Background: Posttraumatic cerebral infarction (PTCI) is very rare and its pathogenesis is not well defined. In the case presented here, hemorrhagic shock was strongly suspected to be associated with the development of PTCI. Therefore, we hypothesized that a powerful shearing stress affected the pathogenesis of vulnerable endothelium causing damage and resulting in PTCI. By elucidating these mechanisms, it may be possible to predict the occurrence of PTCI.

Case: An 80-year-old woman was transferred to the emergency room after a traffic accident where her car collided against a wall. Upon admission, it was confirmed that she had a low Glasgow Coma Score (GCS); however, neither hemorrhage nor infarction appeared on initial brain computed tomography (CT) scans. Additionally, she had hemorrhagic shock (blood pressure 88/52 mmHg) causing hemothorax with multiple rib fractures, as well as fractures in the left humerus and thigh bone. The patient did not seem to be able to move the left half of her body because of pain, and still had a low GCS 12 h after admission. Hence, diffusion-weighted magnetic resonance imaging (MRI) was performed and revealed acute cerebral infarction in the right temporal lobe, and MR angiography demonstrated moderate stenosis of the horizontal portion of the right middle cerebral artery.

Conclusions: To our knowledge, sudden hypotension following hemorrhagic shock produced a strong shear stress, which induced platelet aggregation and lead to the development of a cerebral infarction in our case.

Key words: Posttraumatic cerebral infarction, hemodynamic shearing stress, hemorrhagic shock.

Introduction

Posttraumatic cerebral infarction (PTCI) is very rare, and makes up only 1.9-3.3% of all traumatic brain injuries. (1,2) Several reports have attempted to explain the association between the pathogenesis of PTCI and the situation in which it occurred, including dissection, thrombus, and vasospasm. However, there is not much literature in supporting the existence of a relationship between PTCI and the situation in which it occurred. (3)

In a prospective multivariate analysis, (4) the occurrence of low systolic blood pressure (BP) was established as one of the statistical risk factors for PTCI, whereas there are currently no reports on the relationship between the pathogenesis of PTCI and low systolic BP. On the other hand, a sudden occurrence of hypotension has been associated with hemodynamic shearing stress to vulnerable endothelial cells. (5)

In the case presented here, hemorrhagic shock was strongly suspected to be associated with the development of PTCI. Therefore, we hypothesized that a powerful shearing stress affected the pathogenesis of vulnerable endothelium causing damage and resulting in PTCI. By elucidating these mechanisms, it may be possible to predict the occurrence of PTCI.
Case report

An 80-year-old woman was sitting in the left passenger seat of the car, when her husband drove down a gentle hill at 40 km/h and collided against a wall. After a brief period of unconsciousness, she was removed from the car by paramedics and police officers. She was transferred to our emergency department and was found to have left-sided head banging, dislocation of the left elbow joint with bone fracture and deformity, and bone fracture of the left thighbone. Although her past medical history indicated she had hypertension for the past 30 years, our physical examination confirmed that she had hypotension (BP 88/52 mmHg), bradycardia (50 beats/min), minor bruising on her forehead, and a Glasgow Coma Score (GCS) of 10/15 (eye opening: 3, best motor response: 4, best verbal response: 3). She did not seem to be able to move the left half of her body because of pain; however, her hemiparesis was not clear at this point in the examination. Her oxygen saturation (SpO2) level was at 90% when breathing room air. Chest examination revealed that her right respiratory sound was weaker than the left. Her extremities were cold and later perfused because of cyanosis.

Laboratory findings revealed anemia (hemoglobin 8.9 g/dL; hematocrit 25.7%; red blood cell 2.82 M/μL) and elevated serum creatine phosphokinase (1911 unit/L). Her heart and bowel activities were normal in echographic examination and Doppler ultrasound. A simple radiography revealed bilateral diffuse hypolucent lung with pleural effusion and multiple rib fractures, humerus and thighbone fractures (Figure 1), and 3D thoracic computed tomography (CT) confirmed a lot of hemothorax (Figure 2). Initial brain CT scans did not show hemorrhaging or an infarction (Figure 3a). At this point, the suspected diagnosis was hemorrhagic shock with multiple fractures caused by traumatic blunt injury. We immediately treated her with 4 units of packed red blood cell administration, had her breathe 100% of the fraction of inspired oxygen, kept her warm and had her rest in bed for the hemorrhagic shock. Additionally, we provided supportive care as directed by an orthopedist in the intensive care unit for her multiple fractures.

Although her state of hemorrhagic shock improved...
Acute cerebral infarction of the deep white matter in the right temporal lobe (Figure 4). MR angiography (MRA) demonstrated moderate stenosis of the horizontal portion of the right middle cerebral artery (MCA) (Figures 5a and b). However, MRI did not show an intimal flap, intramural hematoma, or a dissection. Hence, we intravenously administrated the free radical scavenger Radicut (edaravone; Mitsubishi Tanabe Pharma, Tokyo, Japan) at 120 mg/day for 2 weeks and 10% glycerol (Glyceol Chugai Pharmaceutical Co, Tokyo, Japan) therapy at 400 mL/day for 7 days, and did not add any further anticoagulation medicines so as not to interfere with her multiple fractures. Two days after admission, hemiparesis became clear (manual muscular testing score 1/5) as her level of consciousness increasingly improved. Five days after admission she underwent osteosynthesis for her humerus and thighbone fractures, and was transferred to the rehabilitation ward 20 days after admission with hemiparesis.

Discussion

When considering the diagnosis of PTCI, we took into account the fact that the incident occurred in pre-trauma. Upon admittance, the patient initially looked like a left hemiparesis, mainly because of the massive trauma to the upper and lower extremities on the left side of her body. However, it was not until 12 h after admission that brain CT scans revealed right MCA territory infarcts. The initial CT scan were taken at some time point and...
did not show any signs of infarct, therefore, it had to be at some time between the initial scan and the one at 12 h. Thus, the range of 3 to 6 h before the 12 h scans provides enough time for the infarct to occur to such an extent as to be visible on the CT scan. Therefore, it may be conceivable to diagnose a PTCI.

PTCI after multiple injuries with hemorrhagic shock is very rare. For example, Mirvis et al. (1) reported that the prevalence of PTCI was 1.9% of all traumatic brain injuries, while Tomberg et al. (2) reported that the prevalence of PTCI was around 3.3%. However, Tian et al. (3) reported that the frequency of PTCI increased to 11.9% (42/353) when the trauma severity was taken into account, including moderate or severe head injury. Furthermore, patients admitted with low GCS and PTCI tended to have a higher mortality rate than patients without PTCI. These findings seem to indicate that the frequency of PTCI is associated with head trauma severity. (3)

However, there is some controversy regarding the role severity of head trauma might play in PTCI. A PTCI following even a mild head injury can sometimes be just as aggravated as PTCI in moderate or severe head injuries. (6,7) Our patient was categorized as having a mild head injury according to the Guidelines for the Management of Severe Head Injury, nevertheless the MRI revealed progression of stenosis of the right MCA. (8) Therefore, we believe that the association between the pathogenesis of PTCI and the actual injuries/symptoms themselves within the brain caused by an injury play an important role for diagnosis.

Some explanations for the mechanisms involved in the pathogenesis of PTCI are dissection, thrombus, or vasospasm after trauma, or perhaps, as in our case, low systolic BP with hemorrhage following humerus and thighbone fractures and hemothorax. In their review of 18 autopsy cases, Mobbs RJ et al. (9) reported that subintimal dissection is the most likely cause of MCA occlusion, as it was noted in 14 out of 18 cases (78%), and 2 cases (11%) involved thrombosis in the artery following blunt head trauma. In addition, Rutherford et al. (10) reported that the cause of the infarct in 3 cases of closed head injury was subintimal dissection involving intracranial anterior circulation arteries. These autopsy findings highlight the value of histological examination of vessels that macroscopically appear thrombosed. (10) The pathogenesis of the two described cases had dissection in common, whereas the situation caused by injury was not clear. Because dissection of PTCI was identified in young children, it may be interpreted that the intracranial vessels are affected easily by a high moment of inertia causing an opposing movement of the brain parenchyma in children. However, initial MRI did not show thrombus or intramural hematoma around the stenosis, or the pearl and string sign; therefore, our case is unlikely to be due to dissection and thrombus.

Regarding the possibility of vasospasm after trauma, O’Brien et al. (11) found that with traumatic brain injury in children, the typical day of onset for vasospasm was hospital day 2 to 3, while continuous vasospasm was 2 to 4 days. In our case, PTCI became clear within 12 h after admission in CT findings and stenosis remained for over 4 months. Therefore, it is not likely that our case was due to vasospasm.

Finally, we hypothesized that the sudden occurrence of hypotension affected hemodynamic shearing stress to the vulnerable endothelium, including the horizontal part of MCA, resulting in stenosis with denting forma-
tion as an atherothrombotic brain infarction. Several reports have demonstrated that rheological platelet aggregation induced by shearing forces alone does occasionally occur in patients with various atherothrombotic diseases. (12,13)

Strong fluid shear stress occurring with sudden hypotension including hemorrhagic shock promotes platelet aggregation by direct activation or by enhancing the response to chemical stimuli in vitro. (14) Deposition of platelet aggregates in the arterial circulation occurs preferentially at the site of a vulnerable endothelium with atherosclerosis, where the flow is interrupted. (15) Furthermore, Tian et al. (3) reported that low systolic BP was related to the development of cerebral infarction based on a multivariate analysis of patients with head trauma. There were 3 times as many PTCIs in patients with low systolic BP than in patients who did not have low systolic BP. In sum, our report in combination with previous studies strongly supports our theory that sudden hypotension following hemorrhagic shock produces a strong shear stress, which induces platelet aggregation at the horizontal part of MCA leading to the development of a cerebral infarction.

References