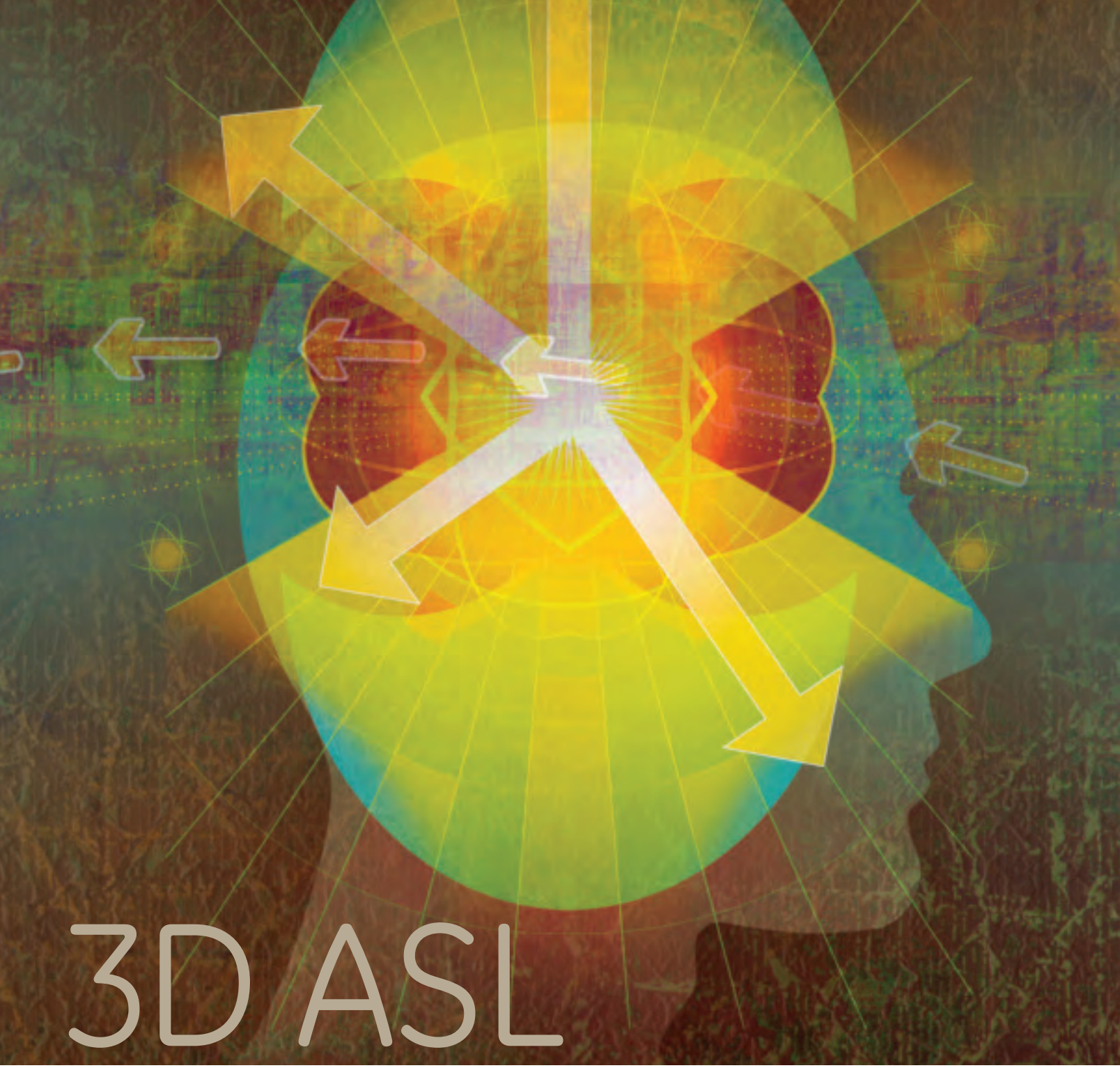

3D ASL

Ready for Clinical use

By Hirohiko Kimura, MD, PhD, Professor, Department of Radiology, University of Fukui

Arterial spin labeling (ASL) is a means of non-invasive MR perfusion assessment, which can provide a quantitative value of cerebral blood flow (CBF). It is undisputed that the most advantageous merit of ASL is noninvasiveness as compared to methods that require the tracer injection to patients. It has been argued, however, that ASL perfusion images are not clinically reliable due to the inherent low signal-to-noise ratio (SNR) of current techniques. The latest ASL sequence, developed by GE Healthcare, 3D ASL, is a for both 1.5T and 3.0T and uses an SNR-efficient labeling technique, namely, pulsed continuous arterial spin labeling (pCASL),

which allows it to be compatible with body coil excitation. In addition, it uses background suppression and a 3D FSE acquisition to provide robustness to motion and susceptibility artifacts. The result is whole-brain perfusion coverage with improved SNR (Figure 1).

Pulsed versus continuous ASL

There are two types of ASL: continuous ASL (CASL) and pulsed ASL (PASL). In CASL, the blood spins, pass through the labeling plane are repeatedly inverted to augment the brain perfusion signal. In PASL, a single pulse is used for the labeling, which usually attains less perfusion contrast than CASL. Although it is more difficult to implement CASL due to hardware demands, the perfusion signal is much stronger in CASL than PASL, making it easier to detect. Since the time between label and imaging is long in CASL, the perfusion signal is more homogenously distributed, resulting in the perfusion signal becoming less sensitive to arterial transit time.[2]

Since both PASL and CASL techniques have room for improvement, GE Healthcare has developed a pulsed-continous 3D ASL technique that provides the excellent image quality of continuous labeling approaches without requiring specialized hardware. In addition, since it is 3D, it is capable of imaging the entire brain in one scan.

Figure 2 demonstrates the comparison of a PASL and pCASL perfusion imaging technique from the same subject. The images show an over-estimation of CBF in the occipital cortex and thalamic regions on PASL maps, likely due to the delayed arterial transit time resulting in a larger vascular signal component.

CBF quantification

Quantitative measurement of CBF with 3D ASL signal depends on the model and its assumption with a number of parameters including labeling efficiency, cerebral blood volume (CBV), permeability of blood vessels, blood/brain partition coefficient, T1 of tissue or arterial blood, and arterial transit time (ATT). Patients with chronic occlusive cerebrovascular disease have longer ATT in the affected cortex. This could cause the underestimation of CBF values without ATT correction.[3]

CBF and ATT measurements using ASL in a patient with carotid artery stenosis

The 3D ASL sequence with background suppression was used for perfusion imaging on a Signa HD 3.0T.[1] The acquisitions with different post-label wait (PW) were also performed for the evaluation of ATT (PW=1.0, 1.5, 2.0, 2.5, 3.0 sec). PD (TR=2000 ms) and FLAIR (TR/IR=4300/1650 ms) sequences were also utilized for T1 and fully relaxed proton density images. Both CBF and ATT were calculated in a pixel-by-pixel basis using a two-compartment model.[3]

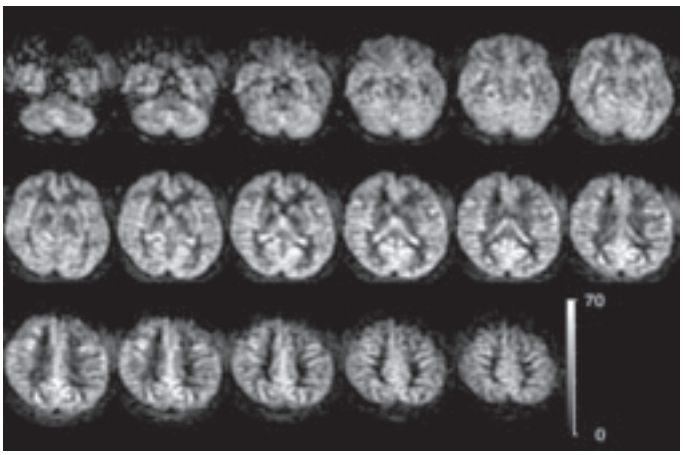

Figure 1. 3D ASL perfusion images of normal brain. 3D ASL prepped 3D FSE acquired with the total acquisition time of 6 minutes and the section thickness of 4.5 mm. Total of 35 sections cover the whole brain region from cerebellum to parietal brain region.

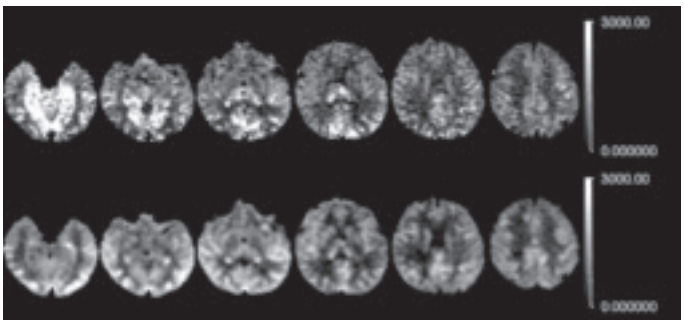

Figure 2. Top row: MR PASL and flow-sensitive alternating inversion recovery technique (FAIR). Bottom row: pCASL perfusion images from normal brain. Both FAIR and pCASL were acquired with the total acquisition time of 4 min and the section thickness of 7 mm. Other parameters of FAIR: TR/TE/TI/NEX=3000/16/1200/80; pCASL: TR/TE/ PW/NEX=5300/16/1200/46.

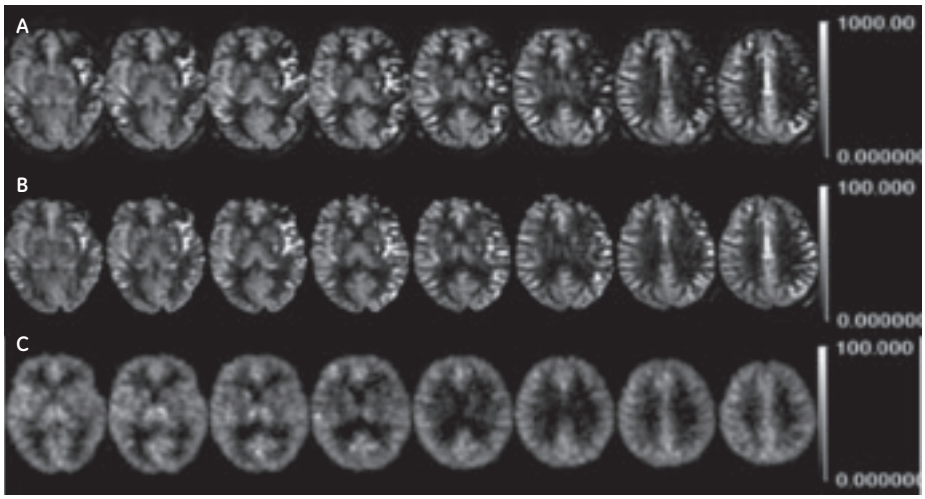

Figure 3. CBF maps from a patient with left ICA stenosis. A) ASL without delay compensation, B) 3D ASL with delay compensation, C) PET-CBF.

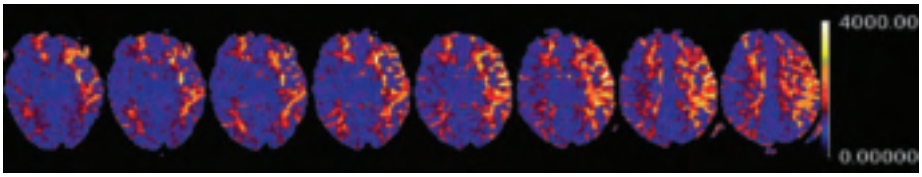

Figure 4. Arterial transit map. Same subject as Figure 1. Left cerebral cortical region is clearly imaged as longer arterial transit time.

Figure 3 shows 3D ASL-CBF maps with and without delay compensation in a patient with left carotid artery stenosis. The territory of left MCA is imaged as prominent perfusion defect with bright vascular signal. However, the slight hypo-perfusion of the left cortical region is observed in delay compensated 3D ASL-CBF maps. The left cerebral cortical lesion is clearly imaged as longer transit time on ATT maps (Figure 4).

Comparison of 3D ASL with PET

The 3D ASL perfusion values were validated by performing a pixel-by-pixel comparison with PET perfusion (Figure 5).

When compared with PET, the correlation of the CBF values between 3D ASL and PET were significant even with an altered hemodynamic state. The elongation of arterial transit time in the affected side was very consistent with the expected hemodynamics in occlusive cerebrovascular disease. The results of this study show 3D ASL is clinically applicable to patients with chronic occlusive cerebrovascular disease and the large range of hemodynamic conditions present.

Clinical application of 3D ASL perfusion imaging

When evaluating central nervous system tumors in a clinical setting using dynamic susceptibility contrast (DSC) perfusion imaging, high-tumor blood flow (TBF) or tumor blood volume (TBV) are the most commonly used criteria for high-grade gliomas. Early reports have shown that both ASL and DSC perfusion images enabled the distinction of high-grade from low-grade gliomas with hyper-perfused brain lesions.[4] Moreover, in some cases, ASL produces better contrast than DSC in the visual demonstration of tumor recurrence via hyperperfusion. Figure 6 shows both DSC and 3D ASL perfusion images in a patient with glioma in the left temporal lobe. The 3D ASL image reveals the hyper-intense perfusion signal, which is often a characteristic feature of malignant brain lesions. It is important to note that the focused lesion is located in the skull base region, where DSC-EPI is less reliable due to susceptibility-induced signal loss.

Summary

GE's 3D ASL sequence has successfully demonstrated the feasibility of continuous ASL-perfusion imaging with ATT compensation in chronic cerebrovascular disease. The correlation between the values of 3D ASL CBF and PET-CBF was significant on the pixel-by-pixel basis comparison. In a patient with a brain tumor, the 3D ASL signal produces a better contrast than DSC, even when the focused area is located near the skull base region, where DSC is unreliable due to the susceptibility-induced signal loss inherent with EPI. ■

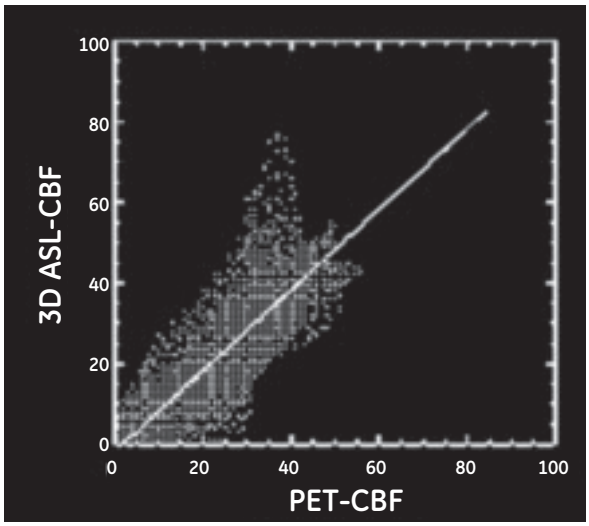

Figure 5. Plot of 3D ASL-CBF and PET-CBF values from a section through basal ganglia level. The linear regression line is drawn on the graph.

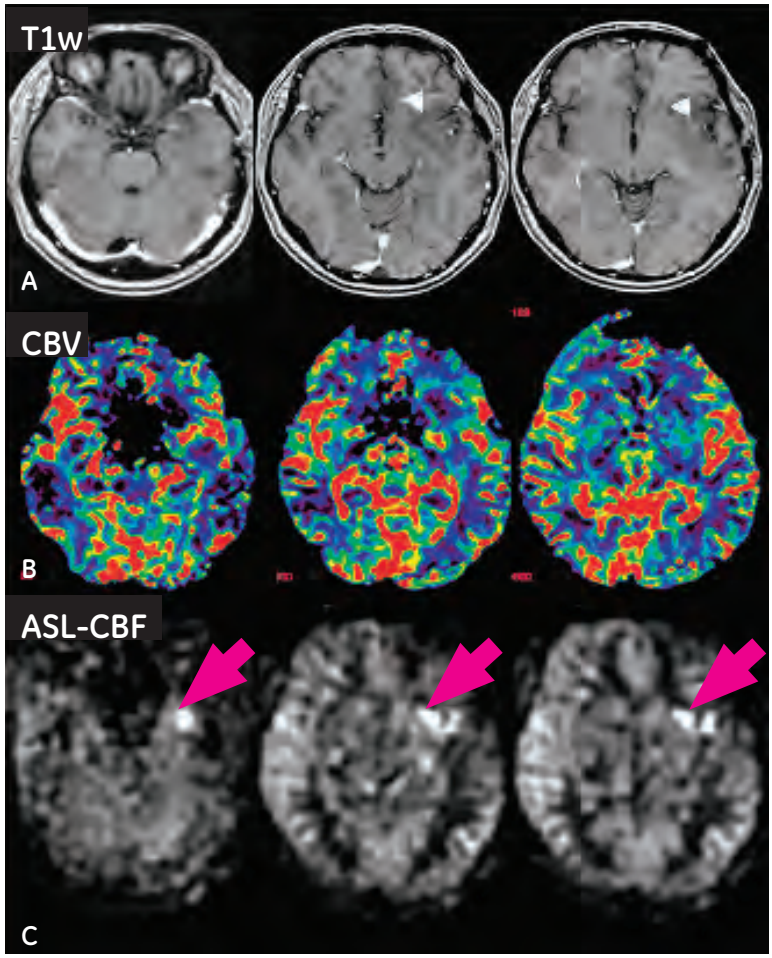

Figure 6. The comparison of DSC and 3D ASL perfusion images in a patient with brain tumor. A) Post Gd-T1 weighted images, B) T2 DSC perfusion images, C) ASL-CBF maps. Post Gd-T1w reveals the subtle contrast enhacement in the left insular region (arrow heads). It may be difficult to point out the increase of perfusion signal on T2 DSC CBV maps. The hyper intensity in the tumor lesion is clearly shown on ASL-CBF images (arrows).

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Hirohiko Kimura, MD, PhD, is a professor at the Department of Radiology, University of Fukui in Japan. Dr. Kimura has been extensively published for his ground-breaking work in MR and is recognized as an MR Thought Leader, 2010.

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