



## Clinical Efficacy of Minipterional Craniotomy with Rostral Transsylvian-Transinsular Approach for Hypertensive Basal Ganglion Hemorrhage

Bon-Jour Lin<sup>1,2</sup>, Yi-An Chen<sup>1,3</sup>, Tzu-Tsao Chung<sup>1</sup>, Wei-Hsiu Liu<sup>1</sup>, Chi-Tun Tang<sup>1</sup>, Dueng-Yuan Hueng<sup>1</sup>, Yuan-Hao Chen<sup>1</sup>, Hsin-I Ma<sup>1</sup>, Ming-Ying Liu<sup>1</sup>, Hung-Chang Hung<sup>4,5</sup>, Da-Tong Ju<sup>1</sup>

<sup>1</sup>Department of Neurological Surgery, Tri-Service General Hospital, National Defense Medical Center, Taipei, Departments of <sup>2</sup>Surgery and <sup>4</sup>Internal Medicine, Nantou Hospital, Nantou, <sup>3</sup>Department of Surgery, Taichung Armed Forces General Hospital, <sup>5</sup>Department of Healthcare Administration, Central Taiwan University of Science and Technology, Taichung, Taiwan

**Background:** Clinical applications of transsylvian-transinsular (TS-TI) approaches to hypertensive basal ganglia hemorrhages (HBGHs) have an enormous difference in functional independence rate. The aim of this study is to investigate the clinical efficacy of minipterional craniotomy with rostral TS-TI approach to HBGH and compare functional independence rate with distal TS-TI variant. **Methods:** From April 2017 to April 2019, eleven patients with symptomatic HBGH accepting minipterional craniotomies with rostral TS-TI approaches were analyzed retrospectively. **Results:** The mean volume of preoperative hematoma was 57.08 ml with a 99.20% evacuation rate. Postoperative images revealed no rebleeding or newly developed hypodense lesion. Nine out of eleven patients got clear consciousness with functional independence at 3 months postoperatively. **Conclusions:** In comparison with distal TS-TI approach, minipterional craniotomy with rostral TS-TI approach to HBGH provides satisfactory outcome with higher functional independence rate.

Key words: Minipterional, transsylvian-transinsular, hemorrhage

### INTRODUCTION

Sylvian fissure is a reliable landmark over the lateral surface of the cerebral hemisphere. It has complex anatomy but provides a natural gateway to reach the deep-seated structure and skull base.<sup>1</sup> Accompanying with widely clinical application of transsylvian (TS) access, more studies utilize TS-transinsular (TI) approaches for managing hypertensive basal ganglia hemorrhages (HBGHs).<sup>2-12</sup> Although the role of surgery in treating intracerebral hemorrhage is controversial, it is announced that TS-TI approach provides a better outcome than conservative treatment and transcortical approach to HBGH.<sup>6,7,9,12</sup> Interestingly, tremendous difference in functional independence rate exists among different studies using TS-TI approaches to HBGH. The authors hypothesize that the phenomenon is attributed to different degrees of iatrogenic neurological damage secondary to brain manipulation.

Received: November 14, 2019; Revised: December 30, 2019; Accepted: February 17, 2020; Published: April 22, 2020  
Corresponding Author: Dr. Da-Tong Ju, Department of Neurological Surgery, Tri-Service General Hospital, No 325, Section 2, Cheng-Kung Road, Neihu 114, Taipei, Taiwan. Tel: 886-2-87927177; Fax: 886-2-87927178. E-mail: wxyz670628@yahoo.com.tw

According to the entry point to the Sylvian fissure, the TS-TI approach is divided into rostral TS-TI and distal TS-TI variants.<sup>13</sup> Until now, there is no study to make a comparison between these two variants. The aim of this study is to report our clinical experience using rostral TS-TI approach to HBGH and compare the functional independence rate with other published studies.

### METHODS

#### Patient demographics

A review of medical record was conducted following the Institutional Review Board (IRB) approval (IRB: 2-108-05-160). From April 2017 to June 2019, twenty-four

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: WKHLRPMedknow\_reprints@wolterskluwer.com

**How to cite this article:** Lin BJ, Chen YA, Chung TT, Liu WH, Tang CT, Hueng DY, et al. Clinical efficacy of minipterional craniotomy with rostral transsylvian-transinsular approach for hypertensive basal ganglion hemorrhage. J Med Sci 2020;40:175-80.

consecutive patients with HBGH were admitted to the neurosurgical intensive care unit (ICU) of Nantou Hospital. Among these twenty-four patients, eleven selected patients fulfilling our surgical criteria were arranged for emergency operations and included in this study.

Inclusion criteria were listed as follows: (1) acute stage of HBGH was diagnosed on the basis of patient-reported symptoms and clinical signs with corresponding computed tomography (CT) imaging; (2) the hematoma volume of HBGH, calculated by utilizing computer-assisted volumetric analysis, was more than 30 ml; and (3) impairment of consciousness and focal neurological deficits were attributed to HBGH only. Exclusion criteria were summarized as below: (1) the patient presented with deep coma or fixed dilated pupil; (2) the patient had a history of previous cerebrovascular accident or decompensated organ failure; and (3) etiology of HBGH was attributed to trauma, vascular anomaly, coagulopathy, and tumor.

### Surgical procedure

The detailed step-by-step surgical procedure was introduced by our previous study.<sup>14</sup> One 5-cm curved skin incision was created around the pterion region followed by elevating the myocutaneous flap. After that, one small bone flap (2 cm in diameter) was established with a reverse T-shaped dural incision. Starting from the pars triangularis of the inferior frontal gyrus, the outer arachnoid membrane of Sylvian fissure was opened and dissected from distal to proximal. After completing the splitting of the rostral Sylvian fissure, the insular cortex located between superior and inferior trunks of the M2 segment of the middle cerebral artery was exposed widely without brain retraction. Incising the insular cortex could reveal the basal ganglion hematoma below. Further, the hematoma evacuation and adequate hemostasis were executed under microscope by gentle suction and bipolar cautery. The dura was closed by watertight suture, and the bone flap was repositioned by titanium miniplate fixation.

### Postoperative care and follow-up

After accomplishing the operation, the patient accepted intensive care and monitor in the neurosurgical ICU with targeted blood pressure therapy. Routine postoperative image was scheduled within 48 h to check rebleeding and observe residual blood volume. With stable condition, the patient started to accept rehabilitation therapy in the acute neurosurgical ward.

Hematoma volume, calculated by utilizing computer-assisted volumetric analysis, was recorded from the preoperative and postoperative CT images. The hematoma evacuation rate was defined as follows: (preoperative

hematoma volume – postoperative hematoma volume)/ (preoperative hematoma volume) × 100%. In comparison to preoperative condition, the level of consciousness (Glasgow Coma Scale [GCS] score) and muscle strength gradient of affected limbs (modified Medical Research Council system) were evaluated at 3 months postoperatively. The functional prognosis (Glasgow Outcome Scale [GOS]) was accessed and scored at the same time.

In addition, the functional outcome of this research was compared with other published studies utilizing distal TS-TI approaches to HBGH. Functional independence was defined as being able to perform daily activities with no helper or minimal assistance. Thus, the functional independence rate was percentage of patients with postoperative activities of daily living Grade 1 or 2 or GOS score 4 or 5.

## RESULTS

The clinical and radiological characteristics of eleven patients are summarized in Table 1. This study included 11 patients (9 men and 2 women) with age ranging from 52 to 57 years (mean, 54 years). Preoperative GCS scores ranged from 7 to 12, and the extent of midline shifting ranged from 1.60 to 12.40 mm (mean, 4.74 mm). The mean hematoma volume on preoperative CT imaging was 57.08 ml.

The average residual hematoma on postoperative CT imaging was 0.65 ml with 99.20% evacuation rate. No patient had delayed rebleeding or newly hypodense lesion on postoperative CT scans. The preoperative and postoperative CT imagings for representative patients are revealed in Figure 1. One patient (case number: 2) suffered from severe sepsis secondary to postoperative aspiration pneumonia, and he died at 6 months postoperatively. Another patient (case number: 4) remained in condition of impaired consciousness (GCS: E3M5Vt) with functional disability at 3 months postoperatively. In addition, the other nine patients got clear consciousness with obvious improvement in muscle strength of affected limbs and functional independence.

A comparison of functional independence rate among different studies is summarized in Table 2.

### Illustrative case (case number: 1)

A 41-year-old male patient presented with sudden onset loss of consciousness. While arriving at Nantou Hospital, neurological examination revealed a GCS score of 10 (E3M5V2) and left-sided extremity weakness with muscle strength 0/5. CT imaging showed right basal ganglion hemorrhage (66.09 ml) with ventricular extension and 4.2 mm midline shifting [Figure 2a]. Emergency minipterional craniotomy with rostral TS-TI approach was performed in an

Table 1: Clinical and radiological characteristics of 11 patients with hypertensive basal ganglia hemorrhages

| Age | Gender | Lesion side | ICH score | Midline shift (mm) | Preoperative BV (mm) | Postoperative BV (mm) <sup>§</sup> | Evacuation rate (%) | Preoperative GCS | Postoperative GCS | Preoperative MS |    | Postoperative MS |    | GOS score |
|-----|--------|-------------|-----------|--------------------|----------------------|------------------------------------|---------------------|------------------|-------------------|-----------------|----|------------------|----|-----------|
|     |        |             |           |                    |                      |                                    |                     |                  |                   | UE              | LE | UE               | LE |           |
| 41  | Male   | Right       | 3         | 4.20               | 66.99                | 0.00                               | 100.00              | E3M5V2           | E4M6V5            | 0               | 0  | 4                | 5  | 4         |
| 78  | Male   | Right       | 2         | 1.60               | 33.04                | 0.00                               | 100.00              | E3M5V3           | —— <sup>§</sup>   |                 |    |                  |    |           |
| 57  | Male   | Left        | 2         | 6.20               | 77.23                | 4.01                               | 94.81               | E3M5V1           | E4M6V3            | 1               | 1  | 4                | 5  | 4         |
| 23  | Female | Right       | 2         | 12.40              | 88.50                | 3.19                               | 96.40               | E2M4V2           | E3M5Vt            | 1               | 1  | 4                | 4  | 3         |
| 56  | Male   | Left        | 2         | 2.30               | 35.88                | 0.00                               | 100.00              | E3M5V2           | E4M6V5            | 1               | 1  | 5                | 5  | 5         |
| 78  | Female | Right       | 2         | 3.70               | 34.06                | 0.00                               | 100.00              | E3M5V3           | E4M6V5            | 2               | 2  | 5                | 5  | 5         |
| 50  | Male   | Right       | 3         | 8.60               | 97.22                | 0.00                               | 100.00              | E2M4V1           | E4M6V5            | 0               | 0  | 3                | 5  | 4         |
| 48  | Male   | Right       | 2         | 3.00               | 46.08                | 0.00                               | 100.00              | E2M4V2           | E4M6V5            | 1               | 1  | 4                | 5  | 4         |
| 43  | Male   | Right       | 1         | 2.50               | 30.48                | 0.00                               | 100.00              | E3M5V4           | E4M6V5            | 2               | 2  | 5                | 5  | 5         |
| 48  | Male   | Left        | 2         | 5.10               | 78.55                | 0.00                               | 100.00              | E2M4V1           | E4M6V3            | 0               | 0  | 4                | 5  | 4         |
| 61  | Male   | Right       | 2         | 2.50               | 39.85                | 0.00                               | 100.00              | E3M5V1           | E4M6V5            | 0               | 0  | 4                | 5  | 4         |

<sup>§</sup>Postoperative BV <2 ml was defined as total removal; <sup>§</sup>The patient suffered from postoperative aspiration pneumonia and septic shock, and he was dead at 6 months after surgery. BV=Blood volume; MS=Muscle strength of involved limbs; UE=Upper extremity; LE=Lower extremity; GOS=Glasgow Outcome Scale; ICH=Intracerebral hematoma; GCS=Glasgow Coma Scale

Table 2: Reported studies utilizing transsylvian-transinsular approaches to hypertensive basal ganglia hemorrhages

| Authors               | Years | Number of patients accepting TS-TI approaches | Preoperative hematoma volume (ml) | Keyhole surgery | Rostral/distal TS-TI approach | Functional independence rate <sup>§</sup> |
|-----------------------|-------|-----------------------------------------------|-----------------------------------|-----------------|-------------------------------|-------------------------------------------|
| Kaya <i>et al.</i>    | 2003  | 26 <sup>#</sup>                               | Not available                     | —               | Not available                 | 50% (6 months)                            |
| Shin <i>et al.</i>    | 2008  | 20                                            | 79.3 (mean)                       | —               | Distal                        | 15% (discharge)                           |
| Jianwei <i>et al.</i> | 2009  | 28                                            | 48.0 (mean)                       | —               | Distal                        | 71.4% (6 months)                          |
| Zheng <i>et al.</i>   | 2010  | 28                                            | 45.4 (mean)                       | +               | Not available                 | <80.0% (3 months)                         |
| Zhang <i>et al.</i>   | 2013  | 68                                            | 50.0 (mean)                       | +               | Distal                        | 60.3% (6 months)                          |
| Wang <i>et al.</i>    | 2013  | 39                                            | 42.3 (mean)                       | +               | Not available                 | 40.0% (6 months)                          |
| Kim <i>et al.</i>     | 2015  | 13                                            | 96.0 (mean)                       | —               | Distal                        | 18.2% (discharge)                         |
| Current study         | 2019  | 11                                            | 57.1 (mean)                       | +               | Rostral                       | 81.8% (3 months)                          |

<sup>#</sup>Patients preoperatively having herniation signs or presenting deep coma were excluded; <sup>§</sup>Functional independence was defined as ADLs Grade 1 or 2 and GOS score 4 or 5. TS-TI=Transsylvian-transinsular; HBGH=Hypertensive basal ganglia hemorrhages; ADLs=Activities of daily living; GOS=Glasgow Outcome Scale; BV=Blood volume

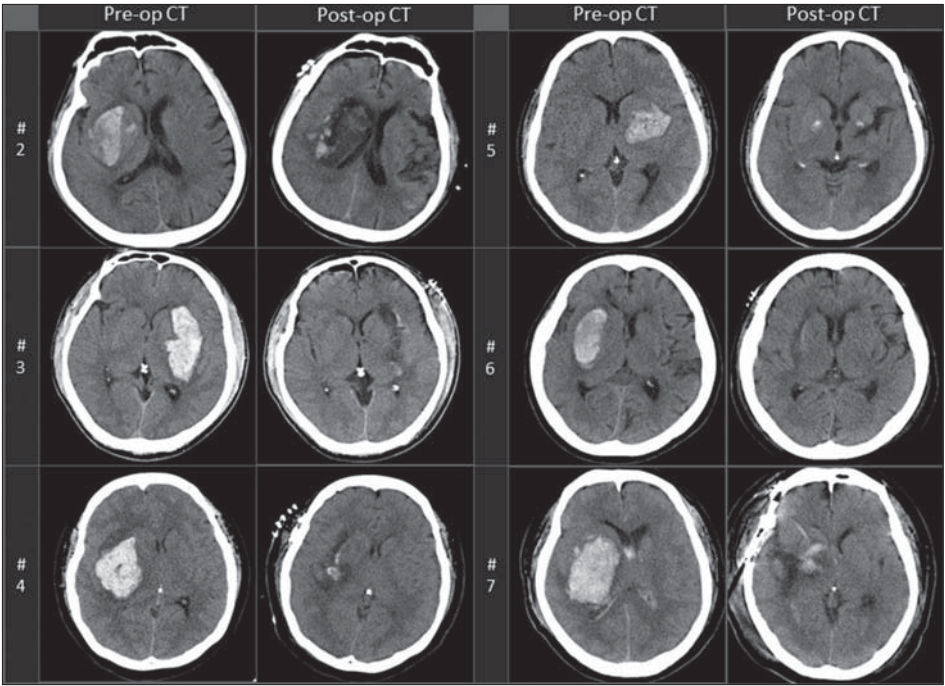
attempt to remove the hematoma for relieving the neurological insult. Postoperative CT imaging revealed nearly complete hematoma evacuation [Figure 2b].

After surgery, the patient got clear consciousness and immediate improvement of left-sided extremity weakness with muscle strength 2/5. Next, he was transferred to acute neurosurgical ward for accepting rehabilitation therapy at 7 days postoperatively. At 3 months postoperatively, the patient had left upper extremity muscle strength 4/5 and left lower extremity muscle strength 5/5 [Figure 2c and d].

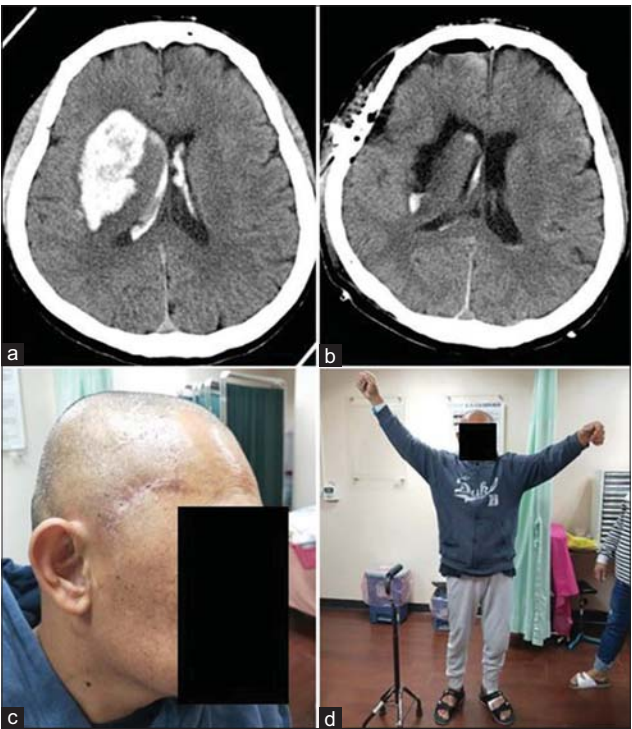
## DISCUSSION

Open surgical evacuation of hematoma plays a vague role in managing spontaneous intracerebral hemorrhage.<sup>15-17</sup> By

contrast, it seems that minimally invasive approaches offer a potential opportunity of getting favorable outcome in selected patients.<sup>5,18</sup> Basal ganglion is the most common location of spontaneous intracerebral hemorrhage. Surprisingly, the patients with basal ganglion hemorrhage are not recommended surgical candidates in the Surgical Trial in Intracerebral Hemorrhage (STICH) I, and even not included in STICH II. On the other hand, early removal of basal ganglion hemorrhage is announced to be associated with alleviating neurological insult and improving functional outcome.<sup>19</sup> In the authors' viewpoint, the clinical efficacy of surgical evacuation for basal ganglion hemorrhage is determined by the delicate balance between the secondary neurological damage caused by hematoma retention and iatrogenic neurological insult caused by surgical manipulation.



**Figure 1:** Preoperative and postoperative images of representative patients (case numbers: 2–7)



**Figure 2:** Illustration of one patient (case number: 1) with right-sided hypertensive basal ganglion hemorrhage and (a) preoperative and (b) postoperative computed tomography images. (c) One small curved incision over the right pterion region. (d) At 3 months postoperatively, the patient was functional independence. The only left neurological deficit was left upper extremity muscle strength 4/5

TS-TI approach and transcortical approach are commonly used surgical techniques for evacuation of HBGH. In 1972, Suzuki and Sato reported the first study of TI approach to the hypertensive intracerebral hemorrhage.<sup>20</sup> Because the TS-TI approach allows efficient evacuation of deep-seated HBGH with minimal brain damage, its clinical application gradually replaces conventional transcortical approach. Better clinical outcome of TS-TI approach than transcortical approach is already approved by several reports.<sup>6,9,12</sup> While reviewing the associated studies utilizing TS-TI approaches to HBGH, the authors incomprehensibly notice that different reports have an enormous difference in functional independence rate from each other. The authors postulate that the phenomenon is attributed to iatrogenic neurological insult caused by surgical manipulation.

Sylvian fissure is the natural gateway for reaching deep-seated structure from the cerebral surface. Splitting of the Sylvian fissure is a core technique of TS-TI approach, and it can be divided into rostral and distal variants according to the entry point of arachnoid dissection.<sup>13</sup> The rostral TS approach is defined as sharply dissecting the outer arachnoid membrane anterior to the pars triangularis of the inferior frontal gyrus, followed by lateral, intermediate, and medial Sylvian membranes. The deep and anterior boundary of arachnoid dissection is proximal Sylvian membrane, separating the Sylvian cistern and carotid cistern.<sup>21</sup> From the viewpoint of microneurosurgery, the rostral TS dissection opens the anterior compartment of superficial Sylvian

fissure and sphenoidal compartment of deep Sylvian fissure. At that time, the limen insulae, anteroinferior aspect of the insular cortex, and transition between M1 and M2 segments of the middle cerebral artery are exposed without any brain retraction.

In comparison with distal TS-TI approach, the rostral TS-TI approach opens the basal cisterns and drains the cerebrospinal fluid before hematoma evacuation. This maneuver not only relaxes the brain parenchyma but also lowers the intracranial pressure, and it is especially paramount for patients suffering from large HBGH.

A rim of neural tissue surrounding the hematoma is vulnerable and succumbed to direct compression, from the hematoma itself, and indirect compression, from the increased intracranial pressure. Even minor manipulation of brain parenchyma may cause further increased intracranial pressure and result in damage of fragile neurons and permanent neurological insult. That is to say, the strategy of rostral TS-TI approach, draining the cerebrospinal fluid and lowering the intracranial pressure before hematoma evacuation, is to establish larger tolerance of iatrogenic brain manipulation. The clinical benefit of rostral TS-TI approach reflects an obvious rise in functional independence rate. By contrast, the cortical incision of rostral TS-TI approach is made in the anteroinferior quadrant of the insular cortex, not in the central region.

Thus, the posterosuperior portion of basal ganglion hematoma is hard to attack due to its increased depth of the surgical corridor. Not surprisingly, this limitation forms the major shortcoming of rostral TS-TI approach.

Until now, no studies make a detailed description and comparison between rostral TS-TI and distal TS-TI approaches for managing HBGH. By the result of our clinical experience, the authors highlight the efficacy of rostral TS-TI approach with high functional independence rate. Further clinical study with larger sample size is needed to confirm our pronouncement.

## CONCLUSIONS

Minipterional craniotomy with rostral TS-TI approach is a feasible and effective strategy for managing symptomatic HBGH. This minimally invasive surgery provides a high rate of functional independence, and it is strongly recommended for suitable candidates.

## Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their

names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

## Financial support and sponsorship

Nil.

## Conflicts of interest

There are no conflicts of interest.

## REFERENCES

1. Safaee MM, Englot DJ, Han SJ, Lawton MT, Berger MS. The transsylvian approach for resection of insular gliomas: Technical nuances of splitting the Sylvian fissure. *J Neurooncol* 2016;130:283-7.
2. Kaya RA, Türkmenoğlu O, Ziyal IM, Dalkılıç T, Sahin Y, Aydin Y. The effects on prognosis of surgical treatment of hypertensive putaminal hematomas through transsylvian transinsular approach. *Surg Neurol* 2003;59:176-83.
3. Shin DS, Yoon SM, Kim SH, Shim JJ, Bae HG, Yun IG. Open surgical evacuation of spontaneous putaminal hematomas: Prognostic factors and comparison of outcomes between transsylvian and transcortical approaches. *J Korean Neurosurg Soc* 2008;44:1-7.
4. Jianwei G, Weiqiao Z, Xiaohua Z, Qizhong L, Jiayao J, Yongming Q. Our experience of transsylvian-transinsular microsurgical approach to hypertensive putaminal hematomas. *J Craniofac Surg* 2009;20:1097-9.
5. Wang WZ, Jiang B, Liu HM, Li D, Lu CZ, Zhao YD, *et al.* Minimally invasive craniopuncture therapy versus conservative treatment for spontaneous intracerebral hemorrhage: Results from a randomized clinical trial in China. *Int J Stroke* 2009;4:11-6.
6. Zheng JS, Yang F, Xu QS, Yu JB, Tang LL. Treatment of hypertensive intracerebral hemorrhage through keyhole transsylvian approach. *J Craniofac Surg* 2010;21:1210-2.
7. Zhang Y, Ding W, Yang Y, Xu H, Xiong F, Liu C. Effects of transsylvian-transinsular approach to hypertensive putaminal hematoma operation and electroacupuncture on motor recovery. *J Craniofac Surg* 2011;22:1626-30.
8. Chen CH, Lee HC, Chuang HC, Chen CC, Lee WY, Huang YI, *et al.* Transsylvian-transinsular approach for the removal of basal ganglia hemorrhage under a Modified Intracerebral Hemorrhage score. *J Craniofac Surg* 2013;24:1388-92.
9. Wang X, Liang H, Xu M, Shen G, Xu L. Comparison between transsylvian-transinsular and transcortical-transtemporal approach for evacuation of intracerebral hematoma. *Acta Cir Bras* 2013;28:112-8.
10. Zhang HT, Chen LH, Xu RX. Distal

- transsylvian-transinsular approach for the putaminal hypertensive hemorrhages: Surgical experience and technical note. *J Craniofac Surg* 2013;24:2073-6.
11. Kim SH, Kim JS, Kim HY, Lee SI. Transsylvian-transinsular approach for deep-seated basal ganglia hemorrhage: An experience at a single institution. *J Cerebrovasc Endovasc Neurosurg* 2015;17:85-92.
  12. Xu T, Liu H, Peng L, Li H, Wang J, Jiang Y, *et al.* Treatment efficacy of the transsylvian approach versus the transtemporal cortex approach to evacuate basal ganglia hematoma under a microscope. *J Craniofac Surg* 2016;27:308-12.
  13. Yamahata H, Tokimura H, Hirahara K, Ishii T, Hanada T, Hirano H, *et al.* Entry point to the sylvian fissure for the pterional transsylvian approach. *J Neurol Surg A Cent Eur Neurosurg* 2013;74:228-33.
  14. Lin BJ, Li CZ, Chung TT, Tang CT, Hueng DY, Ju DT, *et al.* Minipterional craniotomy with transsylvian-transinsular approach for hypertensive putaminal hemorrhage: A preliminary report. *J Med Sci* 2017;37:56-60.
  15. Mendelow AD, Gregson BA, Fernandes HM, Murray GD, Teasdale GM, Hope DT, *et al.* Early surgery versus initial conservative treatment in patients with spontaneous supratentorial intracerebral haematomas in the International Surgical Trial in Intracerebral Haemorrhage (STICH): A randomised trial. *Lancet* 2005;365:387-97.
  16. Mendelow AD, Gregson BA, Rowan EN, Murray GD, Gholkar A, Mitchell PM, *et al.* Early surgery versus initial conservative treatment in patients with spontaneous supratentorial lobar intracerebral haematomas (STICH II): A randomised trial. *Lancet* 2013;382:397-408.
  17. Hemphill JC 3<sup>rd</sup>, Greenberg SM, Anderson CS, Becker K, Bendok BR, Cushman M, *et al.* Guidelines for the management of spontaneous intracerebral hemorrhage: A guideline for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke* 2015;46:2032-60.
  18. Hattori N, Katayama Y, Maya Y, Gatherer A. Impact of stereotactic hematoma evacuation on activities of daily living during the chronic period following spontaneous putaminal hemorrhage: A randomized study. *J Neurosurg* 2004;101:417-20.
  19. Rincon F, Mayer SA. Intracerebral hemorrhage: Getting ready for effective treatments. *Curr Opin Neurol* 2010;23:59-64.
  20. Suzuki J, Sato S. The new transinsular approach to the hypertensive intracerebral hematoma. *Jpn J Surg* 1972;2:47-52.
  21. Inoue K, Seker A, Osawa S, Alencastro LF, Matsushima T, Rhoton AL Jr. Microsurgical and endoscopic anatomy of the supratentorial arachnoidal membranes and cisterns. *Neurosurgery* 2009;65:644-64.