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Original Article

Ventriculoscopic surgery for arachnoid cysts in the lateral ventricle: a comparative study of 21 consecutive cases

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Abstract: Objective: To evaluate neuronavigation-guided ventriculoscopic technique in the treatment of arachnoid cysts in the lateral ventricle. Methods: Between January 2008 to November 2011, twenty-one neuronavigation-guided ventriculoscopic surgery were performed for the treatment of symptomatic arachnoid cysts in 21 patients (14 male and 7 female patients, mean age 24.1 years [ranged 1.5-61 years]) Clinical presentations varied from headache, vomiting, hemiparesis and seizure. The trajectory of ventriculoscopy was dynamically monitored and guided in real time by neuronavigation system. Cysts fenestrations were performed in fourteen cases, and cysts resection in seven cases, respectively. All patients were prospectively had a regular follow-up. Results: After operation, all patients achieved symptom resolution without surgical mortality and morbidity. Aseptic meningitis was noted in four cases with cyst resection, and all recovered quickly without advanced treatments. However, a later ependymal adhesion, occurred in one case during follow-up period. Conclusion: The combination of ventriculoscopy and neuronavigation is an accurate, effective and safe approach for the treatment of the patients with arachnoid cysts in the lateral ventricle, especially, for overcoming the topographic variation caused by intraventricular pathologies. Cystoventriculostomy is the best choice.

Keywords: Ventriculoscopy, neuronavigation, lateral ventricle, arachnoid cyst, fenestration, resection

Introduction

Intracraninal arachnoid cysts account for 1% of intracraninal lesions [1], and 3% of which occurs in children [2]. Arachnoid cyst in the lateral ventricle is rare, and only case reports exist in the literature [1-3]. There is no dedicated review describing their presentations or treatments modalities for this particular disease. Here we described our experience in the treatment of 21 patients with arachnoid cysts in the lateral ventricle using neuroendoscopy assisted with neuronavigation.

Patients and methods

Patient population and clinical materials

From 2001 to 2011, 198 patients with intracranial arachnoid cysts underwent endoscopic procedures in our department. Of these, 21 patients were diagnosed as arachnid cysts in the lateral ventricle, and were enrolled in this study, including 14 male and 7 female patients. The ages ranged from 1.5 to 61 years. The detailed clinical materials were shown in **Table 1**.

Neuronavigational MRI data set acquisition: the routine 3-D neuronavigation MRI data set was acquired with a 3.0-T whole-body MRI scanner (General Electric Medical Systems, Milwaukee, MI) using the T1-weighted 3-D fast spoiled gradient recalled sequence after intravenous contrast administration of gadolinium diethylenetriamine penta-acetic acid. The parameters were as follows: repetition time (TR), 9 ms; echo time (TE), 5.1 ms; thickness, 1.25 mm; a 320 × 224 pixel matrix; field of view (FOV), 240 × 240 mm; number of excitations (NEX), 1; contiguous, non-overlapping axial slices. In total, 150 slices were acquired for complete coverage of the tip of the nose, the top of the head, and all fiducial markers were acquired in approximately 10 minutes.

Table 1. Clinical findings and surgical outcomes in 21 patients with arachnoid cysts in the lateral ventricle

Case	Sex	Age (years)	Symptoms	Site	Operation	Pathological diagnosis	Complications	Outcomes
1	Male	13	seizure, headache	left trigone	fenestration	none	none	Good
2	Female	4	hemiparesis	left trigone	subtotal removal	arachnoid cyst	none	Good
3	Male	4	headache, nausea, vomiting	right trigone	fenestration	none	none	Good
4	Male	1.5	hemiparesis	right body	partial removal	choroid plexus cyst	temporary fever	Good
5	Female	17	headache, nausea, vomiting	right trigone	total removal	arachnoid cyst	temporary fever	Good
6	Male	19	headache, nausea, vomiting	left body	total removal	arachnoid cyst	temporary fever	Good
7	Female	43	hemiparesis	right body	partial removal	choroid plexus cyst	temporary fever	Good
8	Male	14	headache	left trigone	total removal	arachnoid cyst	temporary fever	Good*
9	Male	38	seizure	right trigone	fenestration	none	none	Good
10	Male	37	headache	right trigone	fenestration	none	none	Good
11	Male	21	headache	left trigone	fenestration	none	none	Good
12	Female	14	seizure	right trigone	fenestration	none	none	Good
13	Male	36	headache	left trigone	fenestration	none	none	Good
14	Male	46	headache	left trigone	fenestration	none	none	Good
15	Male	1	hemiparesis	left trigone	fenestration	none	none	Good
16	Female	16	headache	left trigone	fenestration	none	none	Good
17	Female	61	unstable gait	right trigone	fenestration	none	none	Good
18	Male	60	headache	left trigone	fenestration	none	none	Good
19	Male	5	headache	left trigone	fenestration	none	none	Good
20	Male	2	headache	left temporal horn	fenestration	none	none	Good
21	Female	54	headache	right foramen of monro	total removal	arachnoid cyst	none	Good

Good in Outcome means "patients achieved resolution of symptoms, with relative reduced ventricles". *an ependymal adhesion one year later.

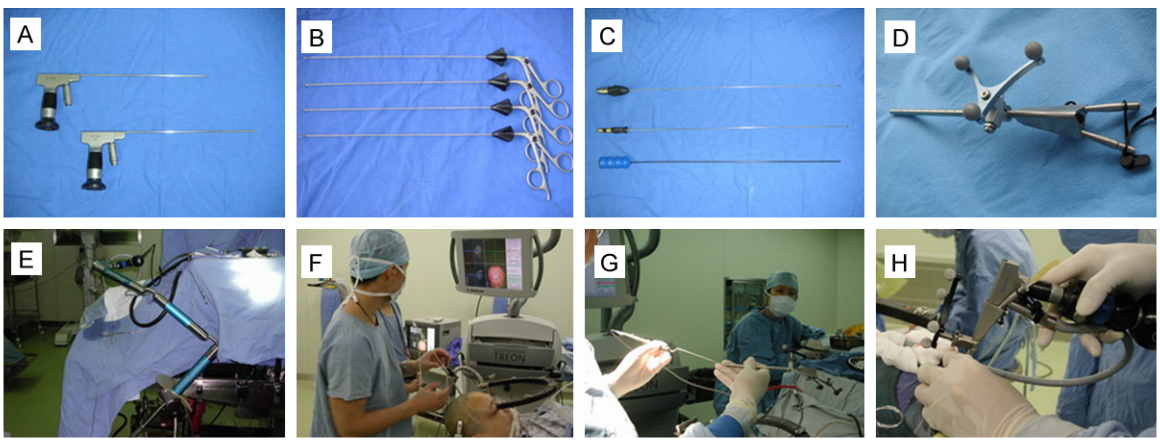

Figure 1. Surgical instruments and procedures of neuronavigation-guided ventriculoscopy. A. Endoscope (0°, 30°); B. Microsurgical instruments (microscissors, puncture needles, and biopsy, grasping forceps); C. Electrosurgical instruments (monopolar, bipolar); D. A SureTrack adaptor which was connected to ventriculoscopy; E. Pneumatic driving arm; F. Registration of neuronavigation; G. Correction of working sheath; H. surgical procedure.

Surgical equipments

Endoscope equipments: The ventriculoscope system (Aesculap, Tuttlingen, Germany) was composed of one rigid endoscope and one working sheath (outer diameter 6.2 mm), which contain four channels, including optic (2.2 mm), working (2.2 mm), suction (1.4 mm) and irrigation channels (1.4 mm). Various mechanical instruments such as microscissors, puncture needles, and biopsy and grasping forceps were used for dissection and tissue removal. Video camera, Xenon lamp, display monitor, and videotape recorder were available (**Figure 1**).

Neuronavigation system: The hardware components of StealthStation neuronavigator (StealthStation, Sofamor Danek, Co, USA) included:

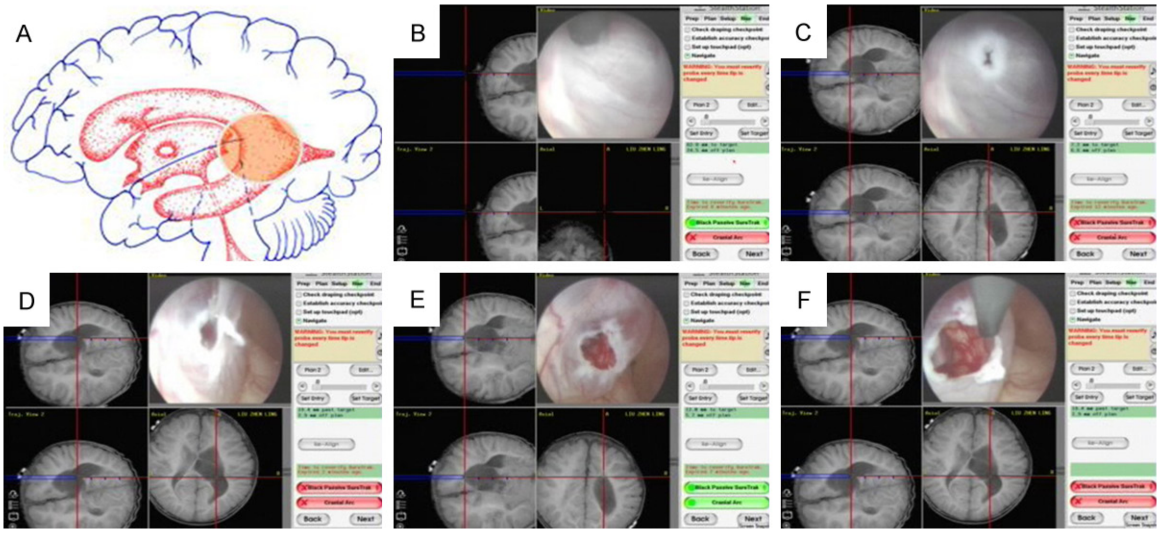

Figure 2. Endoscopic view of the fenestration of an arachnoid cyst in body of the right lateral ventricle by right trans-frontal horn approach (case 4). A. Schematic diagram of navigation model for an archnoid cyst; B. Cauterization of cyst wall; C. Puncture of cyst wall (the tip of the ventriculoscopy was on the surface of the cyst); D. Incision of cyst wall; E. Fenestration of cyst wall; F. Furthur incision of cyst wall (the bottom of the cyst was found to adhere to the wall of the lateral ventricle).

(1) UNIX workstation and high-resolution monitor; (2) Position sensor unit (PSU). The electro-optical camera system digitized and measured the position of IREDs (infrared detectors) in the surgical field. (3) Reference arc. The surgical reference arc that has five IREDs provided a three-dimensional localizing device. (4) Optical probe with IREDs was used to calculate the position of the tip of the instrument.

The SureTrak universal instrument adapter system (Medtronic, USA): The system enables the surgeon to adapt almost any standard instrument for use with the StealthStation Treatment Guidance platform, was coupled to the ventriculoscopy (**Figure 1**). This setup allowed the surgeon to move the ventriculoscopy and neuronavigator as one unit. The intraoperative video was transmitted by a camera to a video recording unit. In this way, the dynamic position of the tip of ventriculoscopy was monitored continuously and in real-time.

Neuronavigator-guided ventriculoscopy

The neuronavigation software provides a display of triplanar reconstruction as well as 3-dimensional reconstruction, therefore, the anatomical sites of the cysts and their connections with the ventricle wall and choroid plexus can be analyzed carefully. The optimal approaches, including entrance point, target point, and surgical trajectory, were preoperatively determined on the monitor screen by the surgeons. The cysts in trigone of the lateral ventricle were manipulated via trans-trigone approach; and the cysts in body of the lateral ventricle were manipulated by trans-frontal horn approach. In the operating room, the patient's head was fixed with a Mayfield head clamp according to the location of the lesion. After calibration and verification, the position of the tip of the ventriculoscopy with SureTrak adapter in relation to the lesion was displayed, allowing the surgeons to determine the entrance point and orientation (**Figure 2**). According to the best surgical plan, a short incision (3 centimeter) and a small burr hole with a diameter of 1.2 centimeter was made. The tip of the ventriculoscopy guided by the StealthStation neuronavigator approached to the target point - the lesion site safely and accurately. The surgical trajectory was shown continuously on both the StealthStation monitor and the endoscopic screen. After approaching the target under navigation guidance, the operation was performed under endoscopic vision.

Surgical procedures

There were two kinds of surgical protocols. 1) Cyst fenestration: if most part of cysts adhered to the surrounding ependyma closely, cyst fenestration was performed. Under the guide of

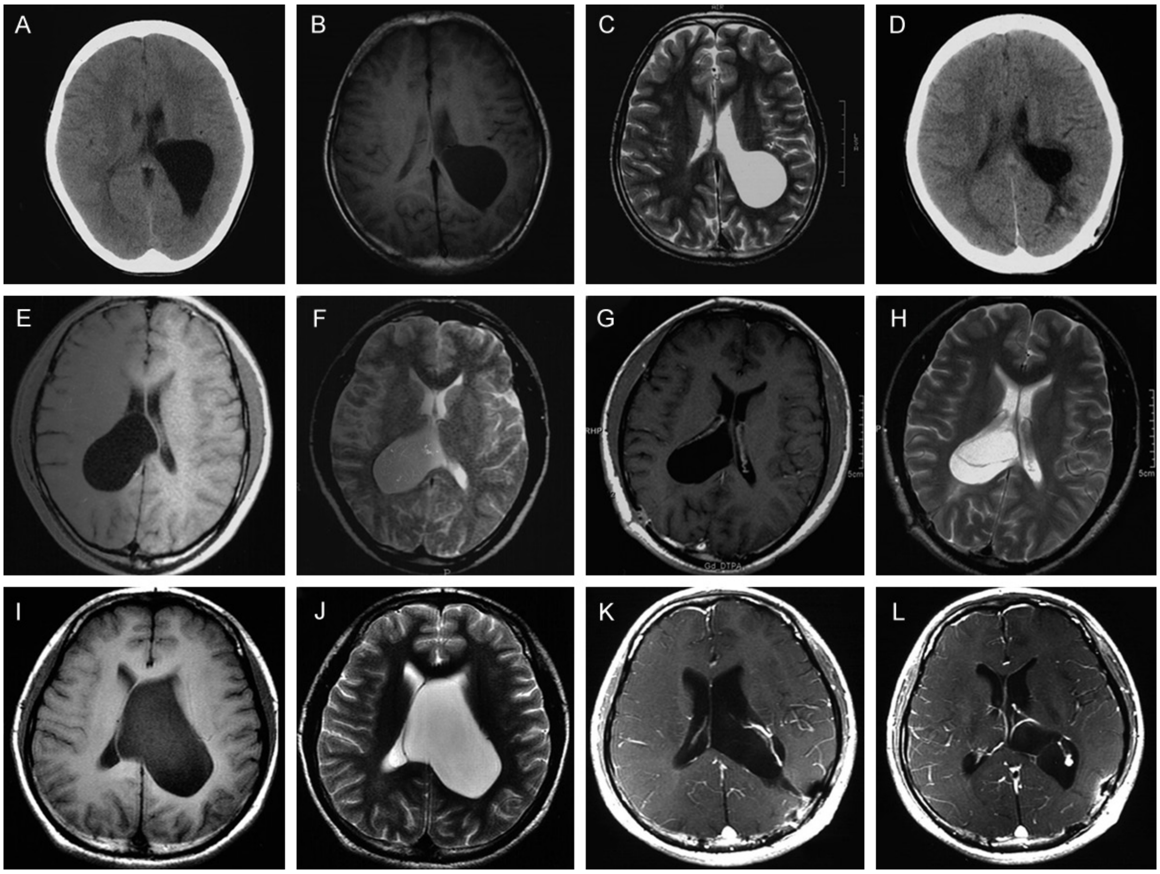

Figure 3. A-C. The preoperative CT and MRI images showing an arachnoid cyst in the trigone of the left lateral ventricle from case 8. D. One month after surgery, a CT scanning image showing a marked reduction in the size of the cyst. E, F. The preoperative MRI images showing an arachnoid cyst in trigone of the right lateral ventricle from case 10. G, H. Two months after surgery, the postoperative MRI showing a marked reduction in the size of the cyst. I, J. The preoperative MRI images showing an arachnoid cyst in trigone of the left lateral ventricle from case 6. K, L. Two months after surgery, the postoperative MRI showing a marked reduction in the size of the cyst.

neuronavigation, the ventriculoscopy entered the ventricle successfully, and the suitable site was selected to perform fenestration, then the wall of the cyst was coagulated by a mono- or bi-polar coagulator, fenestrated and enlarged by puncture needle, micro-scissors and grasping forceps. The optimal fenestration size was 10 millimeter × 10 millimeter. If fenestration on one side of the cyst wall does not make satisfactory, or complete adhesion of the cysts to the surrounding ependyma leads to entire separation of the lateral ventricle, the contralateral cyst wall should also be fenestrated to prevent the recurrence of the cysts or postoperative obstructive hydrocephalus. 2) Cyst resection: If most part of cysts did not adhere to the surrounding ependyma tightly, cyst resection was considered. After dissection, the cyst wall near the choroid plexus was made a circular opening, and most parts of dissected cyst wall were removed. No case was treated by external ventricular drainage.

Results

Pre-operative MRI scans showed an intraventricular cyst lesion with signal being the same as cerebral spinal fluid, which was low-signal on T1-weighted, and high-signal on T2-weighted images. Neither enhanced nodes nor cyst wall enhancement was found (**Figure 3**). In two cases (case 3 and 5), a phase-contrast cine MRI scan was performed to confirm no liquid flow in the cyst, therefore, a diagnosis of non-communicating cyst was made.

Surgical results: cyst fenestrations were done in 14 cases, total cyst removal in four cases, subtotal removal in one case, and partial removal in two cases.

Pathological results: seven cases had pathological results, including five arachnoid cysts and two choroid plexus cysts. Surgical results and pathological results have been summarized in **Table 1**.

All the patients showed a marked improvement of their clinical status after surgery. The patients were able to discharge from the hospital about seven days after the intervention. The symptoms such as seizure, headache, hemiparesis, nausea and vomiting have disappeared completely. There was no operative mortality and serious postoperative complications, such as hemorrhage, central nervous system infection or focal neurological deficits. Four cases (case 4, 5, 6 and 7) presented temporary fever were diagnosed with aseptic meningitis by cerebrospinal fluid test through lumbar puncture, which was mainly related to the manipulation in the ventricle, and recovered quickly without advanced treatments.

The postoperative follow up periods ranged from 32 to 125 months (mean, 79.8 months). All patients were followed up at interval of 3 months in the first year and then 12 months afterward. The follow-up was conducted in outpatient clinic, including survey of clinical presentations and radiological examinations (CT or MRI scan). All the patients achieved resolution of symptoms, with relative reduced ventricles (**Figure 3**, from case 6, 8, 10), and without the recurrence. However, one case developed an ependymal adhesion with no symptoms one year after surgery.

Discussion

Non-congenital factors, such as trauma, hemorrhage and infection would be the contributors to the formation of intracranial cysts. In this study, we excluded the above factors in all patients via thorough and careful history review. Usually, the congenital arachnoid cyst is located in the trigone, the body, the temporal horn and the occipital horn of the lateral ventricle, however, the cyst rarely occurs in the frontal horn, as shown in our cases. It is believed that the arachnoid cyst in the lateral ventricle is closely associated with the distribution of choroid plexuses [1-4].

Pathological diagnosis of intracranial arachnoid cysts is based on the structure of cyst wall, which are composed of collagen and flattened or cuboidal epithelial cells. The cellular components of the cyst wall are similar to those in the normal arachnoid. However, no such cellular structures exist in the lateral ventricle. Therefore, the formation of arachnoid cysts in the lateral ventricle is believed to be different from that in other intracranial regions. Currently, the mechanisms underlying cyst formation is based on histological study. It is believed to be closely associated with choroid plexus of the lateral ventricle [1]. Terminology of congenital cysts with cerebrospinal fluid-like content is different. In addition to arachnoid cysts, the congenial cysts also include choroid plexus cysts and glial cysts. Based on histological findings, we concur with the conclusion that choroid plexus cysts are arachnoid cysts [2, 5]. During the formation of arachnoid cysts, mesenchyme in the blood vessel probably folds into the cavity of the neighboring ventricle, such as choroid fissure, and is covered by a glial cell layer and an ependymal layer. Moreover, pathological examination confirms that the top of cyst wall is very thin and usually lacks the glial cell layer or the ependymal layer, whereas all the cellular structures of cysts near to choroid plexus can be kept intact, thus, different pathological diagnoses could be made.

Intracranial arachnoid cysts can present with space-occupying signs or hydrocephalus on CT or MRI images with or without symptoms. The main symptoms of the patients with congenital arachnoid cysts are headache, nausea, vomiting, seizure and hemiparesis. There is a controversy regarding surgical treatment of patients with unspecific or without symptom. As an increasing number of patients is referred to neurosurgeons and the risk may be underestimated, because the natural history and pathophysiology of arachnoid cysts are not fully understood. In our practice, only arachnoid cysts with symptoms require surgical treatment. For patients with small cysts and no symptomatology, periodic follow-up studies should be mandatory. The optional therapy which includes microsurgical technique, shunt placement and endoscopic surgical technique remains controversial. Cyst puncture produces a high rate of recurrence [6], and cystoperitoneal shunting is now rarely used due to bad outcome [7].

Endoscopy has been used in neurosurgical procedures since the early 1900s. Neuroendoscopy, however, has made slow progress owing

Table 2. Comparison of clinical treatments of arachnoid cysts in the lateral ventricle

Authors	Number	Symptom	Site	Surgical procedure	The treatment of cyst	Complications
H. Koga (1995)	1 (M)	Gait disturbance	right body and trigone	frontal craniotomy	partial resection	transient motor aphasia and right hemiparesis
Maiuri (1997)	1 (M)	Headache and epilepsy	right trigone	parietooccipital craniotomy	total resection	transient left hemiparesis
Sanjay (2001)	1 (M)	Headache and epilepsy	left temporal horn	temporal craniotomy	subtotal resection	mild left eye proptosis
S.W. Park (2006)	1 (F)	Macrocephaly and developmental delay	left lateral ventricle	endoscopy	fenestration	subdural fluid collection
G Tamburrini (2007)	2 (F)	Headache	lateral ventricle	endoscopy	fenestration	none
P. Zhao (2013)	28	Headache and intelligence decline	lateral ventricle body	endoscopy	resection	subdural fluid; subcutaneous fluid
Our study (2014)	21	Headache, epilepsy, and hemiparesis	trigone, body	endoscopy	Fenestration, resection	a later ependymal adhesion

M: male; F: female.

to the rigidity of endoscopy and lack of special instruments suitable for micro-neurosurgery. From the end of 80th of last century, with the development and improvement of modern endoscopic techniques and surgical instruments, neuroendoscopy has undergone a renaissance, and now it becomes an important part of minimally invasive neurosurgery [8]. Moreover, endoscope-assisted micro-neurosurgical and endoscopic techniques, have advantages of minimally invasion, high resolution of imaging and better view of surgical field, thus they have been widely applied to the treatment of intracranial arachnoid cysts [4, 8-10]. In endoscopic procedure in the ventricle system, normal anatomic structures in the ventricle are used for landmarks. The precisely control of the trajectory of endoscope, however, would be difficult under pathological conditions, because the anatomic landmarks are distorted or disappeared. To overcome the limitation, many neurosurgeons have recently combined neuronavigation system with neuroendoscopy to enhance safety and accuracy of ventriculoscopy in the treatment of the intracranial cysts [11-16]. Nevertheless, clinical treatments of arachnoid cysts in the lateral ventricle were relatively less reported, which were summarized in **Table 2** [1-3, 17-20].

Neuronavigation technique has the advantage of precisely targeting the lesion site, and guides neurosurgeons to operate by providing precise images of anatomic structure and three-dimensional localization of the lesion site. Thus, neuronavigation combined with neuroendoscopy can improve the preciseness of surgery and reduce operative damage [11-16]. From our experience, neuronavigation-guided ventriculoscopy has the following advantages: 1) to find the position of skin incision and bone window, and to choose the precise surgical trajectory with the communication between the front and back of cyst wall. 2) dynamically monitor the procedure of ventriculoscopy. Because manual operation of ventriculoscopy occupies most time of the surgery, and it is also hard for operators to notice the surrounding regions of the ventricle during operation, in addition, horizontal movement of working sheath of ventriculoscopy could make brain damage. By contrast, neuronavigation-guided ventriculoscopy is helpful to avoid damage of important nerve tissues such as thalamus, corpus callosum. In this study, no symptoms of neurological deficiency were observed in all 7 cases after surgery. 3) to confirm anatomic landmarks and targets. For example, choroid plexus in lateral ventricle, interventricular foramen, and thalamostriate vein can be used as anatomic landmarks, which can be confirmed by the anatomic images provided by neuronavigation system. Similarly, for the verification of operation targets, neuronavigation system also makes surgery more precise and safer. When bleeding occurs, cerebrospinal fluid mixed with blood covers the surgical field, consequently, increasing the risk of operation. Whereas neuronavigation can assist surgeons to verify anatomic position in which the ventriculoscopy is located and to avoid tissue damage, consequently, saving time to stop bleeding and further operation. However, loss of cerebrospinal fluid may result in an error of neuronavigation [16]. To overcome this problem, continuous washing and drainage device should be used to keep the pressure of the ventricle unchanged. Therefore, in our opinions, intraoperative brain shift induced by an endoscope is insignificant.

There is a controversy regarding the surgical techniques for the treatment of ventricle cysts. In our opinion, cyst fenestration should be the first choice for the treatment, because it is simple and effective. Several techniques to fenestrate the cysts have been reported: electrocoagulation, microsection, microbipolar electrocautery and balloon, and cather [10, 21-26]. Goebel reported an endoscopic laser stereotaxis (ELS) technique which was applied in cyst fenestration [27]. Cyst wall is vaporized and cut using a ND: YAG laser uncontactly. It was believed to make the surgery more effective and have a wider application in the treatment of the intracranial cysts. We summarized the following experience from the courses of fenestrations. 1) A cyst with a thinner wall can be directly cut open by increasing voltage of electrocoagulation. 2) Because the wall of most cysts is tight and become shrinkage after electrocoagulation, microsection is often required. 3) Cyst wall can be first fixed using a microclamp and then be cut open by a microscissor via both working channel and rinsing channel. 4) Microbipolar forceps have functions of both electrocoagulation and electric resection, therefore, it makes fenestration safe and easy. 5) Balloon catheter can also make rapid and effective fenestration. 6F balloon catheter (Edwards Lifesciences, Irvine, CA, USA) is usually used due to its ability of dilation. The maximal diameter of the dilation can reach up to 11 mm. 6) As described above, the top of cyst wall is usually composed of a single layer of epithelial cells, whereas the base of cyst wall near to choroid plexus is made up of a glial cell layer, an ependymal layer and an epithelial cell layer. Thus, cyst incision should be performed at the top; when the incision is performed at the base, completely opening every layer of cyst wall should be considered. Moreover, the size of fenestration should be at least 10 × 10 mm to prevent re-closure of the fenestration or recurrence of cyst.

Cyst resection is considered only when the cyst is free in the ventricle without adhering to blood vessels around choroid plexus. Avoiding resection of the base part of cyst wall is to prevent bleeding. It has been shown that wound surface induced by cyst resection is much larger, and the occurrence of postoperative aseptic meningitis is greater than that by fenestration (**Table 1**). Moreover, we found that an ependymal adhesion occurred 12 months after a total cyst resection. Furthermore, during the follow-up period, we showed the same outcomes of the surgery between cyst fenestration group (14 cases) and cyst resection group (7 cases). Thus, our findings indicated that cyst resection is not necessary as long as enough size of fenestration is available.

In summary, we have demonstrated that neuronavigation-assisted neuroendoscopic microsurgery is a better surgical treatment of arachnoid cysts in lateral ventricular. Moreover, cyst fenestration is a preferred treatment to cyst removal. Neuronavigation-assisted neuroendoscopic microsurgery has advantages of easy manipulation, minimal invasion, better postoperative recovery and a lower rate of recurrence. Thus, the combined approach of neuronavigation and neuroendoscopy will play a significant role in further exploring microsurgical treatment of complicated ventricular cysts.

Disclosure of conflict of interest

None.

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