Where to make burr hole for endoscopic hematoma removal against intracerebral hemorrhage at the basal ganglia to increase the hematoma removal rate – Comparison between trans-forehead and along-the-long-axis approaches

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ABSTRACT

Background: Endoscopic hematoma removal is performed to treat intracerebral hemorrhage (ICH) at the basal ganglia. In our hospital, young neurosurgical trainees perform it for the only 1st to the 3rd time. We perform a “trans-forehead approach” and hypothesized that our technique would contribute to higher hematoma removal rate and easiness despite their inexperience. We compared our dataset with an open dataset with along-the-long-axis approaches using pre- and intraoperative neuronavigation by well-trained neurosurgeons and tested the utility of our trans-forehead approach.

Methods: We retrospectively investigated our 17 consecutive patients with hypertensive ICH who underwent endoscopic hematoma removal using the trans-forehead approach. We obtained the open dataset and compared our data with the 12 patients from the open dataset using the inverse probability weighting method. Operative time, hematoma removal rate, postoperative hematoma volume, Glasgow Coma Scale (GCS) on day 7, and modified Rankin Scale (mRS) at 6 months were assessed as outcomes.

Results: The median age was 68 (interquartile range; 58–78) years. Median postoperative hematoma volume, removal rate, operative time, GCS on day 7, and mRS at 6 months were 9 (2–24) mL, 90 (79–98)%, 53 (41–80) min, 13 (12–13), and 4 (2–5), respectively. The weighted generalized estimating equations revealed that operative time was shorter in the along-the-long-axis group, but other items were not significantly different between the two approaches.

Conclusion: The hematoma removal rate of endoscopic hematoma removal with the trans-forehead approach by young trainees was not different from that of the along-the-long-axis approach by well-trained neurosurgeons using neuronavigation.

Keywords: Endoscopic hematoma removal, Hematoma removal rate, Intracerebral hemorrhage, Less invasive surgery, Training of residents
INTRODUCTION

Intracerebral hemorrhages (ICHs) comprise 10–30% of all strokes and are strongly related to high mortality and morbidity.[6,12] Hypertensive ICH accounts for about 70% of all ICH types. After onset, the median 30-day mortality rate is 15–50%,[1,19] and only 20% regain functional independence 3 months after ICH.[20] Surgical hematoma removal and conservative therapy are the main treatments for ICH, but the meaning of surgery for most ICH patients remains under discussion. The effectiveness of surgery has been repeatedly evaluated,[14,15] and the surgical treatment for ICH (STICH) and STICH II trials did not exhibit comprehensive benefits for the functional outcome over medical therapy.[13] However, almost all of the patients underwent craniotomy in these previous studies; therefore, the benefit and efficacy of endoscopic hematoma removal remain unknown.

In 2016, Phase II of the Minimally Invasive Surgery with Thrombolysis for ICH Evacuation (MISTIE) trial showed favorable preliminary results for the stereotactic aspiration and catheter drainage with a tissue plasminogen activator.[2,16] Furthermore, an endoscopic evacuation arm of MISTIE II, called the intraoperative stereotactic computed tomography-guided endoscopic surgery (ICES), showed the safety and effectiveness of the chronic neurological outcome.[22] Recently, the MISTIE trial Phase III demonstrated no functional benefit for the MISTIE procedure in selected patients; however, a subgroup analysis demonstrated improvement of the 1-year outcomes in patients with an increased hematoma removal rate (≤15 mL residual hematoma after the surgery).[4] These minimally invasive surgeries are becoming popular, and endoscopic hematoma removal has been widely practiced and reduces operative time and invasiveness compared to traditional craniotomy.[11]

Considering these previous studies on minimally invasive surgery, although the effect of endoscopic surgery for intracerebral hematoma remains unclear, a higher removal rate of hematoma would be important for outcome improvement.[4] However, Hayashi et al. reported that surgeons who experienced less than 10 cases of endoscopic hematoma removal achieved poor hematoma removal rates.[5] Therefore, we should invent a superior endoscopic hematoma removal procedure to achieve a high removal rate of the hematoma that even less experienced surgeons can do well.

In our hospital, young neurosurgical trainees of 3–7 years perform endoscopic hematoma removal under a mentor's supervision over 60 years old, who were not skill qualified by the Japanese Society for Neuroendoscopy.[8] The trainees experienced endoscopic hematoma removal for the only 1st to the 3rd time. We perform a “trans-forehead approach” for the ICH at the basal ganglia and hypothesized that our trans-forehead approach would contribute to higher hematoma removal rate and easiness despite their inexperience. In this study, we compared our database with the open dataset of endoscopic hematoma removal for ICH at the basal ganglia with along-the-long-axis using pre- and intraoperative neuronavigation by well-trained neurosurgeons[10] and tested the utility of our trans-forehead approach.

MATERIALS AND METHODS

Study population

From the medical records between 2013 and 2020, we retrospectively investigated 17 consecutive patients with hypertensive ICH who underwent endoscopic hematoma removal. The ICH diagnosis was based on the clinical history and the presence of ICH on computed tomography (CT). The inclusion criteria for the study were as follows: (1) patients with ICH at the basal ganglia, (2) patients indicated for surgical treatment according to the Japanese Guidelines for the Management of Stroke 2009[21] and 2015[22] (described in detail in the next section) and treated endoscopically, and (3) interval between onset and hematoma removal less than 24 h. Exclusion criteria were as follows: (1) ICHs due to tumor, trauma, aneurysm, arteriovenous malformation, and hemorrhage after infarction and (2) patients who had the thalamic or caudate head hemorrhage with intraventricular hemorrhage treated by neuroendoscope for removing intraventricular hematoma only. The hospital's research ethics committee approved this study, and we gained the written informed consent for this study from all of the patients or patients' families. This retrospective study was performed following the Declaration of Helsinki.

General management

All patients received standard management according to the Japanese Guidelines for the Management of Stroke 2009[21] and 2015.[22] They were first treated with nicardipine and kept with normal blood pressure. In patients under anticoagulation therapy, their prothrombin time was normalized by administering Vitamin K and/or fresh frozen plasma. A surgical indication was also made according to the guidelines (same described in both versions).[21,22] Patients with hematoma at the basal ganglia, which was more than 30 mL and who were deteriorating neurologically were surgically indicated. Rehabilitation and nutritional support were started as soon as possible after the operation, and the prevention and treatment of complications were also performed. Patients with antithrombotic drugs were postoperatively discontinued for several days, depending on their condition and comorbidities.
**Neuroendoscopic procedure**

We have performed trans-forehead endoscopic procedures regardless of age, comorbidities, and presence of antithrombotic drugs. Endoscopic hematoma removal was performed under local anesthesia. We also prepared for conversion to craniotomy under general anesthesia simultaneously just in case the brain expanded rapidly or hemostasis was difficult endoscopically. The patient’s head was placed on the horseshoe headrest. We first confirmed the orbitomeatal line (OM line). We then checked the CT images slice in which the hematoma was described most vigorously and write its line parallel to the OM line. As the mark, the electrocardiogram electrode was fixed [Figure 1a].

A 3 cm skin incision along the wrinkling and burr hole 3–4 cm outside the midline was made parallel to the cross-sectional line of the CT slice [Figure 1b]. After a cruciate dural incision and corticotomy, we prepared a transparent sheath with a diameter of 10 mm (Neuroport regular type; Olympus, Tokyo, Japan). The stopper was clamped so that the sheath’s tip reached 1/3 of the length from the hematoma’s deepest part. We made the cut out and the clamp orientation the same direction as a mark [Figure 1c]. A neurosurgeon introduced the sheath with the observation by the rigid endoscope (A70960, 2.7 mm, 0° angle; Olympus Corporation, Tokyo, Japan) through the sheath. The ECG electrode helps determine the inserting orientation, and we just considered the lateral angle [Figure 1d]. First, we saw the white matter [Figure 1e], and then, we saw the red hematoma cavity and confirmed the reach into the hematoma [Figure 1f]. The sheath was inserted to the stopper’s pre-clamped cavity, and we removed the hematoma by the suction cannula.

We did not aggressively change the sheath’s direction but just rotated the sheath and removed the hematoma that came out naturally from the cut out into the sheath [Figure 1g]. The hematoma was removed by gradually pulling out and rotating the sheath. When the bleeding arteries were observed, we coagulated it by monopolar electrocautery through the suction cannula. We conserved white matter by refraining from aggressively changing the sheath’s direction.

We also refrained from aggressive hematoma removal near the internal capsule to save the pyramidal tract, which was not destroyed by hemorrhage, and left some part of the hematoma [Figure 1h]. After hematoma removal, we reinsert the sheath and left the drainage tube [Figure 1i]. We filled the

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*Figure 1: Intraoperative findings. We first confirmed the orbitomeatal line (OM line). We then checked the computed tomography images slice in which the hematoma was described most vigorously and write its line parallel to the OM line. As the mark, the electrocardiogram electrode was fixed (a). A 3 cm skin incision along the wrinkling and burr hole 3–4 cm outside the midline were made parallel to the cross-sectional line of the CT slice (b). After a cruciate dural incision and corticotomy, we prepared a transparent sheath. The stopper was clamped so that the sheath’s tip reached 1/3 of the length from the hematoma’s deepest part. We made the cut out and the clamp orientation the same direction as a mark (c). A neurosurgeon introduced the sheath with the observation by the rigid endoscope through the sheath. The ECG electrode helps to determine the inserting orientation, and we just considered the lateral angle (d). First, we saw the white matter (e), and then, we saw the red hematoma cavity and confirmed the reach into the hematoma (f). The sheath was inserted to the stopper’s preclamped position, and we removed the hematoma by the suction cannula. We did not aggressively change the sheath’s direction but just rotated the sheath and removed the hematoma that came out naturally into the sheath (g). We refrained from aggressive hematoma removal near the internal capsule to save the pyramidal tract, which was not destroyed by hemorrhage, and left some part of the hematoma (h). After hematoma removal, we reinsert the sheath and left the drainage tube (i). The burr hole was covered with the burr hole cover, and the skin was sutured.*
hematoma cavity with the artificial cerebrospinal fluid. The burr hole was covered with the burr hole cover, and the skin was sutured. The drainage tube was removed on the next day.

Clinical variables and outcomes

We collected data regarding physiological symptoms and medical history on admission; age, sex, hematoma location, Glasgow Coma Scale (GCS) score, systolic blood pressure on admission, presence of smoking, heavy drinking, comorbidities, use of antithrombotic drugs, and operative time. We also measured the hematoma volume and the hematoma removal rate from the head CT on admission and just after the operation. The hematoma volume was calculated by the ABC/2 method.[2] To evaluate the outcomes, operative time, postoperative hematoma volume, hematoma removal rate, GCS on day seven, and modified Rankin Scale (mRS) 6 months after the operation were investigated from the medical records or by telephonic or personal interview.

Comparative data

We gained the comparative data from the open dataset of Suwa Red Cross Hospital.[10] Twelve patients who had ICH at the basal ganglia underwent the trans-forehead approach using pre- and intraoperative neuronavigation. The data were acquired on their age, sex, GCS score on admission and day 7, systolic blood pressure on admission, presence of smoking, heavy drinking, comorbidities, use of antithrombotic drugs, pre- and postoperative hematoma volume, operative time, and mRS 6 months after the operation. We asked the corresponding author and confirmed that all the 12 patients were treated by the well-trained (over 11 years) neurosurgeons who were skill qualified by the Japanese Society for Neuroendoscopy.[9] The detail of the surgical procedures was described in their previous reports.[9,11]

Statistical analysis

Results were presented as median (interquartile range). We investigated all the 29 ICH patients focusing on the clinical variables described above, using the Mann–Whitney U-test and Fisher’s exact test as univariate analysis. We performed the inverse probability weighting (IPW) method to address confounding by observed covariates, a type of propensity score analysis. The propensity score was calculated by a logistic regression model predicting treatment (trans-forehead or along-the-long-axis approaches) and adjusting the baseline characteristics of age, sex, past history, systolic blood pressure on admission, GCS score on admission, and preoperative hematoma volume as independent variables. The calculated probability of receiving the treatment was evaluated by the Hosmer–Lemeshow test and c-statistic. The weights for each patient were calculated as the inverse of the probability of receiving the treatment. After balancing with the IPW method, we made generalized estimating equations to assess the association between the surgical procedure and each outcome. We conducted these analyses using version 21.0.0 of SPSS software (IBM, NY, USA). A two-tailed P < 0.05 was considered as statistically significant.

RESULTS

General characteristics

[Table 1] shows the characteristics of 29 patients (17 trans-forehead approach and 12 along-the-long-axis approach) with ICH at the basal ganglia. Thirteen women and 16 men were included. The median age was 68 (58–78) years. Median postoperative hematoma volume, removal rate, operative time, GCS on day 7, and mRS at 6 months were 9 (2–24) mL, 90 (79–98)% and 53 (41–80) min, 13 (12–13), and 4 (2–5), respectively. Only the preoperative GCS E score was significantly worse in the along-the-long-axis group (P = 0.011). Other variables were not significantly different between the two datasets. In all 29 patients, no one had chronic renal failure treated with hemodialysis or liver cirrhosis, reported as related to the hematoma removal rate.[5]

Among both patients who underwent trans-forehead approach and along-the-long-axis approach, no one needed conversion to craniotomy during endoscopic hematoma removal. All the patients could undergo endoscopic surgery under local anesthesia without the patient’s body movement, change of the vital signs, or worsening respiratory conditions.

Comparison of the trans-forehead approach and along-the-long-axis approach using IPW method

Regarding the probability of receiving the treatment, P-value was 0.821 according to the Hosmer–Lemeshow test, and the c-statistic was 0.873 (95% confident interval 0.745–1.000). The weighted generalized estimating equations revealed that operative time was shorter in the along-the-long-axis group (P < 0.001). However, postoperative hematoma volume, removal rate, GCS score on day 7, and mRS at 6 months were not significantly different between the two approaches [Table 2].

Representative case

A 79-woman presented with the left hemiplegia and her GCS score was 7 (E2V1M4) on admission. CT showed 75 mL of the right putaminal hemorrhage [Figure 2a]. Endoscopic hematoma removal with a trans-forehead approach was performed. Postoperative CT showed 3 mL of the rest, and the hematoma removal rate was 96% [Figure 2b]. Her GCS score was 14 on postoperative day 7, and mRS at 6 months was 4 due to severe left hemiparesis.
DISCUSSION

The concept of our surgical strategy is as follows: (1) easiness for young trainees by inserting sheath parallel to the CT slice to understand the orientation, (2) conserve white matter by refraining from aggressively changing the sheath’s direction but just rotating the sheath and removed the hematoma that came out naturally into the sheath, and (3) not requiring specialized tools for endoscopic hematoma removal,\cite{[17]} the neuronavigation,\cite{[9,11,24,25]} nor echo sonography.\cite{[26]} Of course, when a surgeon is to perform the endoscopic procedure for the 1st time, he or she should be supervised by a skilled surgeon.\cite{[5,18]} However, our results suggested that the hematoma removal rate of endoscopic hematoma removal with the trans-forehead approach for ICH at the basal ganglia by young trainees was not different from that with the along-the-long-axis approach by well-trained neurosurgeons using neuronavigation.

Where to make burr hole

Burr hole for endoscopic hematoma removal at the basal ganglia is often made at the frontal region for trans-forehead or along-the-long-axis (frontal approaches), near the Kocher’s point, or on the point which was shortest to the hematoma (temporal approach). Hsieh et al. investigated the

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**Table 1: Characteristics of the patients and dataset.**

| Variables                                      | Total (n=29) | Trans-forehead (n=17) | along-the-long-axis (n=12) | P-value |
|------------------------------------------------|--------------|-----------------------|---------------------------|---------|
| Age (years)                                    | 68 (58–78)   | 65.5 (60–72)          | 63 (43–79)                | 0.556   |
| 36–65                                          | 14 (48%)     | 8 (47%)               | 6 (50%)                   |         |
| 66–75                                          | 6 (21%)      | 4 (24%)               | 2 (17%)                   |         |
| 76–85                                          | 8 (28%)      | 5 (29%)               | 3 (25%)                   |         |
| 86–90                                          | 1 (3%)       | 0                     | 1 (8%)                    |         |
| Women:men (%women)                             | 13:16 (45%)  | 7:10 (41%)            | 6:6 (50%)                 | 0.716   |
| History                                        |              |                       |                           |         |
| History of smoking                             | 11 (38%)     | 6 (35%)               | 5 (42%)                   | 0.999   |
| History of drinking                            | 6 (21%)      | 4 (21%)               | 2 (17%)                   | 0.999   |
| Hypertension                                   | 21 (72%)     | 12 (71%)              | 9 (75%)                   | 0.999   |
| Dyslipidemia                                   | 12 (41%)     | 6 (35%)               | 6 (50%)                   | 0.471   |
| Diabetes mellitus                              | 6 (21%)      | 5 (29%)               | 1 (85%)                   | 0.354   |
| Antiplatelet drugs                             | 21 (9%)      | 14 (48%)              | 7 (47%)                   |         |
| Systolic blood pressure on admission (mmHg)     | 181 (155–204)| 175 (155–192)         | 186 (161–207)             | 0.711   |
| GCS score preoperative                         |              |                       |                           |         |
| E                                              | 3 (1–4)      | 3 (2–4)               | 1.5 (1–3)                 | 0.011*  |
| V                                              | 1 (1–3)      | 1 (1–3)               | 1 (1–2)                   | 0.777   |
| M                                              | 5 (4–6)      | 5 (4–6)               | 4.5 (2–6)                 | 0.499   |
| Total                                          | 9 (7–11)     | 10 (7–11)             | 7.5 (4–10)                | 0.152   |
| Hematoma volume preoperative (mL)              | 97 (60–161)  | 97 (69–158)           | 98 (59–163)               | 0.983   |
| Presence of intraventricular hematoma          | 15 (52%)     | 7 (41%)               | 8 (67%)                   | 0.264   |
| Hematoma volume postoperative (mL)             | 9 (2–24)     | 10 (4–24)             | 4 (1–20)                  | 0.245   |
| Hematoma volume postoperative > 15 mL          | 12 (41%)     | 7 (41%)               | 5 (42%)                   | 0.999   |
| Hematoma removal rate (%)                      | 90 (79–98)   | 90 (79–95)            | 93 (77–99)                | 0.303   |
| Operative time (min)                           | 53 (41–80)   | 60 (46–88)            | 48 (40–61)                | 0.107   |
| GCS score POD 7                                |              |                       |                           |         |
| E                                              | 4 (3–4)      | 4 (4–4)               | 4 (3–4)                   | 0.251   |
| V                                              | 3 (2–4)      | 3 (2–3)               | 3 (2–5)                   | 0.610   |
| M                                              | 6 (5–6)      | 6 (6–6)               | 6 (4–6)                   | 0.294   |
| Total                                          | 13 (11–14)   | 13 (12–13)            | 12 (9–15)                 | 0.746   |
| mRS 6-mo postoperative                         | 4 (2–5)      | 4 (3–5)               | 4 (2–5)                   | 0.811   |
| mRS 0–3                                       | 10 (34%)     | 5 (29%)               | 5 (42%)                   |         |
| mRS 4                                          | 8 (28%)      | 6 (35%)               | 2 (17%)                   |         |
| mRS 5                                          | 5 (17%)      | 3 (17%)               | 2 (17%)                   |         |
| mRS 6                                          | 6 (21%)      | 3 (17%)               | 3 (24%)                   |         |

*The results are shown with the number (%) or the median (interquartile range). P-value was calculated by Fisher’s exact test or Mann–Whitney U-test.

GCS: Glasgow Coma Scale, mRS 6-mo postoperative: Modified Rankin Scale 6 months after the operation, POD: Postoperative day, *P<0.05
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Efficacy of the two entry sites (frontal or temporal approach), and they concluded that the frontal approach could facilitate the optimal evacuation of putaminal hemorrhage. The frontal approach is through the noneloquent area, and the hematoma evacuation rate can be better than the temporal approach because the visualization of the frontal part of the hematoma might be blocked due to the limited inclination of the tube through a small burr hole in the temporal approach.\(^7\) Their concepts of the surgical procedure are similar to ours.

Yokosuka et al. reported a freehand technique with making a burr hole near the Kocher’s point, which is used for the cerebral ventricular drainage\(^26\) and its utility for simplicity and safety. Their technique contributes to understanding the orientation during the puncture and hematoma removal, but their technique sometimes requires a change of the sheath’s direction to remove the hematoma. The damages of sheath insertion and inclination during this technique are unknown, so we should further discuss whether to make a burr hole near the Kocher’s point or along-the-long-axis (frontal) approaches. As described above, various points for making a burr hole were reported, and each point has advantages and disadvantages. Although the endoscopic hematoma removal procedure still varies from surgeon to surgeon, our results suggest that our technique contributes to the removal rate even for inexperienced young trainees.

**Disadvantages of our technique**

Sometimes, we could not take the sheath into the hematoma by one trial and injured the white matter. Neuronavigation enables us to precisely reach into the hematoma by one trial and avoid injuring the eloquent area and vessels while making the entry tract.\(^9,11,24,25\) Intraoperative echo sonography is also helpful.\(^26\) Furthermore, we did not use specialized tools for endoscopic hematoma removal like the combined

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**Table 2:** Effect of trans-forehead approach for outcome tested by inverse probability of where to make burr hole weighting methods.

| Outcome                               | B       | Standard error | P-value | Beta     | 95% confidence interval for beta |
|---------------------------------------|---------|----------------|---------|----------|---------------------------------|
| Operative time                        | 20.787  | 5.8840         | <0.001* | 1×10^9   | 1.039×10^7–1.081×10^14          |
| Hematoma volume postoperative         | -1.188  | 5.2937         | 0.822   | 0.305    | 0.9507×10^4–9772                |
| Hematoma volume postoperative >15 mL  | -0.071  | 0.5582         | 0.899   | 0.932    | 0.312–2.782                    |
| Removal rate                          | -0.032  | 0.0388         | 0.415   | 0.969    | 0.889–1.045                    |
| Total GCS score POD 7                 | 1.103   | 0.6841         | 0.107   | 3.013    | 0.788–11.514                   |
| mRS 6-mo postoperative                | 0.506   | 0.3379         | 0.134   | 1.659    | 0.855–3.217                    |
| mRS 4–6                               | 0.717   | 0.5728         | 0.211   | 2.048    | 0.667–6.294                    |

Weights are based on results from a selection model for where to make burr hole, estimated using logistic regression with trans-forehead or along-the-long-axis approach as the dependent variables and the baseline characteristics of age, sex, history, systolic blood pressure on admission, GCS score on admission, and preoperative hematoma volume. The weights for each patient were calculated as the inverse of the probability of approaches. We made a generalized estimating equation to assess the association between the approaches and each outcome after weighting. As to the probability of receiving the treatment, p value was 0.821 by the Hosmer–Lemeshow test, and the c-statistic was 0.873 (95% confident interval 0.745–1.000). GCS: Glasgow Coma Scale, mRS 6-mo postoperative: Modified Rankin Scale 6 months after the operation, POD: Postoperative day; *P<0.05 by weighted generalized estimating equations.

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**Figure 2:** Representative case: a 79 year old woman presented with the left hemiplegia, and her GCS score was 7 (E2V1M4) on admission. The preoperative CT showed 75 mL of the right putaminal hemorrhage (a). Endoscopic hematoma removal with a trans-forehead approach was performed. Postoperative CT showed 3 mL of the rest, and the hematoma removal rate was 96% (b).
irrigation-coagulation suction cannula (Fujita Medical Instrument, Tokyo, Japan), which can also be simultaneously used for irrigation and monopolar coagulation at its tip.[17] We could have performed wet and dry field techniques by irrigation[27,28] to removed more hematoma under clear visualization if we could use this. Although preparation and familiarity with those devices are required, they should be used depending on the situation and the surgeon’s skill level.

Limitation

Our study’s sample size was small, and quantification of the hematoma volume by ABC/2 methods is not so exact. Thus, a prospective, multicenter study with a large number of patients is needed to evaluate the difference of where to make a burr hole. However, every surgical procedure has its advantages and disadvantages. It is impossible to say which method is superior for endoscopic hematoma removal. We hope that the trans-forehead approach would help us when there is no navigation or when a young neurosurgeon is unfamiliar with the endoscopic hematoma removal for ICH at basal ganglia.

CONCLUSION

The hematoma removal rate of endoscopic hematoma removal with the trans-forehead approach for ICH at the basal ganglia by young trainees was not different from that of the along-the-long-axis approach well-trained neurosurgeons using neuronavigation.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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