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Perfusion imaging of brain tissue using continuous arterial spin labelling

Several methods have been described to measure regional blood flow in brain. The digital subtraction angiography (DSA) and magnetic resonance imaging (MRI) provide adequate anatomical analysis, but they do not give sufficient information about the parameters of blood flow. That is why other neuroradiological examinations, such as positron emission tomography (PET), functional MRI or perfusion MRI are used in some centres for research purposes, prior to and after treatment of cerebral diseases.

The aim of the paper was presentation of one of the new methods of perfusion imaging, arterial spin labelling, on the basis of the literature review.

DISCUSSION

MRI-based methods have made significant advances in measuring perfusion and are now in widespread use in the evaluation and management of cerebrovascular disease (1, 11, 12).

Cerebral perfusion is typically determined by using dynamic susceptibility-weighted contrast material-enhanced MR imaging with echo-planar MR imaging sequences. Perfusion can be calculated using the principle of the indicator dilution theory, which postulates that the increase in blood susceptibility induced by a contrast agent is proportional to its concentration in the blood pool which reflects on changes in relaxation times (9).

Another method for determining perfusion is arterial spin labelling. With arterial spin labelling, water is used as a freely diffusible intrinsic tracer. Arterial blood outside the imaging section is labelled by an inversion pulse. After a transit time from the labelling region to the imaging section, blood spins exchange with tissue water at the capillaries (8). The perfusion contrast in the images gathered by this technique comes from the substraction of two successively aquired images: one with, and one without proximal labelling of arterial water spins after a small delay time (2) (Fig 1).

Until now, several ASL schemes have been proposed (1). This techniques are capable of measuring relative cerebral blood flow (rCBF) without using extrinsic contrast agents by labelling spins of flowing arterial blood. They have been successfully used to measure rCBF noninvasively in various pathologic conditions, such as epilepsy, stroke, Alzheimer's disease, and brain tumours (9).

Each method has advantages and disadvantages. DSC perfusion MR technique can provide reasonable estimates of absolute blood flow, but requires rapid infusion of a contrast agent. This is sometimes problematic, such as when adequate intravenous access cannot be obtained. DSC

perfusion MR method is sensitive to increased permeability, although correction schemes exist and a loading dose can also be given to help minimize the effect (10).

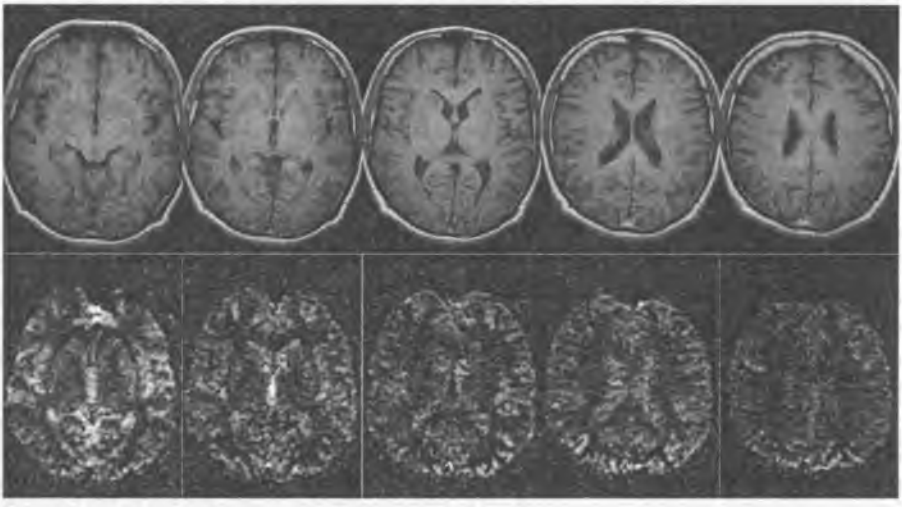

Fig 1. CASL CBF maps and T1-weigted MR images of a 34-year-old male

Accurate quantification of CBF by using ASL sequences depends on arterial transit times to the voxels, local relaxation times of tissue and blood, and the equilibrium magnetization of the blood (13). ASL is more suitable for assessment of hypervascularized lesions, whereas it has a higher error rate in the assessment of hypovascularized abnormalities. One of the few consistencies among the values in both procedures was the ratio of gray to white matter signal, which was typically close to 2.6 (4).

Arterial spin labelling has the advantage of being noninvasive and does not require administration of an extrinsic tracer. Hence, no contrast medium affects the physical, chemical, or physiologic properties of the blood (1). This technique relies on a diffusible tracer and is thus much less sensitive to abnormal permeability. Studies can be repeated immediately and as often as desired. ASL is particularly useful in volunteers for functional brain imaging studies and in follow-up studies, such as monitoring the effects of radiosurgery or embolization on tumor or AVM blood flow (9).

The main disadvantage of ASL techniques is that the signal-to-noise ratio (SNR) is lower than with DSC EPI MRI, because only up to 4% of the voxel volumes consist of capillary volume filled with potentially labelled blood in gray matter. Hence, a longer acquisition time is needed for the ASL sequences to create images with a sufficient SNR (about 5 min compared with 1 min of the first-pass DSC EPI MRI). Moreover, venous blood causes artifacts in the sagittal sinus and other large intracerebral veins using ASL imaging (9, 12). Images can be of poor image quality even after lengthy signal averaging, resulting in reduced diagnostic reliability and sensitivity to brain activity with the ASL technique. Another limitation is the relatively short signal decay rate. In humans, the arterial transit time for the flow of blood from the tagged region to the imaging slices is comparable with the T1 of blood. As a result, the amount of spin labelling is greatly reduced by the time it reaches brain tissue, leading to further difficulty in perfusion signal detection, and the potential for errors in perfusion quantification due to uncertainties in transit time. In addition, some of the existing ASL techniques are unable to provide satisfactory imaging coverage because T1 limits the time available

for multislice acquisition before the label decays (2, 8). Also contamination of the microvascular perfusion with macrovascular flow and different arrival times for the labelled blood in different regions might result in inaccurate perfusion values (10). That is why reliable quantification is still a great challenge and currently limits the clinical usefullness (4, 13).

Advantages of contrast medium–based techniques, besides a far better SNR, are the possibility of acquiring a larger total number of sections and more sections in a shorter time than with ASL imaging. Furthermore, other perfusion-related parameters such as cerebral blood volume (CBV) and mean transit time (MTT) can be calculated using DSC MRI (8, 10). However, this requires an independent measurement of arterial input function.

Pursuing ASL at high magnetic field strengths (3.0 T and higher) is expected to improve the image quality and reduce transit-related effects on ASL perfusion images by taking advantage of the joint benefits provided by the increased T1 and SNR at high field strengths (5, 6). Because of the increase in the relaxation time T1 at high field, the loss of spin labelling during the transit time is decreased and the accumulation of labelled spins is increased. This T1 effect, in combination with the increased SNR, could yield major improvements in the perfusion signal, allowing increased spatial and temporal resolution (7).

As a fully noninvasive method, ASL might be particularly advantageous where a technique not necessitating intravenous injection is required, especially when repeated scans are needed (2). It can be used for functional imaging and to monitor the course of perfusion changes in brain diseases and during treatment, for instance in patients after radiosurgery (3).

ASL is also attractive for studying cerebral perfusion in paediatric population. However, dynamic contrast medium-based techniques are still the preferred technique today because of superior SNR and increased anatomic coverage. Furthermore, patients with brain diseases usually undergo contrast-enhanced scans as part of conventional imaging protocols, but the advent of high field imaging will soon allow measurement of perfusion without the need for an increase in contrast reagent dose (2).

In conclusion, CASL is a completely non-invasive method allowing repeated measurements as needed for treatment monitoring. Additionally, it quantifies the therapeutic effect and might be used for treatment assessment and planning.

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SUMMARY

MRI-based methods have made significant advances in measuring perfusion and are now in widespread use in the evaluation and management of cerebrovascular disease. Arterial spin labelling techniques are capable of measuring relative cerebral blood flow without using extrinsic contrast agents by labelling spins of flowing arterial blood. They have been successfully used to measure perfusion in various pathologic conditions, such as epilepsy, stroke, Alzheimer's disease, and brain tumours. ASL is a completely non-invasive method allowing repeated measurements as needed for treatment monitoring.

Obrazowanie perfuzyjne tkanki mózgowej z wykorzystaniem oznaczania spinów krwi tętniczej

Metody pomiaru perfuzji opierające się na magnetycznym rezonansie zyskują coraz szersze zastosowanie w ocenie chorób naczyniowych mózgu. Oznaczanie spinów napływającej krwi tętniczej pozwala na określenie relatywnego przepływu mózgowego bez używania środków kontrastowych. Z powodzeniem zastosowano tę technikę w ocenie różnych patologii, takich jak padaczka, udar, choroba Alzheimera czy guzy mózgu. Oznaczanie spinów krwi tętniczej jest badaniem nieinwazyjnym, pozwalającym na kontrolne pomiary wymagane w monitorowaniu leczenia.