The Evaluation of Cerebral Blood Flow in Patients with Traumatic Head Injury

Yasushi Shibata* and Ryota Mashiko
Department of Neurosurgery, University of Tsukuba, Mito Medical Center, Mito Kyodo General Hospital, Japan

*Corresponding author: Yasushi Shibata, Department of Neurosurgery, University of Tsukuba, Mito Medical Center, Mito Kyodo General Hospital, Japan, Tel: +81-29231-2371, Email: yasushishibatamd@yahoo.co.jp

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ABSTRACT

Tc ECD SPECT is the standard method for evaluating Cerebral Blood Flow (CBF); however this method of examination is associated with some drawbacks, including high cost, radiation exposure and its limited availability for emergency patients. Arterial Spin Labeling (ASL) perfusion MRI is a method of CBF examination that does not involve the use of contrast media or radiation exposure. This imaging method has become possible with the availability of 3T MRI. Because of its short image acquisition time, ASL can be performed in the course of a routine MRI examination. While CBF evaluation is known to be useful in the evaluation cerebral function in cases of traumatic head injury, ASL perfusion MRI has not been fully evaluated in head injury patients.

A total of 21 patients (male: n=16; female: n=5) were registered in the present study. The age of the patients ranged from 18 to 90 years. The final diagnoses were as follows contusion (n=8), ASDH (n=5), CSDH (n=3), concussion (n=3), traumatic SAH (n=2), DAI (n=2).
We intravenously injected Tc99m ECD 600MBq into the right cubital vein and acquired SPECT images using an E CAM (Siemens) system. ASL perfusion MRI was performed using a Magnetom Skyra 3.0 Tesla (Siemens) and 3 delay times (1600, 1990 and 2400 ms). Whole brain axial color images were visually evaluated.

The patients with cerebral contusion always showed low CBF with both ASL perfusion MRI and SPECT. In the DAI cases, low CBF were compatible with functional impairment and higher brain dysfunction. In the cases with ASDH or CSDH, cerebral compression was not revealed as a CBF change; a CBF study was therefore useful to determine the surgical indication and prognosis.

SPECT was capable of providing quantitative and statistically-standardized evaluations. In contrast, ASL was only capable of providing qualitative images. SPECT is more useful than ASL for CBF studies. However, the time required for ASL imaging is very short, thus ASL can be performed in the course of a routine MRI examination. Although radiation exposure is not evitable in SPECT, ASL involves neither radiation nor intravenous injection. SPECT remains the gold standard of CBF evaluation.

**Keywords:** ASL; MRI; CBF; SPECT; Head injury; Trauma; Tc-ECD

**INTRODUCTION**

An imaging-based diagnosis of traumatic brain injury is generally made using Computed Tomography (CT) and Magnetic Resonance Imaging (MRI). CT is performed first because it is sensitive in the detection of hemorrhagic lesions and can be performed in a short amount of time. The length of time required to perform MRI makes it challenging for patients with unstable vital signs or respiratory distress. Although regular CT and MRI provide anatomical imaging, functional imaging can provide more useful information about brain function for patients with head injuries. Cerebral Blood Flow (CBF) imaging is one such modality that has been subject of numerous investigations. The significant diagnostic value of cerebral blood flow evaluation in traumatic brain injury patients has been extensively reported [1]. CBF imaging can reveal the functional damage of the brain. Unlike MRI, it does not reveal the anatomical damage; however, the functional damage can be used to determine the diagnosis and prognosis [1].

Recently, the diagnostic application of ASL MRI has been reported in cases of traumatic head injury [2,3]. Functional imaging provided by ASL MRI and SPECT can determine the prognosis and reveal functional abnormalities before anatomical abnormalities are identified on MRI [2,3].

Technetium-99m Ethyl Cysteinate Dimer Single Photon Emission Computed Tomography (Tc ECD SPECT) is the standard method for evaluating Cerebral Blood Flow (CBF); however this method of examination is associated with some drawbacks, including high cost, radiation exposure and its limited availability for emergency patients. Arterial Spin Labeling (ASL) perfusion Magnetic Resonance Imaging (MRI) is a method of CBF examination that does not involve the use of contrast media or radiation exposure. This imaging method has become possible with the
availability of 3 Tesla MRI. Because of its short image acquisition time, ASL can be performed in the course of a routine MRI examination. While CBF evaluation is known to be useful in the evaluation cerebral function in cases of traumatic head injury, ASL perfusion MRI has not been fully evaluated in head injury patients. We performed ASL perfusion MRI and Tc ECD SPECT in patients with head injury and compared the imaging findings.

**PATIENTS**

A total of 21 patients (male: n=16; female: n=5) were registered in the present study. The age of the patients ranged from 18 to 90 years. MRI and SPECT images were examined in 15 acute-phase patients (within 1 month after head injury), and 6 chronic-phase patients (more than 2 months after head injury). The final diagnoses were as follows, cerebral contusion (n=8), Acute Subdural Hematoma (ASDH) (n=5), Chronic Subdural Hematoma (CSDH) (n=3), concussion (n=3), traumatic Subarachnoid Hemorrhage (SAH) (n=2), Diffuse Axonal Injury (DAI) (n=2). Some patients were examined twice.

**METHODS**

We intravenously injected Tc99m ECD 600MBq into the right cubital vein and acquired SPECT images using an E CAM system (Siemens, Germany). An axial image was statistically evaluated using the easy Z-score Imaging System (eZIS) software program. ASL perfusion MRI was performed using a Magnetom Skyra 3.0 Tesla (Siemens, Germany) and 3 delay times (1600, 1990 and 2400 msec). We used a turbo gradient spinecho pulse sequence for ASL with a 3mm slice thickness, a TR/TE of 5000/36 msec, a matrix size of 64x64, and a Field of View (FOV) of 192x192 mm. The acquisition time was 2 min 5 sec for each delay time. Whole brain axial color images were visually evaluated.

**Case 1: A 57-Year-Old Man**

The patient was injured in a bicycle accident after drinking. He was transferred to our hospital. He was initially awake and responsive. An initial brain CT showed mild traumatic SAH and mild bi-frontal contusion. His consciousness decreased 3 hours later, and brain CT demonstrated an increase in the frontal contusional hematoma. We promptly performed right frontal craniotomy and the evacuation of the right contusional hematoma. Later, MRI demonstrated bi-frontal contusional hematoma and left MCA area infarction (Figure 1).
Figure 1: MRI (axial T1 weighted images) of case 1 demonstrated bi-frontal contusional hematoma and left MCA area infarction.

MRA showed bilateral Anterior Cerebral Artery (ACA) and Middle Cerebral Artery (MCA) vasospasm, which was the cause of the patient’s cerebral infarction. CBF SPECT and ASL MRI showed extremely low perfusion at the bifrontal and left MCA area, where a large contusion or infarction was observed on MRI (Figure 2). His consciousness did not recover. After undergoing tracheostomy, he was moved to a rehabilitation hospital. He was tube-fed and remained in a bed ridden state.
Figure 2: CBF SPECT (upper) and ASL MRI (lower) of case 1 showed extremely low perfusion at the bifrontal and left MCA area, where a large contusion or infarction was observed on MRI.

Case 2: An 80-year-Old Man

The patient visited our emergency ward after falling from stairs and injuring his head and back. The initial neurological examination confirmed that he was awake with no paresis; however brain CT showed right ASDH (Figure 3).
Figure 3: Initial brain CT (upper) of case 2 showed right ASDH. Follow up brain MRI (middle) and CT (lower) demonstrated the progression of ASDH to CSDH. After a few weeks his consciousness gradually became aggravated and brain CT and MRI demonstrated the progression of ASDH to CSDH. SPECT and ASL MRI showed mild low perfusion (Figure 4). After drainage surgery for CSDH, his consciousness improved. He was later discharged to his home without any complications.
Case 3: A 53-Year-Old Man

The patient had been involved in a traffic accident 2 years previously. At that time, he was treated at another hospital, thus the detailed clinical findings were unknown; however, he was known to have lost consciousness for at least several hours. He visited our hospital complaining of memory and concentration dysfunction. He has been suffering from headache, vertigo, tremor and bilateral hand dysesthesia since his head injury. The Wechsler Adult Intelligence Scale (WAIS) demonstrated a normal mean Intelligence Quotient (IQ), but partial dysfunction in working memory and conduction speed (Figure 5).
Figure 5: The Wechsler Adult Intelligence Scale (WAIS) of case 2 demonstrated a normal mean Intelligence Quotient (IQ), but partial dysfunction in working memory and conduction speed (right). MRI (left) showed a few white matter lesions in the bifrontal subcortical white matter. No apparent contusion or atrophy was observed.

MRI showed a few white matter lesions in the bifrontal subcortical white matter. No apparent contusion or atrophy was observed (Figure 5). CBF SPECT and ASL MRI demonstrated minimal bi-frontal low perfusion and statistical SPECT imaging clearly demonstrated significant bi-frontal low perfusion (Figure 6). He was diagnosed with higher brain dysfunction caused by head injury. Continuous rehabilitation brought some improvement to his higher function. CBF SPECT and ASL MRI demonstrated no change at 1 year after his initial presentation.
**RESULTS**

The patients with cerebral contusion always showed low CBF with both ASL perfusion MRI and Tc ECD SPECT (Figure 1, 2).

In the cases with ASDH or CSDH, cerebral compression was not revealed as a CBF change (Figure 3, 4); a CBF study was therefore useful to determine the surgical indication and prognosis.

In the DAI cases, low CBF were compatible with functional impairment and higher brain dysfunction (Figure 5, 6).

**DISCUSSION**

SPECT was capable of providing quantitative and statistically-standardized evaluations. In contrast, ASL was only capable of providing qualitative images. The most appropriate delay time differed in each patient. SPECT is more useful than ASL for CBF studies. However, the time required for ASL imaging is very short, thus ASL can be performed in the course of a routine MRI.
examination. Although radiation exposure is not evitable in SPECT, ASL involves neither radiation nor intravenous injection. SPECT remains the gold standard of CBF evaluation. However, ASL is sufficient as a routine evaluation for the follow-up examination of patients in whom low CBF has been diagnosed and of new patients with cerebral concussion.

**CONCLUSION**

SPECT remains the gold standard of CBF evaluation. However, ASL is sufficient as a routine evaluation for the follow-up examination of patients in whom low CBF has been diagnosed.

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**References**

