Diffusion and perfusion MRI findings with clinical correlation in patients with subarachnoid haemorrhage related vasospasm

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Summary

Background. Early radiological diagnosis of vasospasm as well as the detection of ischemic areas and the definition of cerebral perfusion changes may have an impact on the current unfavorable results in patients with vasospasm. We investigated diffusion weighted (DW) and perfusion weighted (PW) magnetic resonance (MR) changes together with catheter angiography findings and tried to correlate radiological and clinical findings.

Method. Twenty patients (11 females, 9 males, 10–71 years old) with aneurysmal subarachnoid haemorrhage and admitted by the Neurosurgery Department at the Istanbul School of Medicine between December 2003 and March 2006 were included in the study. Thirteen patients were World Federation of Neurological Societies (WFNS) grade I and 7 were WFNS grade II on admission. All patients underwent angiography pre- and postoperatively. Cranial magnetic resonance imaging (MRI) with diffusion weighted imaging (DWI) and perfusion weighted imaging (PWI) was performed in all patients. Radiological data was assessed by two neuroradiologists.

Findings. All patients underwent surgery (13 microsurgical clipping, 7 coil embolization) for a total of 23 aneurysms. Angiographic vasospasm was detected in 14 patients and clinical vasospasm in 7. DWI and PWI abnormalities were detected in 12 patients. Perfusion MRI findings were classified as prolongation of time to peak (TTP) (normal, 2–4 sec, 4–6 sec and >6 sec). Reversibility was investigated on MR control scans. There was relatively good correlation between clinical and perfusion MR findings. Significant DWI abnormalities were not very frequent even in patients with clinical signs.

Conclusions. DWI and PWI MR have provided an insight into hemodynamic and metabolic changes in vasospasm. Many issues are not yet clear and no study carried out so far is large enough for drawing significant conclusions. In this study, multimodal MR detected early ischemic changes in vasospasm.

Keywords: Vasospasm; perfusion magnetic resonance; diffusion magnetic resonance.

Introduction

Many studies testing the value of different methods in early recognition of vasospasm are being carried out because of the rapid onset of invasive monitoring and the possibility that aggressive treatment may reverse the negative prognosis [1, 2, 4]. The most widely used techniques in the diagnosis of vascular and parenchymal changes in vasospasm are transcranial Doppler (TCD) sonography, cerebral angiography, magnetic resonance angiography (MRA), computed tomographic angiography (CTA) and multimodal MRI, each with advantages and shortcomings discussed in length in the literature [5, 10]. Diffusion and perfusion MRI have received much interest in ischemic stroke studies in the evaluation of early hemodynamic changes; however, multimodal imaging findings in subarachnoid haemorrhage (SAH) related vasospasm have not been discussed in length in the literature [3, 8, 11]. We investigated DWI and PWI data and tried to correlate them with cerebral angiography and clinical findings in patients with aneurismal SAH.

Methods and materials

Twenty patients with subarachnoid haemorrhage due to the rupture of a brain aneurysm admitted by the Neurosurgery Department of Istanbul Medical Faculty, between December 2003 and March 2006, have been included in this study. Patients who were intubated or who needed monitoring were excluded from the study since our imaging laboratory did not possess MR compatible life support equipment. There were 11 females and 9 males (10–73 years old; median 52 years). On admission to the hospital, 13 patients were evaluated as WFNS grade I and 7 as grade II.

A non-enhanced brain CT was performed in each patient. All patients received a four-vessel cerebral angiography at our neuroradiology
digital subtraction angiography (DSA) unit (Philips Integris V 2000, Amsterdam, Holland) within 24 h of admission and also after the operation. A brain MRI study, including DWI and PWI series, was performed before and after treatment. The time interval between ictus to second MRI was 5–25 (median, 8) days. A control MRI was also performed 2–20 (median, 4) months after SAH.

MR studies were performed with a 1.5 T scanner (Siemens Symphony, Erlangen, Germany) using a quadrature head coil. On each examination, T1W axial, T2W axial and fast low angle shot inversion recovery (FLAIR) coronal series of the whole brain, followed by echo planar DWI ($b$ value: 0, 500 and 1000 mm$^2$/sec) and PWI images, were acquired. On PWI, 12 slices covering relevant regions of the brain were acquired via 40 dynamic sequences lasting a total of 1 min 4 sec following injection of 0.2 mmol/kg gadolinium chelate at a rate of 4 ml/sec pushed by saline. All perfusion data including automated time to peak images were generated by the scanner at a remote work station. Colour maps of TTP delays were generated using commercially available software (Matlab, The Mathworks Inc., MA, U.S.A.). A total of 10 points in the normal hemisphere/region were taken as reference and the colour scale of TTP delays (time curves) were arranged to show differences between 0–6 sec.

Only conventional and DWI series were performed in the follow up MRI studies.

**Results**

In the study group, all patients had SAH on initial brain CT. After DSA, two patients had multiple aneurysms and a total of 23 aneurysms in the 20 patients was present at these locations: middle cerebral artery (MCA) bifurcation, 7; internal carotid artery (ICA), 2; basilar tip, 1; posterior communicating artery, 5; anterior communicating artery, 6; distal anterior cerebral artery (ACA), 2.

All patients were operated on for the bleeding aneurysm. Thirteen microsurgical clippings and 7 coil embolizations were performed. Depending upon their time of arrival at our hospital, the surgical procedures were performed at 2–23 days (median four days) following SAH.

Headache, disturbed consciousness and new neurological deficit unaccounted for in brain CT was assessed as clinical vasospasm. Angiographical vasospasm was evaluated as mild (minimal vessel narrowing), moderate (25–50% narrowing) and severe (>50% narrowing). Clinical vasospasm was present in seven patients (35%) and angiographical vasospasm in 14 patients (70%, severe; two cases, moderate; six cases and mild six cases).

Neurological assessment of the study group revealed good recovery (Glasgow outcome score; GOS 4–5) in 19 patients (95%) and there was one death due to cardiopulmonary problems. Inspection of MRI studies revealed DWI/PWI abnormality in 12 patients (60%) and normal findings in eight (40%). In patients with normal MRI, GOS was favorable in all and there were no infarctions on follow up MRI. There was angiographical vasospasm in only two of these patients (20%).

A summary of MRI, DSA and clinical findings of the 12 patients with DWI/PWI abnormalities can be found in Table 1. All of these patients had vasospasm on DSA and 10 had perfusion abnormalities. Three patients with both DWI and PWI abnormalities were found to have infarctions on control MRI. One of these patients was an elderly female who had a relatively larger infarction and died due to cardiac infarction leading to cardiopulmonary failure.

There were a total of 20 areas with PWI abnormality in 12 patients. Inspection of TTP delay colour maps showed 11 areas with 2–4 sec of delay, none of which

Fig. 1. (a) Seventy one year old lady with right MCA aneurysm and vasospasm in the same territory on DSA has right parietal perfusion abnormality. The larger TTP delay is close to the center and displayed by yellow. (b) On DWI, this area is bright suggesting cytotoxic edema. (c) Follow up MRI shows this region has high T2 signal proving infarction. MCA Middle cerebral artery; DSA digital subtraction angiography; TTP time to peak; DWI diffusion weighted imaging