Observational Study

Medicine®

OPEN

# Comparison of keyhole endoscopy and craniotomy for the treatment of patients with hypertensive cerebral hemorrhage

Guoqing Sun, PhD[a], Xiaolong Li, PhD[a], Xiangtao Chen, PhD[b], Yuhai Zhang, PhD[a], Zhen Xu, PhD[c,*]

**Abstract**

By comparing the intraoperative and postoperative conditions under different surgical methods, namely, keyhole endoscopy and craniotomy, we aim to provide more reasonable surgical treatment for patients with hypertensive cerebral hemorrhage.

Eighty-nine patients with cerebral hemorrhage at Rizhao People's Hospital between January 2015 and December 2016 were analyzed retrospectively. Patients were assigned to the keyhole endoscopy group and the craniotomy group. The intraoperative (the duration of operation, operative blood transfusion and loss, and hematoma clearance rate) and the postoperative parameters (death rate, rebleeding rate, edema, and postoperative activity of daily living [ADL] scores) of the 2 groups were compared.

Compared with the craniotomy group, the keyhole endoscopy group exhibited decreases in mean blood loss ($P < .05$, 180 ± 13.6 mL vs 812 ± 35.2 mL), blood transfusion ($P < .05$, 0 mL vs 480 ± 13.6 mL), the average surgical duration of operation ($P < .05$, 113 ± 14.3 minutes vs 231 ± 26.1 minutes), and the severe edema rate ($P < .05$, 10.9% vs 72.1%) and increases in the average hematoma clearance rate ($P < .05$, 95.6% vs 82.3%) and postoperative ADL scores ($P < .05$, 85.2% vs 39.0%). Neither the death rate ($P > .05$, 4.3% vs 4.7%) nor rebleeding rate ($P > .05$, 2.2% vs 2.3%) showed any obvious changes.

Keyhole endoscopy for the treatment of hypertensive intracerebral hemorrhage has the advantages of minimal trauma with good effects, and its main reason for short operation time, reduced bleeding, and high hematoma clearance rate is the "brain-hematoma" pressure gradient. Use of the intraoperative micropull technique and removal of intracerebral hematoma in the shortest time possible are critical factors contributing to the high ADL scores in the keyhole endoscopy group. However, further validation on a larger sample size is required.

**Abbreviations:** ADL = activity of daily living, HICH = hypertensive cerebral hemorrhage.

**Keywords:** "brain-hematoma" pressure gradient, craniectomy, endoscope, hypertensive cerebral hemorrhage, keyhole, micropull technique

## 1. Introduction

Hypertensive intracerebral hemorrhage (HICH) is a common disease treated by neurosurgery departments. The incidence of intracerebral hemorrhage in China is as high as 50.6 to 80.7 per 100,000, accounting for 18.8% to 47.6% of all acute cerebrovascular diseases.[1] The mortality and disability rates of intracerebral hemorrhage are very high, and most survivors have impairments.[2–5] Minimally invasive endoscopic techniques have the advantages of reduced trauma, fewer complications, and better curative effects. We retrospectively analyzed 89 cases of intracerebral hemorrhage treated from January 2015 to December 2016 and conducted a comparative study of keyhole endoscopy and craniotomy to examine the advantages and disadvantages of both methods to provide more rational individualized surgical treatments for patients with HICH.

Editor: Bernhard Schaller.

Funding: Research Support Fund for Teachers of Jining Medical University, 2017: No. JY2017FS031.

The authors have no funding and conflicts of interest to disclose.

[a] Department of Neurosurgery, Rizhao Peoples Hospital Affiliated with Jining Medical University, [b] Department of Neurosurgery, Rizhao Central Hospital, [c] Department of Neurosurgery, Rizhao People's Hospital Affiliated with Jining Medical University Shandong Province, China.

[*] Correspondence: Zhen Xu, Department of Neurosurgery, Rizhao People's Hospital Affiliated with Jining Medical University, Rizhao 276826, Shandong Province, China (e-mail: sungq.1234@163.com).



Medicine (2019) 98:2(e14123)

Received: 4 July 2018 / Received in final form: 17 December 2018 / Accepted: 20 December 2018

http://dx.doi.org/10.1097/MD.0000000000014123

## 2. Materials and methods

### 2.1. Ethics

This study was approved by the Medical Ethical Committee of Rizhao People's Hospital Affiliated with Jining Medical University. Written informed consent was obtained from all patients.

### 2.2. Clinical materials

Head computed tomography (CT) was used to diagnose cerebral hemorrhage. Patients with unrelated causes of bleeding such as intracranial aneurysm, intracranial arteriovenous malformation, and other tumors were excluded, as were those with cerebral hernia. Patients whose supratentorial hematoma was >30 mL and who were treated with surgery within 24 hours after hospital admission were enrolled as research subjects. There were 46 cases in the keyhole endoscopy group, including 26 males and 20 females with a mean age of (50.3 ± 7.1) years. The average preoperative hematoma volume was (47.2 ± 5) mL, the GCS score was (8.7 ± 2.9), 28 cases had basal ganglia hemorrhage, 13 cases had hemorrhage in the extracapsular zone, and 5 cases had cerebral lobe hemorrhage. There were 43 cases in the craniotomy group, including 21 males and 22 females with a mean age of (48.9 ± 6.5) years. The average preoperative hematoma volume was (46.8 ± 7.6) mL, the GCS score was (8.6 ± 3.1), 24 cases had basal ganglia hemorrhage, 15 cases had hemorrhage in the extracapsular zone, and 4 cases had cerebral lobe hemorrhage. Before surgery, the general situations of the 2 groups of patients were compared, and the difference was not statistically significant ($P > .05$).

### 2.3. Surgical method

In the keyhole endoscopy group, as shown in Figure 1A, the keyhole position was established according to the hematoma location, the milling cutter formed a circular bone window approximately 2 to 2.5 cm in diameter, a brain needle was inserted into the hematoma center, and part of the hematoma was extracted to reduce intracranial pressure. A cortical fistula approximately 0.5 cm in diameter was made parallel with the direction of the brain needle puncture, then sterile X-ray film was spun into a column and inserted into the fistula. Therefore, a working channel close to the size of the bone window was formed by self-expansion and fixation of the bone window (Fig. 1A). Then, the endoscope was placed, the hematoma was removed via suction, and bipolar electrocoagulation was used to stop bleeding (Fig. 1B). When eliminating the hematoma, the surgeon needs to operate with both hands; the left hand holds the endoscope, and the right hand manipulates the suction to remove the hematoma. When the bleeding was stopped by bipolar electrocoagulation, a 2-person 3-hand operation mode was employed: the assistant held endoscope, and surgeon used the left hand to suction and the right hand to stop the bleeding. After eliminating the hematoma, the sleeve was shrunken and removed, the brain tissue around the channel retracted (Fig. 1C), the dura mater was sutured, and a connector was used to fix the bone flap.

In the craniotomy group, a modified pterion approach was employed in the basal ganglia region, and the size of the bone window was approximately (5–6) cm × (6–8) cm. The lateral cleft was separated under the microscope to expose the cortex of the insula and to make a cortical fistula. Then, in the hematoma cavity, the brain spatula was adjusted such that the hematoma could be removed without touching the surrounding brain parenchyma, and bipolar electrocoagulation was used to stop the bleeding. In instances where the hemorrhage was located on the surface of the brain lobe, such as the occipital lobe or frontal lobe, a horseshoe or coronary incision was employed, and the craniotomy was performed according to the location of the hematoma. A cortical fistula was used to access the hematoma cavity, upon which the hematoma was removed by pulling with a brain spatula. When closing the crania, loose suturing of the dura and decompressive craniectomy were performed based on the patient's condition.

### 2.4. Operation evaluation

Intraoperative evaluation was conducted with 4 aspects for statistical comparative analysis: duration of operation (including total operation time, time for craniotomy and closing the crania, and time for hematoma removal), blood loss volume during operation, blood transfusion volume, and the hematoma clearance rate, which was mainly calculated based on the 24-hour postoperative CT examination (residual hematoma volume/total hematoma volume).

### 2.5. Postoperative evaluation

Postoperative evaluation was also reflected in 4 aspects: death rate, rebleeding rate, postoperative cerebral edema, and activity of daily living (ADL) scores. Twenty-four hours after surgery, a CT scan was performed, and the maximum diameter of the edema (denoted by D) was measured at the maximum level of edema. The degree of cerebral edema was graded as follows. Level 0: $D = 0$; Level 1, $D < 2$ cm; Level 2, $2\text{ cm} < D < 4$ cm; and Level 3, $D > 4$ cm. In addition, Levels 0 and 1 were considered mild edema, whereas Levels 2 and 3 were considered severe edema. The postoperative follow-up was performed 6 months after surgery, and ADL was employed for clinical efficacy. Patients with an ADL grades I to III had a good prognosis, whereas the patients with an ADL grades IV- and V had a poor prognosis.

### 2.6. Statistical methods

Using SPSS 19.0 for statistical analysis, measurement data that were normally distributed are denoted by $x \pm s$ and were

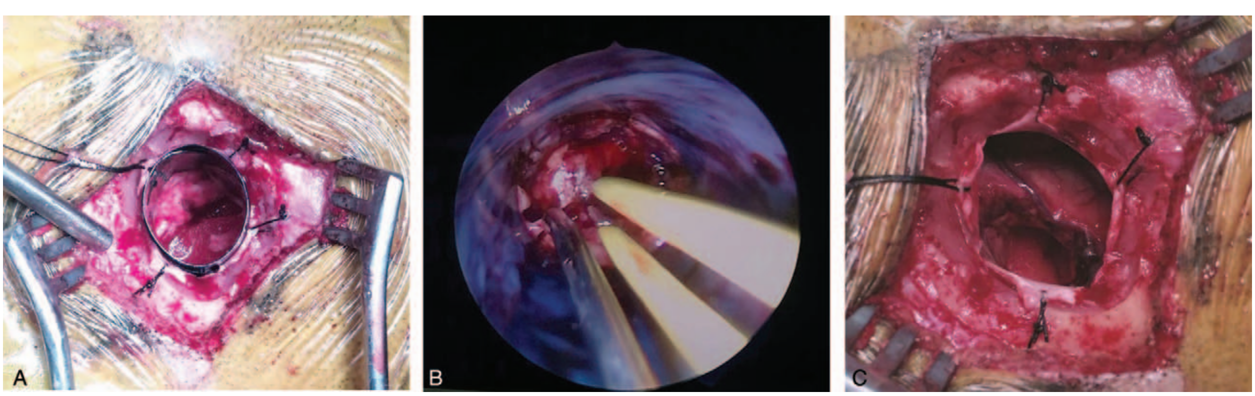


Figure 1. The surgical procedure of the keyhole endoscopy group. (A) Aseptic film was spun into a column and then inserted into the cortical fistula cavity with a homemade cannula. The homemade cannula expanded by elasticity, and its degree of expansion is limited by bone window; thus, the endoscopic working channel approximately the size of the bone window was formed. (B) The intracerebral hematoma was slowly extracted. Bipolar electrocoagulation was used to stop bleeding. (C) At the end of surgery, the homemade channels were removed, the brain tissue around the channel retracted, and the cortical fistula diameter was approximately 1 cm.

Table 1

Intraoperative comparison of the 2 patient groups.

| Groups | Mean operative time, min | Mean time for craniotomy, min | Mean time for removal of hematoma, min | Average intraoperative blood loss, mL | Average intraoperative blood transfusion, mL | Average hematoma clearance rate, % |
|---|---|---|---|---|---|---|
| Keyhole endoscopy group | 83 ± 4.3 | 38 ± 2.3 | 65 ± 6.8 | 180 ± 13.6 | 0 | 95.6 |
| Craniotomy group | 132 ± 6.1 | 113 ± 13.4 | 125 ± 11.5 | 812 ± 35.2 | 480 ± 13.6 | 82.3 |
| Chi-squared test | $\chi^2 = 173.39$ $P < .01$ | $\chi^2 = 170.46$ $P < .001$ | $\chi^2 = 33.15$ $P < .01$ | $\chi^2 = 305.85$ $P < .001$ | $\chi^2 = 25.69$ $P < .01$ | $\chi^2 = 53.97$ $P < .001$ |

compared with the *t*-test. Enumeration data were tested by the Chi-squared test. $P < .05$ was considered statistically significant.

## 3. Results

### 3.1. Intraoperative situation

Compared with the craniotomy group, the keyhole endoscopy group had less intraoperative blood loss ($P < .05$, 180 ± 13.6 mL vs 812 ± 35.2 mL) and a shorter mean operative time ($P < .05$, 113 ± 14.3 minutes vs 231 ± 26.1 minutes). Craniotomy took less time in the keyhole endoscopy group compared with the craniotomy group ($P < .001$, 38 ± 2.3 minutes vs 113 ± 13.4 minutes), hematoma removal also took less time in the keyhole endoscopy group compared with the craniotomy group ($P < .01$, 65 ± 6.8 minutes vs 125 ± 11.4 minutes). The keyhole endoscopy group also had a higher average hematoma clearance rate compared with the craniotomy group ($P < .05$, 95.6% vs 82.3%). Furthermore, the keyhole endoscopy group required no intraoperative blood transfusions; in contrast, the average blood transfusion volume was 480 + 13.6 mL in the craniotomy group (Table 1).

### 3.2. Postoperative situation

Compared with the craniotomy group, the keyhole endoscopy group exhibited a less severe edema rate ($P < .05$, 10.9% vs 72.1%) and a higher rate of good prognosis based on ADL scores ($P < .05$, 85.2% vs 39.0%). However, no significant differences were observed in the death and rebleeding rates, as neither the death rate ($P > .05$, 4.3% vs 4.7%) nor the rehemorrhage ratio ($P > .05$, 2.2% vs 2.3%) were obviously altered (Table 2).

## 4. Discussion

The HICH has the characteristics of high morbidity, high mortality and high rate of disability. According to Rincon, the natural mortality rate within 30 days after HICH is approximately 45%.[6] Therefore, it is imperative to remove intracerebral hematoma in the shortest time possible to relieve pain, reduce intracranial pressure, and preserve neurological function to the utmost extent to create favorable conditions for the recovery of brain function.[7–9]

Currently, there are many surgical treatments for cerebral hemorrhage, most of which are empirical treatments at medical centers; however, no consensus on the optimal procedure has been reached.[10] Common surgical methods, such as trepanation and drainage, craniotomy evacuation of hematoma, and neuroendoscopic treatment for cerebral hemorrhage, have their own advantages and disadvantages and respective indications for adaptation.[11,12] A meta-analysis of 12 RCTs suggested that minimally invasive surgeries provide more benefit than do other treatments in appropriate patients with HICH.[13] However, some studies showed that minimally invasive surgical procedures did not improve the long-term outcomes.[14] Keyhole endoscopy for hematoma removal comprises the combination of microneurosurgical and endoscopic techniques, which enable this procedure to produce less trauma, absorb the hematoma directly, provide good lighting and a clear image with direct vision of the site, achieve better surgical effects with a shorter operation time, reduce the amount of hemorrhage during surgery, require no blood transfusion, and elicit a high postoperative hematoma removal rate, small postoperative edema area (Fig. 2A) compared with the craniotomy group (Fig. 2B), low postoperative rebleeding rate and better postoperative recovery of neurologic function.

Keyhole endoscopy offers a number of advantages. First, the procedure has shorter operating time, leads to less bleeding, and requires only simple technical manipulations during craniotomy and closing of the cranium, which greatly helps to reduce the incidence of various complications. Second, the use of a small bone hole approximately 2 cm in diameter can minimize the exposure of brain tissue to the external environment under the principle that no exposure is the best protection for brain tissue. Third, the "brain-hematoma" pressure gradient formed during this procedure allows for easy removal of the hematoma and thus a shorter operation time. The space occupying effect of cerebral hemorrhage makes the pressure of the hematoma higher than that of the brain tissue and forces the surrounding brain tissue to shift during postcerebral hemorrhage (Fig. 3A). But in the process of the keyhole endoscopic surgery, the hematoma in the endoscopic

Table 2

Comparison of 2 groups of patients in postoperative situation.

| Groups | Death rate | Rebleeding rate | Severe edema rate | Rate of good prognosis in ADL |
|---|---|---|---|---|
| Keyhole endoscopy group | 4.3% | 2.2% | 10.9% | 85.2% |
| Craniotomy group | 4.7% | 2.3% | 72.1% | 39.0% |
| Chi-squared test | $\chi^2 = 419.48$ $P > .05$ | $\chi^2 = 347.37$ $P > .05$ | $\chi^2 = 11.25$, $P < .05$ | $\chi^2 = 22.37$, $P < .01$ |

ADL = activity of daily living.

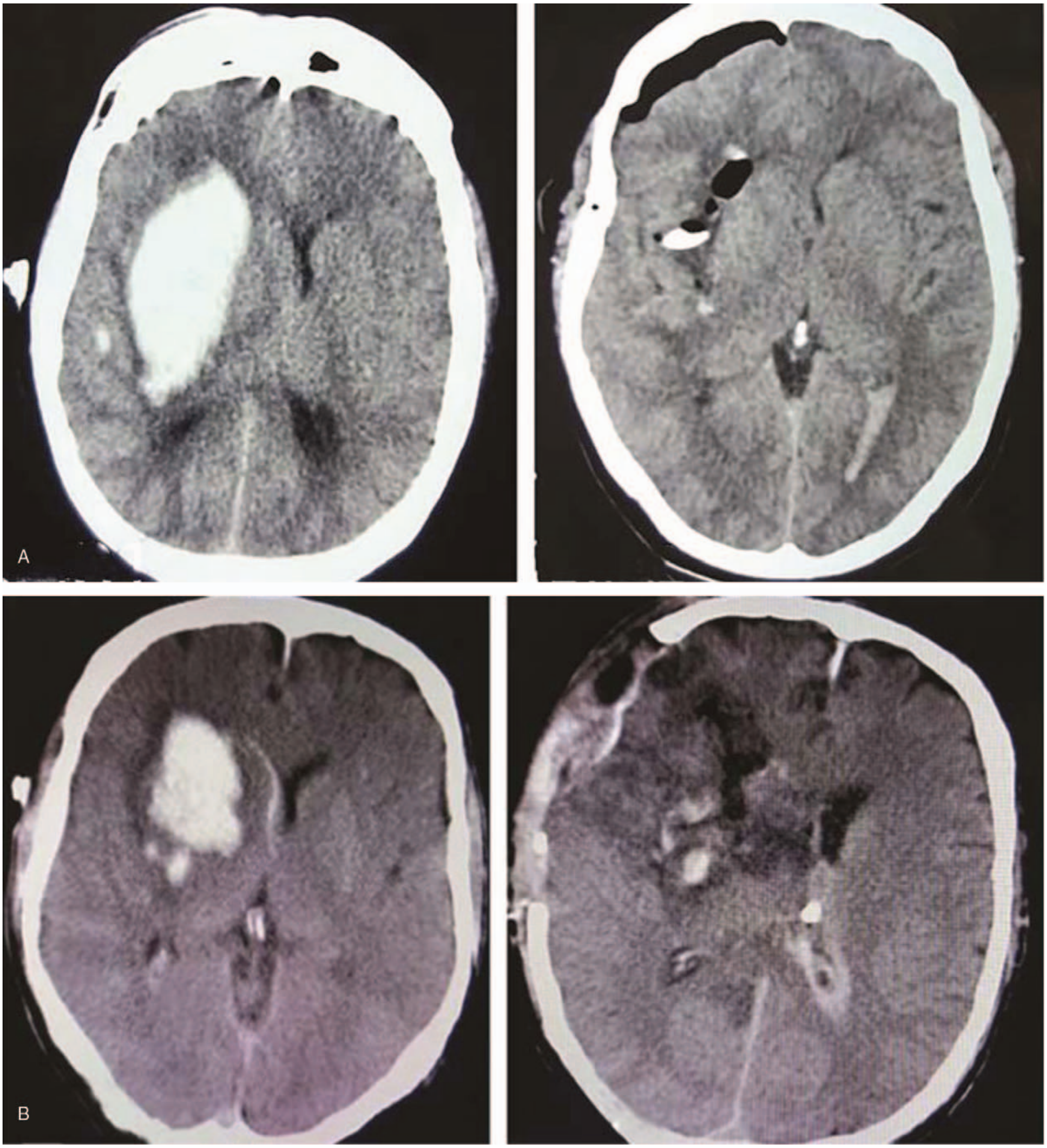


**Figure 2.** Comparison of postoperative brain edema between the keyhole endoscopy group and the craniotomy group. (A) The volume of the hemorrhage in the right basal ganglia region is 60 mL, the hematoma is completely cleared, and the degree of cerebral edema is Level 0. (B) The volume of hemorrhage in the right basal ganglia region is 45 mL, the hematoma is completely cleared, and the degree of cerebral edema is Level 3.

channel has negative pressure relative to other hematomas and brain tissue, brain tissue retraction forces the intracerebral hematoma to shift into the visible channel (Fig. 3B), and various angles of the endoscope can be used to observe hematoma clearance[15]; with high definition and high-power imaging, endoscopy permits surgery with a direct line of sight. The hematoma shifts toward the endoscopic channel automatically due to the "brain-hematoma" pressure gradient and without the use of a brain spatula or other devices to manipulate brain tissue. As a result, intraoperative micropulling can be achieved, thereby minimizing damage to the brain tissue while increasing the hematoma clearance rate. By contrast, craniotomy can cause the brain tissue to distend into the extracranial area under the influence of the pressure difference caused by intracerebral hematoma. In addition, a "brain-hematoma" pressure gradient cannot form after completion of a cortical fistula (Fig. 3C); therefore, the hematoma cannot fully retract and becomes more challenging to remove. Instead of retraction and removal, the hematoma can only be accessed by using a brain spatula to pull the brain tissue, leading to prolonged operating times, low hematoma clearance rates, and brain tissue damage caused by excessive stretching.

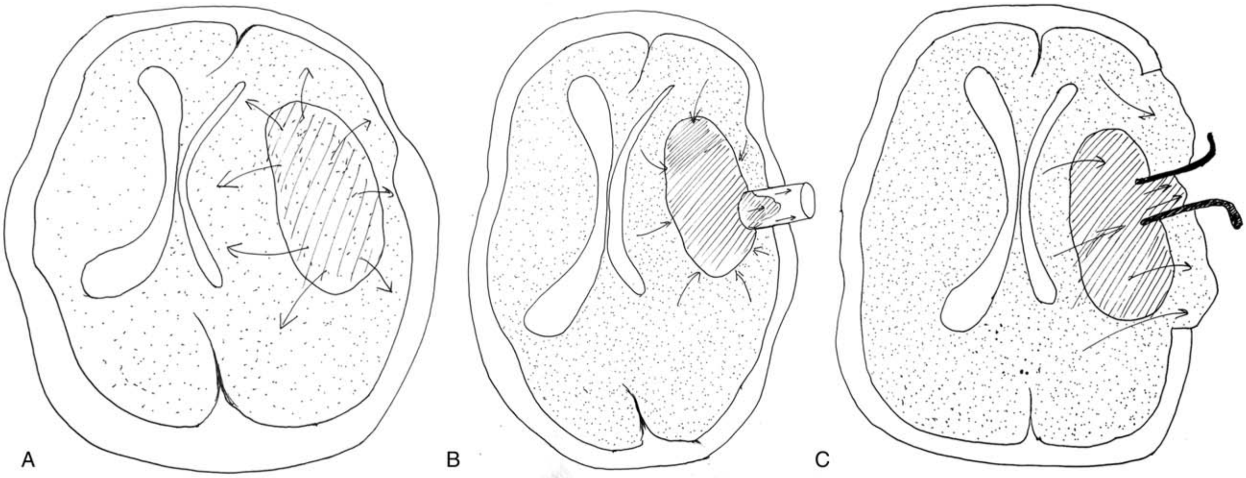


**Figure 3.** Variation diagram of the "brain-hematoma" pressure gradient under three conditions: postcerebral hemorrhage, keyhole endoscopy and craniotomy, where the arrows represent the direction of the pressure shift of the brain tissue and hematoma. (A) The space occupying effect of cerebral hemorrhage makes the pressure of the hematoma higher than that of the brain tissue and forces the surrounding brain tissue to shift until the pressure of the hematoma equals that of the brain tissue. (B) In the keyhole endoscopy group, the hematoma in the endoscopic channel has negative pressure relative to the remaining hematoma and brain tissue, thus forming a pressure gradient of "brain-hematoma-endoscopic channel." Thus, the brain tissue further retracts, forcing the intracerebral hematoma to shift into the work channel area, and hematoma removal can be completed under synthetic action without any extraneous tissue exposure. (C) In the craniotomy group, after removing the flap and opening the dura, because of the pressure difference of "distant brain-hematoma-brain tissue around bone window," some brain tissue bulged out from bone window under the influence of brain tissue pressure and hematoma pressure, significantly decreasing the brain tissue pressure. Thus, in the process of hematoma removal, the pressure difference of "brain-hematoma" hardly forms. The hematoma does not retract and is not easy to remove. The only way for removal is the use of a brain spatula to pull brain tissue and reveal hematoma for clearance, which is also challenging because excessive pulling can easily damage brain tissue.

Previously, evacuations were carried out through the endoscopic trocar or a customized syringe,[16] but, currently, more available sheaths, such as stainless steel sheaths,[17] NeuroPort,[18,19] ViewSite,[20] and other expandable cannula systems,[21–23] have been designed to reduce damage to normal brain tissue along the cannulation and provide further advantages. However, these tools require consumables expenditures that exacerbate the patient's financial burden. Therefore, to achieve the same surgical effect, X-ray film was used to make a channel by sterilizing it, spinning it into column, and then placing it into a cortical fistula whose diameter is approximately 0.5 cm, so that the brain did not suffer any significant cutting damage. Due to the flexibility of the film, the brain tissue could slowly expand and respond to movements of the channel. In this way, a simple and cost-effective working channel for endoscopy can be formed. This technique evenly distributed pressure across the brain tissue, such that no significant stretching was inflicted on the brain tissue, and serious brain edema was not generated. In addition, after surgery, the fistula retracted significantly, and the stoma retracted significantly to a diameter $<1$ cm, leading to minimal damage to the brain tissue.

Regarding the position of the keyhole, approaches are carefully designed according to the location of the hematoma. For hematoma in the basal ganglia, 2 to 3 cm anterior to the coronal suture and 3 to 4 cm lateral to the midline are preferred as the entry point. For thalamic hematoma, a parietal entry point is preferred. For subcostal hematoma, the shortest approach possible is preferred.[12] If nerve navigation is applied to positioning during surgery, more desirable results can be achieved.[21,22]

However, there are some limitations using a keyhole endoscope. First, it is not suitable for patients with cerebral hernia, the application of craniotomy removal through the bone window and debridement decompression is recommended. Second, when combining the benefits of keyhole surgery and endoscopic surgery, a relatively small space to accommodate the endoscope, suction apparatus and bipolar coagulation to remove and reveal hematoma, and completely stop bleeding is required, which requires surgeon to have proficient microneurosurgery operating skills and experienced endoscopic application skills. Third, when removing hematoma, the surgeon needs to use the left hand to hold endoscope and the right hand to clear hematoma, which means that the surgeon should be ambidextrous for optimal implementation of this procedure. When stopping the bleeding, cooperation between the surgeon and an assistant is indispensable because in this process, the assistant holds the endoscope, the surgeon's left hand holds the suction apparatus, and the right hand carries the bipolar electrocoagulation device. Fourth, the depth and angle of the endoscope need to be adjusted continuously during surgery, which requires repeated cleaning to avoid blood contamination. All these factors influence the operation time.[24]

In conclusion, we believe that the main reason for the short operation time, less bleeding, and high hematoma clearance rate in the keyhole endoscopy group is the "brain-hematoma" pressure gradient. Use of the intraoperative micropull technique and intracerebral hematoma removal in the shortest time possible are important factors for high ADL scores in the keyhole endoscopy group. Keyhole endoscopy for the treatment of HICH has the advantages of minimal trauma and good effect, does not require a dedicated neuroendoscope, and does not increase the patients' economic burden, all of which make this technique easy to promote and implement in primary hospitals. However, due to the small number of patients in this study, a larger sample for further comparative study is still necessary.

## Author contributions

**Conceptualization:** Guoqing Sun.
**Data curation:** Guoqing Sun, Xiaolong Li, Zhen Xu.

**Formal analysis:** Xiangtao Chen.
**Investigation:** Guoqing Sun, Zhen Xu.
**Methodology:** Guoqing Sun.
**Project administration:** Guoqing Sun.
**Resources:** Guoqing Sun.
**Software:** Xiaolong Li, Xiangtao Chen, Zhen Xu.
**Supervision:** Yuhai Zhang.
**Validation:** Yuhai Zhang.
**Writing – original draft:** Guoqing Sun.
**Writing – review & editing:** Yuhai Zhang.

## References

[1] Liu M, Wu B, Wang WZ, et al. Stroke in China: epidemiology, prevention, and management strategies. Lancet Neurol 2007;6:456–64.
[2] Brodefiek J, Connolly S, Feldmann E, et al. Guidelines for the management of spontaneous intracerebral hemorrhage in adults. Stroke 2007;38:2001–23.
[3] Krishnamurthi RV, Feigin VL, Forouzanfar MH, et al. Global and regional burden of first-ever ischaemic and haemorrhagic stroke during 1990-2010: findings from the Global Burden of Disease Study 2010. Lancet Glob Health 2013;1:259–81.
[4] Rennert RC, Signorelli JW, Abraham P, et al. Minimally invasive treatment of intracerebral hemorrhage. Expert Rev Neurother 2015;15:919–33.
[5] Adeoye O, Broderick JP. Advances in the management of intracerebral hemorrhage. Nat Rev Neurol 2010;6:593–601.
[6] Rincon F, Mayer SA. Intracerebral hemorrhage: getting ready for effective treatments. Curr Opin Neurol 2010;23:59–64.
[7] Li N, Liu YF, Ma L, et al. Association of molecular markers with perihematomal edema and clinical outcome in intracerebral hemorrhage. Stroke 2013;44:658–63.
[8] Gaberel T, Magheru C, Emery E. Management of non-traumatic intraventricular hemorrhage. Neurosurg Rev 2012;35:485–94.
[9] Mould WA, Carhuapoma JR, Muschelli J, et al. Minimally invasive surgery plus recombinant tissue-type plasminogen activator for intracerebral hemorrhage evacuation decreases perihematomal edema. Stroke 2013;44:627–34.
[10] Zhang FZ, Wang CY, Zhang L, et al. Effects of neuroendoscopy and craniotomy on hypertensive cerebral hemorrhage. Chin J Neurosurg 2015;1:19–21.
[11] Chen CH, Lee HT, Shen CC, et al. Aspiration of hypertensive intracerebral hematoma with frameless and fiducial—free navigation system: technical note and preliminary result. Stereotact Funet Neurosurg 2008;86:288–91.
[12] Dye JA, Dusick JR, Lee DJ, et al. Frontal bur hole through an eyebrow incision for image-guided endoscopic evacuation of spontaneous intracerebral hemorrhage. J Neurosurg 2012;117:767–73.
[13] Zhou X, Chen J, Li Q, et al. Minimally invasive surgery for spontaneous supratentorial intracerebral hemorrhage: a meta-analysis of randomized controlled trials. Stroke 2012;43:2923–30.
[14] Chi FL, Lang TC, Sun SJ, et al. Relationship between different surgical methods, hemorrhage position, hemorrhage volume, surgical timing, and treatment outcome of hypertensive intracerebral hemorrhage. World J Emerg Med 2014;5:203–8.
[15] Liu X, Xue P, Liu L. advances in treatment of hypertensive cerebral hemorrhage with neuroendoscopic hematoma removal. Chin J Neurol 2016;04:429–31.
[16] Chen CC, Lin HL, Cho DY. Endoscopic surgery for thalamic hemorrhage: a technical note. Surg Neurol 2007;68:438–42.
[17] Chen CC, Cho DY, Chang CS, et al. A stainless steel sheath for endoscopic surgery and its application in surgical evacuation of putaminal haemorrhage. J Clin Neurosci 2005;12:937–40.
[18] McLaughlin N, Kelly DF, Prevedello DM, et al. Hemostasis management during completely endoscopic removal of a highly vascular intraparenchymal braintumor: technique assessment. J Neurol Surg A Cent Eur Neurosurg 2014;75:42–7.
[19] Kassam AB, Engh JA, Mintz AH, et al. Completely endoscopic resection of intraparenchymal brain tumors. J Neurosurg 2009;110:116–23.
[20] Wang WH, Hung YC, Hsu SP, et al. Endoscopic hematoma evacuation in patients with spontaneous supratentorial intracerebral hemorrhage. J Chin Med Assoc 2015;78:101–7.
[21] Waran V, Vairavan N, Sia SF, et al. A new expandable cannula system for endoscopic evacuation of intraparenchymal hemorrhages. J Neurosurg 2009;111:1127–30.
[22] Sun GC, Chen XL, Hou YZ, et al. Image-guided endoscopic surgery for spontaneous supratentorial intracerebral hematoma. J Neurosurg 2016;1–6.
[23] Hou Y, Ma L, Zhu R, et al. iPhone-assisted augmented reality localization of basal ganglia hypertensive hematoma. World Neurosurg 2016;94:480–92.
[24] Wang G, Tian LX, Lv XB. nerve endoscopy combined with small bone window treatment of hypertensive cerebral hemorrhage. Chin J Neurosurg 2010;9:826–8.