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The clinical efficacy of neuronavigation-assisted minimally invasive operation on hypertensive basal ganglia hemorrhage

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Abstract. – OBJECTIVE: To explore the therapeutic effect of neuronavigation-assisted minimally invasive operation on hypertensive basal ganglia hemorrhage patients with hematoma volume less than 30 mL.

PATIENTS AND METHODS: 25 hypertensive basal ganglia hemorrhage patients with hematoma volume varied from 15 to 30 mL were enrolled. 13 patients were recuited to undertook puncture aspiration and catheter drainage under real-time neuronavigation. The operations were carried out under CT imaging guidance. Twelve patients with conservative treatment were recruited as control.

RESULTS: Neuronavigation operation group was superior to the conservative treatment group in terms of hematoma clearance time, duration of hospitalization, 6-month Glasgow coma score (GCS) scores and neurological deficiency scores.

CONCLUSIONS: Neuronavigation-assisted minimally invasive operation is suitable for low volume hypertensive basal ganglia hemorrhage and improves the prognosis of these patients significantly.

Key Words:
Hypertensive intracranial hemorrhage, Basal ganglia, Small hematoma, Neuronavigation, Minimally invasive operation.

Introduction

Cerebrovascular disease is the third leading cause of death and the primary cause of long-term disability in most developed country. Seventy percent of hypertensive hemorrhage occur in the basal ganglion. Usually, hematoma volume greater than 30 mL is an indication for craniotomy. Conservative treatment is usually applied on those with supratentorial hematoma volume less than 30 mL and particularly for small space-occupying lesion. However, it is not only time-consuming, but also can easily cause secondary damage at the periphery of normal brain tissue during hematoma absorption, which worsens the neurological dysfunction, and will delay the early rehabilitation. In order to explore the therapeutic effect of neuronavigation-assisted minimally invasive operation on the clearance of hematoma volume less than 30 mL after hypertensive basal ganglia hemorrhage, puncture aspiration and catheter drainage were performed on 13 patients with small space-occupying lesion after hypertensive basal ganglia hemorrhage. Patients were recruited between August 2010 and August 2013 from our department. Twelve patients with conservative treatment were recruited as control in the corresponding period.

Patients and Methods

Inclusion and Exclusion Criteria

1) Inclusion criteria: History or presence of hypertension; First onset basal ganglia hemorrhage confirmed by computed tomography (CT); Patients were admitted within 6 hours after hemorrhage; The volume of hematoma was between 15 to 30 mL (calculation is based on multi-Tian formula); Accompanied with varied degree of paralysis and aphasia; Glasgow Coma Score (GCS): 6-10; Age less than 70 years old; Consent forms were obtained from both family members and doctors to agree for the operation.

2) Exclusion criteria: Hemorrhage was caused by cerebral aneurysm, arteriovenous malforma-

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Table I. Comparison of basic conditions between the two groups.

Groups	Gender		Age (years)	Hematoma volume	GCS Scores
	Male	Female	($\bar{x} \pm s$)	($\bar{x} \pm s$, ml)	
Conservative treatment (n=12)	7	5	47.75 ± 9.16	22.42 ± 4.70	9.17 ± 0.84
Neuronavigation operation (n=13)	10	3	55.31 ± 9.97	25.18 ± 4.15	8.83 ± 1.30
Statistic values	0.991		-1.969	-1.565	1.157
p	0.319		0.061	0.131	0.085

tion, injury, intracranial tumors; Combined with ventricle hamatocele; Severe diseases of the heart, lung, liver, kidney and hematological system; Consent form could not be obtained from the patients or patients' families.

Patients and Neuronavigation-Assisted Minimally Invasive Operation

Twenty-five patients were recruited for the study. They were divided into neuronavigation operation group and conservative treatment group. Basic information of the two groups is shown in Table I.

1) Neuronavigation operation group. Operation was performed within 12 hours after hemorrhage. After pre-operative skin preparation, 5-7 navigation paste markers were attached to the scalp. Imaging data were transferred into FDiM excelim-04 computer-assisted infrared-based surgical navigation system via zip disk. Three-dimensional reconstructions were made via neuronavigation workstation. Under general anesthesia, the head of patient was fixed with Doro head frame, and then a reference frame was placed on a head holder arm near the side of hematoma. Spatial registration and pre-operation surgical planning were conducted to define location of hematoma for puncture aspiration. Incision position was then marked. Routine disinfection and draping were performed, and sterilized reference frame was replaced. After an adaptor was fixed to puncture needle, registration for the adaptor was conducted. One bur hole was made on the skull after incision of all layers of the scalp. The cortex was electrocoagulated followed by a crucial incision of the dura mater. The target point of hematoma was punctuated under the guidance of the navigation model. After successful puncture was achieved, the core of the catheter and adaptor were pulled out. A suction syringe (20 mL) was then applied to aspirate the hematoma. However, if it is too difficult to aspirate, aspiration was terminated to avoid re-bleeding. The volume of aspiration was usually one third or half of the original hematoma volume. The catheter was kept within the cavity of the hematoma, and then the scalp was sutured. Routine post-surgery care included hemostasis, intracranial pressure control, prevention of stress ulceration, blood pressure and glucose level control, sedation and nutrition support. Post-surgery blood pressure was maintained approximately 160/90 mmHg.

One day after surgery, the remained hematoma and catheter position were reviewed by CT scan. Based on the volume of the remained hematoma, 8000-10,000 unit of urokinase (diluted in 5 ml saline) could be injected into the hematoma. Open drainage was conducted 2 hours after the injection. The injection was made 1-2 times daily. Head CT scan was performed every other day until the volume of remained hematoma is less than 5 mL, which was considered as an indication for catheter removal. Representative images of one patient with neuronavigation operation are shown in Figure 1.

2) Conservative treatment. All treatment approaches were the same as those for the neuronavigation group except conducting surgery and thrombolysis of hematoma with urokinase. Less than 5 mL of the remained hematoma was the indication for hematoma clearance.

Evaluation of Clinical Efficacy

Time of hematoma clearance, duration of hospitalization, GOS scores and NIHSS scores one-month and 6-month were recorded.

Statistical Analysis

SPSS 20.0 software (SPSS Inc., Chicago, IL, USA) was applied for data analysis. Variables data were normally distributed. Data are expressed as mean ± standard deviation. Two independent sample Student's *t*-test was applied. Attributes data were analyzed with Pearson χ^2 test. $p<0.05$ is considered to be statistically significant.

Results

Baseline characteristics Between the Two Groups were Similar

No significant difference was observed in gender, age, hematoma volume, GCS scores between the conservative treatment group and neuronavigation operation group ($p > 0.05$) (Table I).

Earlier Hematoma Clearance and Shorter Hospitalization Duration in the Neuronavigation Operation Group

Time for hematoma clearance in the neuronavigation operation group was significantly shorter (nearly by 4-folds) than that of the conservative group. Moreover, patients in the neuronavigation operation group had shorter hospitalization period than those of the conservative group (Table II; $p < 0.05$).

Neuronavigation Operation Significantly Improved Long-term Efficacy

No significant differences were seen in short-term efficacy (one-month GCS and NIHSS scores) between two groups as shown in Table III. However, long-term outcomes in the neuronavigation operation group was much better than that in the conservative treatment group ($p < 0.05$).

Rebleeding Rate was Similar Between the Two Groups

No significant difference in rebleeding rate was observed between the two groups (Table IV; $p > 0.05$), indicating that neuronavigation operation did not increase the chance of rebleeding.

Discussion

Hypertensive hemorrhage accounts for 10-15% of acute cerebrovascular diseases, and it is the main cause of mortality and disabilities of the patients with stroke[1,2]. The incidence rate of hypertensive hemorrhage increases continually world wide from the aging population to the youth. The basal ganglion is the most common site of hypertensive hemorrhage in the brain, accounting for over 70% of hypertensive hemor-

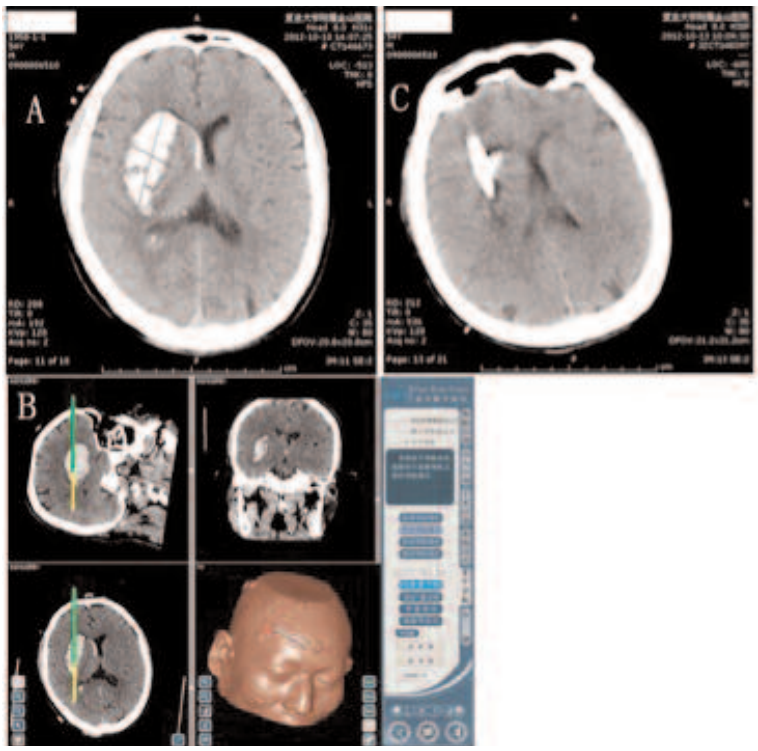

Figure 1. A male 54-year patient was admitted due to sudden left paralysis. ***A,*** Pre-operation head CT scanning showed hemorrhage on the right side of the basal ganglion, the volume of hematoma was approximately 22 ml, accompanied with mild compression of the contralateral cerebral ventricle. There is no shift of midline structures in the brain. ***B,*** Navigation during operation. ***C,*** Three days after operation, CT scan showed that drainage was nearly achieved.

Table II. Comparison of hematoma clearance and duration of hospitalization between the two groups.

Groups	Hematoma clearance	Duration of hospitalization
Conservative treatment (n=12)	16.33 ± 3.70	17.75 ± 8.08
Neuronavigation operation (n=13)	4.15 ± 1.46**	11.15 ± 1.68*
Statistic values	10.657	2.773
p	0.000	0.017

NB: Student *t*-test, compared with the conservative group: ** $p < 0.01$, * $p < 0.05$.

Table III. Comparison of short-term and long-term efficacy between the two groups.

Groups	GOS 1 month	GOS 6months	NIHSS 1 month	NIHSS 6 months
Conservative treatment (n=12)	3.33 ± 0.49	4.17 ± 0.72	9.47 ± 4.76	5.08 ± 3.39
Neuronavigation operation (n=13)	3.54 ± 0.78	4.85 ± 0.69*	6.32 ± 3.39	3.69 ± 2.18*
Statistic values	-0.786	-2.415	0.832	2.574
p	0.443	0.024	0.414	0.017

NB: Student *t*-test. * $p < 0.05$: compared with conservative treatment.

rhage, and the mortality rate after medical treatments is 46.7%-90.0%; Moreover, patients who have survived are usually left with severe disabilities[3]. It has been shown that the main reason for the high mortality and disability rate is the mass effect of intracranial hemorrhage and hematoma that causes damage to brain tissues and blood vessels, which leads to a series of pathological changes[4-9]. On the one hand, a large hematoma formed in a short period of time causes compression on surrounding brain tissues, consequently, leading to neurological deficiency and even cerebral herniation. Also, the degradation of hematoma produces a large amount of toxic degradation products such as cytokines, thrombin, hemoglobin, activated complements, which results in further decreased the local cerebral perfusion and worsen dysfunctions of metabolism and edema of the nerve cells, contributing to deformation and apoptosis of nerve cells and their axons. As a result, neurological dysfunction becomes irreversible. Up to date, no effective treatments are available for completely eliminating the neurotoxicity induced by the breakdown products of hematomas. Therefore, early hematoma clearance after hemorrhage can reduce not only the physical damage to the surrounding brain tissue, but also the chemical damage caused by breakdown products of hematoma and, thus, is an effective approach to improve the prognosis of patients with cerebral hemorrhage. Meanwhile, early hematoma clearance provides the basis for surgical treatment of hypertensive hemorrhage, particularly, for surgical treatment of hematoma with the volume greater than 30 mL and for patients with a space-occupying lesion. Consensus has been reached that surgery is an important treatment for hypertensive hemorrhage, and it has been shown that surgical treatment of hypertensive hemorrhage has an advantage over medical treatment[3,10-11]. Nevertheless, there is still controversial issue about the treatment for hematoma with a volume ranging from 15 mL to 30 mL between surgeons and physicians. The main consideration is whether the benefits of hematoma clearance over weight the surgery risk and unavoidably damages on brain tissues. Therefore, conservative treatment is an-

Table IV. Comparison of rebleeding rate between the two groups.

Groups	Rebleeding: cases (Rate %)
Conservative treatment (n=12)	3 (25.00%)
Neuronavigation operation (n=13)	4 (30.77%)
Statistic values	0.103
p	0.748

other choice. In spite of this, the development of stereotactic technique gradually changes traditional ideas about the treatment approaches, as the stereotactic technique is capable of achieving the precision in positioning of hematoma and provides guidance for puncture aspiration and drainage to remove the hematoma to the maximum extent, which consequently minimizes the surgical damage. It has been demonstrated that stereotactic puncture aspiration and drainage improved prognosis[12]. In the present work, we have confirmed the merits of imaging-guided neuronavigation in puncture aspiration and drainage of hematoma.

Currently, apart from the traditional surgical approaches such as standard large craniotomy, small bone window craniotomy, trepanation and drainage to make hematoma clearance, many new surgical approaches such as stereotactic puncture aspiration and drainage, neuroendoscopic-assisted hematoma clearance have emerged with the development of advanced technology and medical instruments. The advantages of these new approaches are minimal invasion and satisfactory clinical efficacy[13-15]. However, the majority of current research still focuses on studying hematoma volume greater than 30 mL. Therefore, in the present study, neuronavigation-assisted minimally invasive operation technique was applied for puncture aspiration and drainage of hematoma with volume ranging from 15 mL to 30 mL, which efficacy was further compared with conservative treatment.

Neuronavigation technique is a combination of stereotactic technique and digital scanning technology through high performance of computers, and it precisely three-dimensionally locates intracranial lesion in a real-time tracking manner[15]. Neuronavigation technique can create dynamic associations between virtual digital images and real anatomic structures of nervous system, which helps neurosurgeons to solve the problems of pre-operation virtual surgery planning and precise location of a lesion. Moreover, surgery trauma and complications can be reduced to the minimum level. Neuronavigation technique has been widely applied for treating the deep or small brain lesion or lesion in function areas of the brain. However, up to date, there is still lack of relevant systematic reports. Results of our initial study showed that minimally invasive puncture aspiration assisted under early neuronavigation could accurately guide a drainage catheter into the centre of a hematoma. Besides aspiration, injection of thrombolytic drugs (such as urokinase) into the hematoma is also a beneficial approach for post-surgery drainage, which can significantly improve the prognosis as well[17,18]. Compared with conservative treatment, neuronavigation has the following advantages: (1) No need to set up stereotactic frame before CT scan, which shortens pre-operation preparation and avoids risk factors such as increased blood pressure and breathe difficulty caused by neck bending during CT scan; (2) Accurately positioning targets: it can convert invisible targets into visible targets in a real-time tracking manner; (3) It is an easy and simple operation and it shortens the time for operation and anesthesia. All surgeries can be finished within one hour, consequently, reducing the risks during operation[19,20].

During treatment using neuronavigation technique, we gained the following experience: (1) Blind-end round silicon catheter with side holes could effectively prevent the brain tissues and blood vessels from damaging during puncture and, thus, avoided false images caused by the catheter when CT scan was re-checked post-surgery; (2) Frontal approach should be the choice of surgical incision approach, and the route for puncture aspiration via frontal approach is an intracranial area with the absence of the blood vessels. Although hematoma is closer to the cortex via infratemporal fossa approach, this approach increases blood supply of main arteries at injury side and the basal ganglion. Moreover, because the anteroposterior diameter of the majority of hematoma is greater than its horizontal diameter, frontal approach makes the side hole of catheter and the edge of hematoma equal, which allows the urokinase to exert its maximal effect and hematoma to be drained evenly. In contrast, at the early stage of two patients in, our study infratemporal fossa approach could not make hematoma to be drained evenly and consequently prolonged the duration of catherization; (3) Puncture target point should be chosen at the distal part of a hematoma. Drainage should be made by gravity. And aspiration should be performed gently and continuously with small negative pressure. The volume of aspiration should be one third or half of the hematoma volume. If it is too difficult to aspirate, operator should stop aspiration to avoid re-bleeding; (4) The position of navigation paste markers should be placed around hematoma lesion area with three-dimensional distribution. In order to make sure accuracy of registration, the number of markers in the

ipsilateral side should be greater than that of the contralateral side.

There is controversy about the clinical value for blood pressure control in hypertensive hemorrhage. The newest guideline of American Heart Association does not define that neither, and it only states that when systolic blood pressure reaches more than 200 mmHg or average artery pressure reaches up to more than 150 mmHg, blood pressure should be controlled actively[21]. Theoretically, lowering blood pressure can reduce hematoma; however, low blood pressure could increase ischemic damage to the tissues surrounding the hematoma. Although research has shown no correlation between the expansion of hematoma and already formed hematoma and other hemodynamic parameters, concerns about ischemia of the tissues surrounding hematoma often affect the active reduction of blood pressure during acute cerebral hemorrhage[22]. Nevertheless, poor prognosis was observed in the patients with continuous hypertension after hemorrahge[23]. Ohwaki et al[24] revealed that systolic blood pressure more than 160 mmHg was an indication for enlargement of hematoma. In the present report, blood pressure is not well control after rebleeding. Using PET scan, Powers et al[25] evaluated hemodynamic changes around hematoma in 14 patients with average artery pressure decreasing from 143 mmHg to 119 mmHg at the early phase of hemorrhage, and found that hemodynamic level was stable. A recent study also claimed that ultra-early basal ganglia intracerebral hemorrhage can remarkably reduce hematoma enlargement and cerebral edema and lower blood pressure[26]. This result demonstrated that lowering blood pressure was safe at the early stage of cerebral hemorrhage. Therefore, we controlled the blood pressure to approximate 160/90 mmHg after hemorrhage in the basal ganglion.

Conclusions

We demonstrated that neuronavigation operation had an advantage over the conservative treatment in terms of rapid hematoma clearance, shortening hospitalization and improving long-term prognosis; however, the number of cases is relatively small, and more cases are required to confirm indications for surgery and appropriate time for surgery using stratified randomization method.

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Conflict of Interest

The Authors declare that they have no conflict of interests.

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