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Endoscopic Surgery versus Minimal Puncture Drainage Surgery for Treatment of Supratentorial Intracerebral Hemorrhage

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ABSTRACT

AIM: To compare neuroendoscopy versus minimal puncture drainage for surgical treatment of supratentorial hypertensive intracerebral hemorrhage.

MATERIAL and METHODS: A total of 108 cases involving supratentorial intracerebral hemorrhage were retrospectively analyzed. In 30 cases, endoscopic surgery was performed, while 78 cases involved puncture surgery. We compared hematoma clearance rate, postoperative rebleeding rate, incidence of postoperative complications, operation duration, and Glasgow coma score seven days after surgery. Clinical data such as early postoperative rehabilitation time, Glasgow outcome score three months after surgery, and intensive care unit (ICU) stay were also compared between the two groups.

RESULTS: The results showed that endoscopic surgery was associated with a superior clinical therapeutic effect in hematoma clearance rates, GCS scores on postoperative day 7, the average ICU stay, early postoperative rehabilitation time and intracranial infection outcomes than minimal puncture drainage surgery for the treatment of supratentorial intracerebral hemorrhage ($p<0.05$). Three months after surgery, the favorable prognosis rate in the endoscopic treatment group was significantly higher than that in the craniotomy group [83.3% (28/34) vs. 61.5% (31/51), respectively; $\chi^2=4.698$, $p=0.030$]. In contrast, no significant differences in rebleeding, pulmonary infection, tracheotomy, secondary epilepsy, gastrointestinal hemorrhage, death in late postoperative period, or in baseline parameters were observed between the two groups ($p>0.05$).

CONCLUSION: Endoscopic surgery potentially represents a beneficial surgical procedure for treatment of supratentorial spontaneous intracerebral hemorrhage.

KEYWORDS: Intracerebral hemorrhage, Endoscopic surgery, Minimally invasive surgery, Efficacy

ABBREVIATIONS: ICH: Intracerebral hemorrhage, **NS:** Endoscopic surgery, **MIS:** Minimally invasive surgery, **CT:** Computed tomography, **GCS:** Glasgow coma scale, **GOS:** Glasgow outcome scale, **ICU:** Intensive care unit, **ANOVA:** Analysis of variance

INTRODUCTION

Hypertensive intracerebral hemorrhage is a dangerous condition which has a high incidence worldwide (17). In China, a recent study of 480687 participants found that 7672 were diagnosed with prevalent stroke (1596.0/100000 people) and 1643 experienced incident strokes (345.1/100000 person-years). Among incident stroke cases, 23.8% involved intracerebral hemorrhage. The most prevalent risk factor among stroke survivors is hypertension.

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Age-specific stroke prevalence in men aged ≥ 40 years is significantly greater than in women (22). Moreover, the median 30-day mortality rate after intracerebral hemorrhage is approximately 40% (18,20). Many survivors remain severely disabled following hypertensive intracerebral hemorrhage, and this can impose a huge burden on families and society (12).

To date, treatment of intracerebral hemorrhage involves medical treatment and surgical treatment. The latter includes hematoma puncture, craniotomy, endoscopic surgery, and other procedures. While traditional treatments are recognized, there remains a lack of consensus regarding standardized treatment (2,21,27). In recent years, an increasing number of studies have indicated that use of endoscopy to remove hematomas is less invasive and more effective (7,23).

In the present study, both safety and efficacy of neuroendoscopic surgery and traditional puncture drainage surgery for hematoma removal are compared. It is anticipated that the results obtained will provide a reference for clinical selections of treatment strategies for patients with hypertensive intracerebral hemorrhage.

MATERIAL and METHODS

Selection of Patients

A total of 108 patients with hypertensive intracerebral hemorrhage were admitted to the Department of Neurology and Neurosurgery of our Hospital between July 2014 and June 2019. Among these consecutively recruited patients who underwent endoscopy or puncture drainage randomly, 30 were treated with endoscopy and 78 were treated with puncture drainage. The latter group included 40 males and 38 females with an average age of 60 ± 8 years. Blood loss ranged from 32–60 ml (average, 41.74 ± 7.41 ml). Preoperative Glasgow coma scores (GCS) ranged from 7 to 13 points (average, 8.2 ± 1.3 points) and 63 patients had a history of hypertension. Meanwhile, the endoscopy group included 16 males and 14 females with an average age of 61 ± 7 years. Similar to the puncture drainage group, blood loss ranged from 35–60 ml (average, 43.12 ± 8.34 ml) and the preoperative GCS ranged from 7 to 12 points (average, 8.3 ± 1.2 points). A total of 25 patients had a history of hypertension. All of the family members in each group signed informed consent forms for diagnosis and treatment.

Inclusion and Exclusion Criteria

All of the patients in this study received standard management according to guidelines established by the American Heart Association/American Stroke Association Stroke Council (4) for treatment of spontaneous intracerebral hemorrhage (ICH). Inclusion criteria for this study were: (1) confirmation of unilateral supratentorial intracerebral hemorrhage (which could be accompanied by hematoma rupture into the ventricle) by computed tomography (CT); (2) basal ganglia hemorrhage > 30 ml; (3) subcortical hemorrhage > 30 ml and midline displacement > 5 mm; and (4) surgical treatment was performed within 6–24 h of onset of spontaneous ICH. Exclusion criteria for this study were: (1) intracerebellar hemorrhage; (2) intracranial vascular malformations, aneurysms, or intracerebral hemorrhage caused by brain trauma or brain tumor in patients older than 75 years; (3) cerebral hernia requiring standard large craniotomy; (4) patients with severe systemic diseases or coagulation disorders who could not tolerate surgery; (5) patients or their families who did not agree with surgery and did not sign the informed consent; (6) bleeding > 60 ml; or (7) a GCS score ≤ 6.

Research Methods and Evaluation Criteria

Both baseline and clinical data for the patients in each group were recorded and compared. The former included: gender, age, history of hypertension, blood loss, and bleeding site; while the clinical data examined included hematoma clearance rate, postoperative rebleeding rate, postoperative complication rate, operation duration, GCS score seven days after surgery, early postoperative recovery time, Glasgow outcome score (GOS) three months after surgery, and length of stay in an intensive care unit (ICU).

Preoperative blood loss and postoperative residual hematoma volume were calculated by performing a head CT with OsiriX 3-D imaging software and a multi-field formula. The latter included a calculation of blood loss or residual hematoma volume (ml) as follows: length (cm) × width (cm) × thickness (cm) / 2. Hematoma clearance rate (%) was calculated as: (preoperative hematoma volume - postoperative residual hematoma volume) / preoperative hematoma volume × 100%. A diagnosis of intracranial infection was based on published criteria, including clinical symptoms (fever, headache, vomiting), signs (body temperature > 38 °C, positive meningeal stimulation), abnormal laboratory examination (cerebrospinal fluid white blood cell count > 10×10^6/L, cerebrospinal fluid glucose < 2.25 mmol/L, protein content > 0.45 g/L), and/or a positive cerebrospinal fluid bacterial culture. Operation time was calculated as the time from scalp incision to completion of scalp suture. Both groups of patients were admitted to an ICU upon admission, and also after surgery. Early postoperative recovery time was defined as the time starting postoperatively to the beginning of rehabilitation.

Surgical Method

Traditional puncture drainage surgery

A coin was used to locate the hematoma by CT, determine X, Y, and Z coordinate values, determine puncture angle and depth of the hematoma center, and establish the center of the largest layer of the hematoma as the puncture target while avoiding blood vessels (e.g., the superficial temporal artery and the sylvian fissure). For the patients who underwent puncture drainage surgery, all were administered local anesthesia in a supine position with their head turned to the opposite side prior to surgery. Next, an incision was made in the scalp to remove a 5-mm diameter portion of the cranial pyramid of the skull. After puncturing the dura mater with a needle, the skull was drilled to a depth determined prior to the operation to puncture the hematoma. Dark red liquid was excreted and withdrawn with a syringe. A drainage tube and tee were subsequently fixed. On the second day, bleeding

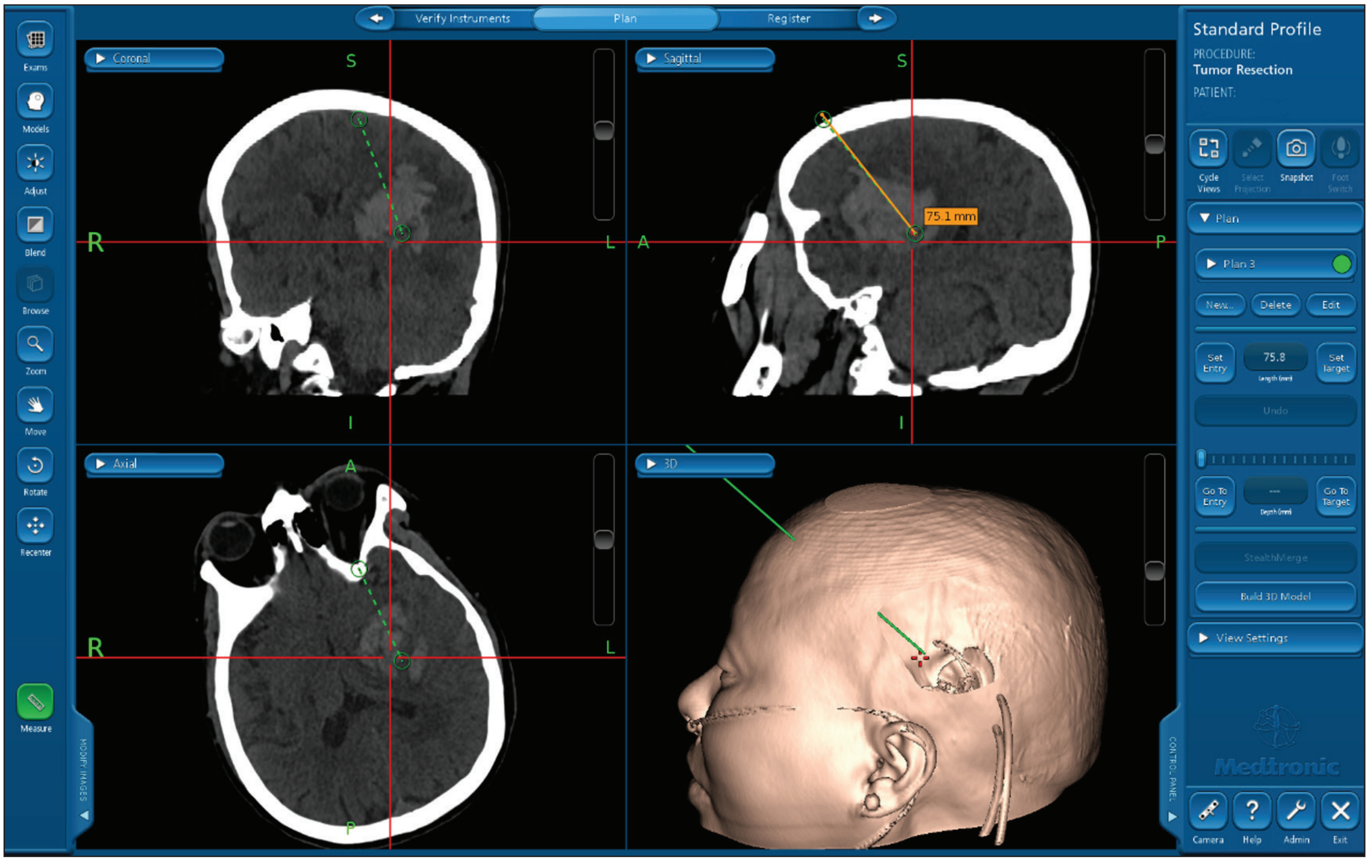

Figure 1: Preoperative neuronavigation was used to identify the location for hematoma puncture. Puncture direction and depth were also determined. Puncture depth was approximately 75 mm from the scalp to the bottom of the hematoma.

was confirmed to be controlled on CT reexamination. The patient then received an injection of urokinase (20–50 × 10^3 units), followed by open drainage for 2–4 h after clipping. Approximately 2–3 days later, hematoma volume was less than 15 ml and the puncture drain was withdrawn.

Endoscopic surgery

All of the patients who underwent endoscopic surgery were in a supine position under general anesthesia. A Mayfield head frame was not routinely used. In all cases, neuronavigation was used to determine puncture direction and depth (Figure 1). With the puncture point as the center, a straight incision approximately 4–5 cm in length was made parallel to the sagittal sinus (Figure 2). A milling cutter was used to create a bone window 3 cm in size. The dura mater was cut in a cross shape, with bipolar coagulation used to avoid cortical blood vessels. After local cortical brain tissue was electrocoagulated for several millimeters, a slight incision was made. For superficial hematomas, a 4–5 cm straight incision was made after positioning by navigation. A puncture was made according to the puncture direction and depth determined preoperatively. As described by Nagasaka et al. (16,26), when a minimally invasive brain surgery expander enters the hematoma, there may be a significant sense of breakthrough. We routinely punctured the bottom of the hematoma and then placed a transparent working sheath to a preset depth along

Figure 2: After determining the puncture point, a 4–5 cm straight parallel midline incision was made with the puncture point as the center.

the dilator (the puncture target was the first 5 mm of the most distal end of the hematoma). When the puncture extender was removed, a transparent working sheath was left. This clear working sheath served as a conduit for the next endoscopic procedure (Figure 3). The right hand held the aspirator and the left hand held the endoscope. Suction at 0° and 30° was used to aspirate the hematoma. The working sheath was rotated and retracted to allow the hematoma to flow into the working sheath and to be removed by using the slanted plane at the bottom of the transparent working sheath. Hemostasis was achieved with bipolar coagulation. The field was flushed with lactated Ringer's solution. In the hematoma cavity, the small hematoma on the cavity wall was not forcibly removed in order to prevent initiation of a new hemorrhage and damage of brain parenchyma (Figure 4). After the hematoma was removed, the working sheath was slowly rotated and removed. A gelatin sponge was applied to stop any bleeding. Subsequently, the dura mater was sutured, a connecting piece was used to fix the skull, and the scalp layers were sutured.

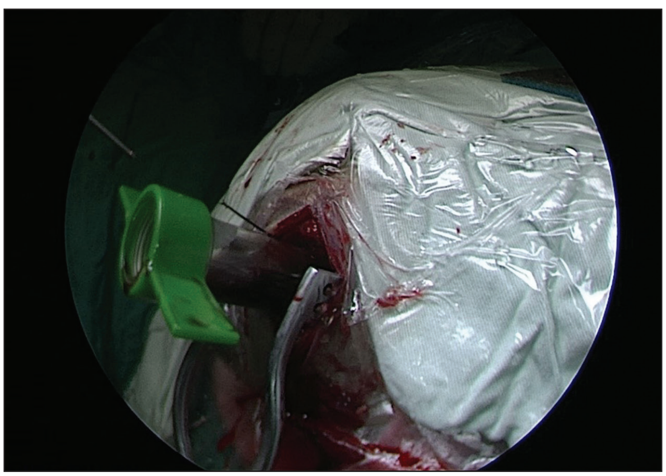

Figure 3: The thin-walled transparent working sheath of the expander was pulled out.

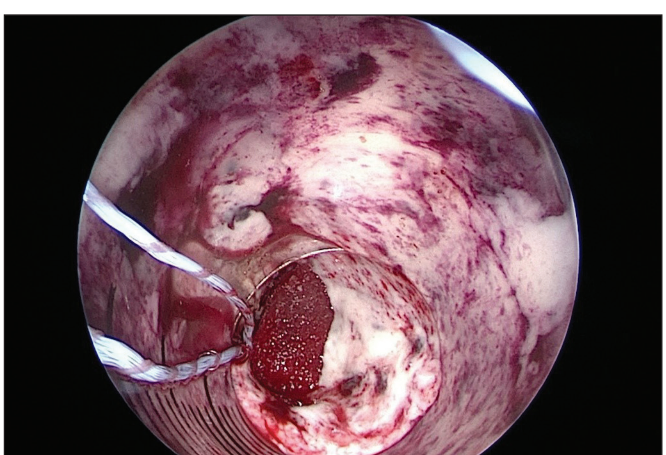

Figure 4: The hematoma wall, bleeding site, and proximal brain tissue were clearly visible during the neuroendoscopy procedure.

Clinical and Radiological Follow-up

All of the patients underwent a brain CT examination to assess residual hematoma size, rebleeding, and peripheral edema on postoperative days 1, 2, 3, 5, and 7. On the first and third post-operative days, hematoma clearance rates were examined. Rebleeding and other surgical complications were also monitored. For postoperative bleeding, a second operation was considered. When an intracranial infection was detected, anti-infection treatment was administered. When the patient's temperature returned to normal and the white blood cell count of the cerebrospinal fluid was $< 10 \times 10^6$/L, the patient was considered to be cured of the infection.

Patients were followed up on an outpatient basis or via telephone for three months. GOS scores were assigned: grade 1: death; grade 2: vegetative state; grade 3: severe disability sequelae; grade 4: moderate disability sequelae; and grade 5: able to take care of oneself. For grade 4 and 5, prognosis was good. In contrast, a poor prognosis was associated with grades 1–3. (Representative imaging data obtained during the follow-up period is presented in Figures 5, 6).

Statistical Analysis

Data analysis was performed with SPSS 19.0 software. The Kolmogorov-Smimov test was applied to normal measurement data. Measurement data exhibiting normal distribution were subjected to the Chi-square t-test, while measurement data which did not exhibit normal distribution were subjected to the rank-sum test (Mann-Whitney U-test). Counting data

Figure 5: Preoperative CT suggested intracerebral hemorrhage in the left basal ganglia.

were expressed as percentages. The Chi-square test and the Fisher exact probability method were used for comparisons among groups, while repeated measures analysis of variance (ANOVA) was used to compare each indicator at different time points. P-values less than 0.05 were considered statistically significant.

Figure 6: Postoperative CT showed satisfactory clearance of a hematoma. (Representative imaging data obtained during the follow-up period is presented in Figures 5 & 6 for a 63-year-old male patient with basal ganglia hemorrhage. Upon experiencing weakness in a limb for 7 h, the patient was admitted to the Department of Neurology at our hospital. Puncture drainage was performed. A CT reexamination showed the hematoma had increased in size. The patient was subsequently transferred to the Department of Neurosurgery for further endoscopic treatment.)

RESULTS

Baseline comparisons

There were no statistically significant differences in hematoma location, preoperative blood loss, previous history of hypertension, age, gender, preoperative GCS score, or among other parameters between the endoscopic and puncture treatment groups (p>0.05) (Table I).

Comparison of Surgery Parameters and Complications

All of the patients in this study underwent surgery within 6–24 hours of the onset of supratentorial hypertensive intracerebral hemorrhage. All of the patients were admitted to the ICU after surgery. The mean ICU stay was 4.3 ± 0.7 days in the endoscopic treatment group and 7.4 ± 0.6 days in the traditional puncture treatment group (p<0.01). The mean duration of surgery (from skin incision to scalp suture) was significantly longer in the endoscopic group (82.44 minutes) compared with the traditional craniotomy group (40.11 minutes) (p<0.05). A CT reexamination on the first postoperative day showed that the hematoma clearance rate in the endoscopic group (86.70%) was also higher than that in the puncture group (25.36%) (p<0.05), when patients exhibiting rebleeding were excluded from both groups. When CT scans were repeated on the third postoperative day, the hematoma clearance rate in the endoscopic group (86.70%) was higher (p<0.05) compared to the puncture group (70.23%). Patients with rebleeding were also excluded from both groups for these repeated CT scans. For patients exhibiting ventricular hemorrhage, extracentricular drainage was necessary. This drainage was subsequently extracted 4–6 days after surgery. None of the inserted drains became occluded and all drained successfully. However, in the traditional craniotomy group, 5 patients (6.4%) presented re-bleeding after surgery and underwent a second operation (craniotomy). In the endoscopic group, 1 patient (3.3%) presented re-bleeding on CT 10 h after surgery. The latter patient's family refused to approve a second operation and the patient died during follow-up. However, there was no significant statistics difference between the two groups regard to re-bleeding (p>0.05). Meanwhile, 2 patients (6.6%) in the

Table I: Clinical Baseline Parameters

		NS group (n = 30)	MIS group (n = 78)	T/χ2	p
Age		61.32 ± 12.43	62.45 ± 12.29	-0.427	0.671
Hypertension		25 (83.3%)	63 (80.7%)	0.538	0.463#
man		16 (53.3%)	40 (51.3%)	0.037	0.848
	Putamen	19 (63.3%)	47 (60.3%)		
Location	Thalamus	7 (23.3%)	18 (23.1%)	0.192	0.908#
	Subcortical	4 (13.3%)	13 (16.7%)		
Ventricular hemorrhage		6 (20%)	17 (21.8%)	0.042	0.838
Hematoma volume		43.12 ± 4.34	41.74 ± 4.41	1.463	0.146
Preoperative GCS		8.23 ± 2.23	8.22 ± 2.31	0.020	0.984

***#:** Continuity correction*

endoscopy group and 9 patients (11.5%) in the puncture group died due to various complications during follow-up at 90 days post-surgery (p>0.05). There were no early deaths (e.g., within 7 days of surgery) in either group (1 abandoned patient with excluded endoscopy). Among the 11 deaths that occurred, 9 involved patients > 65 years of age and 9 patients had a history of hypertension. Among the patients in the endoscopy group (n=6) and the puncture group (n=30) who underwent tracheotomy (p>0.05), there were no significant differences in the incidence of pulmonary infection, digestive system complications, or epilepsy (p>0.05). Intracranial infection occurred more common in the puncture group than in the endoscopy group (e.g., 18 cases (23.1%) vs. 2 cases (6.6%), respectively), and this difference was significant (p<0.05). Furthermore, GCS scores after 1 week increased from 8 to 10 in the endoscopy group and from 8 to 9 in the conventional craniotomy group (p<0.05) (Table II).

Prognostic Ratio

Good prognosis was observed in 28 cases (83.3%) in the endoscopy group and in 31 cases (61.5%) in the craniotomy group. This difference was statistically significant (Chi-square =4.698; p=0.030) (Table III).

DISCUSSION

To date, treatment of intracerebral hemorrhage remains controversial (2). With advances in medical technology and the development of minimally invasive treatments for intracranial hematomas, a greater number of hospitals have introduced endoscopic treatments for intracerebral hemorrhage (7,13). Auer et al. were the first to treat intracerebral hemorrhage endoscopically (1). In their study, conservative medical management of intracerebral hemorrhage was associated with a mortality rate of 70%, whereas endoscopic management had a mortality rate of 30% (1).

Brain damage after intracerebral hemorrhage occurs due to the toxic effects of blood and mechanical compression (11). The main goal of surgical treatment is hematoma removal in order

Table II: Comparison of Surgery Parameters and Complications for Endoscopic (NS) and Conventional Craniotomy (MIS) Treatments of Intracerebral Hemorrhage (X ± SD)

	NS group (n=30)	MIS group (n=78)	T/χ2	p
Evacuation rate on day 1 (%)	86.70 ± 2.23 (excludes rebleeding)	25.36 ± 7.22 (excludes rebleeding)	45.587	**< 0.001**
Evacuation rate on day 3 (%)	86.70 ± 2.23 (excludes rebleeding)	70.23 ± 8.52 (excludes rebleeding)	10.424	**< 0.001**
ICU stay (days)	4.3 ± 0.7	7.4 ± 0.6	-22.943	**< 0.001**
Postoperative recovery time	5.2 ± 0.6	9.2 ± 0.4	-40.181	**< 0.001**
Operation time (min)	82.44 ± 5.65	40.11 ± 11.45	19.324	**< 0.001**
Rebleeding (n/%)	1 (3.3%)	5 (6.4%)		1.000*
Death in late (%) postoperative period	2 (6.6%)	9 (11.5%)	0.172	0.679#
GCS after surgery 7 day	10.23 ± 1.23	9.12 ± 1.43	3.749	**< 0.001**
Tracheotomy (%)	6 (20%)	30 (38.5%)	3.323	0.068
Pulmonary infection (%)	27 (90%)	75 (96.2%)		0.345*
Gastrointestinal bleeding (%)	4 (13.3%)	8 (10.3%)	0.013	0.909#
Infectious meningitis (%)	2 (6.7%)	18 (23.1%)	3.867	0.049
Epilepsy (%)	5 (16.7%)	14 (17.9%)	0.025	0.875

***** *Fisher's exact probability method; # continuity correction.*

Table III: Follow-up Data for Endoscopic (NS) and Conventional Craniotomy (MIS) Treatment Groups

Group	Poor prognosis			Good prognosis		χ2	p
	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5		
NS (n=30)	3	1	1	7	18	4.698	**0.030**
MIS (n=78)	12	6	12	15	33		

to reduce cytotoxic reactions and surrounding brain edema, thereby improving regional blood flow (10,19,24). However, negative side effects can develop, including additional trauma caused by the hematoma removal procedure. Increased risks of rebleeding and intracranial infection have also been associated with hematoma removal (9). Theoretically, surgical removal of a hematoma will not only reduce the mass effect of a hematoma and improve local ischemia, but it will also reduce indirect damage caused by toxic substances released by a decomposing hematoma. This can potentially improve the survival rate and quality of life of patients and improve their prognosis. Previous studies have suggested that surgical outcome is not affected by hematoma clearance (8). However, more recent studies have shown that hematoma clearance rate is significantly associated with prognosis, and endoscopic surgery has a significantly higher hematoma clearance rate than puncture surgery (16). Consequently, endoscopic surgery has been found to have a better prognosis than traditional puncture surgery (5,14,25), and the present data support this conclusion. Furthermore, it has been observed that both toxic and compressive effects disappear earlier following endoscopic surgery (5).

Intracerebral hemorrhage mainly occurs in the thalamus and basal ganglia, and most of the hematoma was the longitudinal axis. Traditionally, a craniotomy hematoma is removed through a subcortical hematoma (15). As a result, relatively large operation-induced injuries can occur (6,15). In contrast, endoscopic surgery protects tracts along the longitudinal columns of white matter fibers and hematomas, thereby reducing secondary brain injury (6). Alternatively, a minimally invasive puncture and drainage hematoma treatment involves less trauma. However, repeated injections of urokinase are required after surgery, and these can increase the risk of intracranial infection and other adverse side effects (14). These patients are also subject to a more extended monitoring time in an ICU, a prolonged tracheotomy in an ICU setting, as well as an extended postoperative rehabilitation start time (3). However, accumulating evidence further suggests that stroke rehabilitation time starts earlier and better functional recovery is observed, especially in patients who exhibit more severe dysfunction(16). In the present study, the endoscopy group was characterized by lower intracranial infection rates, a shorter ICU monitoring time, a lower postoperative tracheotomy rate, a shorter postoperative recovery time, and better patient prognosis.

A neuroendoscopic working sheath is a key instrument in neuroendoscopy procedures (14,16). During surgery, the working sheath can be rotated and a peripheral hematoma can be squeezed into the surgical field by gravity. As a result, a large extent of a hematoma can be removed while traction injury to brain tissue is reduced. In addition, smaller bleeding points are more readily observed and this can prevent damage to parenchymal structures (6). Compared with puncture surgery, endoscopic surgery is more complicated and it requires higher intra-operative requirements. Hemostasis has also remained an issue for surgeons due to space constraints. Some scholars perform coagulation hemostasis by introducing a current of monopolar coagulation into the suction tube, or they take out the suction device and then perform coagulation hemostasis via deep penetration of the bipolar into the working sheath (26). In our experience, the hematoma should not be blindly removed. Once the responsible artery is found during surgery, electrocoagulation should be performed before suctioning blood. For bleeding spots which cannot be judged or when bleeding is heavy, suction can be used to remove the gelatin sponge and cotton piece used to compress bleeding. After bleeding is reduced, the gelatin sponge and cotton piece should immediately be taken out to judge the relevant responsible vessel. Bipolar coagulation should subsequently be used to stop the bleeding. Secondly, during the endoscopy procedure, it is critical to puncture the bottom of the hematoma center. Due to the puncture being made from the forehead, the puncture distance is long. During intraoperative surgery, if the hematoma location that is determined preoperatively is not accurate, or if the puncture direction slightly deviates, the bottom of the hematoma center is not punctured. As a result, the direction of the working sheath needs to be adjusted during surgery, and this can cause secondary damage to surrounding brain tissue and reduce the hematoma clearance rate. In the present study, the puncture direction in one patient was slightly medial and a deep puncture was made. As a result, brain tissue was squeezed in the direction of the medial basal ganglia thalamus, and this compressed the ipsilateral oculomotor nerve. As a consequence, asymmetric pupil dilation was observed following surgery.

To date, surgical indications and procedures for treatment of intracerebral hemorrhage are not standardized. However, the data presented here indicate that complication and mortality rates associated with minimally invasive endoscopic hematoma evacuation are acceptable compared to minimally invasive puncture procedures. Moreover, despite the limitations that our data derive from a retrospective analysis of a limited number of patients from a single center, the present results support the use of an endoscopic surgical approach for treatment of supratentorial spontaneous intracerebral hemorrhage. Thus, further studies of this approach are warranted.

CONCLUSION

Endoscopic Surgery hematoma evacuation may be a good alternative surgical method for treating supratentorial spontaneous intracerebral hematomas.

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