Acta Scientific Neurology (ISSN: 2582-1121)

Volume 6 Issue 5 May 2023

Research Article

Spectrum of Arterial Spin Labelling (ASL) and MRI Applications in Neuroimaging-Preliminary Experience

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DOI: 10.31080/ASNE.2023.06.0624

Received: January 19, 2023

Published: April 17, 2023

Abstract

Arterial spin labeling (ASL) is an MRI perfusion technique which helps in non-invasive assessment of the cerebral blood flow (CBF). It is a technique that uses the labeled protons in the arterial blood as an endogenous tracer. Assessment of the perfusion plays a vital role in evaluation of various brain pathologies like neoplasms. Various techniques are available for assessment of the perfusion such as DSC MRI, CT perfusion imaging, SPECT, H2[15O] PET etc. which are invasive and require administration of the exogenous contrast media or use of ionizing radiation. In the recent years, ASL has become an easily available imaging technique due to advances in the technology related to image acquisition, post processing software's and therefore with an increasing spectrum of ASL applications in various neurological pathologies such as stroke, transient ischemic attack, seizures, migraine, neoplasm, headaches and neuropsychiatric diseases such as Alzheimer's dementia and Parkinson's disease.

ASL can provide important physiological information which cannot be provided by the conventional MRI. Knowledge of the perfusion characteristics of brain and brain lesions is important as it may be helpful in providing a specific diagnosis or important physiological information which can be difficult to interpret on anatomic imaging or can be crucial in-patient management. The absence of irradiation, or the exogenous injection of the contrast media and no need of IV access, as well as its property to quantify CBF and reproduce the findings makes ASL an important noninvasive perfusion technique especially in patients with impaired renal functions where injection of contrast media is contraindicated. Moreover, with advances in imaging techniques and post processing soft wares, the spectrum of ASL applications has been increasing in various neurological disorders.

Keywords: Spectrum; Arterial Spin Labelling (ASL); MRI

Introduction

Arterial spin labeling (ASL) is an MRI perfusion technique which helps in non invasive assessment of the cerebral blood flow (CBF). It is a technique that uses the labeled protons in the arterial blood as an endogenous tracer. The protons in the arterial blood are labeled by using radiofrequency waves thus obviating the need for exogenous contrast media injection. Perfusion is defined as delivery of the oxygen and nutrients to the tissues by means of blood circulation and is usually measured in tissue specific units of ml/g/min.

Assessment of the perfusion plays a vital role in evaluation of various brain pathologies like neoplasms. Various techniques are available for assessment of the perfusion such as DSC MRI, CT perfusion imaging, SPECT, H2[15O] PET etc. which are invasive and require administration of the exogenous contrast media or use of ionizing radiation.

In the recent years, ASL has become an easily available imaging technique due to advances in the technology related to image acquisition, post processing software's and therefore with an increasing spectrum of ASL applications in various neurological pathologies such as stroke, transient ischemic attack, seizures, migraine, neoplasm, headaches and neuropsychiatric diseases such as Alzheimer's dementia and Parkinson's disease.

MRI DSC has certain disadvantages like it requires IV access, is limited by maximum contrast dose, is semiquantitative, requires dedicated post-processing software and signal dropout due to gradient echo acquisition which can be overcome by ASL.

ASL can provide important physiological information which cannot be provided by the conventional MRI.

Knowledge of the perfusion characteristics of brain and brain lesions is important as it may be helpful in providing a specific diagnosis or important physiological information which can be difficult to interpret on anatomic imaging or can be crucial in patient management.

In this study we have made an attempt to understand the basic principle of ASL, its types and to study the application of the ASL in the various neurological pathologies.

Materials and Methods

Imaging protocol- patients referred to the radiology department were subjected to MRI BRAIN according to following protocol

Source of data: cases referred to department of radiodiagnosis for MRI brain in LTMGH sion, Mumbai

- **Study span:** 11 months
- **Sample size:** 35 patients
- **Statistical method:** Observational study

Study population

The following criteria was used for selection of patients

Inclusion criteria

- Patients with suspected cerebrovascular disease, epilepsy, headache, neoplasm
- Patients who were cooperative during the study

Exclusion criteria

- Non co-operative patients
- Patients with claustrophobia, pace maker

Equipment

Philips Achieva 3T machine.

Protocol

The MRI protocol in our institution included-fast spin echo T1WI (TR-500ms and TE-8ms), T2WI (TR-3000ms and TE-80 ms), FLAIR(TR-11000ms and TE 125ms), DWI (0,100 and 1000s/m2), T2 FFE sequences. pCASL was performed before administration of the contrast. MR perfusion was performed followed by 3D post contrast T1 weighted spin echo sequence with slice thickness of 1mm. Post processing of the ASL and DSC perfusion study was done to generate colour coded maps and to assess the CBF, rCBV, rCBF and TTP.

Results

We assessed ASL in 35 patients. Out of 35 patients, 15 patients had infarct, 10 patients had neoplasm, demyelination in three patients and cavernoma in two patients.

Areas of hypoperfusion was seen in patients with infarct and helped in identifying areas of infarct core and penumbra. Luxury perfusion was also noted in one patient seen as area of hyperfusion on ASL.

ASL as well as DSC was performed in evaluation of brain tumors. The ASL as well as DSC parameters were compared and we found concordance between ASL and DSC values.

The most common brain neoplasm assessed was meningioma. The other tumors assessed were pituitary macroadenoma, low grade glioma, esthesioneuroblastoma. ASL was performed in patients with demyelination which showed hypoperfusion in areas of demyelination which was in concordance with DSC finding.

ASL was performed in 2 patients with cavernoma which showed susceptibility artifact. The adjacent vessels showed bright signal on ASL.

ASL was also performed in patients with migraine which revealed hyperperfusion in the affected cerebral hemisphere.

Aims and Objectives

- To understand the basic principle of ASL, types of ASL and methods of data acquisition
- To understand and review its applications in various routine neurological pathologies in addition to the conventional MRI.

Discussion

Basic principle of ASL- (Figure 1 and 2)

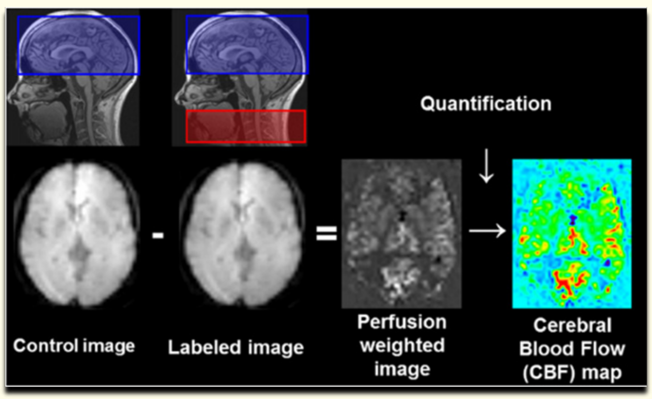


Figure 1: General principle of arterial spin labeling.

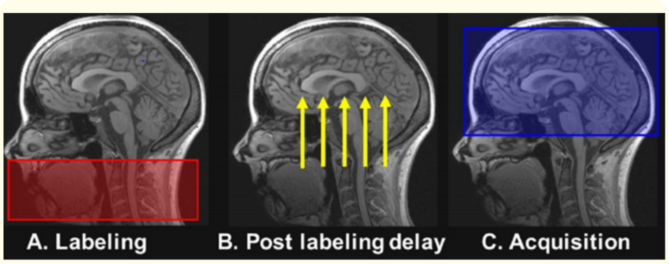


Figure 2: Principle for arterial spin labeling acquisition.

ASL is a technique in which two acquisitions are carried out one being the control image and other being with labeling of the arterial protons. Radiofrequency pulses are used for magnetic labeling of the arterial protons which is done at the level of neck vessels upstream from the volume of the interest. The labeled protons in the arterial vessels on reaching the brain parenchyma pass from the capillary compartment to the extra vascular compartment. At the time TI after the pulse labeling, corresponding to the time required for the labeled protons to perfuse the brain tissue, the images are acquired with rapid imaging technique.

The control image is obtained without arterial labeling and the arterial protons of the volume of interest are then in equilibrium and completely relaxed.

With subtraction of the labeled and control images the signal from the static tissue gets suppressed and a perfusion-weighted image is obtained. Repetitive acquisitions of the labeled-controlled paired images need to be acquired and averaged for an adequate SNR.

Cerebral blood flow can be measured in ml/100 gm tissue/min using a perfusion quantification model.

Main methods of data acquisition

It involves two basic steps i.e.,

- Labeling the circulating blood protons
- Acquisition of the images.

Proton labeling techniques

There are 3 main techniques of proton labeling

- Continuous labeling (CASL),
- Pulsed labeling (PASL),
- pseudo-continuous labeling(pCASL).

Continuous labeling (CASL)

- This method was initially proposed by Williams., et al. in 1992.
- CASL involves continuous labeling at the level of the neck using a thin slice.
- Magnetization inversion is obtained by simultaneous application of the continuous pulsed radiofrequency for 2 - 4 seconds and a magnetic field gradient in the direction of the flow.
- **Advantage:** Provides higher perfusion contrast than other types of labeling
- **Disadvantage:** Higher magnetization transfer effects and high level of energy deposited in tissue. The MT can be reduced by application of additional pulsed radiofrequencies during the control acquisition.

- SAR can be avoided by using labeling-specific coils differing from the image acquisition coil.

Pseudo-continuous labeling (PCASL)

The CASL may be approached by using the body coil and the use of several RF pulses, thereby limiting the duration of the application of the radiofrequency pulse. This method called ''pseudo-continuous ASL'' has the combined advantages of CASL and PASL.

Pulsed labeling

This technique uses very short RF pulses over large labeling zones. There is symmetrical and asymmetrical method of PASL sequences according to the zone of labeling with respect to the slices. Flow alternating inversion recovery (FAIR), a type of symmetrical PASL method, uses a non selective inversion pulse during the control that becomes selective with addition of the slice selection gradient for labeling.

Echoplanar MR imaging and signal targeting with alternative radio frequency (EPISTAR), a type of asymmetrical method, the first version, described in 1994, has a labeling zone with a thickness of 10-15 mm, located upstream from the volume of interest. With the EPISTAR sequence, an inversion pulse provides the labeling after saturation of the magnetization. During the control acquisition, the labeling volume is located downstream from the volume of interest in order to control the MT effects.

Other methods

Several approaches have also been developed to obtain the selective labeling of an artery to study its downstream territory or to selectively label some arterial velocities.

Emerging techniques

Territorial ASL (TASL) [selective ASL, regional perfusion imaging, vessel-encoded ASL (VE-ASL)]

It is a technique that allows labeling and visualization of perfusion in territories of individual arteries.

Vascular territories can be mapped with ASL by labeling only the blood flowing through the artery/arteries of interest.

One of the major application of the territorial ASL is in diagnosis and prognosis of the cerebrovascular disease. It can help in delineation of individual perfusion territories in acute stroke and demonstrate collateral contributions to the ischemic penumbra.

It can help in differentiating thromboembolic and hemodynamic etiologies.

TASL may help in the evaluation of the actual territorial contribution of individual collateral arteries in chronic cerebrovascular disease, particularly in patients with extracranial steno-occlusive disease.

ASL at multiple TIs

ASL at multiple TIs is useful in patients with internal carotid artery (ICA) occlusion to assess the CBF in ipsilateral cerebral hemisphere.

Perfusion based fMRI.

ASL perfusion can be used as a measure of brain function and to localize task activation. ASL perfusion fMRI uses a freely diffusible tracer that can exchange with tissue water and directly measure the amount of arterial blood that has been delivered to the capillary bed.

The temporal resolution of ASL perfusion fMRI is poor as the tagged blood takes time to reach to the region of interest.

Image acquisition

Many labeled: Controlled paired images need to be acquired to achieve an adequate SNR.

The most commonly used technique is the Echoplanar imaging, however distortion is seen in region of high magnetic susceptibility.

To improve the image quality various 3D sequences can be used such as Ultra-fast, single shot 3D sequence combined with gradient echo and spin-echo acquisition (GRASE) which helps to eliminate the signal from static tissue and provides a better SNR, a better cover and fewer magnetic susceptibility artifacts than 2D EPI sequences.

Image optimization

Various factors affecting the image optimization are

Magnetic field the higher the magnetic field better is the quality of ASL images with resultant increase in the SNR.

The perfusion signal in ASL can be increased by lengthening the T1 of the tissues and thereby the proton labeling time.

Phased array coils

These coils help in improving SNR of ASL and increases with the number of coil elements. These coils enable the use of parallel imaging techniques to improve the quality of images. Magnetic susceptibility artifacts are reduced with the possible reduction of the TE.

Data processing and quantification

It is important to use a model that takes into account the labeling type and parameters necessary to quantify tissue perfusion from the perfusion-weighted imaging.

Data pre-processing

Pre-processing of the data before quantification helps to improve image quality. Patients movements needs to be corrected.

Models have been developed for automatic detection of brain vessels, to facilitate their elimination during multi-TI acquisitions. Several ASL de-noising methods have been developed.

Quantification

The subtraction between labeled images and control images provides a perfusion-weighted image. The relationship between the perfusion weighted image and the CBF depends on various factors such as the proton density of the tissue, the relaxation time T1 of the labeled tissue and blood, as well as their difference. It also depends on the transit time between the labeling area and the volume of interest.

The various perfusion parameters that can be estimated with ASL include CBF, arterial arrival time (AAT) and the volume of arterial blood with a multi-TI sequence, provided that the specific methods of acquisition or different quantification models are used.

Artifacts in ASL

vascular artifacts

These are seen with PASL and CASL and are visualized as bright signals located in the vascular, arterial or venous, deep or juxtacortical structures due to labeled protons in the vessels. This artifact can be of significance in patients with Moya Moya disease as an indicator of presence and intensity of the collateral arterial network.

Crushers are bipolar gradients that are applied in several directions just before the acquisition of images, to eliminate the rapid flow. Crushers can be used to reduce the signal from the vessels in a homogenous manner.

Venous artifacts are visible with long TI or with certain types of labeling such as the FAIR technique.

Signal loss in upper slice

It is seen due to the relaxation of labeled protons over time mainly in the upper slices with a caudocranial 2D acquisition. Mostly seen at 1.5 T, as the labeling duration is shorter due to the shorter T1 of the blood.

It can be reduced with 3D acquisition and parallel imaging that may reduce the time of acquisition of slices, therefore the time between the slices.

Physiological hyperperfusion/hypoperfusion

Seen because of physiological modifications in perfusion.

Areas of hyperperfusion

Seen mostly in the occipital region mostly due to activation of the visual areas in the MRI environment and internal frontal region (Figure 3).

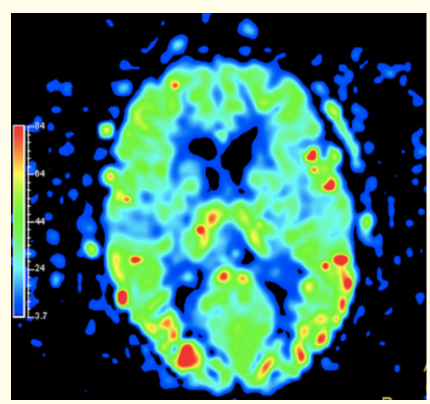


Figure 3: Zone of physiological hyperperfusion, these perfusion weighted images show internal bilateral occipital physiological hyperperfusion.

This finding is considered as normal in the young and middle-aged subject and decreases with age.

Areas of hypoperfusion

These areas extend from the frontal and occipital horns to the frontal and parieto-occipital cortex and correspond to the arterial border-zones. This may be associated with the difficulty, in some situations, of obtaining a reliable CBF measurement in the white matter.

Post gadolinium arterial spin labeling (Figure 4)

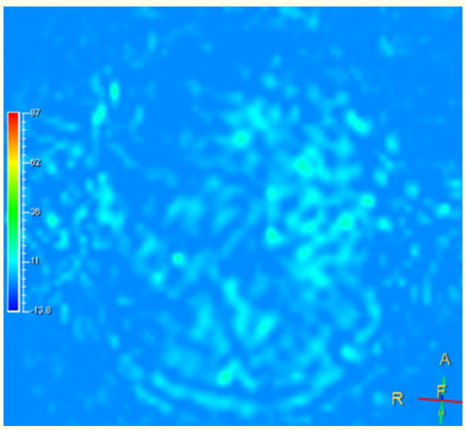


Figure 4: ASL images after the administration of gadolinium (E) shows signal loss and are not analyzable, hence ASL images are acquired before contrast administration

ASL sequence cannot be carried out immediately after the administration of the gadolinium as the gadolinium based contrast media significantly reduce the T1 of the blood such that the minor difference between the control and the labeled image cannot be detected. Therefore a minimum of 12 hours of gap is necessary considering the half life of the gadolinium contrast media.

Magnetic susceptibility artifacts

These artifacts are usually seen with EPI sequences and are due to rapid acquisition of the images. These artifacts are seen as focal areas of reduced perfusion at skull base, in frontal region and in temporal regions. They are also seen with bleed, calcification, metallic density materials and in early post surgical changes.

These artifacts can be minimized by using less sensitive techniques of image acquisition such as True-FISP or 3D GRASE and/or use parallel imaging.

Movement artifacts (Figure 5)

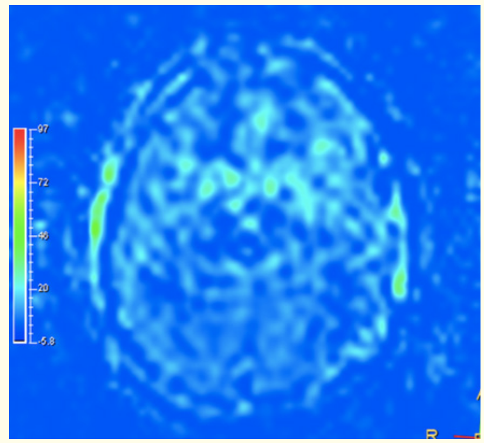


Figure 5: Motion artifacts. The concentric circles around the brain denotes the presence of motion artifacts.

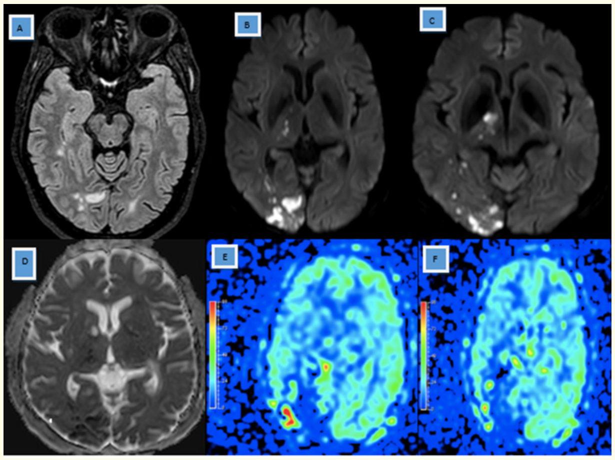
In order to obtain an adequate SNR, multiple repetitions are required, thereby making it susceptible for movement artifacts. These artifacts can result in focal or diffuse areas of false hypo or hyperperfusion. It is therefore preferable to exclude those images from analysis.

Sensitivity of the coil artifacts

The sensitivity of the different elements in a phase array coil differs slightly. If an element is defective or if the sensitivity differs greatly from the other elements, this results in a peripheral focal area where the perfusion differs. It is necessary to confirm this artifact by obtaining a second sequence acquisition by positioning the patient's head differently in the coil.

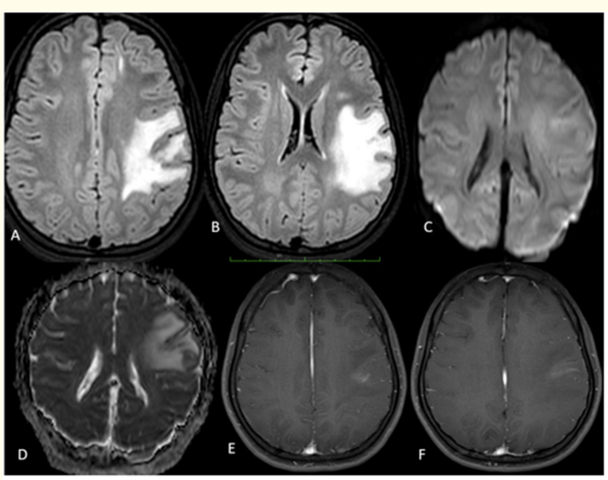
Parallel imaging artifacts

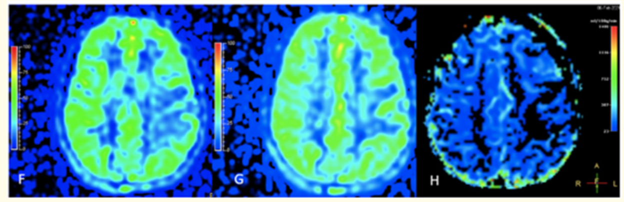
These artifacts produce diffuse or even grainy image with high acceleration factors with GRAPPA technique.



Case 1: Infarct.

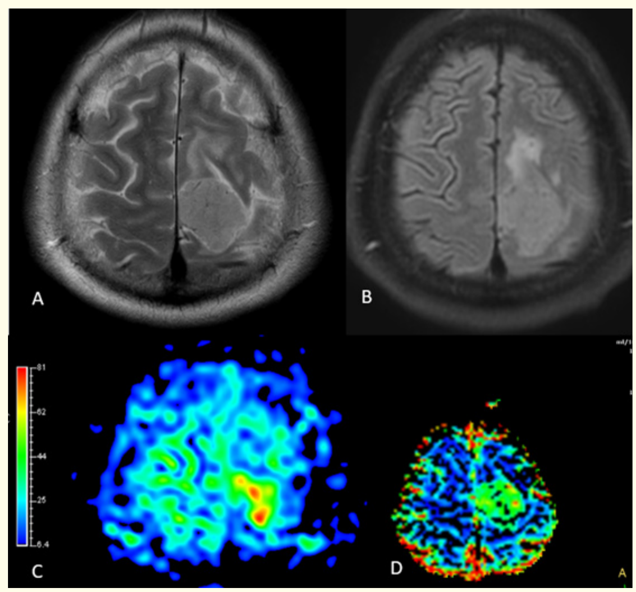
FLAIR (A), DWI (B, C), ADC (D) and ASL-CBF (E, F) images reveal FLAIR hyperintensity with restricted diffusion in the right posterior cerebral artery (PCA) territory involving the right occipital lobe and the genu and posterior limb of right internal capsule and the right thalamus. ASL demonstrates the corresponding hypoperfused area (infarct core) and larger area of hypoperfusion around the infarction bed in right occipital lobe suggesting persistent hypoperfusion of ischemic territory ('penumbra'). A focal area of hyperperfusion is seen around the infraction bed representing luxury perfusion.





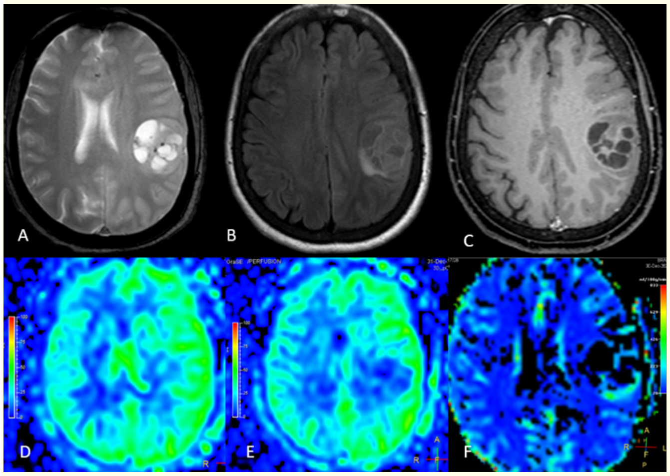
Case 2: Low grade glioma.

Axial Flair(A, B) images show hyperintense lesion involving the subcortical white matter in left high parietal region, not showing restricted diffusion on DWI(C), with facilitated diffusion on ADC (D), and minimal post contrast enhancement(E,F). ASL–CBF (G, H) and dynamic perfusion (I) images show a reduced CBF in the corresponding region compared to contralateral cerebral hemisphere.



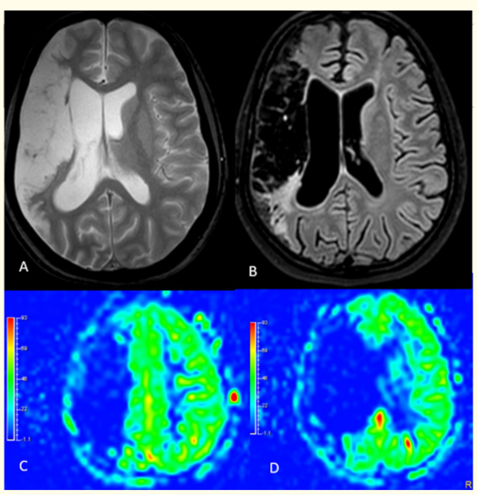
Case 3: Meningioma.

Axial T2WI (A), axial FLAIR (B) images reveal a isointense to hyperintense lesion in left parafalcine location in left high parietal region with surrounding vasogenic edema. ASL–CBF(C), Perfusion(D) images reveal a hyperperfused lesion as compared to the surrounding brain parenchyma with few tiny foci of increased vascularity within the lesion.



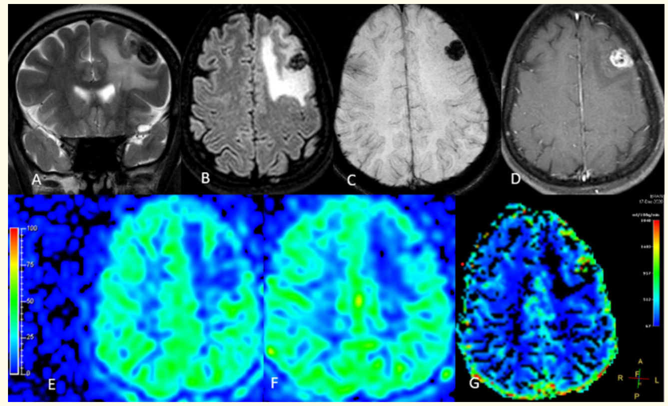
Case 4: Neoplastic lesion.

Axial T2WI(a) reveal a solid cystic lesion in left frontoparietal region with the cystic component suppressed on flair(b) images and showing peripheral enhancement(c). ASL –CBF maps (D, E) reveal hypoperfused cystic areas with solid areas showing hyperperfusion as compared to surrounding brain parenchyma. Dynamic perfusion imaging (f) confirms the perfusion findings of ASL.



Case 5: Cystic encephalomalacia.

Axial T2WI(A), FLAIR (B) images show a large area of cystic encephalomalacia in right cerebral hemisphere. ASL- CBF maps (C, D) show area of hypoperfusion in the area of cystic encephalomalacia. ASL images after the administration of gadolinium (E) shows signal loss and are not analysable, hence ASL images are acquired before contrast administration.



Case 6: Vascular malformation Cavernoma.

Coronal T2WI(A), Axial FLAIR (B) images show a hypointense lesion in left high parietal region with surrounding vasogenic edema and showing blooming on GRE (C) and post contrast enhancement(D). ASL-CBF maps (E, F) reveal the hypoperfused lesion along with hypoperfused region of vasogenic edema. MRI DSC perfusion (G) image confirms the ASL findings.

Clinical applications

ASL in acute infarct

Addition of the ASL in patients with stroke can aid in providing important physiological information of diagnostic and prognostic significance. Its non invasive nature and ability to measure cerebral perfusion along with fast imaging tools and automated post processing helps in acquiring this information.

ASL helps in identifying hypoperfused area associated with the ischemic territory.

It can help in distinguishing the irreversibly damaged tissue i.e., the core area from the surrounding still viable tissue at risk of infarction(penumbra).

ASL also helps in better representation of tissue hyperperfusion, either spontaneous or after therapy as compared to the invasive method of bolus perfusion weighted imaging (PWI) with dynamic susceptibility contrast (DSC).

Multidelay ASL can provide better assessment of the quantitative CBF.

Hypoperfused areas on ASL in region of ischemic territory in patients with acute infarct are likely to have poor functional outcome and infarct growth.

The DWI-ASL mismatch, where the ASL defect is larger than DWI lesion, has been used for clinical decision making in certain studies. Patients with subjective large areas of hypoperfusion were interpreted as having hypoperfusion around a core infarct which is useful in guiding the physician in the medical management of the patient.

However areas of hypoperfusion seen in ASL should be interpreted with caution as there is chance of overestimation of the hypoperfused area due to sluggish arterial blood flow and arterial transit delay [1].

Areas of hyperperfusion on ASL in patients with acute ischemic stroke can be useful especially in large vessel involvement as few studies have shown that ASL hyperfusion within or surrounding areas of DWI lesions predict hypertension or developing parenchymal hemorrhage.

Areas of focal hyperperfusion seen early after thrombolysis are associated with final infarct volume and improved functional outcome at later stages. Areas of ASL hyperperfusion in or around the infarction bed demonstrates luxury perfusion of the zone of infarction suggesting infarct reperfusion whereas hypoperfused areas around the infarct bed suggest persistent hypoperfusion of the ischemic territory [2].

ASL can be utilized for serial assessment brain perfusion in the setting of the acute stroke. Restoration of flow to regions of the ischemic core or penumbra either after spontaneous recanalization of clot, administration of systemic or transcatheter thrombolytics or extracranial-to-intracranial bypass is seen as high signal intensity on ASL [3].

ASL in chronic cerebravascular disease

ASL can be applied in chronic cerebrovascular disease, including carotid stenosis and occlusion and Moyamoya disease affecting the internal carotid artery (ICA) terminus and the proximal branches of the circle of Willis.

Perfusion imaging is commonly performed in patients with Moyamoya disease to determine the disease severity and to assess the cerebrovascular reserve for treatment planning and monitoring of patients under consideration for bypass surgery. These diseases are usually characterized by near normal CBF, but often have abnormal arterial arrival time, as the blood arrives at the parenchyma through alternative pathways [4].

Therefore multidelay ASL has been applied in such patients to assess the correct CBF and to map the transit time abnormalities.

However it is at times impossible in patients with severe Moyamoya disease to apply multidelay ASL due to extreme delay in arrival of blood and loss of magnetic label during the transit between the labeling region and the brain parenchyma.

ASL in tumors

Role of ASL in tumor evaluation has been studied and studies have found correlation between flow and tumor grade. A good correlation between ASL and DSC imaging for determination of relative tumor blood flow (rTBF) has been observed.

ASL provides quantitative CBF values which are not related to disruptions of the blood-brain barrier, while DSC provides information about tumor blood volume and vessel permeability [5].

ASL helps in preoperative assessment of the tumor grade and severity especially in meningiomas and gliomas.

In qualitative clinical interpretations, high grade primary brain tumors usually demonstrate high perfusion on ASL maps while low grade tumors usually show hypoperfusion. However areas of cysts, hemorrhage, calcification within tumors may appear hypoperfused on ASL and demonstrate artificial low signal intensity [1].

Hyperperfusion can be seen in meningiomas, oligodendrogliomas, hemangioblastomas and glomus tumors. Metastases can have variable appearance with either hypo- or hyperperfusion patterns on ASL maps.

In a study by Qiao., *et al*, they have used ASL in differentiation of the WHO grade I from WHO grade II and III tumors based on tumor blood perfusion patterns. The grade I tumors demonstrated homogeneous hyperperfusion signal with a higher mean CBF as compared to WHO grade II and III tumors, which displayed heterogeneously hyperperfused, isoperfused, or hypoperfused signals with a lower mean CBF. ASL can be useful in identifying feeding arteries to meningiomas. They utilized ASL to differentiate whether the tumor was supplied by the ECA or the ICA, thus aiding in assessment of the operative risk and surgical decision-making [6].

The ability of the ASL to quantify the perfusion helps in monitoring of tumor response to therapy.

ASL can also help in distinguishing areas of tumor recurrence from areas of radiation necrosis.

ASL can be helpful to target stereotactic biopsy sites at the most malignant portion.

Other cerebral perfusion methods rely on dynamic bolus techniques requiring large bore intravenous access devices and adequate renal function. In patients who have undergone extensive chemotherapy for metastatic disease or primary neoplasms or in patients with impaired renal function, routine follow-up examinations with large-bore intravenous devices may not be possible. ASL can be applied in these patients as it requires no contrast, and thus the complication of nephrogenic systemic fibrosis can be avoided [2].

Surgical craniotomy closure devices can hinder perfusion evaluation secondary to susceptibility artifacts. As modifications in closure device materials are made, perfusion imaging evaluation adjacent to the craniotomy site is likely to improve.

In our study we found ASL CBF strongly correlated with DSC rCBF and rCBV.

ASL in vascular malformations

Arteriovenous malformations (AVMs) are vascular malformations with arteriovenous shunting with a nidus and draining veins which may appear as bright signal intensity on ASL perfusion maps representing AV shunting or rapid transit.

Susceptibility artifacts seen as dark signals can be seen due to hemorrhage or embolic material.

ASL can help in identifying subtle AV shunting.

Perfusion abnormalities in the region adjacent to the vascular malformations can be identified on ASL.

Cavernomas can be seen as areas of signal loss on pCASL, and CBF maps with no evidence of shunting.

ASL in dementia and cognitive disorders

In the recent years imaging modalities are gaining importance in evaluation of the cognitive disorders to assess the various differentials, monitor disease progression and as surrogate marker in treatment trials.

Various MR imaging techniques have been employed in evaluation of cognitive disorders including anatomic and volumetric imaging, functional MRI, MR perfusion and diffusion tensor imaging. PET and SPECT are the other modalities being employed.

Areas of regional hypoperfusion detected by ASL have been reported in Alzheimer's disease (AD), frontotemporal dementia (FTD), and mild cognitive impairment (MCI). This is in consistence with findings described in PET and SPECT studies.

ASL perfusion techniques can play an important role in assessment of cognitive decline and conversion from MCI to dementia. It can be helpful in identifying candidates for AD treatment trials.

According to Du., *et al*, regional cerebral hypoperfusion, detected by ASL may help in the differentiation of FTD from AD.

ASL in epilepsy

The major application of ASL in epileptic patients is to identify the epileptogenic focus. ASL can help in assessment of the differentials for epilepsy.

ASL can demonstrate areas of cerebral hyperperfusion in the acute peri-ictal period due to increased neuronal activity whereas it can demonstrate areas of cerebral hypoperfusion in the chronic interictal period due to diminished activity of the epileptogenic focus. Thus ASL can provide important physiological information with very less efforts. Studies have shown that the ASL findings correlated with nuclear PET and SPECT findings.

ASL in Migraines

Utility of ASL in migraine has been studied been reported by certain studies. According to study by Kato., *et al*, which was done during migraine attack, after treatment with a triptan and in the attack-free period revealed reduced CBF in bilateral median thalamic areas, including hypothalamus and increased in the frontal cortex in comparison with baseline. Thirty minutes after treatment initiation, CBF was increased in the thalamus and hypothalamus.

In case series by Pollock., *et al*, regional cerebral hyperperfusion was demonstrated during the headache episodes in three out of eleven patients.

In various studies it has been proved that there exists perfusion abnormality on ASL in patients who have migraine with aura. In patients who have migraine without aura, however, there may not be any perfusion abnormality as assessed by ASL.

According to a case series in pediatric patients, ASL appears to be the most sensitive in detecting hemiplegic migraine amongst ASL, susceptibility weighted imaging, MRA and diffusion weighted imaging.

Thus ASL can be helpful in differentiating between hemiplegic migraine and stroke.

Application of ASL in patients with migraine can provide an insight into its pathophysiology as it is mostly related to vascular dysfunction.

ASL in demyelination

ASL showed reduced CBF in the demyelinating lesions. Demyelinating lesions appear hypoperfused on ASL as frank neovascularization is absent in TDL. TDL are characterized by intrinsically normal or inflamed vessels and have a low rCBF and rCBV.

High-grade gliomas are characterized by the presence of neoangiogenesis and show a high regional cerebral blood flow r(CBF) and regional cerebral blood volume r (CBV). Thus perfusion MRI can be used to differentiate TDL from a high-grade glioma.

ASL in CNS infections

ASL application in various CNS infections has not been studied extensively.

It has been stated that ASL hypoperfusion is seen in most of the CNS infections, however hyperperfusion has been demonstrated in some infections like herpes encephalitis.

ASL can be useful in differentiating toxoplasmosis and lymphoma in immunocompromised patients as ASL hypoperfusion is seen in toxoplasmosis and hyperperfusion seen in lymphoma.

Decreased perfusion is seen within cerebral abscesses and in the surrounding edema, whereas the enhancing rim demonstrates increased perfusion signal intensity.

However ASL still has certain limitations like low signal-noise ratio, limited spatial resolution, inability to quantify tissue blood volume, absence of harmonization of techniques between the manufacturers and post-treatment optimization, automation and standardization.

Conclusion

The absence of irradiation, or the exogenous injection of the contrast media and no need of IV access, as well as its property to quantify CBF and reproduce the findings makes ASL an important non-invasive perfusion technique especially in patients with impaired renal functions where injection of contrast media is contraindicated. Moreover, with advances in imaging techniques and post processing soft wares, the spectrum of ASL applications has been increasing in various neurological disorders.

Highlights

Arterial spin labeling (ASL) is an MRI perfusion technique which helps in non invasive assessment of the cerebral blood flow (CBF). It is a technique that uses the labeled protons in the arterial blood as an endogenous tracer.

Assessment of the perfusion plays a vital role in evaluation of various brain pathologies like neoplasms. Various techniques are available for assessment of the perfusion such as DSC MRI, CT perfusion imaging, SPECT, H2[15O] PET etc. which are invasive and require administration of the exogenous contrast media or use of ionizing radiation.

In the recent years, ASL has become an easily available imaging technique due to advances in the technology related to image acquisition, post processing software's and therefore with an increasing spectrum of ASL applications in various neurological pathologies such as stroke , transient ischemic attack, seizures, migraine, neoplasm, headaches and neuropsychiatric diseases such as Alzheimer's dementia and Parkinson's disease.

ASL can provide important physiological information which cannot be provided by the conventional MRI.

Knowledge of the perfusion characteristics of brain and brain lesions is important as it may be helpful in providing a specific diagnosis or important physiological information which can be difficult to interpret on anatomic imaging or can be crucial in patient management.

The absence of irradiation, or the exogenous injection of the contrast media and no need of IV access, as well as its property to quantify CBF and reproduce the findings makes ASL an important noninvasive perfusion technique especially in patients with impaired renal functions where injection of contrast media is contraindicated. Moreover , with advances in imaging techniques and post processing soft wares, the spectrum of ASL applications has been increasing in various neurological disorders.

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