The Optimal Entry Point for Endoscopic Third Ventriculostomy (ETV) in the Treatment of Thai Patients with Obstructive Hydrocephalus

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Background: *One of the serious complications associated with endoscopic ventriculostomy (ETV) is memory impairment cause by injury of the memory pathway at the foramen of Monro. The optimal landmark of burr hole for the endoscope entry point decreases the risk of traumatizing important anatomical structures around the foramen of Monro.*

Objective: *To define the optimal landmark of entry site for ETV in Thai patients in order to reduce postoperative complications.*

Material and Method: *The practical entry point was obtained from 3D reconstructive postoperative cranial CT scans of patients who underwent an ETV procedure. Favorable practical entry point is associated with intraoperative uninjured anatomical structures around the foramen of Monro. In addition, the ideal entry point was obtained from mergence of cranial MR images and CT scans.*

Results: *The mean perpendicular distance from the favorable practical entry point was 2.91 cm lateral to the midline and 0.96 cm anterior to the coronal suture. The mean perpendicular distance from the ideal entry point was 2.51 cm lateral to the midline and 0.24 cm posterior to the coronal suture.*

Conclusion: *The authors suggest that the optimal entry point for ETV is 2.5 cm perpendicular to the midline and centered at the coronal suture, especially in Thai people.*

Keywords: *Endoscopic third ventriculostomy, Entry point, Midline, Coronal suture, Obstructive hydrocephalus*

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The standard treatment for obstructive hydrocephalus is ventriculoperitoneal shunt but this therapeutic procedure has several possible complications, such as intracerebral bleeding, infection, shunt obstruction and shunt overdrainage[1-6]. Recently, an effective alternative option of treatment of obstructive hydrocephalus is endoscopic third ventriculostomy (ETV). The effectiveness of this procedure in treating obstructive hydrocephaus is equal to that of ventriculoperitoneal shunt. ETV has been successful in treating non-communicating hydrocephalus caused by tumors, aqueductal stenosis, hemorrhages, and infarctions[7-15]. The fenestration of floor of the third ventricle makes the cerebrospinal fluid flow from the ventricle to subaracnoid space, resulting in controlling hydrocephalus.

Although ETV is considered to be simple and safe procedure, severe but rare fatal complications may occur, such as basilar artery injury, hypothalamic injury and oculomotor palsy. The correct point of the perforation of the floor of the third ventricle and the appropriated entry point is the most importance in order to avoid neural damage and vascular injury. One of the important complications associated with ETV is memory impairment which occurs from memory pathway damage of the fornix at the level of foramen of Monro[16,17]. Intraoperative bleeding also occurs from choroid plexus injury at the foramen of Monro.

The optimal position of a burr hole for the endoscope entry point that traverses the center of the foramen of Monro, decreases the risk of traumatizing important anatomical structures around the foramen of Monro. Although there were some reports of optimum entry point for ETV[18,19], these position may be not suitable for Asian people resulting from difference in head contour. Therefore, our objective in this study is to review practical operative and imaging data to define

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the optimal position of the entry site for ETV in Thai patients.

Material and Method

We conducted a retrospective study of 21 patients who underwent ETV between April 2007 and September 2013. The reviewed data included demographic data, principle diagnosis, head computed tomography (CT), brain magnetic resonance imaging (MRI), and intraoperative video recording of ETV. The exclusion criteria included patients younger than 3 years of age and patients with incomplete closure of the skull. The patients were stratified into 3 groups, including the group of favorable practical entry point (favorable group or group A), unfavorable practical entry point (unfavorable group or group B) and ideal entry point (ideal group or group C) (Fig. 1).

Data acquirement

The intraoperative video recordings of ETV were reviewed to identify intraoperative damage around the foramen of Monro (Fig. 2). Fornix injury was defined as contusion or laceration of the fornix at the foramen of Monro (Fig. 3A and B) as well as the choroid plexus injury that defined as either presence or absence (Fig. 3C).

The imaging data were reviewed from the database to record preoperative Evans' index. The postoperative CT images were reloaded onto Osirix v.5.8 32-bit program. The 3D skull surface was reconstructed on this program. The perpendicular distance was measured from center of burr hole to

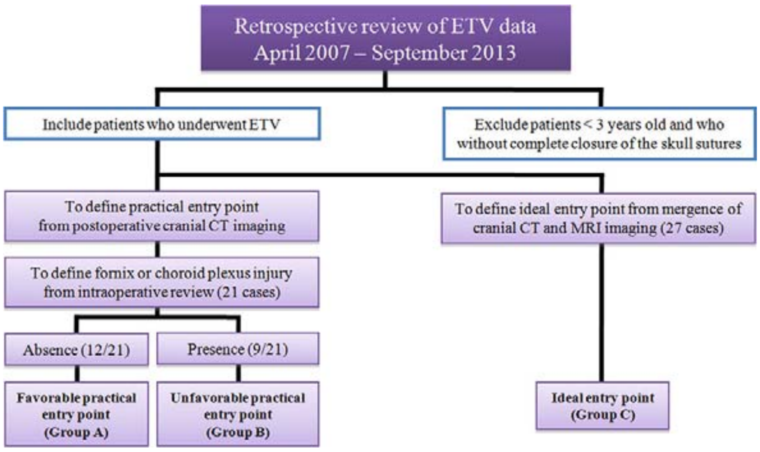

Fig. 1 Algorithm of the study showing three groups of entry point, including the group of favorable practical, unfavorable practical and ideal entry points.

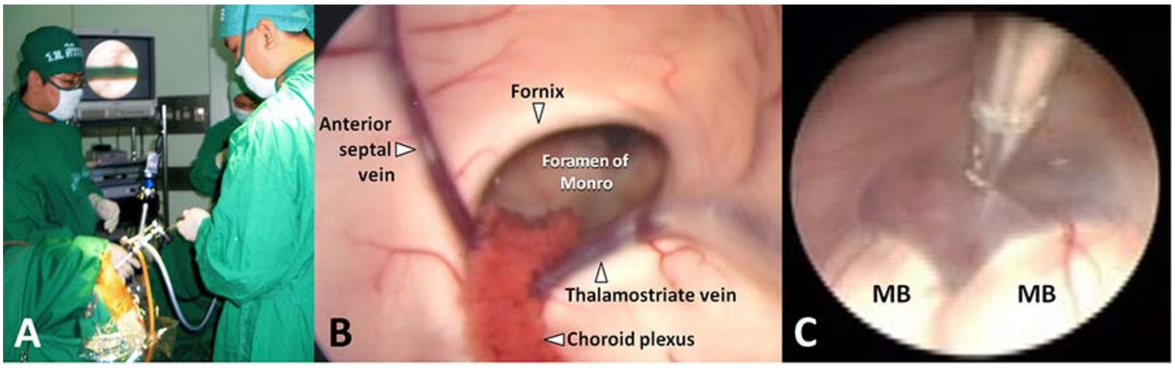

Fig. 2 Endoscopic third ventriculostomy (ETV): (A) intraoperative setting of ETV procedure; (B) endoscopic view showing normal right foramen of Monro, fornix, choroid plexus, anterior septal and thalamostriate veins; (C) the fenestration site is the area between the mammillary bodies (MB) and infundibular recess.

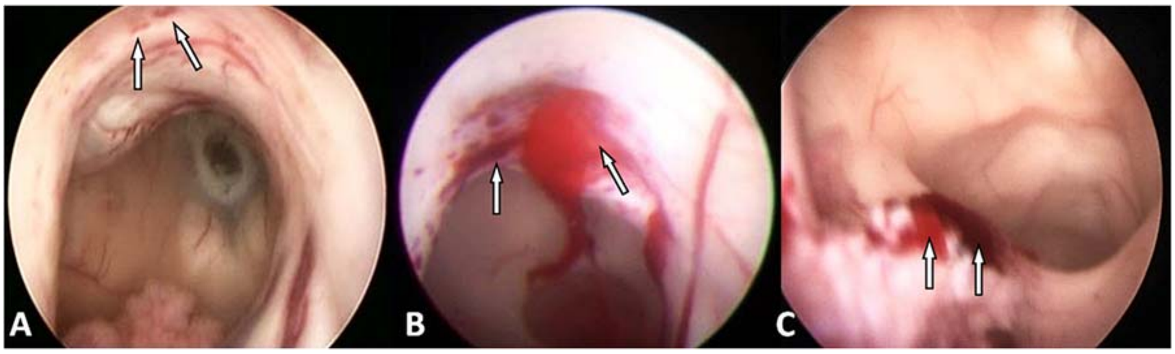

Fig. 3 Intraoperative endoscopic view showing injury of the structures around the foramen of Monro: (A) fornix contusion (arrows); (B) fornix laceration (arrows); (C) bleeding from the choroid plexus (arrows).

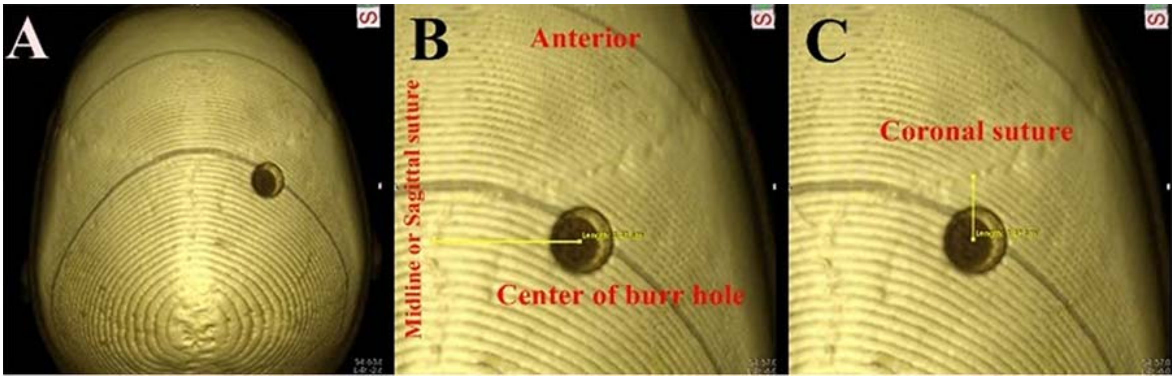

Fig. 4 The 3D skull reconstruction of postoperative head CT (A); the measurement of perpendicular distance from the center of burr hole to the midline (B) and to the coronal suture (C).

midline and center of burr hole to coronal suture, respectively (Fig. 4).

The DICOM data of brain MRI and head CT were reloaded onto a neuronavigation workstation (Brainlab). The images of MRI and CT were merged on software iPlan stereotaxie 3.0.2. Respectively, the axial, coronal, and sagittal views were displayed on the workstation. A target point on the tuber cinereum between the infundibular recess and mammillary bodies was marked. An entry point was marked at the center of the right foramen of Monro (Fig. 5A-C). The two points were connected with a straight line (Fig. 5A-C). This straight line was extended from entry point until it encountered the skull surface (Fig. 5A-C). This trajectory track was checked in 3 dimensions to ensure that this track did not intersect important surrounding anatomical structures, such as fornix, caudate nucleus, thalamus and hypothalamus. The meeting point of the skull surface with this trajectory line was designated as an ideal entry point (Fig. 5D-E). The perpendicular distance from the ideal entry point to the midline and to the coronal suture was obtained.

Equipment

In our institution, two types of rigid endoscope were used including KARL STORZ LOTTA™ ventriculoscope with length 18 cm, outer diameter 6.1 mm equipped with 3 channels for optic, instruments, irrigation, suction, and AESCULAP MINOP® ventriculoscope with length 15 cm, outer diameter of 6 mm equipped with 4 channels for optic, working, irrigation, and overflow. The choice of equipment depended on the availability of equipment and preference of neurosurgeons.

Statistical analysis

The statistical analysis was achieved by the Statistical Package for the Social Sciences (SPSS) version 18.0. The data, including age, gender and principle diseases, were interpreted by descriptive analysis. Comparison of parameters between 3 groups was analyzed using one-way ANOVA. Comparison of

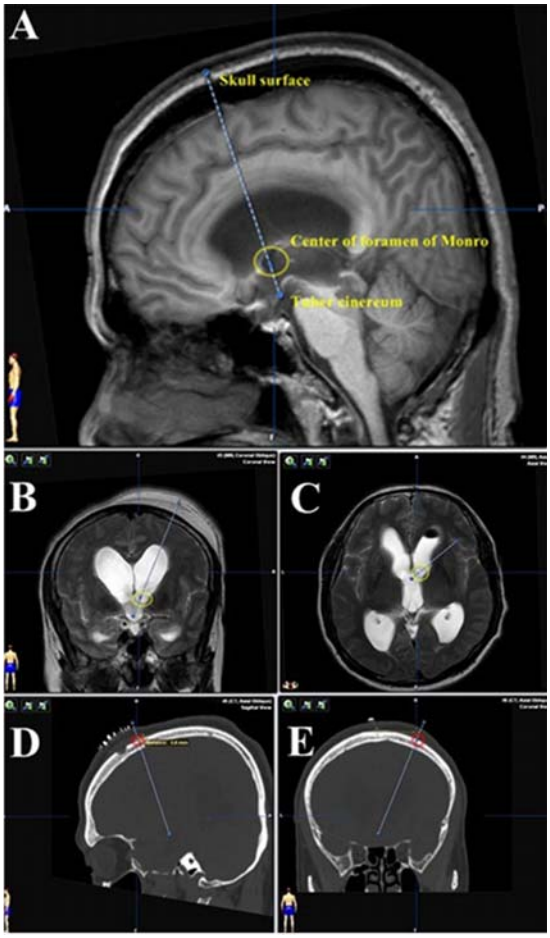

Fig. 5 The "ideal entry point" determination: The trajectory straight line is passed at 3 points, including the tuber cinereum, foramen of Monro and skull surface (A, B, C). The trajectory tip is passed into center of foramen of Monro (ring in A, B, C) and does not contact any important anatomical structures. The measurement of perpendicular distance from the meeting point of the skull surface (ring in D and E) to the coronal suture (D) and to the midline (E).

Evans' index between favorable and unfavorable groups was analyzed by the Mann-Whitney U test. We indicated a statistically significant result with *p*-value <0.05.

Results

The authors studied all available complete data of 21 patients (12 males and 9 females) who underwent ETV for the treatment of obstructive hydrocephalus. The patients' age ranged from 7 to 71 years (mean 34.2 years). The distribution of the patients according to principle diseases is shown in Table 1.

Table 1. Patients' principle disease

Principle disease	n (%)
Aqueductal stenosis	5 (23.8)
Cerebellar tumor	5 (23.8)
Pineal tumor	4 (19)
Brainstem tumor	2 (9.5)
Cerebellar infarction	2 (9.5)
Supratentorial ependymoma	2 (9.5)
Cerebellar hemorrhage	1 (4.8)

In the favorable group (group A), the mean perpendicular distance between the center of burr hole and the midline was 2.91 ± 0.57 cm and ranged from 2 to 4.1 cm. The mean perpendicular distance between the center of burr hole and the coronal suture was 0.96 ± 0.81 cm and ranged from -0.5 to 2.41 cm; minus (-) and plus (+) values indicated that the center of burr hole was posterior and anterior to the coronal suture, respectively. The mean Evans' index was 0.39 ± 0.08 and ranged from 0.33 to 0.58.

In the unfavorable group (group B), the mean perpendicular distance between the center of burr hole and the midline was 3.37 ± 0.50 cm and ranged from 2.36 to 4.14 cm. The mean perpendicular distance between the center of burr hole and the coronal suture was 1.33 ± 1.93 cm and ranged from -1.7 to 3.45 cm. The mean Evans' index was 0.34 ± 0.04 and ranged from 0.31 to 0.43.

We also collected images of 27 patients (the group of ideal entry point or group C) who had obstructive hydrocephalus, including head CT and MRI scans, for defining ideal entry point. The mean perpendicular distance between the ideal entry point and the midline was 2.51 ± 0.43 cm and ranged from 2.0 to 3.41 cm. The mean perpendicular distance between the ideal entry point and the coronal suture was -0.24 ± 0.71 cm and ranged from -1.3 to 1.07 cm (Fig. 6). The comparisons of these and Evan's index between the groups were summarized in Fig. 7.

Discussion

ETV is an effective option for the treatment of obstructive hydrocephalus. A possible complication of this procedure is memory impairment due to intraoperative injury of the memory pathway, particularly the fornix around the foramen of Monro[16,17]. Injury of the fornix can be caused by direct damage from the ventriculoscope or too anterior entry point. The choroid plexus is also a concerned structure around the foramen of Monro, which may be injured during the procedure. Choroid plexus injury may be caused by poor trajectory or direct trauma from the endoscope and surgical instruments. As a result, bleeding from the choroid plexus may impair endoscopic visualization or cause postoperative intraventricular hematoma. Thereby the necessity of entry position of rigid endoscope for ETV affects the success and complications of the procedure. In our study, all ETV operations of 21 patients were successful, but there were 9 patients with intraoperative injuries of fornix or choroid plexus.

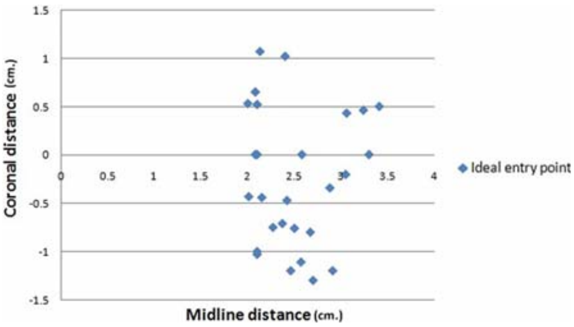

Fig. 6 Distribution of the center of the ideal entry point in 27 patients.

There have been two publications about the optimal position of the burr hole as the entrance for the rigid endoscope to perform ETV. Kanner et al proposed that the optimal burr hole position for ETV was 1 cm anterior to the coronal suture and 3 cm lateral to the midline[18]. The another study of Chen and Nakaji

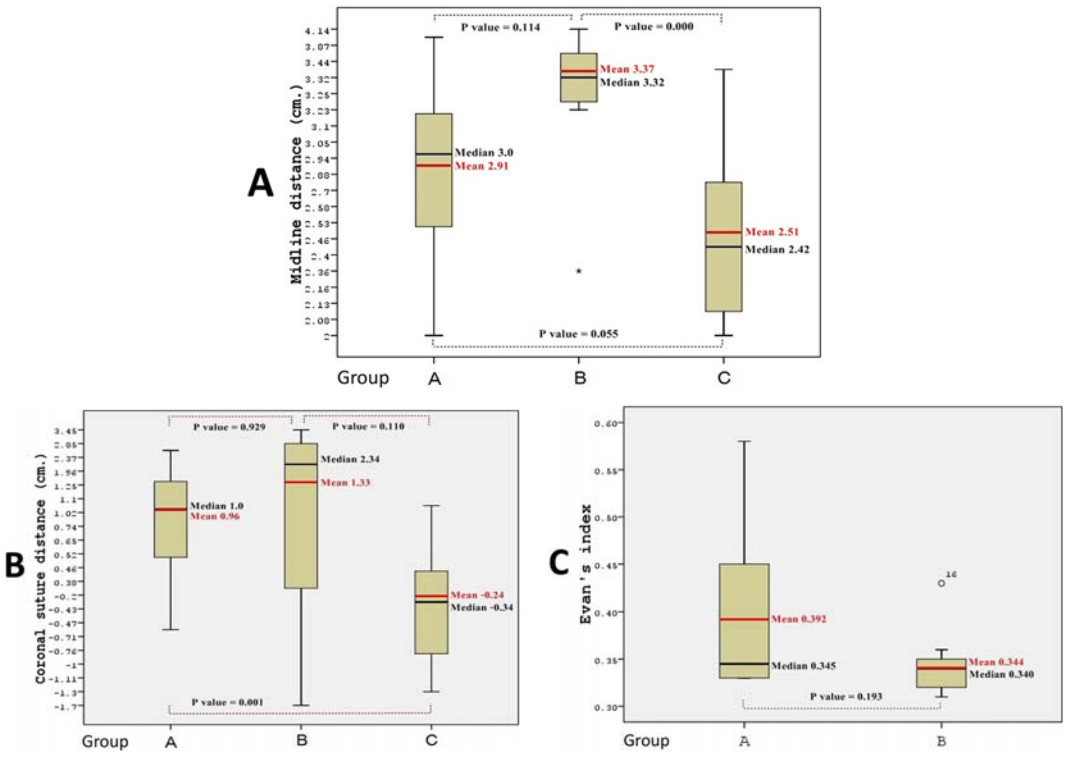

Fig. 7 The comparisons of parameters between three groups: (A) The comparison of the lateral distance between the entry point and midline of three groups. There was a statistically significant difference of the lateral distance between the unfavorable (group B) and ideal (group C) groups (p<0.001), but there was no statistically significant difference of the lateral distance between the favorable (group A), unfavorable and ideal groups (p = 0.114 and 0.055, respectively); (B) The comparison of the AP distance between the entry point and coronal suture of three groups. There was a statistically significant difference of the AP distance between the favorable and ideal groups (p = 0.001), but there was no statistically significant difference of the AP distance between the unfavorable, favorable practical group and ideal group (p = 0.929 and 0.110, respectively); the minus (-) and plus (+) values indicated that the center of the entry point was posterior and anterior to the coronal suture, respectively; (C) The comparison of Evans' index between the favorable and unfavorable groups. There was no statistically significant difference of Evans' index between both groups (p = 0.193).

suggested that the optimal point for ETV entry was 3.1±7 mm lateral to the midline and 8.9±14.1 mm posterior to the coronal suture[19]. Both studies obtained the ideal entry position from only evaluation of brain imaging.

Based on our study, we obtained the favorable and unfavorable practical entry positions from postoperative brain imaging and correlation with intraoperative finding, and also obtained the ideal entry point from evaluation of brain imaging. The mean lateral distance of the favorable practical entry point was 2.91±0.57 cm lateral to the midline, which was close to those of previous studies and was not significantly different from that of the ideal group, while the distance of the unfavorable group was significantly different from that of the ideal group. The mean anteroposterior (AP) distance of the favorable group was 0.96±0.81 cm anterior to coronal suture, which was similar to that of the study of Kanner et al; however, some range was overlapped with that of the study of Chen and Nakaji. Although there was statistically significant difference of the mean AP distance between the favorable and ideal groups, the mean AP distance of favorable group was close to that of the ideal group rather than that of the unfavorable group.

Our ideal entry point was 2.51±0.43 cm lateral to the midline and 0.24±0.71 cm posterior to the coronal suture, which was slightly different from those of the study of Chen and Nakaji. When compared with their ideal entry points, ours is less variable.

There has never been any study of the relationship between Evans' index and intraoperative complication of ETV. In our study, there was no statistically significant difference of Evans' index between the favorable and unfavorable groups. However, we observed that there was only one who had Evans' index more than 0.36 in the unfavorable group. That case had Evans' index 0.43 but there was intraoperative choroid plexus injury. The entry point of this case was 3.58 cm lateral to the midline and 1.37 cm posterior to the coronal suture, which was behind coronal suture excessively and may be the cause of choroid plexus injury.

Limitation of the study

In this retrospective study, there was only a small sample size due to limitation of complete available data.

Conclusion

The optimal entry point for ETV is 2.91±0.57 cm lateral perpendicular to the midline and 0.96±0.81 cm. anterior to the coronal suture. To make easy for routine practice, we suggest that the ideal entry point for ETV is 2.5 cm perpendicular to the midline and centered at the coronal suture. Our proposed optimal point is appropriate for Thai patients (Southeast Asia) who are older than 3 years old and have complete closure of the skull sutures. The ventricular size may be a factor of patient selection for ETV.

What is already known from this topic?

Appropriate location of the entry point for ETV can reduce surgical morbidity, particularly memory impairment caused by injury of the fornix. The most popular surface landmarks for localizing the entry point include the midline and coronal suture.

What this study adds?

The favorable practical entry point is situated in close proximity to the ideal entry point. The optimal entry point for ETV in Thai people was purposed.

Potential conflicts of interest

None.

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ตำแหน่งที่เหมาะสมของทางเข้าสำหรับการผ่าตัดส่องกล้องเพื่อเจาะรูระบายน้ำในโพรงสมองที่สามในการรักษาผู้ป่วยชาวไทยที่มีภาวะโพรงสมองคั่งน้ำแบบอุดกั้น

ธีรพล วิทธิเวช, ศุภพนธ์ ตั้งพงศ์สิริกุล, ปฤณัต อิทธิเมธินทร์, บรรพต สิทธินามสุวรรณ

_ภูมิหลัง:_ _ภาวะแทรกซ้อนที่สำคัญอย่างหนึ่งของการผ่าตัดส่องกล้องเพื่อเจาะรูระบายน้ำในโพรงสมองที่สามคือภาวะความจำแย่ลง ซึ่งมีสาเหตุจากการบาดเจ็บของทางเดินระบบประสาทที่เกี่ยวข้องกับความจำบริเวณช่องของมอนโร ตำแหน่งที่เหมาะสมสำหรับการเจาะรูที่กะโหลกศีรษะเพื่อเป็นทางเข้าในการส่องกล้องเข้าไปยังโพรงสมองจะลดความเสี่ยงของการบาดเจ็บของโครงสร้างทางกายวิภาคศาสตร์โดยรอบช่องของมอนโร_

วัตถุประสงค์: _เพื่อหาตำแหน่งที่เหมาะสมของทางเข้าสำหรับการผ่าตัดส่องกล้องเพื่อเจาะรูระบายน้ำในโพรงสมองที่สามในผู้ป่วยชาวไทยเพื่อลดภาวะแทรกซ้อนหลังผ่าตัด_

วัสดุและวิธีการ: _ตำแหน่งทางเข้าในทางปฏิบัติได้จากภาพเอกซเรย์คอมพิวเตอร์สามมิติของศีรษะผู้ป่วย ซึ่งได้รับการผ่าตัดส่องกล้องเพื่อเจาะรูระบายน้ำในโพรงสมองที่สาม ตำแหน่งทางเข้าที่ดีในทางปฏิบัติคือตำแหน่ง ทางเข้าของการผ่าตัดที่ไม่ทำให้เกิดการบาดเจ็บของโครงสร้างทางกายวิภาคศาสตร์โดยรอบช่องของมอนโร นอกจากนี้ตำแหน่งทางเข้าในอุดมคติได้จากการรวมภาพเอ็กซเรย์คอมพิวเตอร์และภาพแม่เหล็กไฟฟ้าของศีรษะ_

ผลการศึกษา: _ค่าเฉลี่ยของระยะทางในแนวตั้งฉากจากตำแหน่งทางเข้าที่ดีในทางปฏิบัติคือ 2.91 เซนติเมตร จากแนวกลางของกะโหลกศีรษะและ 0.96 เซนติเมตรหน้าต่อรอยประสานคร่อมขม่อมหน้า ค่าเฉลี่ยของระยะทางในแนวตั้งฉากจากตำแหน่งทางเข้าในอุดมคติคือ 2.51 เซนติเมตรจากแนวกลางของกะโหลกศีรษะและ 0.24 เซนติเมตร หลังต่อรอยประสานคร่อมขม่อมหน้า_

_สรุป:_ _ผู้นิพนธ์มีความเห็นว่าตำแหน่งที่เหมาะสมของทางเข้าสำหรับการผ่าตัดส่องกล้องเพื่อเจาะรูระบายน้ำในโพรงสมองที่สามคือ ระยะทาง 2.5 เซนติเมตรตั้งฉากกับแนวกลางของกะโหลกศีรษะและมีศูนย์กลางตรงกับตำแหน่งของรอยประสาทคร่อมขม่อมหน้าโดยเฉพาะในชาวไทย_