CLINICAL STUDY

"No-reflow" phenomenon as a cause of hypoperfusion after severe head injury?

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Abstract

Introduction: **Severe head injuries are known to cause secondary ischaemic brain damage. Ischaemia may develop due to transtentorial herniation or due to increased intracranial pressure leading to decreased perfusion. Compression of the brain due to extracerebral haematoma may cause hypoperfusion as well.**
Methods: **29 patients with postraumatic transtentorial herniation were studied. Haematoma was urgently removed in these patients and CT and SPECT was performed on the 1st and 5th postoperative day. 26 patients had hypoperfusion on SPECT in the vicinity of the previous haematoma. Only 9 of them, however, had ischaemia on CT. There were 11 patients in whom the previous ischaemia seen on SPECT improved on the follow up SPECT examination. 10 of them had a good treatment result.**
Conclusion: **A possible mechanism of hypoperfusion caused by compression of the brain may be a kind of "no-reflow" phenomenon which is known from pathophysiology of classical brain ischaemia. Patients in whom the collateral blood flow overcomes the decreased perfusion in the microcirculation should have a better outcome.** ***(Tab. 1, Fig. 1, Ref. 13.)***
Key words: brain ischaemia, severe head injury, "no-reflow" phenomenon.

Severe head injuries are defined by a postresuscitation GCS (Glasgow Coma Scale) ≤ 8. A subgroup of these patients have transtentorial herniation due to a decompensated intracranial hypertension. These injuries are known by their potential to cause secondary ischaemic brain damage due to several pathophysiological mechanisms (3). Transtentorial herniation may cause focal ischaemia by a direct pressure of the temporal lobe on the posterior cerebral artery which is pressed against the edge of tentorium. More diffuse ischaemic changes may occur in cases where severe intracranial hypertension and edema cause a decreased cerebral perfussion pressure (11). This situation is potentiated by a systemic hypotension that leads to the development of so called watershed ischaemia in the border zones of the main vessel territories. We have observed that there is another pathophysiological mechanism of brain posttraumatic hypoperfusion similar to what is known as "no-reflow" phenomenon (2) which might be caused by the pressure of the extracerebral haematoma on a brain tissue. In recent years SPECT (single photon emission computed tomography) has been found to be very sensitive in detecting the regions of cerebral hypoperfusion (1, 6, 9, 10). SPECT was also found to have prognostic value in determining outcome (4, 5).

Material and methods

We prospectively studied 29 severely head injured patients who were admitted to neurosurgery with the syndrome of transtentorial herniation (GCS 3-5, homolateral dilated pupil and disturbed vital functions). There were 11 epidural, 17 subdural and one intracerebral hematomas. Mean age was 43.4. All patients had urgent surgery with the removal of the haematoma and then continuous monitoring of ICP (intracranial pressure), CPP (cerebral perfusion pressure), blood pressure and jugular bulb oxymetry was instituted. Two postoperative CT and SPECT examinations were performed in each patient. Besides other variables we concentrated on the presence of ischaemia seen on the

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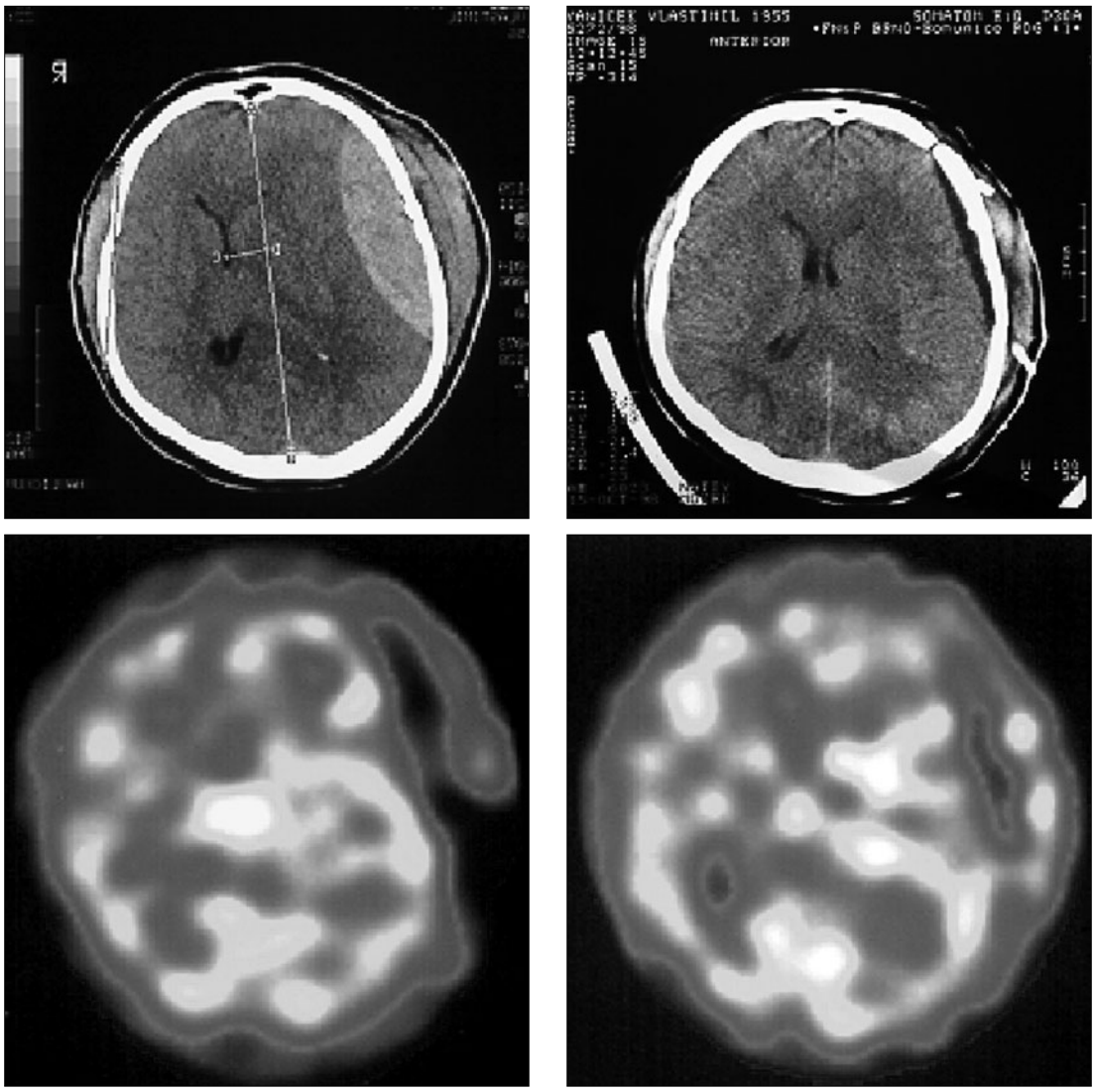

Fig. 1. Epidural haematoma on a CT scan in a 25-years-old male which was evacuated by craniotomy (upper left), follow-up CT scan 12 hours after the operation with no signs of ischaemia (upper right), SPECT 14 hours after the operation with marked cortical and subcortical hypoperfusion in the region close to the previous haematoma (lower left), follow up SPECT 5 days later with a significant improvement of perfusion (lower right). This patient had a good outcome.

CT and SPECT examination and we correlated these findings with the final Glasgow Outcome Score (GOS). We considered a good outcome and moderate disability as a favourable outcome.

Results

9 patients had visible ischaemia on the first postoperative CT scan and 7 of them died. All patients except 3 had ischaemia on SPECT. Ischaemia improved on the 2nd SPECT in 11 patients and 10 of them (91 %) had a favourable outcome. On the other hand there were 15 patients with no change or even worse ischaemia on the 2nd SPECT and only 4 (27 %) of them had a favourable outcome ($p<0.05$).

GOS (mean follow up 9 month) is: 12 patients good, 5 moderately disabled, 2 vegetative, and 10 died (Tab. 1).

On SPECT, ischaemia was usually characterised by a large zone of subcortically or cortically located hypoperfusion in the vicinity of the previous haematoma. Some patients had improvement of perfusion seen on the follow-up SPECT which started from cortical microcirculation (Fig. 1).

Discussion

The "no-reflow" phenomenon was described by Ames (2). Brain ischaemia causes some degree of edema which closes the microcirculation due to the pressure on the capillary wall from

Tab. 1. Ischaemia seen on CT and SPECT and its development on the follow-up examination.

Patient	Ischaemia CT(1)	Ischaemia CT(2)	Ischaemia SPECT(1)	Ischaemia SPECT (2)	GOS
1	-	-	+	++	MD
2	-	+	+	++	MD
3	-	-	+	+	exitus
4	-	-	++	+	good
5	+	+-	++	+	exitus
6	-	-	+	+-	good
7	-	-	+	+-	good
8	-	-	+	+-	good
9	-	+	++	+	good
10	-	-	-	-	good
11	-	-	-	-	good
12	++	++	+	+++	exitus
13	-	-	-	-	good
14	-	-	+	+-	good
15	-	+-	+-	+-	MD
16	+	+	++	++	exitus
17	-	-	+-	-	good
18	-	-	+-	+-	exitus
19	+	+	++	++	exitus
20	+	+	++	+	good
21	+	+	++	++	vegetative
22	++	++	++	++	exitus
23	-	+	++	+	good
24	-	++	++	++	vegetative
25	-	-	+	+	MD
26	+	+	++	++	exitus
27	++	++	++	++	exitus
28	-	-	++	+	good
29	-	++	++	++	exitus

GOS – Glasgow Outcome Score, CT – Computed tomography, SPECT – Single proton emission computed tomography, MD – moderate disability

outside. In the reperfusion phase the larger branches are perfused again, but the microcirculation remaines closed due to the persistent edema. In some severe head injuries with large extracerebral haematomas causing brain compression the hypoperfusion or even ischaemia can be detected even after the blood clot has been removed. The pressure of the haematoma probably stops the microcirculation particularly in the regions closest to the previous haematoma. The phase after the haematoma removal is then analogous to a reperfusion phase in a classical ischaemia.

The "no-reflow" phenomenon in neurotrauma has been discussed so far only as a pathophysiological mechanism underlying the so-called false autoregulation (7, 8, 12). According to this theory many capillaries collapse after head injury due to oedema. Increases of cerebral perfusion pressure fail to open the collapsed vessels and therefore the cerebral blood flow does not change. On the other hand a fall in cerebral perfusion pressure permits more capillaries to collapse and cerebral blood flow to decrease. Our hypothesis suggests that not only oedema but also compression of the brain tissue by haematoma might cause collapsed microcirculation. And even though the haematoma has been removed, the circulation remains collapsed at least for some period of time – the "no-reflow" phenomenon. Hypoperfusion after head injury occurs very often also in cases of diffuse injuries where there is no possible effect of compression by extracerebral haematoma. Pathophysiologically this hypoperfusion is usually explained by decreases in cerebral perfusion pressure after the trauma and by impaired autoregulation (11, 13). In cases of extracerebral haematomas the hypoperfusion is located always in the vicinity of the previous haematoma. Therefore the haematoma itself, by the means of compressive mechanism, may be responsible for this type of hypoperfusion. The no-reflow phenomenon might be the explanation.

If ischaemia is seen already on the first postoperative CT scan, the prognosis is poor. The majority of severely head injured patients, however, have ischaemia seen on SPECT. More than the extend of ischaemia on the first SPECT it is the development of perfusion on the second SPECT which influences the outcome in these patients. Therefore, the ischaemia seen only on SPECT might not be irreversible and could be therapeutically influenced in the intensive care unit. This theory also supports the need to remove the blood clot as soon as possible, not only to decrease the intracranial pressure but also to improve the perfusion of the underlying brain tissue.

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