Journal of Neuroradiology xxx (2018) xxx–xxx

Available online at
ScienceDirect
www.sciencedirect.com

Elsevier Masson France
EM|consulte
www.em-consulte.com

Review

Arterial spin labeling: Clinical applications

Mai-Lan Ho

Division of Neuroradiology, Mayo Clinic, 200 First St. SW, 55905 Rochester, MN, United States

ARTICLE INFO

Article history:
Available online xxx

Keywords:
Arterial spin labeling
Cerebral blood flow
Perfusion
Postlabel delay

ABSTRACT

Arterial spin labeling (ASL) is a magnetic resonance imaging perfusion technique that enables quantification of cerebral blood flow (CBF) without the use of intravenous gadolinium contrast. An understanding of the technical basis of ASL and physiologic variations in perfusion are important for recognizing normal variants and artifacts. Pathologic variations in perfusion can be seen in a number of disorders including acute and chronic ischemia, vasculopathy, vascular malformations, tumors, trauma, infection/inflammation, epilepsy and dementia.

Introduction

Arterial spin labeling (ASL) is a magnetic resonance imaging perfusion technique that enables quantification of cerebral blood flow (CBF) without the use of intravenous (IV) gadolinium contrast. As compared to contrast-enhanced techniques such as dynamic susceptibility contrast (DSC) and dynamic contrast-enhanced (DCE) perfusion, ASL is easily repeatable; less prone to susceptibility artifacts and is useful in situations where gadolinium contrast is contraindicated, e.g. young children, pregnant women and debilitated patients with liver and/or renal failure. Furthermore, ASL image postprocessing is relatively automated; does not rely on IV contrast injection profiles and enables quantification of absolute rather than relative CBF. An understanding of the technical basis of ASL and physiologic variations in perfusion are important for recognizing normal variants and artifacts. Pathologic variations in perfusion can be seen in a number of disorders including acute and chronic ischemia, vasculopathy, vascular malformations, tumors, trauma, infection/inflammation, epilepsy and dementia. In the past, ASL has primarily been utilized in acute and chronic stroke evaluation at specialized medical centers. More routine use in additional disease processes has historically been limited by technical understanding and practical availability. With ongoing advances in MRI technology and increasing concerns about gadolinium deposition, it is important for the neuroradiologist to be aware of the physics and applications of this alternative perfusion modality. Given the many interpretive subtleties, wider use of the sequence is encouraged so that radiologists can become familiar with the broad variety of imaging appearances. In this pictorial essay, we will present multiple imaging examples to highlight the various clinical applications of this technique, as well as discuss pearls and pitfalls in the interpretation of ASL images.

Technique

ASL techniques use radiofrequency (RF) pulses to invert free water protons at the base of the brain. Following a subsequent postlabel delay (PLD), labeled protons within the arterial circulation flow into the brain parenchyma and equilibrate with the capillary circulation. Because signal decay is on the order of seconds, clinical PLD values are typically set between 1000–3000 milliseconds. A high signal-to-noise (SNR) sequence — for example echo-planar imaging, fast spin echo, or gradient-echo — is used to assess changes in brain signal between labeled and control (nonlabeled) images. Due to variations in labeling efficiency, signal decay and blood flow rates; a clinical ASL sequence involves multiple interleaved acquisitions of label and control images. Perfusion is then calculated by pairwise subtraction of label and control images, with subsequent factor correction based on general kinetic modeling with at least two compartments (blood and tissue). This yields an absolute CBF parameter in physiological units of ml/100 g/min and a visual CBF map that can be displayed in grayscale (conventional) or various color schematics. Several different techniques are available for

Abbreviations: ACA, anterior cerebral artery; AVF, arteriovenous fistula; AVM, arteriovenous malformation; ASL, arterial spin labeling; ATA, arterial transit artifact; ATT, arterial transit time; CBF, cerebral blood flow; CBV, cerebral blood volume; CT, computed tomography; DCE, dynamic contrast-enhanced; DSC, dynamic susceptibility contrast; DVA, developmental venous anomaly; DWI, diffusion-weighted imaging; FLAIR, fluid-attenuated inversion recovery; GRE, gradient-recalled echo; ICA, internal carotid artery; IV, intravenous; MCA, middle cerebral artery; MR, magnetic resonance; MRA, magnetic resonance angiography; ms, milliseconds; PCA, posterior cerebral artery; PET, positron emission tomography; PLD, postlabel delay; RF, radiofrequency; SNR, signal-to-noise; SWI, susceptibility-weighted imaging; TBI, traumatic brain injury.

E-mail address: ho.mai-lan@mayo.edu

https://doi.org/10.1016/j.neurad.2018.06.003
0150-9861/

Please cite this article in press as: Ho M-L. Arterial spin labeling: Clinical applications. J Neuroradiol (2018), https://doi.org/10.1016/j.neurad.2018.06.003

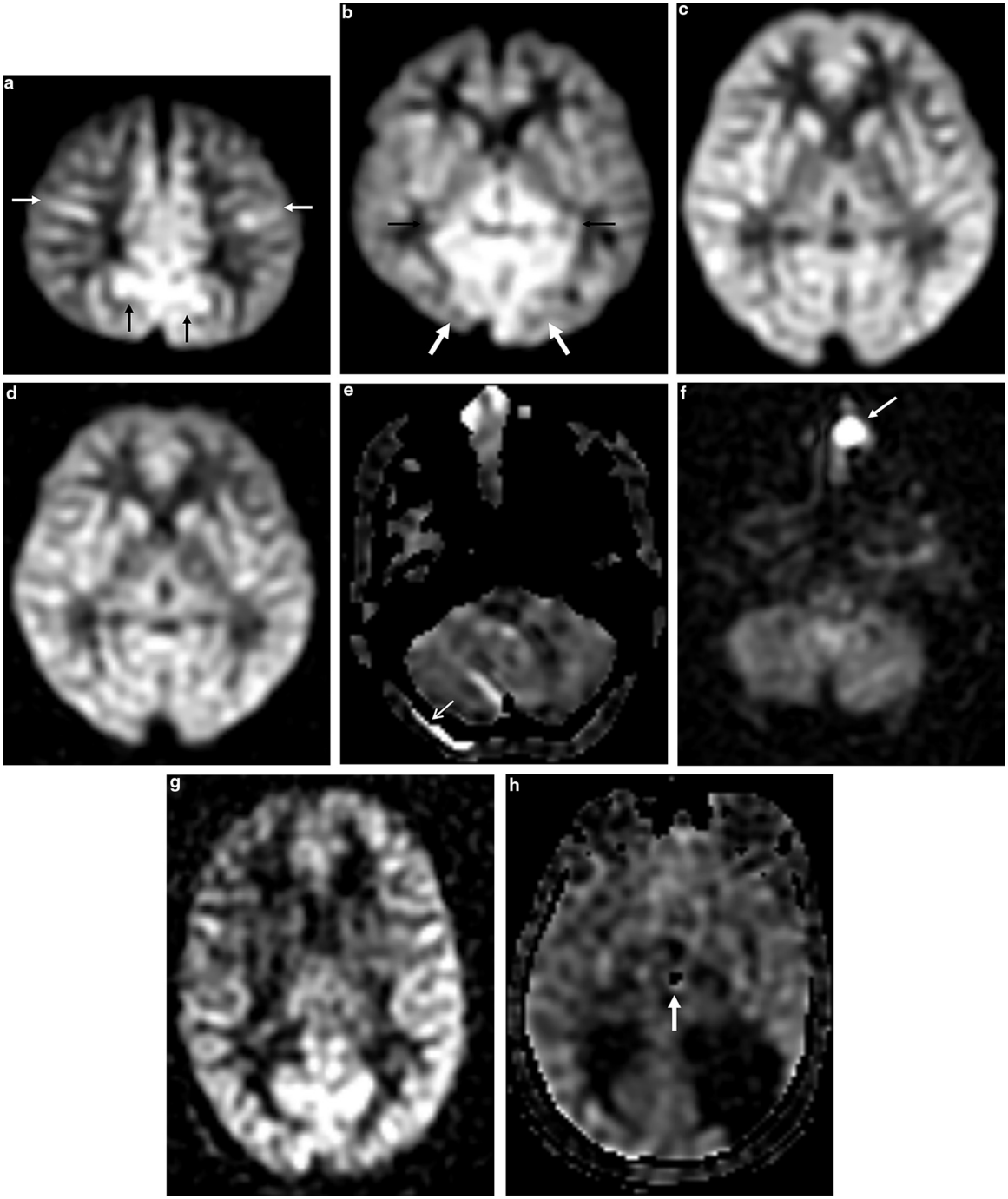

Fig. 1. Normal variants and artifacts. A. Healthy 1-year-old male infant. ASL shows globally low CBF with selective hyperperfusion of corticospinal tracts (white arrows) and default mode network (black arrows). B. Healthy 1-year-old male infant. Visual activation results in hyperperfusion of lateral geniculate nuclei (black arrows) and occipital cortex (white arrows). C. Healthy 3-year-old female child. ASL at PLD = 2000 ms shows robust and homogeneous flow throughout the cerebral cortex, exceeding that of white matter. D. Healthy 3-year-old female child. ASL at PLD = 2500 ms shows overall decreased and more heterogeneous signal, due to spin tag decay. E. Scalp venous varix. ASL shows curvilinear hyperintensity in the right occipital soft tissues (thin white arrow). F. Nasal cycling. ASL shows asymmetric hyperperfusion of left nasal mucosa (arrow), with confirmation of transient ipsilateral mucosal edema on anatomic images. G. Coil heterogeneity. ASL shows asymmetric signal dropoff along the right and anterior field of view in a nonphysiologic distribution. H. Ring artifact. Patient motion results in circumferential visualization of scalp tissues. There is also focal signal dropout from a basilar tip aneurysm coil (arrow).

proton labeling, including pulsed, continuous, pseudocontinuous and velocity-selective ASL. In pulsed ASL (PASL), multiple short RF pulses are used for labeling, while continuous ASL (CASL) requires specialized coils and enables continuous labeling of protons passing through a given plane. Pseudocontinuous ASL (PCASL) is a hybrid approach that simulates CASL, using multiple short pulses without the need for specialized hardware. Each of these techniques can be applied for selective arterial labeling to map perfusion territories. Additional techniques being developed include multidelay ASL and velocity-selective ASL (VS-ASL), which enable calculation of cerebral blood volume (CBV) and arterial transit time (ATT) and time-resolved ASL for dynamic angiography [1–7].

Please cite this article in press as: Ho M-L. Arterial spin labeling: Clinical applications. J Neuroradiol (2018), https://doi.org/10.1016/j.neurad.2018.06.003