The role of noninvasive monitoring of cerebral electrical impedance in stroke

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Summary

Objective. To explore the change regularity of cerebral electrical impedance (CEI) in the healthy people and patients with intracerebral hemorrhage (ICH) and ischemic stroke.

Methods. CEI of 100 healthy volunteers, 52 patients with ICH and 33 patients with ischemic stroke was measured by noninvasive Brain-Edema Monitor. The results of perturbative index (PI) converted from CEI were compared with the volume of infarction, hematoma and surrounding edema, which calculated by image analyzing system according to MRI or CT.

Results. In the normal groups, PI in the left and right sides of cerebral hemispheres was respectively 7.76 ± 0.75 and 7.79 ± 0.58, and there was no significant difference between the two sides (P > 0.05). In the patients with ICH, PI in the hematoma side decreased and was lower than the other side, and then increased gradually, finally exceeded that of the other side. The average “cross” time was (16.25 ± 8.96) h. It showed that the volume of hematoma was no obvious change before and after the “cross” time [(31.25 ± 21.59) vs (37.59 ± 27.57)] (P > 0.05). However, the volume of peri-hematoma edema was significantly larger after the “cross” time than before the “cross” time [(26.35 ± 13.96) vs (14.68 ± 5.30)] (P < 0.05). There was a positive correlation between the PI of hematoma side and the volume of peri-hematoma edema (r = 0.8811, P < 0.01). In the patients with arterothrombotic cerebral infarction, PI in the infarct side had a positive correlation with the volume of infarction (r = 0.8496, P < 0.01).

Conclusions. CEI is a stable physical parameter reflecting the electrical character of human brain tissue. It is useful for monitoring edema and hematoma in stroke.

Keywords: Brain edema; electrical impedance; hematoma; monitoring; stroke.

Introduction

Ischemic stroke is the most common disease affecting the neurological function. And intracerebral hemorrhage (ICH) is the most serious form of all acute strokes. The mortality in spontaneous ICH is high, and the mechanism of death is usually related to cerebral herniation, which results from a combination of the mass produced by the hemorrhage itself, and by the mass effect created by surrounding edema [1]. The mass effect of ischemic stroke is also associated with the volume and position of infarct. Therefore, monitoring brain edema or hematoma is important. As it is well-known, CT and MRI can accurately delineate the region of brain edema or hemorrhage, but it is difficult to repeat them frequently. Moreover, these could not be performed on the bedside. Could we find out a method which can monitor edema and hematoma continually, non-invasively and cost-effectively? In the previous study, we have found that edema and hemorrhage can lead to the change of cerebral electrical impedance (CEI). That is, edema can increase the CEI [5, 9, 10, 12, 13], while hemorrhage decrease it [5, 12, 13]. According to this principle, measurement of CEI is probably a new method in detecting and monitoring the evolution of cerebral edema and hemorrhage on the patients at bedside. Therefore, the purpose of our study is to explore the change of CEI in the normal people and patients with intracerebral hemorrhage (ICH) and ischemic stroke.

Materials and methods

Patients

In a prospective study from July 2003 to May 2004, we studied 52 patients with ICH and 33 patients with ischemic stroke on the wards of our department. All of the ICH patients were confirmed at the first day after onset by a CT scan which showed the volume of hematoma was between 7.69~176.50 ml and the position of hematoma was respectively basal ganglia (39 cases), cerebral lobe (4 cases), cerebral ventricle (4 cases), brain stem (4 cases) and cerebella (1 case). The volume of infarction in 33 ischemic stroke was among 2.73~210.30 ml according to MRI operated at the first or second day after admission. There were also 100 healthy volunteers allowed to the study in order to compare with the patients.
Methods

We developed and used a kind of noninvasive Brain-Edema monitor (Born Science & Technology Corporation, China). A constant current was given into a person’s brain, and the CEI of the two hemispheres was measured respectively. The measurement were then converted into perturbative index (PI). The position of three electrodes was: the left frontal, the right frontal, and the middle of occipital.

The volume of infarction, hematoma and surrounding edema was calculated automatically by image analyzing system according to MRI or CT scan.

Results

The normal group

In the normal group, PI in the left and right hemisphere was respectively 7.76 ± 0.75 and 7.79 ± 0.58, and there was no significant difference between the two sides (P > 0.05). Moreover, no person had any complaint of the device during 3~6 hours monitoring.

The ICH group

In the ICH group, the range of PI in all patients was 5.36~12.50. Thirty-three of 52 patients were monitored continuously within 24 h after onset. The PI of hematoma side decreased firstly, which was lower than the other side, and then increased gradually, finally exceeded that of the other side. The average “cross” time was (16.25 ± 8.96) hours after onset. We calculated the volume of hematoma and surrounding edema according to the results of CT scan. It showed that the volume of hematoma was no obvious change before and after the “cross” time [(31.25 ± 21.59) vs (37.59 ± 27.57)] (n = 33, P > 0.05). On the other hand, the volume of peri-hematoma edema became to increase and was significantly larger just after the “cross” time than before the “cross” time [(26.35 ± 13.96) vs (14.68 ± 5.30)] (n = 33, P < 0.05).

A typical example was interpretative in Fig. 1. It showed the change of PI in a patient with left ICH. PI of the left (PI = 6.77) was lower than that of the right (PI = 7.07) at 4 hours after onset, and the volume of peri-hematoma was 12.31 ml. It then increased and exceeded that of the right side at 16 hours after onset (PI in the left = 7.18, PI in the right = 7.12). At 30 hours after onset, PI in the left had increased to 7.38 and the volume of peri-hematoma had also increased to 27.66 ml. The situation persisted throughout the next 6 days. Above results suggested that it was the hematoma possessing predominant before the “cross” time, and the surrounding edema possessed predominant after the “cross” time.

However, there were 3 of 52 patients whose PI didn’t increase but decreased during the continuous monitoring. We can see the situation in Fig. 2. It showed another patient with left ICH. Mannitol was injected immediately 2 h after onset, and repeated 2 h later. The patient’s condition was deteriorating. CT scan showed one day later the volume of hematoma became much larger than before.

Moreover, there was a positive correlation between the PI of hematoma side and the volume of peri-hematoma edema in the patients who were all detected within 7 days after onset (n = 52, r = 0.8811, P < 0.01).

Fig. 1. Relationship between the PI and the volume of focal lesions in a patient with left ICH: (A) 4 h after onset, volume of hematoma was 18.26 ml, volume of peri-hematoma was 12.31 ml; PI in the left was 6.77, PI in the right was 7.07; (B) 30 h after onset, volume of hematoma was 20.80 ml, volume of peri-hematoma was 27.66 ml; PI in the left was 7.38, PI in the right was 7.09