Arachnoid cysts account for 1% of all intracranial lesions. Intracranial arachnoid cysts usually occur in the subarachnoid space of the major cerebral fissures and arachnoid cisterns. They are very rarely located within the brain parenchyma devoid of communication with the subarachnoid space. They are predominantly located in the sylvian fissure; however, they can be found in other locations such as the suprasellar region, quadrigeminal cistern, and, in rare instances, within the ventricles or inside the brain parenchyma. The optimal surgical treatment is still debatable. Many operative procedures have been recommended including stereotactic aspiration, craniotomy and excision or fenestration of the cyst, or cystoperitoneal shunting. 

Neuroendoscopic management is emerging as a promising alternative procedure that avoids the invasiveness of open craniotomy and the complications caused by shunt treatment. Many studies discuss the role of endoscopy in the treatment of intraparenchymal arachnoid cysts (IPACs), which have a paraventricular location noncontiguous with the basal cisterns. Neuroendoscopic management is emerging as a promising alternative procedure that avoids the invasiveness of open craniotomy and the complications caused by shunt treatment. Many studies discuss the role of endoscopy in the treatment of intracranial arachnoid cysts, including some cases of intraparenchymal arachnoid cysts (IPACs), and only one study specifically addresses the endoscopic treatment of IPACs. In previous papers, we reported on the endoscopic treatment of pediatric patients with middle cranial fossa, suprasellar, and quadrigeminal cistern arachnoid cysts. The present paper focuses on the role of endoscopy in the treatment of IPACs, which have a paraventricular location noncontiguous with the basal cisterns. The group discussed in this paper is a subset from the same overall population of pediatric patients with arachnoid cysts treated using endoscopy at our institution.

**Key Words**
- arachnoid cyst
- cystoventriculostomy
- endoscopy
- intraparenchymal
- congenital

**Abbreviations used in this paper:**
EEG = electroencephalography; ETV = endoscopic third ventriculostomy; IPAC = intraparenchymal arachnoid cyst.
Methods

The records of all patients who had undergone surgery performed by one neurosurgeon (N.M.F.E.G.) between March 2004 and October 2011 were retrospectively reviewed to find cases of arachnoid cysts (confirmed histologically) with a para-ventricular location noncontiguous with the basilar cisterns (confirmed radiologically) that were treated with a purely endoscopic cystoventriculostomy. Data were collected, summarized, and analyzed as regards improvement in symptomatology, decrease in cyst size, improvement in hydrocephalus, incidence of complications, surgical failure, and incidence of recurrence.

Endoscopic Technique

All procedures are performed with the patient under general anesthesia. The approach is individually designed for each case depending on the location of the arachnoid cyst. The skin incision is made and a bur hole is placed according to the best trajectory obtained from preoperative multiplanar MRI studies. The trajectory is planned to start from the skin incision through the body of the cyst to the lateral ventricle. A cruciate dural incision is made, and bleeding is stanched completely with electrocautery to induce or enhance adhesions with the arachnoid plane. The cyst is cannulated with a 14-Fr peel-away sheath and stylet. I advise an opening exactly the same size as the operating sheath diameter to avoid any significant CSF leakage (to minimize brain shift and keep the neuronavigation procedure as accurate as possible), to prevent collapse of the cyst with subsequent opening of the subarachnoid space and occurrence of subdural hygroma, and to avoid the entrance of air, which hinders the procedure significantly. After the endoscopic working sheath is referenced as the neuronavigational tool, direct puncture of the cyst is performed, the stylet is withdrawn, and a 2-mm-diameter rigid lens (wide angle, straight forward, 0°) with angled eye piece and working channel diameter of 3 mm is introduced inside the cyst cavity. The ideal point of cystoventriculostomy is easily identified under neuronavigational guidance (Fig. 1). However, because of the absence of any cerebral mantle at the place of contact between the cyst wall and the lateral ventricle in all cases included in the study, it was possible to visualize vivid pulsations of a translucent membrane at this area (Fig. 2A). Such pulsations can be used as an indicator of the target area for fenestration in cases in which surgery is performed without neuronavigational guidance. Blunt perforation is easily performed using the tip of a 3-Fr Fogarty catheter without a stylet or by using a coagulation probe without electric current (Fig. 2B). The fenestration is then gently widened to prevent reclosure (Fig. 2C). Any bleeding from the cyst wall usually stops with irrigation or coagulation. Pulsed irrigation with lactated Ringer solution is used to prevent thermal injury and collapse of the ventricles. The endoscope is then advanced through the fenestration to visualize ependyma of the lateral ventricle and to ensure the creation of an adequate communication. Part of the outer cyst wall can be removed for histopathological examination by using the punch forceps (Fig. 2D).

The cyst is vigorously irrigated to remove any blood clots, which may promote fibrosis with closure of the fenestration, and to make sure that there is no air left inside the cyst cavity. The operating sheath is then withdrawn with the endoscope inside to look for active bleeding in the puncture canal. Because suturing of the dura mater is not feasible, the bur hole is packed with a gelatin sponge, and the galea is tightly sutured to prevent subgaleal CSF accumulation with fistula formation. The skin is carefully closed with interrupted sutures. No external ventricular drain was left at the end of the procedure.

Results

A full history was taken, and all patients were subjected to a complete neurological examination including developmental milestones. Preoperative CT and MRI studies were reviewed, with special attention given to the size of the cyst, its location, its relationship to the ventricular system, the presence of mass effect in the form of midline shift or ventricular compression, and the presence of hydrocephalus or associated congenital anomalies such as porencephaly or holoprosencephaly. Patients who had epilepsy were evaluated using electroencephalography (EEG).

Preoperative CT and MRI studies revealed an intraparenchymal fluid-filled cavity having a paraventricular location and exerting mass effect (Fig. 3 left). Of the 12 patients with IPACs included in this study, 7 were male and 5 were female, for a male/female ratio of 1.4:1. The youngest patient was 21 months old, the oldest patient was 11.5 years old, and the mean age was 5.2 years. All patients had supratentorial arachnoid cysts, and in none of the cysts were there any signs or symptoms relating to obstructive hydrocephalus.

Figure 1. A–C: Axial (A), coronal (B), and sagittal (C) T1-weighted MR images obtained in the case of a left frontal IPAC, showing intraoperative localization of the target area (using neuronavigation) for fenestration at the place of contact between the cyst and left frontal horn. D: Live video capture taken during the endoscopic procedure, showing the thin translucent membrane at the place of contact between the cyst and left frontal horn (arrows).
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them was the cyst located in the posterior fossa. In all cases there was an area of contiguity with the ventricular system, and in none of them was there a place of contact with the subarachnoid cisterns. The main location of the cyst was frontal (5 cases), temporoparietal (4 cases), and frontoparietal (3 cases). Presenting symptoms were headache (8 cases), hemiparesis (4 cases), seizures (4 cases), ataxia (2 cases), and developmental delay (1 case; Table 1). The duration of symptoms ranged from 2 months to 1.5 years with a mean of 8.3 months. All 4 patients who presented with epilepsy showed focal dysrhythmia on EEG. Concomitant hydrocephalus was present in 3 cases (25%). There was a history of head trauma in 1 patient. The cyst was right-sided in 6 cases and left-sided in 6 cases (right/left ratio 1:1). The maximum cyst diameter ranged from 5.6 to 9.5 cm with a mean of 7.6 ± 1.3 cm.

The indications for surgery are variable and not well established. In the current study, patients were considered to be candidates for surgical treatment only if they had specific cyst-related symptoms. Headache was considered to be an indication for surgery if it was attributable to increased intracranial pressure (as evidenced by the presence of papilledema) or if it was associated with other cyst-related symptoms. Developmental delay alone was not considered an indication for surgery, and patients with epilepsy were candidates for surgical treatment only if seizures were focal, localized to the region of the cyst on EEG, and refractory to medical treatment.

All patients underwent a purely endoscopic procedure (endoscopic cystoventriculostomy) while under general anesthesia. The surgeries were all primary, and there was no history of a direct surgical approach to the arachnoid cyst itself or shunt placement. Intraoperative findings were noted, for example, thickness and transparency of the membranes, whether fenestration of the cyst wall was technically easy or difficult, and any complications such as bleeding. The surgical procedure was considered successful if the fenestration was completed and enlarged, good CSF pulsations were observed, and it was possible to directly visualize ependyma of the lateral ventricle. Surgical failure meant that the fenestration procedure could not be completed successfully.

Surgical treatment included endoscopic cystoventriculostomy in 12 cases and endoscopic third ventriculostomy (ETV) in 3 cases. The presence of hydrocephalus in 3 of the patients facilitated the procedure significantly and made the use of neuronavigation dispensable. In the patients without hydrocephalus (9 cases), the deep cyst wall at the area of contiguity with the ventricular system was translucent and showing vivid-like CSF pulsations. Fenestration of the deep cyst wall and communication of the cyst with the lateral ventricle (cystoventriculostomy) was successful in all the patients (100%). Excision of the outer cyst wall was never attempted in any of the patients. However, parts of the outer cyst wall were resected using the punch forceps. Histopathological examination of the cyst wall showed a thin layer of flattened arachnoid cells with elongated nuclei and overlying gliotic tissue, without a glial limiting membrane, a picture that is characteristic of arachnoid cysts. The procedure time ranged from 35 to 95 minutes with a mean of 54 minutes.

Patients were clinically assessed postoperatively, with any improvement in preoperative symptoms or the occurrence of new neurological deficits or complications noted. Patients who had epilepsy were considered to have improvement if attacks were better controlled and/or antiepileptic drugs could be reduced. A follow-up CT scan was obtained the next postoperative day to detect any
intracystic hemorrhage or subdural effusion. Magnetic resonance imaging and/or CT scanning were performed 3–6 months postoperatively, and the results were compared with preoperative studies as regards any decrease in cyst size or ventricular size (in patients who had hydrocephalus). Any recurrence or progression of symptoms was considered to be an indication for repeating MRI. Recurrence or progression of symptoms associated with an increase in cyst size on postoperative imaging was considered to be an indication for reoperation or revision surgery.

There were no intraoperative complications, and there were no deaths or cases of permanent morbidity. None of the patients experienced any new neurological deficits or seizures postoperatively. Subdural hygroma occurred in 2 patients (16.7%), although it was small in size and resolved without any surgical treatment in one of these 2 patients. A subduroperitoneal shunt was implanted in the other patient.

Clinical improvement after surgery was encountered in 10 (83.3%) of 12 cases. All patients who had headache (8 patients), hemiparesis (4 patients), and seizures (4 patients) showed remarkable postoperative improvement (100% improvement in each category). One (50%) of the 2 patients who had ataxia reported clinical improvement. However, the patient with developmental delay did not show any improvement.

Postoperative imaging showed a decrease in cyst size in 9 cases (75%); in the other 3 cases (25%), the cyst size remained unchanged. The maximum postoperative cyst diameter ranged from 3.9 to 7.2 cm with a mean of 5.9 ± 0.89 cm. The difference in the mean cyst size before and after surgery was statistically significant (7.6 vs 5.9 cm, p < 0.001). Nevertheless, in none of the patients did the cyst totally collapse following the endoscopic procedure. A reduction in ventricular size occurred in 2 (66.7%) of the 3 patients who had hydrocephalus.

The follow-up period ranged from 15 to 72 months with a mean of 42.5 months. During that period, a repeat endoscopic procedure was performed in 1 patient (8.3%). In this patient, a new-onset headache occurred 38 months postoperatively. Magnetic resonance imaging revealed an increase in both cyst and ventricle size. At the second endoscopic procedure, the cystoventriculostomy fenestration was found to be patent, whereas the third ventriculostomy stoma was closed. It was reopened with postoperative improvement of headache, although there was no decrease in cyst or ventricular size. None of the patients required the insertion of a ventriculoperitoneal or cystoperitoneal shunt.

**Discussion**

**Endoscopic Treatment**

The significant potential morbidity of microsurgical fenestration and the current overall favorable opinion to use a shunt-independent approach prompted neurosurgeons to search for an alternative procedure. The endoscope is an ideal instrument for the exploration of fluid-filled cavities, and the proximity of IPACs to the
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The ventricular system makes such lesions accessible for endoscopic treatment. In the presence of hydrocephalus, an endoscopic procedure seems to be an appropriate option for the treatment of IPACs. Only one other study, by Oertel et al., has reported on a group of patients with IPACs treated endoscopically.

**Endoscopic Localization**

The contribution of frameless neuronavigation in neuroendoscopy for the treatment of IPACs is of the utmost importance, since no anatomical landmarks are found within the cysts. The value of the concomitant use of neuronavigation and endoscopy in dealing with these cases has also been proved. However, one should expect the occurrence of intraoperative brain shift and errors in measurements if significant CSF loss occurs while puncturing the cyst or if vigorous irrigation is needed during the procedure. If there is no cerebral mantle at the place of contact between the cyst wall and the lateral ventricle, the target area for fenestration can be intraoperatively recognized as a thin translucent membrane showing vivid-like CSF pulsations. It can be identified if the view is not obscured and if the neurosurgeon is familiar with such cases of distorted anatomy. An endoscopic ultrasound probe might be a better option than neuronavigation in the future, since it gives live feedback on the surgical progress. Consequently, it overcomes the problem of the intraoperative brain shift that can occur during the surgery. If hydrocephalus is present, there is usually a large area of contiguity between the cyst wall and the lateral ventricle, which facilitates the procedure significantly and makes the use of neuronavigation dispensable.

**Endoscopic Fenestration**

In contrast to arachnoid cyst surgery, the fenestration procedure is usually performed very easily, and even a small stoma without stent insertion may be sufficient in the treatment of patients. One of the reasons may be the absence of a definite cyst membrane at the area of contiguity with the lateral ventricle. Consequently, a corticotomy can be performed for cyst drainage, similar to the ETV used to treat acute hydrocephalus, in which a small drainage opening allows sufficient CSF flow through the stoma with a very low recurrence rate. The present report provides evidence that blunt fenestration can be easily performed for IPACs by using the tip of a Fogarty catheter (without stylet) or a coagulation probe (without electric current). This contrasts with the procedure for other types of arachnoid cysts in which the cyst wall may be tough, making the procedure difficult and requiring sharp fenestration using bipolar coagulation or scissors.

**Morbidity and Mortality**

In the present study, there were no deaths or cases of permanent morbidity. None of the patients experienced intraoperative complications or any new neurological deficits or seizures postoperatively. Subdural hygroma occurred in 2 patients (16.7%), requiring the insertion of a subduralperitoneal shunt in one of them. In the Oertel et al. study of 11 patients with IPACs treated with endoscopic cystoventriculostomy, chronic subdural hematoma occurred 3 months postoperatively in 1 patient and required surgical treatment. Another patient suffered from an abscess formation in the area of the cyst after a second endoscopic procedure.

**Operative Outcome**

Clinical improvement was encountered after surgery in 10 (83.3%) of 12 patients in the present study. Postoperative imaging showed a decrease in cyst size in 9 patients (75%; Fig. 3 right); the cyst size was unchanged in the remaining 3 patients (25%). A reduction in ventricular size occurred in 2 of the 3 patients who had hydrocephalus (66.7%). Clinical improvement occurred in 10 (90.9%) of 11 patients in the study by Oertel et al. All patients who had complained of headache reported clinical improvement, and all patients who had suffered from seizures became seizure free without any medication. A decrease in cyst size was observed on early postoperative MRI performed within the 1st week in 10 patients.

**Treatment Failure and Recurrence**

A paucity of data in the literature concerns the outcomes of endoscopic treatment of IPACs as well as the incidence and cause of treatment failure or cyst recurrence during long-term follow-up. There is a complete absence of information on a secondary endoscopic procedure in the treatment of recurrent cases. Many factors affect outcome, such as size of the fenestration, insertion of cystoventricular catheter or stent, resection of the cyst wall, presence of hydrocephalus, and occurrence of intraoperative bleeding. Whether such factors influence the long-term outcome still needs to be addressed.

During a mean follow-up of 48.8 months in the Oertel et al. study, an arachnoid cyst recurred in 1 of 11 patients 89 months after the initial endoscopic procedure. A repeated cystoventriculostomy was performed, and the patient’s condition clinically improved postoperatively with a further postoperative decrease in cyst size. During a mean follow-up of 42.5 months in the present study, 1 patient developed a new-onset headache 38 months after the initial endoscopic procedure. The headache was associated with an increase in both cyst and ventricular size. At a second endoscopic procedure, the fenestration was seen to be patent. The third ventriculostomy stoma was closed and therefore reopened. There was postoperative improvement of headache; however, there was no decrease in either the cyst or ventricular size.

There is no consensus on how wide the cystoventriculostomy fenestration should be or whether the applied technique (Fogarty balloon catheter, laser, coagulation probe, or blunt biopsy forceps) has any bearing on the outcome. Oertel and colleagues have suggested that even a small stoma may be sufficient for cyst drainage in IPACs. This contrasts with the approach for other types of arachnoid cysts, in which enlarging the size of the cyst fenestration has been described as an important step for avoiding recurrence. Nevertheless, in the absence of long-term follow-up reports about the endoscopic treat-
ment of IPACs, fenestration of the entire length of the area of contiguity (in patients without hydrocephalus) is recommended by the author to offer the best chance for cyst drainage and as a precaution against recurrence, taking into consideration the low pressure differential existing between the cyst and the ventricular system.

Some neurosurgeons advise placing a stent through the fenestration to prevent occlusion of the stoma by a collapsed cyst and later scarring as well as recurrence.18,22 However, implanting such a prosthesis carries the long-term risks of an internal shunt, such as shunt displacement or occlusion. Moreover, it has been reported that cystoventricular stenting appears to be an unnecessary step in the endoscopic treatment of IPACs because there is no definite cyst membrane that can reclose.15 A fimbrial catheter was not implanted in any of the cases in the current study. Nor was there any attempt to excise the cyst wall completely during the endoscopic procedure, it has not been reported in the literature. Decq and colleagues have stated that a true cleavable arachnoid cyst wall has never been noted during perioperative macroscopic observation or on microscopic analysis.2

Some authors have reported that the presence of hydrocephalus is significantly correlated with the need for ventricular shunting among patients with arachnoid cysts.13 It has also been noted that shunting of the cyst alone does not lead to the resolution of hydrocephalus, and therefore both cyst fenestration and ventricular shunting are required for these cases. Other studies have not supported such findings, in particular, two in which endoscopic cystoisternostomy was used in the treatment of middle cranial fossa arachnoid cysts associated with hydrocephalus and in which a postoperative reduction in ventricular size was reported.10,20 In the current study, although the presence of hydrocephalus made the procedure technically easier, it seems that it negatively affected the prognosis. Hydrocephalus was encountered in 3 patients who were treated with ETV (in addition to the cystoventriculostomy), and a postoperative reduction in cyst and ventricle size was noted in 2 patients. Nevertheless, 1 of these 3 patients encountered a postoperative complication (subdural hygroma), and another patient had a recurrence and required a repeat endoscopic procedure.

Intraoperative bleeding during endoscopic treatment of arachnoid cysts appears to be one of the important factors predicting a bad outcome during long-term follow-up; it accelerates reclosure of the fenestration with cyst recurrence. Interestingly, in another study, the cyst recurred in all 3 patients with middle cranial fossa arachnoid cysts who had undergone endoscopic cystoisternostomy and also had intraoperative bleeding.5 Consequently, much effort should be made to avoid the occurrence of intraoperative bleeding. It is noteworthy that intraoperative bleeding was not encountered in any of the patients in the current study. I believe that the incidence of bleeding during the endoscopic treatment of IPACs is much lower than for other types of arachnoid cysts, simply because the fenestration procedure is technically very easy in these patients since there is no definite cyst membrane at the area of contiguity with the lateral ventricle.

Conclusions

Endoscopic cystoventriculostomy is recommended in the treatment of symptomatic intraparenchymal arachnoid cysts, which do not have an area of contiguity with the basal cisterns. The procedure can be associated with ETV if there is concomitant hydrocephalus. Since endoscopic cystoisternostomy could not be performed in such cases, endoscopic cystoventriculostomy seems to be a good alternative. It maintains the basic strategy of cyst fenestration into the lateral ventricle without the invasiveness of open craniotomy and without the implantation of foreign bodies such as shunt systems, which carry the risk of malfunction. The procedure is simple, effective, and minimally invasive. It saves operative and recovery times and is associated with low morbidity and mortality rates.

Disclosure

The author reports no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

References

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