Cerebral blood flow measured by pseudo-continuous arterial spin labelling: a potential marker for outcome in aneurysmal subarachnoid haemorrhage

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Background
Delayed cerebral ischaemia (DCI) is the major cause of morbidity and mortality following subarachnoid haemorrhage (SAH). Following either surgical clipping or endovascular coiling to secure the initial bleed, ~30% of survivors go on to develop DCI. Vasconstrictive processes in the cerebral vasculature have been considered fundamental in the genesis of DCI. Recently other mechanisms have been proposed. Early brain injury (EBI) describes global brain changes in the first 72 hours post SAH. A component of EBI, transitory ischaemia, leads to a global reduction in cerebral blood flow (CBF) and is thought to play a key role in the development of DCI post SAH.

Objectives
We aim to investigate the feasibility of longitudinally tracking CBF in the whole brain following SAH using pseudo-continuous arterial spin labelling (pCASL). This approach may allow early identification of perfusion deficits that may be indicative of the onset of DCI.

Methods
6 SAH patients (5 x Grade I and 1 x Grade II, World Federation of Neurosurgeons) were scanned on a 3 Tesla Siemens MRI scanner with a 12-channel head coil. Patients were scanned on varying days post endovascular coiling (Patient 1: days 2 and 4, Patient 2: day 1, Patient 3: days 1, 5 and 7, Patient 4: days 1, 3 and 10, Patient 5: day 1, Patient 6: days 1, 4 and 6). A pCASL sequence was used to assess CBF. The sequence consisted of a 1.4 s labelling duration followed by five post labelling delays (0.2s to 1.2 s) and a gradient-echo echo planar imaging (EPI) readout (TR=3.75s, TE=14ms, 6/8 k-space). 24 axial slices were acquired in ascending order (4x4x5.5mm, 0.5mm inter-slice gap). Total ASL scanning time was 9.5 minutes (15 signal averages). Additional scans included a time-of-flight angiography image for optimal positioning of the pCASL labelling plane (1.5 min duration) and two ASL calibration scans (2 x 18 secs). The first calibration image was acquired with the same acquisition parameters as the pCASL sequence but without labelling and background suppression turned off. The equilibrium magnetization of blood was calculated from the mean signal within a ventricular CSF mask in the calibration image to allow quantification of CBF in absolute physiological units (ml/100/min). The second calibration image was acquired with the same parameters but the body coil was used as the receive coil. A spatial sensitivity map was generated (head coil calibration image / body coil calibration image) to correct the pCASL data for the uneven sensitivity of the 12-channel head coil. CBF was quantified by fitting the data to the ASL kinetic model, using a Bayesian inference approach.

Results
The average grey matter CBF across all subjects was 61.4 ± 9.3 ml/100g/min. Figure 1 shows a plot of mean grey matter CBF versus number of days post-endovascular coiling in the three patients that were scanned on three occasions (Patients 3, 4 and 6). Patient 4 demonstrated a global CBF reduction on the second scanning day that correlated with assessment of clinical symptoms (headache, photophobia, nausea). A return to baseline CBF was recorded on day day 10 post SAH. Figure 2 shows sample CBF maps from patient 4 on day 1, 3 and 10 post endovascular coiling respectively. A decrease in grey matter perfusion is apparent in figure 2(b) compared to figure 2(a) and 2(c).

Discussion & Conclusions
The findings of this preliminary study demonstrate the feasibility of using ASL (specifically pCASL in this instance) to non-invasively track changes in CBF in SAH patients. The presence of the endovascular coils used to secure the haemorrhage did not result in significant artefacts. The CBF decrease measured on the second scanning day of patient 4 (figure 1(c)) would not normally be detected by routine clinical assessment of this patient group. Patient 4 scored a maximum 15 (fully awake / conscious patient) on the Glasgow Coma Scale (GCS), which is routinely used to assess SAH patients. This implies that clinical scales such as GCS are not sensitive to subtle changes in cerebral perfusion in SAH patients. Such perfusion deficits may be an important indicator of deterioration and/or the onset of DCI. The role of non-invasive MRI techniques such as ASL in assessing SAH patients during the acute phase requires further investigation in a large patient study.

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