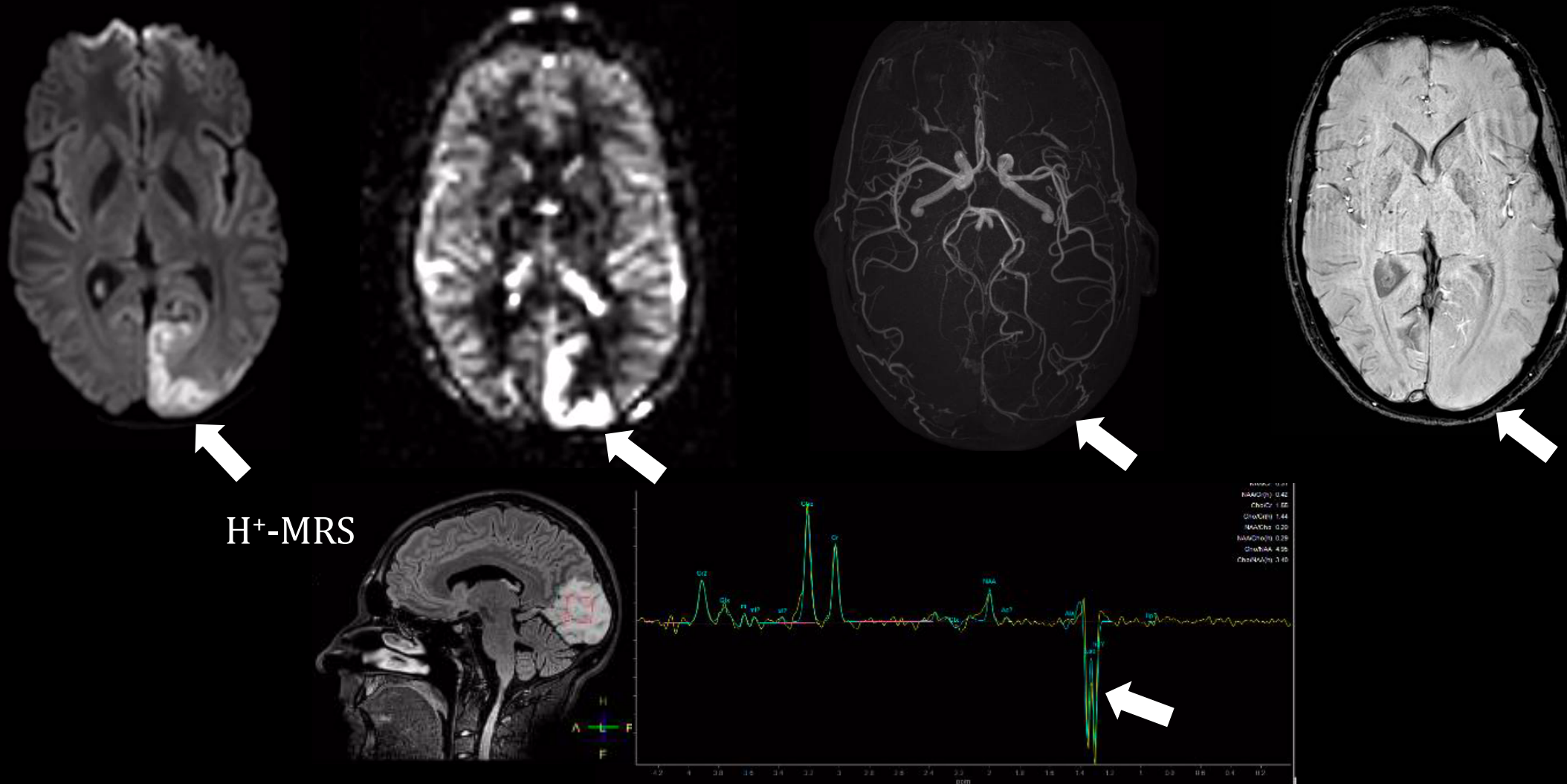
DWI

PCASL

ANGIO-TOF

SWI

H⁺-MRS

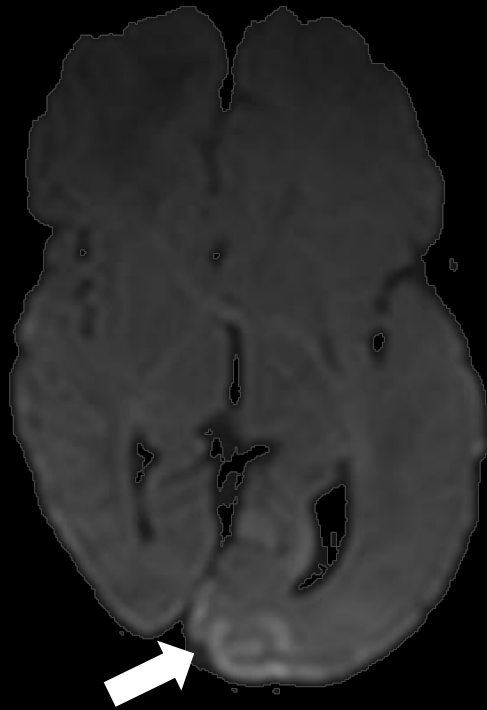


Stroke-like events

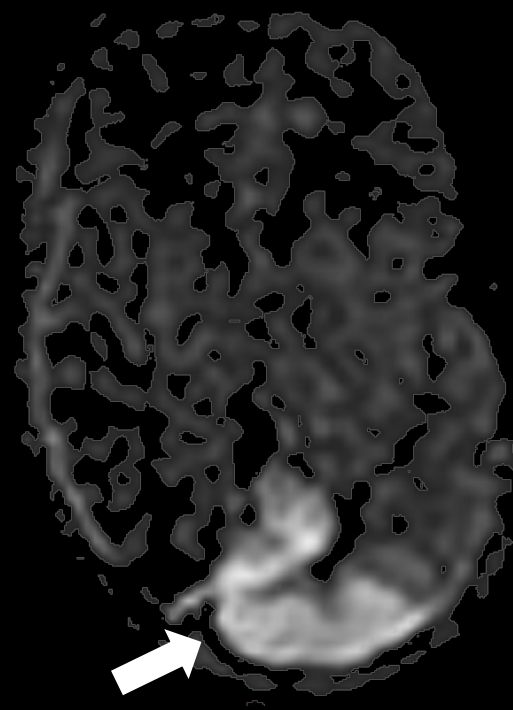
M, neonate, MRI at term, right upper arm seizure

**ICTAL CHANGES
in hemimegalencephaly**

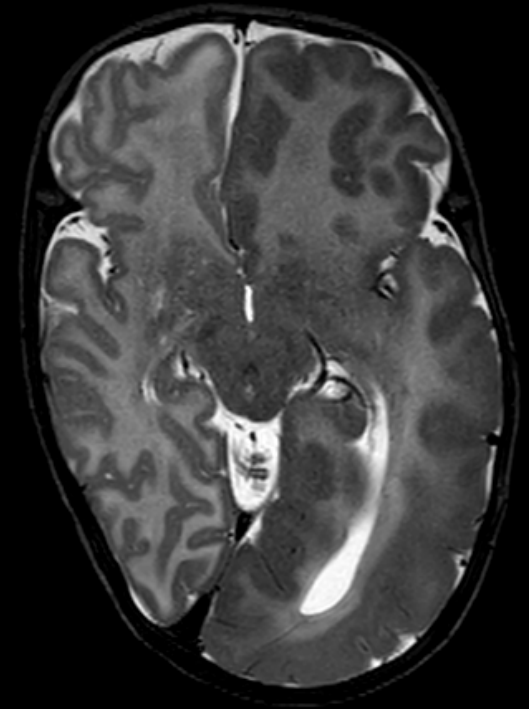
DWI



PCASL

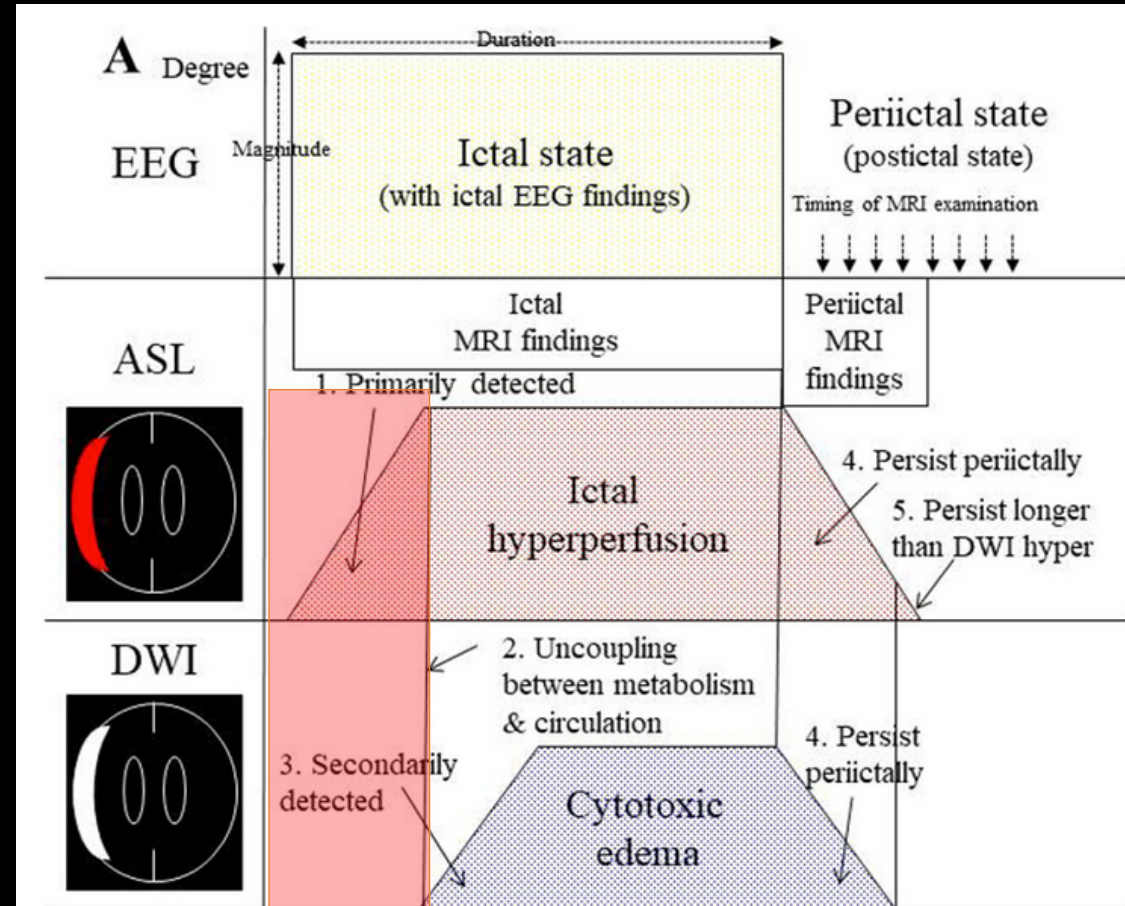
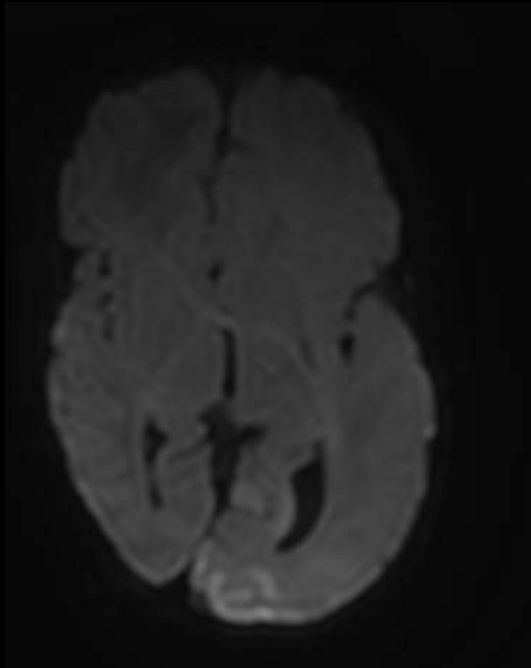


T2

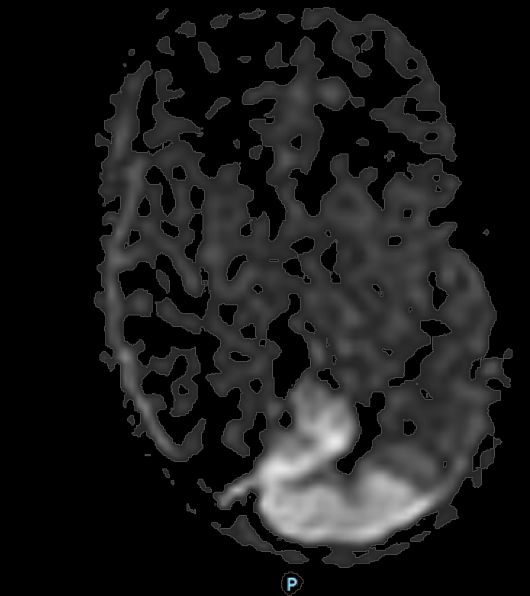


Stroke-like events

DWI



PCASL

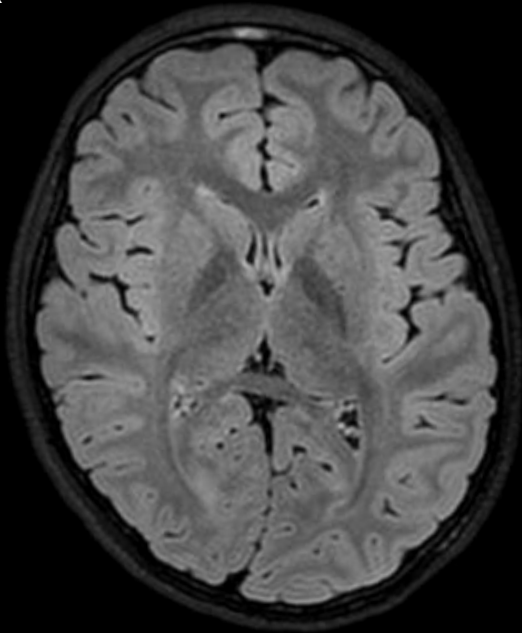


During ictal states epileptogenic cortex is in an extreme electrophysiological state, thereby causing compensatory “ictal hyperperfusion”

When hyperperfusion is no longer sufficient to supply the hyperactive cortical area, cytotoxic edema in epileptic cortical neurons can occur

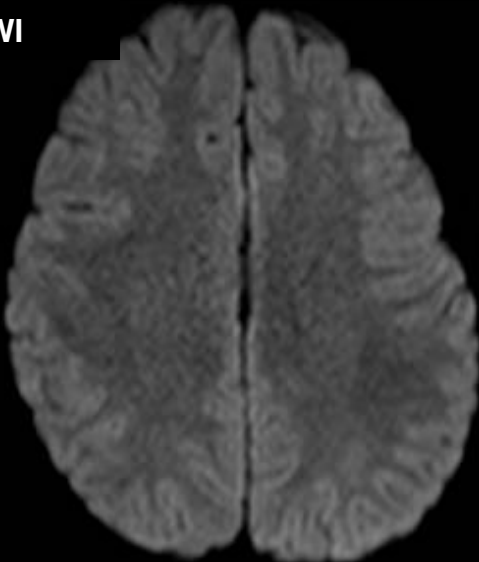
Negative structural MRI: 20-40% of subjects with focal epilepsy

FLAIR

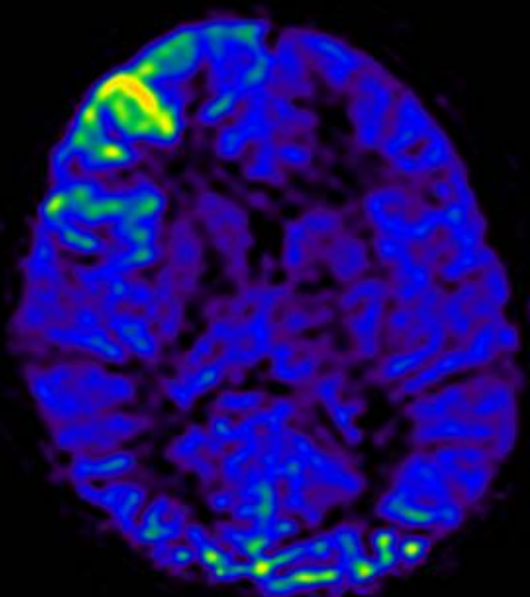


F, 11 y.o. prolonged seizures

DWI

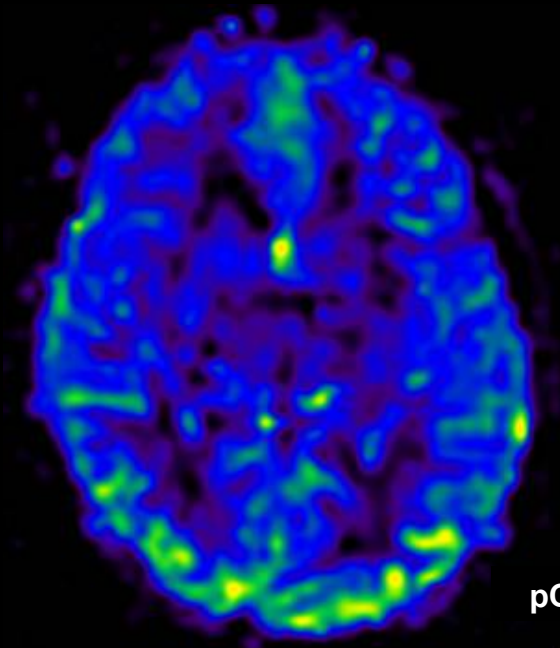


pCASL 3T



1 month later

pCASL 3T



ASL Signal changes in Epilepsy

PERICTAL

Hyperperfusion on ASL
“functional hyperemia”

Cortical hyperintensity on DWI
“cytotoxic edema”



Development of the “ictal” MRI findings depends on the **magnitude** and **duration** of epileptic activity during ictal periods

INTERICTAL

Hypoperfusion on ASL

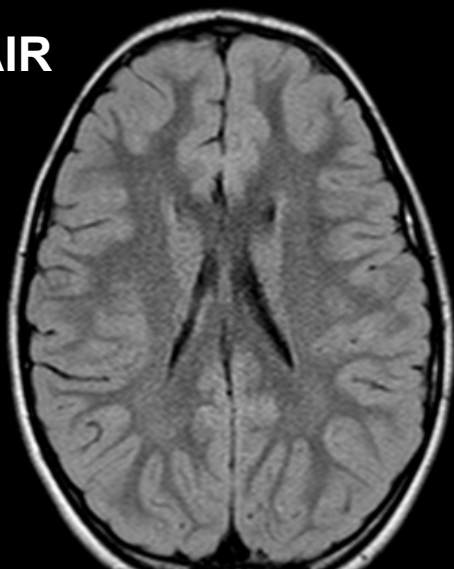
No abnormalities on DWI



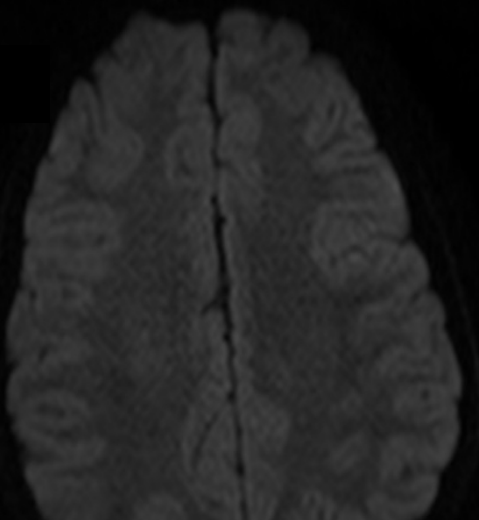
Focal “Interictal” hypoperfusion is more frequent in lesional focal epilepsy

M, 6 y.o. First generalized seizure, left frontal EEG abnormalities, post-ictal right paralysis, ***MRI performed 4 hours after seizure***

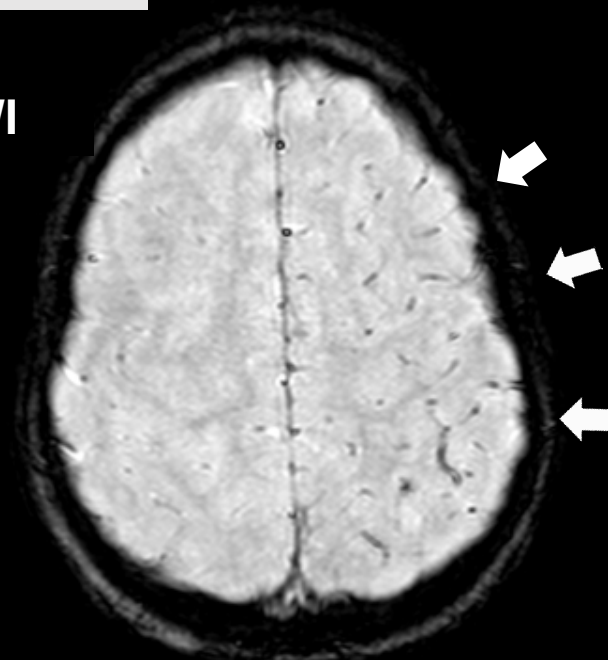
FLAIR



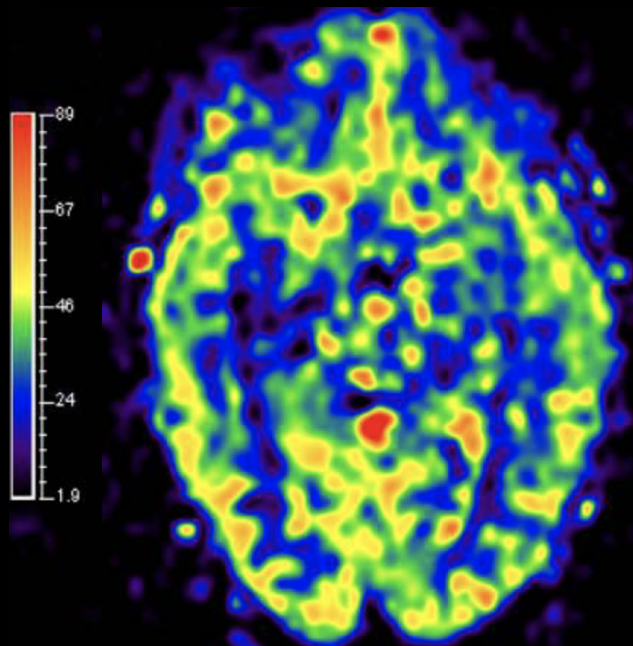
DWI



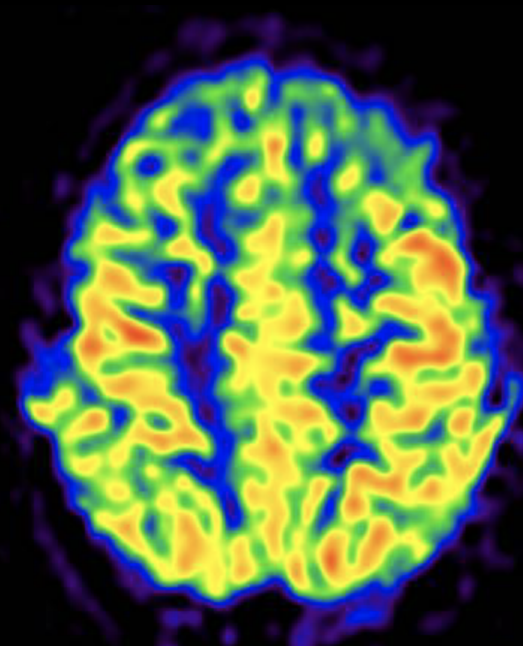
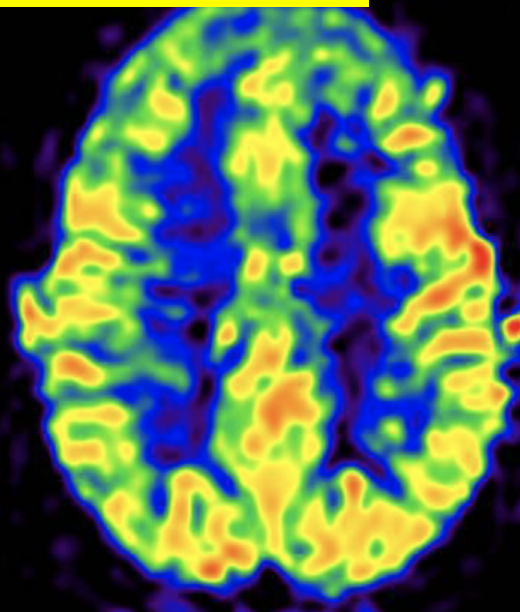
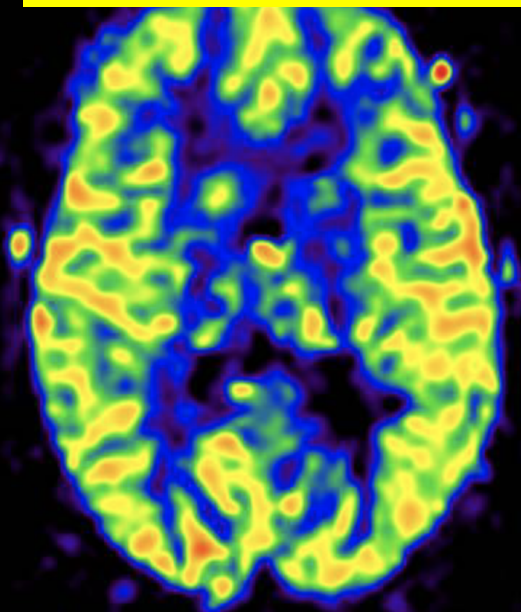
SWI



PCASL, 48h later



TODD Paralysis



Pediatric Encephalitis

- One of the most challenging illnesses in medicine
- Broad range of causative agents (infections & autoimmune)
- Clinical findings are aspecific (headache, lethargy, photophobia, seizures)
- Few specific diagnostic tests:
 - EEG (diffuse slowing, specific patterns)
 - CSF (lymphocytic pleocytosis, normal/elevated protein, normal glucose, normal/elevated pressure)
 - PCR & serology (variable sensitivity/specificity)
 - Neuroimaging

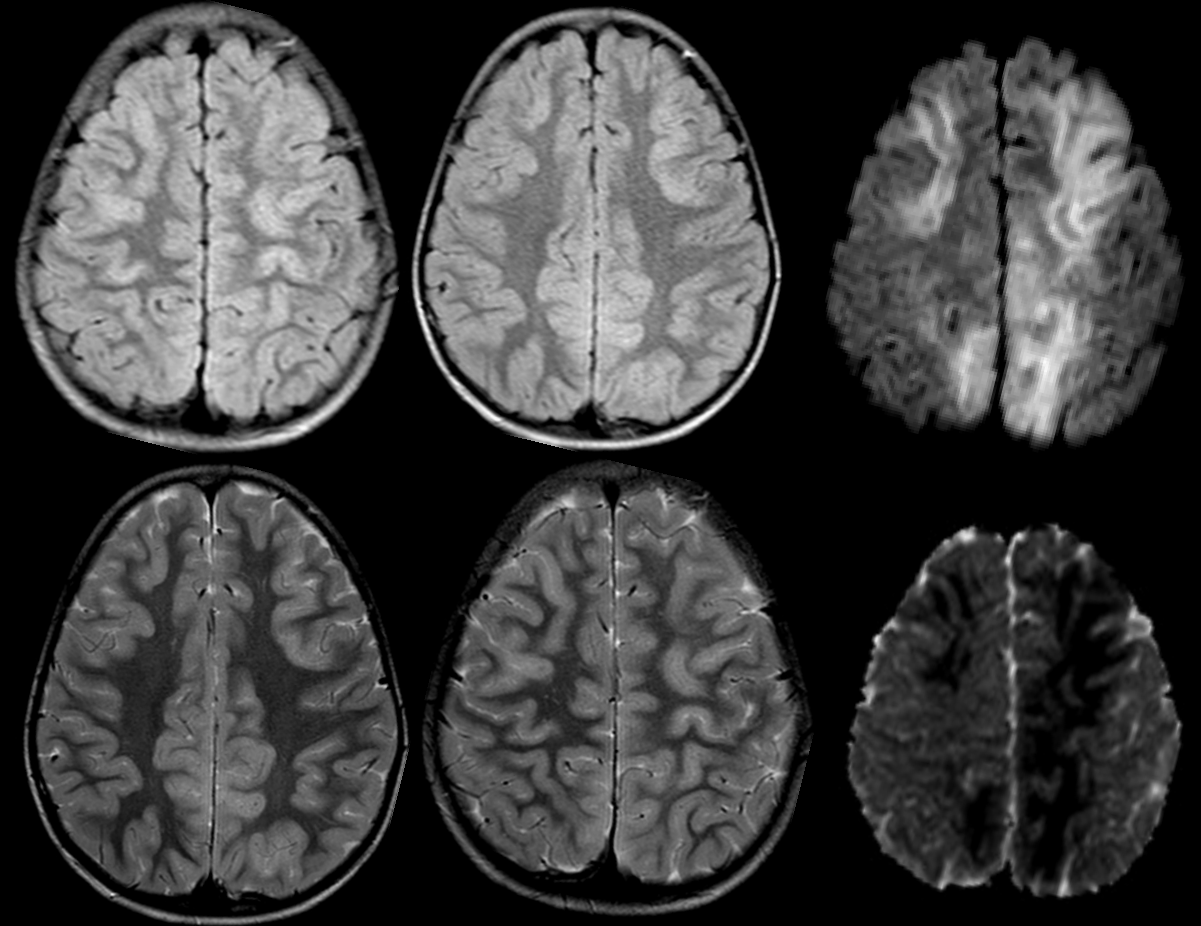
Pediatric Encephalitis

F 4y Echovirus 6

- MRI could be inconspicuous or thoroughly negative in 65% of cases at clinical onset !!!!

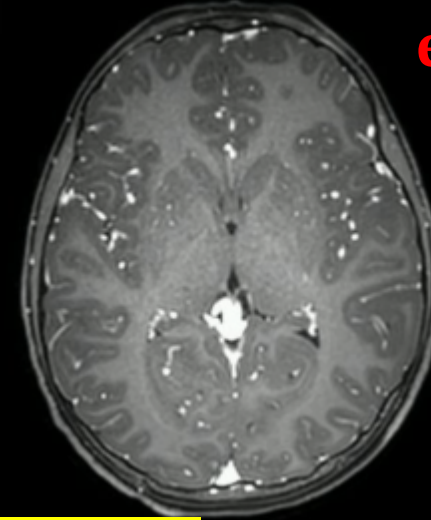
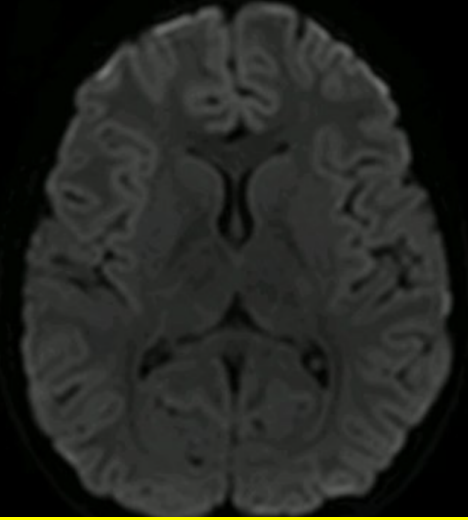
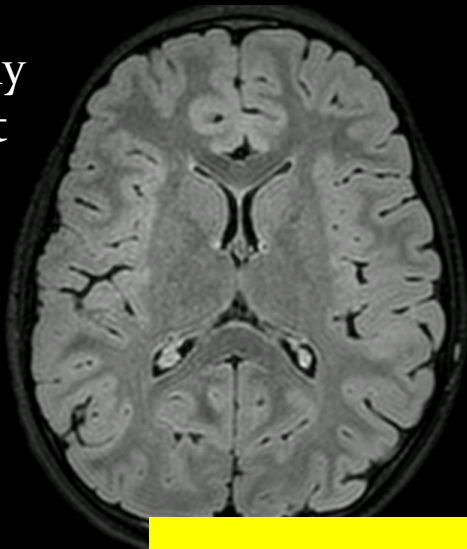
Typical MR findings:

- Asymmetric involvement of the cerebral cortex
- DWI is more conspicuous in the early stages of the disease
- ASL shows mixed pattern of hyper/hypoperfusion



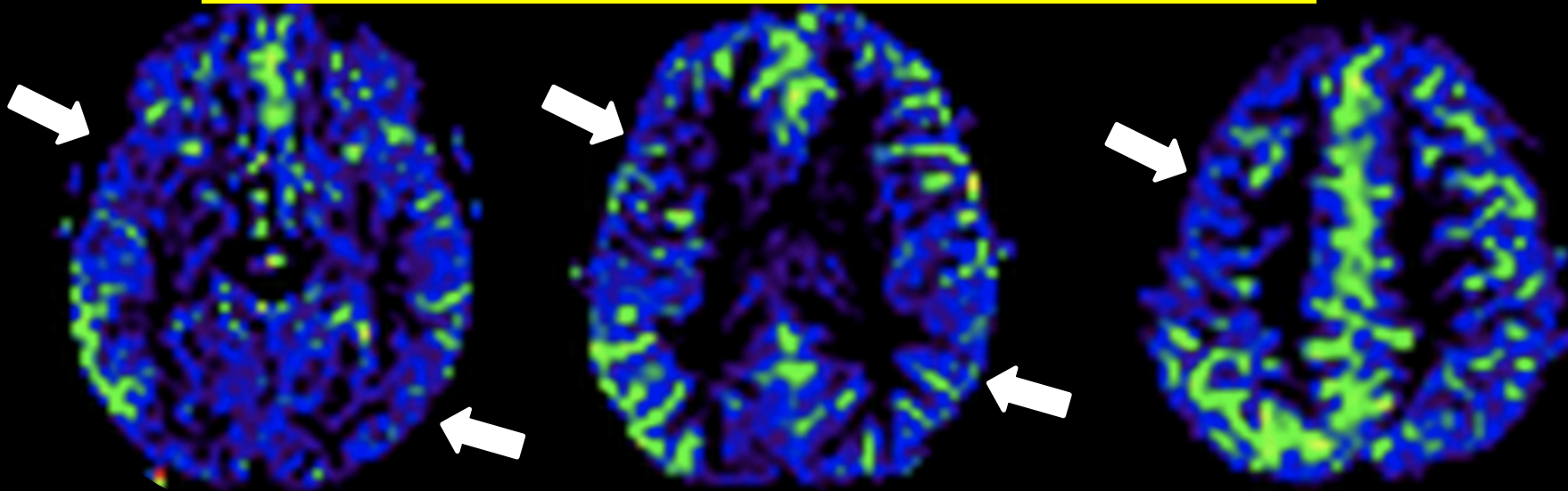
Pediatric Encephalitis

8 years old, F
Acute encephalopathy
MRI at clinical onset



**Anti NMDA-receptor
encephalitis**

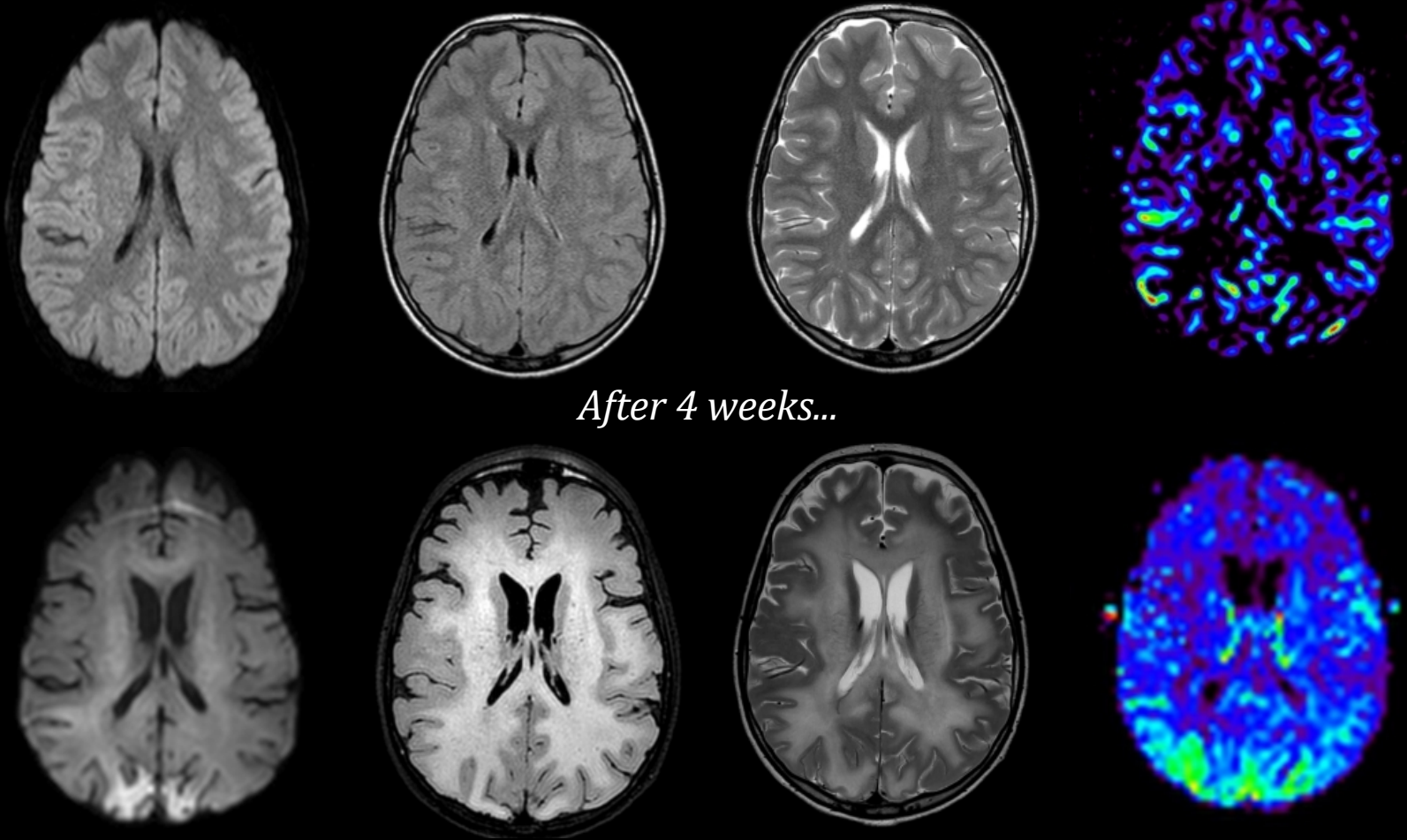
Patchy Perfusion Abnormalities



Pediatric Encephalitis

M, 4y, fever and altered consciousness

Anti-neurexin-3α encephalitis



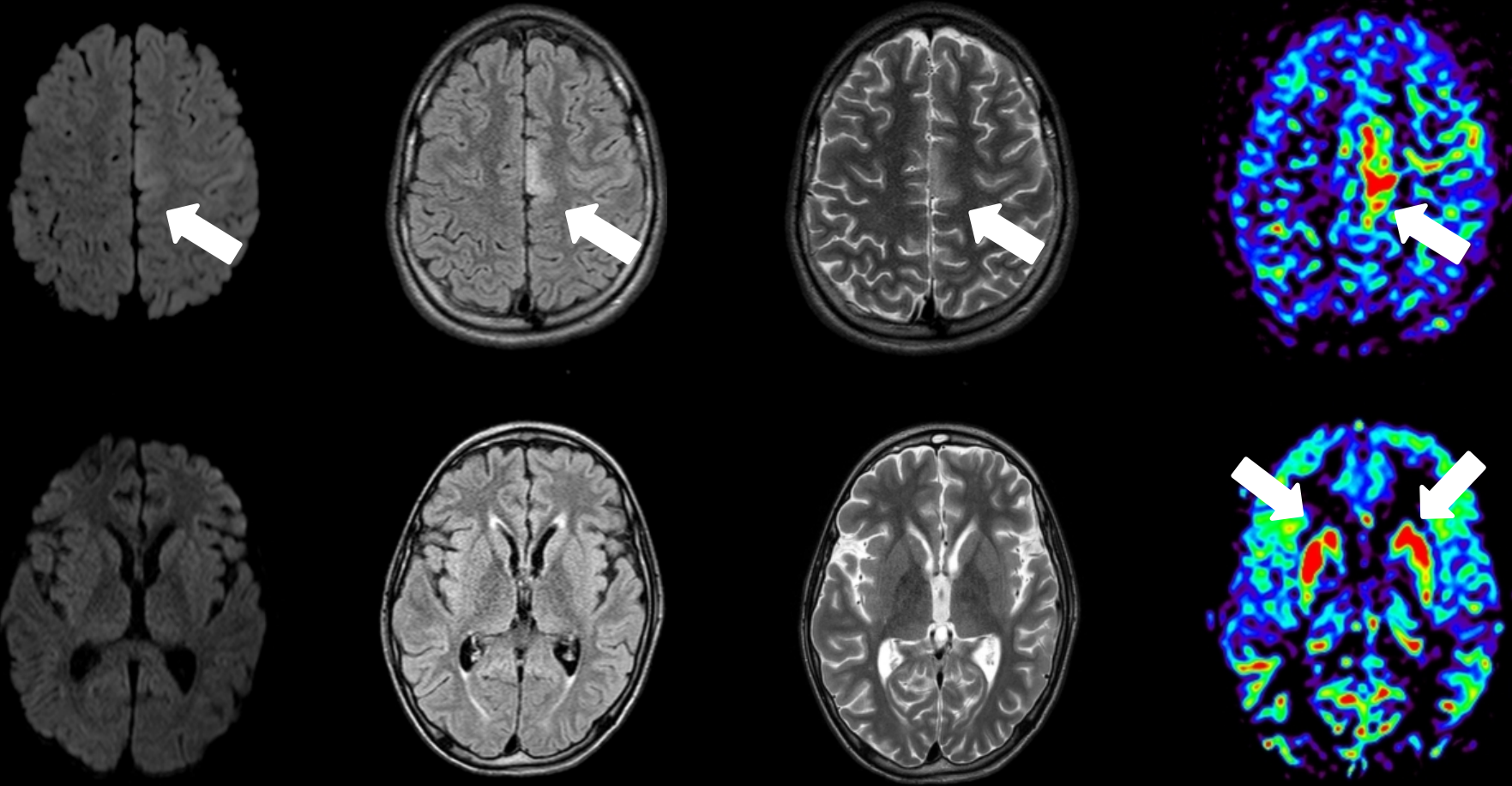
**Global hypoperfusion may predict poor outcome
in childhood encephalitis**

Mun-Ching Wong et al. 2018 Neuroradiology

Pediatric Encephalitis

M, 12y, fever, seizure and altered consciousness

**Anti NMDA-receptor
encephalitis**



**Focal hyperperfusion is a significant predictor of seizure in
childhood encephalitis**



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Conclusions

In neurologic emergencies ASL provides information not available with DWI and vascular imaging alone

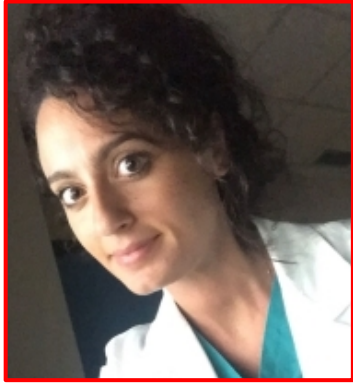
- **It may help identify tissue at risk of infarction : DWI-ASL mismatch**
- **High negative predictive value for patient outcome:** Low risk of neurological deficit with normal ASL
- **ASL assists in diagnosing stroke mimics:** ASL Hyperperfusion with normal/restricted DWI

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THANKS