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Continuous monitoring of intracranial pressure for prediction of postoperative complications of hypertensive intracerebral hemorrhage

S.-X. YU[1], Q.-S. ZHANG[2], Y. YIN[1], Z. LIU[1], J.-M. WU[2], M.-X. YANG[1]

[1]Department of Neurosurgery, The Second People's Hospital of Longgang District, Shenzhen, China
[2]Department of Neurosurgery, The Second People's Hospital of Shenzhen, Shenzhen, China

Qiu-Sheng Zhang is co-first author

Abstract. – OBJECTIVE: This study evaluates the value of continuous dynamic monitoring of intracranial pressure (ICP) in patients with hypertensive intracerebral hemorrhage to predict early postoperative complications.

PATIENTS AND METHODS: Data from 80 patients treated in our hospital from February 2014 to February 2015 were analyzed. The patients all underwent decompressive craniectomies, and their ICP changes were monitored invasively and continuously for 1 to 7 days after surgery. The average blood loss during surgery for the group of patients was 65.3 ± 12.4 ml and the mean GCS score 8.7 ± 2.4. Cases were divided into three groups according to ICP values to compare early postoperative complications of the groups: a normal and mildly increased group (51 cases), a moderately increased group (19 cases) and a severely increased group (10 cases).

RESULTS: To validate the analysis we first showed that comparisons among groups based on gender, age, systolic pressure, diastolic pressure, bleeding time, blood loss, operation time, craniectomy localization, and preoperative mannitol dosage yielded no statistically significant differences. In contrast, the following comparisons produced statistically significant differences: the comparison of postoperative Glasgow Coma Scale (GCS) scores showing that the lower intracranial pressure, the higher the GCS score; the postoperative rehemorrhage, cerebral edema and death ratios showing the higher the intracranial pressure, the higher the rehemorrhage ratio; the average ICP and the time to occurrence of rehemorrhage, cerebral edema or cerebral infarction, showing the relationship between the average ICP and the time to a complication. Patients with higher ICP averages suffered a complication of rehemorrhage within the first 9.6 ± 2.5 hours on average. Nevertheless, the comparison of GCS scores in those patients and the others showed no significant differences.

CONCLUSIONS: Based on the findings, the dynamic monitoring of intracranial pressure can early and sensitively predict postoperative complications of patients with hypertensive cerebral hemorrhage, and guide the clinical intervention actively to improve the surgery outcome.

Key Words:
Dynamic monitoring of intracranial pressure, Hypertension intracerebral hemorrhage, GCS score.

Introduction

Hypertensive intracerebral hemorrhage (HICH) is the most common type of cerebral hemorrhage in the clinical practice, accounting for about 56.7-84.9% of the cases[1,2]; it presents high morbidity during the first 30 days leading to mortality of up to 30-50% of the cases[1]. Hematoma oppression and edema caused by cerebral hemorrhage and postoperative rehemorrhage can induce increased intracranial pressure, which is a leading cause of death. Different surgical techniques in the early stages can effectively relieve increased intracranial pressure after a cerebral hemorrhage and improve prognosis[3]. It was confirmed by clinical practice that decompressive craniectomy is superior to small window craniectomy[4]; unfortunately, there are still quite a lot of patients with postoperative recurrence of increased intracranial pressure that aggravate the prognosis of the disease. Many researches have already pointed out that dynamic monitoring of intracranial pressure can guide the drug and surgical treatment after cerebral hemorrhage to improve the survival rate[5,6], but reports of continuous intracranial pressure monitoring after surgery in the literature are scarce. Based on this, our hospital team retrospectively analyzed the histories of 80 cases of hypertensive intracerebral hemorrhage with intracranial pressure monitoring to evaluate its predictive value for early complications.

Corresponding Author: Jian-Ming Wu, MD; e-mail: nt1492028yashanhu@163.com

Patients and Methods

Patients

Data from 80 patients diagnosed with hypertensive intracerebral hemorrhage in our hospital from February 2014 to February 2015 were analyzed. There were 38 males and 42 females, with ages ranging from 30 to 82 years and an average age of 54.3 ± 12.4 years. All the patients had a medical history of hypertension, the preoperative average systolic blood pressure was 125.9 ± 25.3 mmHg, with an average diastolic blood pressure of 125.9 ± 25.3 mmHg, and the postoperative average systolic blood pressure was 152.7 ± 32.1 mmHg, with an average diastolic blood pressure of 95.2 ± 5.6 mmHg. According to the preoperative Glasgow Coma Scale (GCS) score, there are 30 cases with 9-10 points, 38 cases with 6-8 points, and 12 cases with 3-5 points, with an average GCS score of 8.7 ± 2.4 points. 25 cases had a preoperative cerebral hernia. According to CT imaging, patients were classified by cerebral hemorrhage location: 35 cases had basal ganglia hemorrhage, 20 cases had putamen hemorrhage and 10 cases had a cerebellar hemorrhage. The amount of blood in the hematoma ranged from 10-100 ml with an average of 65.3 ± 12.4 ml. There were 20 cases with broken lateral ventricles, 12 cases with shifting midline structure over 2.0 cm, 32 cases with shifting of 1.0-2.0 cm and 36 cases with shifting of less than 1.0 cm.

Inclusion criteria: 1. Complete data with a medical history of high blood pressure and the clinical symptoms, signs and imaging manifestations of intracerebral hemorrhage. 2. History of intracranial pressure monitoring on the first hemorrhagic episode. 3. The patient consented to intracranial pressure monitoring.

Exclusion criteria: 1. Other causes of cerebral hemorrhages, such as trauma, autoimmune diseases, arteriovenous malformation and aneurysm etc. 2. Other types of cerebral hemorrhage, such as subarachnoid hemorrhage, epidural hemorrhage and others. 3. Pregnancy. 4. History of head surgery, etc.

The study was approved by the Ethics Committee of the Second People's Hospital of Shenzhen. Signed written informed consents were obtained from all participants before the study.

Experimental Methods

All patients received decompressive craniectomy within 24 hours of the diagnosis by way of craniotomy hematoma clearance and probe implantation for intracranial pressure (ICP) monitoring. The dynamic intracranial pressure changes were monitored invasively and continuously for 1 to 7 days after the surgery (probe imbedded in hematoma cavity or lateral ventricle). After hematoma clearance, the intracranial pressure probe was inserted about 2.0-3.0 cm into the hematoma cavity; and for the patients whose hematoma cavity and encephalocele were connected, the probe was placed in the lateral ventricle. The recorded data included the ICP value (point value and average value) for 24 hours, the top and valley values for 24 hours, the speed of ICP change, the duration of time of ICP fluctuation and the corresponding timing of the GCS scoring, drug reactions, patients performances and so on. The Codman ICP device (Johnson & Johnson, Brunswick, NJ, USA) and an intracranial pressure probe, an ECG monitor (Shenzhen Mindray Biomedical Corporation, Shenzhen, China) and a Moller-Wedel surgery microscope (Wedel, Germany) were used during the ICP monitoring.

According to ICP values, the cases were divided into groups as normal (5 to 15.0 mmHg), mildly increased (15.0 to 20.0 mmHg), moderately increased (20.1 to 40.0 mmHg) and severely increased (more than 40.1 mmHg). After surgery, the patients received standard medical treatment for their condition including hemostasis, intracranial pressure control, encephaledema prevention, nutritional support, and complications preventive measures. The unconscious patients underwent tracheotomy and enhanced respiratory tract management. Patients with mildly increased ICP were observed closely and provided with position change, respiratory assistance, and fever and elevated blood pressure control, without using a dehydrating agent. Patients with moderate increased ICP lasting more than 10 minutes were offered 20 mg furosemide or 125 ml mannitol (20% solution), the patients who did not respond to treatment were examined with a craniocerebral CT: if rehemorrhage was discovered, the patients with surgical indications underwent another hematoma evacuation procedure. The patients with severely increased ICP had CT reexamination at once while on dehydration therapy (250 ml 20% mannitol, every 6 hours), and the patients with surgical indications had another surgery for hematoma evacuation or decompression.

Clinical Observations

The postoperative GCS scores of patients, the overtime values of ICP and the length of time with high ICP were recorded, as well as clin-

Table I. Comparison of Baseline Information of patients from three groups.

Groups	Normal and Mildly Increased Group (n = 51 cases)	Moderately Increased Group (n = 19 cases)	Severely Increased Group (n = 10 cases)	F (X^2)	*p*
M/F	26/25	8/11	4/6	0.695	0.706
Average age	53.7 ± 10.5	55.7 ± 12.3	54.9 ± 11.5	0.958	0.632
Average systolic pressure (mmHg)	148.9 ± 25.6	153.2 ± 31.2	158.6 ± 35.4	0.967	0.465
Average diastolic pressure (mmHg)	86.7 ± 15.4	92.4 ± 23.1	96.5 ± 24.5	0.825	0.426
Bleeding time (h)	1.5 ± 0.3	1.3 ± 0.4	1.7 ± 0.5	0.203	0.417
Blood loss (ml)	54.2 ± 4.7	63.5 ± 6.8	65.8 ± 7.2	0.429	0.703
Operation time (min)	64.5 ± 15.4	67.9 ± 16.8	68.3 ± 18.4	0.224	0.361
Area of craniectomy (cm^2)	68.7 ± 15.9	65.4 ± 16.7	63.8 ± 15.9	0.382	0.162
Mannitol dosage (ml)	759.8 ± 105.3	789.2 ± 154.2	771.6 ± 163.7	0.238	0.169

ical findings like postoperative rehemorrhage, cerebral edema and cerebral infarction. Rehemorrhage was diagnosed based on the degree of hematoma removal or evacuation, the images on a craniocerebral CT, and the hematoma volume calculated by a Dorian formula being higher than 10 ml. Encephaledema was diagnosed in postoperative CT images where the midline shift was more than 5.0 mm, in the absence of intracranial factors such as rehemorrhage or cerebral infarction.

Statistical Analysis

The SPSS19.0 software (IBM, Armonk, NY, USA) was used for data entry and statistical analysis. The quantitative data were represented by average ± standard deviation. Comparison between groups was done using One-way ANOVA test followed by Post Hoc Test (LSD). Qualitative data were represented by case number or percentage (%), and comparison among groups used the (calibration) χ_2 to test. A $p < 0.05$ was taken to point to a difference with statistical significance.

Results

Comparison of Baseline Information of Patients from Three Groups

Cases were assigned to different groups according to ICP value. Comparisons of gender, age, systolic pressure, diastolic pressure, bleeding time, blood loss, operation time, location of craniectomy, and preoperative mannitol dosage of patients from these three groups were done during the statistical analysis and the differences found had no statistical significance ($p > 0.05$) (Table I).

Comparison of Postoperative GCS Score and Complications in Patients from Three Groups

Postoperative GCS scores were compared and the differences found were statistically significant ($p < 0.05$), the lower the intracranial pressure, the higher the GCS score with negative correlation (from Pearson correlation analysis, r = -0.563, $p = 0.024$). Also, differences of postoperative rehemorrhage, cerebral edema and death ratios among the three groups were statistically significant ($p < 0.05$), in these cases the higher the intracranial pressure, the higher the rehemorrhage ratio (Table II).

Comparison of Time to a Complication and Average ICP

There were 16 cases of postoperative rehemorrhage, 54 of cerebral edema and 10 of cerebral infarction among patients with different intracranial pressures. The elapsed times from the initial repair surgery to a complication were compared to the average ICPs during the same times, and the differences found were significant ($p < 0.05$). The higher the average ICPs, the shorter the times to a complication. However, the GCS scores were not significantly different when compared amongst patients with complications happening at different times, showing the scores were not useful for guiding immediate interventions (Table III).

Discussion

Clinical Significance of Postoperative Monitoring of Intracranial Pressure for Hypertensive Intracerebral Hemorrhage

Postoperative dynamic monitoring of ICP for 24 hours after a hypertensive cerebral hemor-

Table II. Comparison of Postoperative GCS Score and Complications in Patients from Three Groups.

Groups	Normal and Mildly Increased Group (n = 51 cases)	Moderately Increased Group (n = 19 cases)	Severely Increased Group (n = 10 cases)	F (X^2)	*p*
GCS Score	9.2 ± 1.5	8.4 ± 1.8	7.6 ± 2.1	5.856	0.037
Rehemorrhage	5 (9.8 %)	6 (31.6%)	5 (50.0%)	9.786	0.007
Cerebral Edema	40 (78.4 %)	10 (52.6%)	4 (40.0%)	7.964	0.019
Cerebral Infarction	6 (11.8 %)	3 (15.8%)	1 (10.0%)	0.262	0.877
Death	3 (5.9 %)	5 (26.3%)	5 (50.0%)	12.424	0.002

Note: *p* value represents difference among the three groups.

rhage is the key to adjust the treatment in a timely manner. In the clinical practice, the early symptoms of patients are sometimes not typical, so they may get ignored; however, once symptoms appear, the patient condition may deteriorate significantly and the window of opportunity for intervention may be missed[7]. Currently, ICP monitoring technologies allow for accurate and fast readings. 59 cases in this study were found to have postoperative increased ICP within the first 24 h after surgery. The GCS scores during that time did not differ from the scores obtained right after the operations and, therefore, were not as useful as the ICP monitoring for guiding immediate treatment at those times[8].

Intracranial pressure alterations precede changes in clinical signs and symptoms and consequently on the GCS score. Dynamic intracranial pressure monitoring signals the time when additional imaging examinations are needed in order to single out the cause of the increased ICP[9]. Furthermore, for the patients under sedation and muscle relaxant treatments, dynamic monitoring of intracranial pressure is particularly important[10]. Also, the degree and duration of time of increased intracranial pressure have a great impact on prognosis[9,10], and the patients with refractory increased intracranial pressure often have a poor prognosis[11].

Manifestation and Analysis of Postoperative Complications

There were 16 patients who suffered a postoperative rehemorrhagia, with ICP beginning to increase 1-23 hours after surgery. The ICP of most patients reached and exceeded 20 mmHg within 1 hour, generally remaining at 30-40 mmHg. Reducing intracranial pressure treatment measures such as 250 ml mannitol of 20% were given and ICP decreased to 5-10 mmHg. A craniocerebral CT was reordered to evaluate the need for a new surgical intervention, which could recover the ICP to around 20 mmHg.

54 cases suffered from postoperative encephaledema, which is a normal process of disease evolution. In these cases the ICP started to increase slowly 6-48 hours after surgery, it usually reached less than 10 mmHg within 2 hours and peaked after around 3-7 days after surgery, generally remaining at 10-25 mmHg. Reducing ICP treatment measures were given and the pressure could be controlled and kept at around 20 mmHg. There were 5 cases of severe encephaledema with ICP reaching more than 30 mmHg, aggressive measures for reducing ICP were provided, but the values did not decrease enough.

10 patients in the group had cerebral infarction, ICP began to increase 8-48 hours after sur-

Table III. Grouping according to length of time before a complication, average ICP and GCS score during the first day after initial surgery.

Types	Rehemorrhage	Cerebral Edema	Cerebral Infarction	F	*p*
Time from surgery to complication (h)	9.6 ± 2.5	15.7 ± 4.3	24.3 ± 5.8	6.629	0.027
Average ICP (mm Hg)	35.7 ± 6.9	15.4 ± 5.3	18.7 ± 7.2	5.759	0.032
GCS Score	5.7 ± 1.8	6.1 ± 2.2	6.2 ± 2.4	0.938	0.625

Note: *p* value represents difference among the three groups.

gery and peaked around 2-7 days after surgery. In 7 of these cases the ICP remained at 10-30 mmHg but in 3 cases it went over 40 mmHg, all patients developed a massive cerebral infarction.

Among the reasons for increased ICP after the cerebral hemorrhage repair surgery, encephaledema was the leading cause and postoperative rehemorrhagia, and cerebral infarction followed. Rehemorrhage should be suspected in those with markedly increased ICP during the first 24 hours who do not respond to pressure reducing measures, and a CT scan should be used to to rule out the complication. Normally, within the first 6-48 postoperative hours, ICP increases gradually and slowly due to acute encephaledema. For the patients with strong fluctuations of ICP, the following elements should be excluded: ICP probe position, patient dysphoria, respiratory tract problems, and high body temperature. It has been reported that an ICP higher than 40 mmHg indicates the presence of an intracranial hematoma[12]. 10 cases in the study with postoperative ICP higher than 40 mmHg, and 4 cases with intracranial rehemorrhage underwent an immediate surgery and recovered well after surgery. Patients with postoperative ICP more than 40 mmHg should have hematoma removal or extensive decompression surgery to prevent a cerebral hernia, which still can lead to a positive prognosis.

Effect of Intracranial Pressure Monitoring for Prognosis Improvement

At present, most of the scholars hold that dynamic monitoring of intracranial pressure has improved patient's prognosis significantly[13]. One report showed that the fatality rate of 1202 cases under intracranial pressure monitoring within two weeks was 19.6% and that of 244 cases without intracranial pressure monitoring reached 33.2%[14]. There are, however, still some scholars who believe that intracranial pressure monitoring cannot improve a patient's prognosis. A large-scale clinical double-blind controlled study found that the prognosis at 3-6 months for a treatment group with intracranial pressure kept below 20 mmHg and a treatment group treated only based on CT and clinical signs demonstrated there were no differences[8]. Our study results seem to contradict those findings.

The mortality of patients with hypertensive cerebral hemorrhage in this study whose intracranial pressures were higher than 40 mmHg reached 50%, proving that an ICP higher than 40 mmHg is at least a warning sign of cerebral lesion, which can lead to poor prognosis. Postoperative intracranial pressure monitoring of hypertensive cerebral hemorrhage allows for treatment adjustments when the ICP values are only slightly high, decreasing the occurrences of severely increased ICPs, so in theory it should help improve the prognosis of patients. Intervention before the occurrence of irreversible cerebral injury is at the core of the value of intracranial pressure monitoring[15]. Therefore, postoperative intracranial pressure monitoring should be applied to the patients with cerebral hemorrhage, and it should help in guiding clinicians to achieve an effective timely treatment.

Announcements of Intracranial Pressure Monitoring

Intracranial pressure (ICP) monitoring itself is a real-time system, but the recording of intracranial pressure is intermittent and limited by conditions. The postoperative intracranial pressure monitoring method in this study consisted of recording the ICP every 30 minutes and getting a mean value after 24 hours, obtaining the highest and the lowest values, the speed of ICP change, the duration of ICP fluctuations and recording the GCS scores at corresponding time points, after drug administration, or during clinical manifestation, etc.

For effective ICP measurements, it is important to distinguish real data from anomalies caused by wrong placement of intracranial pressure probe, shifting, traction, and wrong values caused by an uncalibrated device. Transient abnormal intracranial pressure caused by dysphoria, epileptic seizure and uroschesis should be symptomatically treatment at once, and an ICP value should be recorded again within an interval of 5-10 minutes. There were 2 cases whose ICPs were normal, but who had aggravating clinical manifestations, upon CT reexamination they were found to have rehemorrhage. Analysis of the cases showed probe shifting in a highly dysphoric patient and false reading due to a drainage pipe in the lateral ventricle. For patients with drainage catheters, ICP values should be recorded after drainage is closed for 5 minutes.

Conclusions

Patients with hypertensive cerebral hemorrhage often suffer from underlying diseases and postoperative complications. Postoperative intracranial pressure monitoring can help in prompt identification of progressive brain lesions to be able to adjust treatment plans in a timely manner, which is crucial in the postoperative treatment of cerebral hemorrhage. It is, however, important to exercise the judicial use of the intracranial pressure monitoring technology because ultimately it is the clinician who needs to analyze each case in its context to make the appropriate decisions.

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Conflicts of interest

The authors declare no conflicts of interest.

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