

# Preventing Surgical Complications During Microscopic Fenestration in Middle Fossa Arachnoid Cysts: A Retrospective Study for 38 Cases and Literature Review

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## Research Article

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# Abstract

**Purpose** Middle fossa arachnoid cyst (MFAC) is one of the most common cranial cysts in children. The various postoperative complications following cyst fenestration are still the major concern for most surgeons. We systemically review the short-term postoperative complications in the literature and introduce our experience in preventing these complications.

**Methods** A retrospective survey was conducted on the 38 cases of patients having MFAC (<14 years old) who underwent microscopic fenestration from January 2019 to December 2020. Short-term postoperative complications including postoperative hemorrhage/hematoma, subdural hygroma (SH), cranial nerve palsy, and central nervous system infection (PCNSI), and cerebrospinal fluid (CSF) leak were collected. A systematic PubMed search for cohort studies of surgically treated MFAC published from 2000 was performed. The short-term postoperative complications in the included studies were illustrated.

**Results** The overall complication rate in our series is 5.2%. Eight patients (21.1%) developed postoperative SH. One of them required reoperation. Patients who developed SH were significantly younger ( $4.1 \pm 1.6$  versus  $6.2 \pm 3.4$  y.o.,  $p=0.018$ ). Binary logistic analysis showed that a lower age could be a risk factor for developing SH ( $P=0.115$ ). No postoperative hemorrhage, cranial nerve palsy, or CSF leak was observed. In the systemic review, eighteen studies were included, comprising 649 cases of MFAC. The most common complication was SH (4.9%). The short-term postoperative complication rate between microscopic and endoscopic techniques was similar.

**Conclusion** The complication rate in MFAC fenestration is low in children. SH is the most common postoperative complication, and it is prone to occur in young children.

## Introduction

Primary arachnoid cysts (AC) are benign cysts that result from abnormal splitting or duplication of the arachnoid membrane during development.[32] The prevalence in children is 0.3–2.6%.[40, 2] One of the most commonly seen AC is middle fossa AC (MFAC), comprising 47%–65% of all types of AC.[2, 25] There is no definite surgical indication for MFAC. Many surgeons believe that cysts causing clinical symptoms and signs or compressing brain/bone tissue are operable.[18, 15] The surgical options are cyst fenestration, cyst-peritoneal shunting, and cyst marsupialization. The latter two approaches have significant complications namely shunt-dependency syndrome[41] and tense subdural hygroma (SH) [38]. It has been accepted that fenestration is the best surgical approach nowadays for MFAC extending to the carotid or basal cistern[4, 12]. But the postoperative complications such as SH, postoperative hemorrhage, and cranial nerve palsy are still the major concerns for most surgeons. Recently, some surgeons point out that the complication rate of MFAC fenestration is considerable [18]. Here we retrospectively reviewed 38 cases of MFACs that underwent microscopic fenestration in our department. The short-term postoperative complications are collected in our series and are systemically reviewed in the literature. The technical nuances to prevent those complications are demonstrated.

# Materials And Methods

## Patients' selection

Forty-two patients (< 14 years old) who had primary MFAC underwent microscopic fenestration in the department of Pediatric Neurosurgery, Beijing Tiantan Hospital from January 2019 to December 2020. Surgical indications included: 1) the largest diameter of the cyst was larger than 5 cm in axial CT or MR image; 2) Patient had symptoms possibly related to MFAC, such as headache, dizziness, speech problem, or seizure (which was supported by an electroencephalogram), etc.; 3) The cyst compresses the neighboring cerebral tissue, causing midline shift, skull bulging or hydrocephalus. Patients who fulfill the criteria "1 + 2" or "3" were indicated for surgery. Four patients were excluded after review because of prior brain surgery, bilateral MFAC, or loss of follow-up (Fig. 1). A total of 38 patients were included in the retrospective study. All patients were diagnosed using 3D-computed tomography (CT) and magnetic resonance imaging (MRI). All Patients underwent at least three-month follow-up. A signed release from your facility is acceptable.

## Surgical technique

All cases were performed by Dr. Gong and Dr. Lu. The head of the patient is tilted contralaterally. A 7 to 8 cm curved incision is performed over the temporalis behind the hairline (Fig. 2A). The temporal fascia is harvested in advance. A 3\*3 cm bone flap was created, and the dura tenting is performed with 2 to 3 sutures. To avoid bleeding of the cyst, the dura mater is carefully dissected to expose the cyst's outer wall. The dura is circularly cut to a 2\*2 cm opening (Fig. 2B). The cyst fluid is evacuated to create a clear vision. The fenestrated site is decided under microscopic inspection. There are usually three spaces for fenestration: 1) space between the tentorial edge and oculomotor nerve (Fig. 3A-B); 2) space between the oculomotor nerve and internal carotid artery (Fig. 3C-D); 3) space between the internal carotid artery (ICA) and optic nerve (Fig. 3E-F).[17] The cyst membrane is fixed with the suction, and holes are made with scissors. The deep arachnoid membrane in the basal cistern and the Liliequist membrane in the carotid cistern are also fenestrated as large as possible. A water-tight duraplasty with temporal muscle fascia is performed (Fig. 2C). The bone flap is replaced.

## Data collection

Age, sex, onset symptom, cyst's size and Galassi classification[28], fenestration site (basal cistern/ICA cistern), surgical duration, short-term postoperative complications, and hospital stay were recorded. The cyst's size was estimated by  $1/2 \times \text{length} \times \text{width} \times \text{height}$  in MRI. Skull deformation is defined as the bulging or thinning of the ipsilateral temporal bone. Short-term postoperative complications are defined as complications that occurred in the first month, including postoperative hemorrhage/hematoma (epidural/subdural/cerebral/intracystic), SH, cranial nerve palsy, central nervous system infection (PCNSI), and cerebrospinal fluid (CSF) leak. Criteria for the diagnosis of PCNSI were as follows: 1) clinical signs such as fever, altered consciousness, nuchal rigidity, focal neurologic deficits, positive meningitis sign (e.g., Kernig sign); 2) CSF glucose level < 2.5 mmol/L, leukocytes >  $10^7$ /L with > 50%

polymorphonuclear neutrophils; and 3) positive CSF culture. Patients meeting criteria 1 and 2 or 1 and 3 were diagnosed as having PCNSI. Of note, SH was regarded as a surgical complication only if the patients require secondary surgery.

## **Systematic review**

On December 12, 2020, we performed a systematic PubMed search for cohort studies of surgically treated MFAC published in English from 2000. “Arachnoid cyst,” “endoscopic,” “microscopic” and “surgery” were used as keywords in relevant combinations. A study was eligible if it: 1) included primary treated MFAC; 2) surgically treated with endoscopic or microscopic fenestration; 3) included MFACs > 20 cases; 4) had at least one-month follow-up. The eligible studies were excluded if they: 1) did not describe postoperative complications; 2) were not available in full text. The reference lists of identified articles were also manually searched for additional studies. Two authors (ZHENG WJ and HAN X) independently conducted the literature search. The difference of opinion on study inclusion was solved by discussion. Disagreements were resolved through discussion with the third author (GONG). The duplicate records were removed. The short-term complications of included studies were collected.

## **Data analysis**

Data were analyzed with SPSS 17.0 (Chicago, IL, USA). Statistical analyses of categorical variables were carried out using Chi-square tests or Fisher's exact tests as appropriate. Statistics of means were carried out with independent Student's t-tests or non-parametric tests. A p-value < 0.05 was considered significant.

## **Results**

### **Clinical characteristics**

There were 31 males and 7 females. Age ranged from 1 to 13-year-old. Patients' information and clinical characteristics appear in Supplemental table 1. For continuous variables, values are expressed as mean  $\pm$  standard deviation. For dichotomous variables, values are presented as percentage (n).

### **Complications in our series**

The overall complication rate is 5.2% (2/38). A 13-year-old male patient developed PCNSI. His CSF culture was negative and he was successfully treated with intravenous vancomycin and meropenem. Eight patients (21.1%) showed SH in postoperative head CT. SH was managed only if the patients developed symptoms or signs of high intracranial pressure, such as headache, vomiting, or blurred vision. Among them, a 6-year-old patient developed tensive SH in the postoperative 2nd month and received a cyst-peritoneal shunting in the local hospital. No postoperative hemorrhage, cranial nerve palsy, or CSF leak was observed.

Patients who developed SH were significantly younger ( $4.1 \pm 1.6$  versus  $6.2 \pm 3.4$  y.o.,  $p = 0.018$ ), while their cyst was significantly smaller ( $97.7 \pm 63.1$  cm<sup>3</sup> versus  $163.2 \pm 120.9$  cm<sup>3</sup>,  $p = 0.049$ ) (Supplemental

table 2). Binary logistic analysis including these two factors showed that a lower age could be a risk factor for developing SH. The cyst's volume should be regarded as a confounding factor for postoperative SH (Supplemental table 3).

## Complications in the literature

The initial search obtained 326 articles. After reading the title and abstracts, a total of 271 studies were excluded due to inappropriate article types. Fifty-five studies were eligible for full-text review. Thirty-seven studies were excluded because: included less than 20 cases of MFACs (13 studies), included traumatic or re-operative MFACs (9 studies), included MFACs which were not treated by fenestration (10 studies), and did not report complications (5 studies). The PRISMA flow diagram was described (Figure. 3).

Eighteen studies were included in the analysis.[18, 9, 4, 42, 27, 7, 6, 22, 21, 11, 39, 17, 10, 13, 37, 26, 14, 20] The sample size ranged from 20 to 103, comprising 649 cases of MFAC which were treated by microscopic or endoscopic fenestration. The overall short-term postoperative complications rate ranged from 0–20.8% (Supplemental table 4). Three studies did not separately describe short-term and long-term complications. Therefore, their total short-term complication rates were unavailable.

The most common complication was SH. A total of 32 cases (4.9%) that required re-operation were reported among 649 cases. Other complications included cranial nerve palsy (23 cases, 3.5%), postoperative hemorrhage (17 cases, 2.6%), and postoperative hemorrhage (12 cases, 1.8%).

Thirteen studies reported complications separately in microscopic (5 studies) or endoscopic (10 studies) fenestration. No meta-analysis was performed to obtain pooled estimates because the studies were heterogeneous in surgery indication and complication reports. There were no significant differences in the complication rates between the two techniques ( $P > 0.05$ ).

Complications reported in different groups of patients were shown in Supplemental table 5.

## Discussion

There is not a well-recognized surgical indication for MFAC. Symptomatic MFACs are the absolute indication.[36] Most of MFACs are incidentally identified and the patients usually have no obvious symptom or clinical sign, even the cysts are quite large. [15] It has been shown that AC larger than 5 cm was associated with cyst rupture or hemorrhage[8]. For these MFACs, some researchers believe that they should be operated on for their mass effect[36], While others argue that surgery may hurt rather than help asymptomatic patients in their cognitive function, especially for young children.[18] Recently, more evidences have shown that MFACs have a negative effect on general cognitive ability and that this impairment can be improved by surgery.[34, 19, 1] But the remarkable complications reported in recent years' studies hinder the pursuit of these functional improvements. The surgical techniques of MFAC fenestration have been demonstrated in numerous studies. Many postoperative short-term complications are directly attributed to inappropriate manipulations during surgery. Based on the experience in this

relatively large series, we share some techniques which, in our opinion, are important in preventing these complications.

## **Subdural hygroma**

SH is one of the most common complications following AC fenestration. As the subdural space was opened during surgery, a certain amount of SH showed in the postoperative head CT is reasonable. Many researchers did not recognize this as a complication. As reported, it occurred in 4–10% of patients who underwent MFAC marsupialization, and nearly 60% of patients require secondary surgery.[38, 24] In this study, SH was regarded as a complication only if it required re-operation.

It was proposed that the wide excision of the cyst's membrane and increased production of fluid from the cyst wall contributing to the complication.[3] We agree with the theory that there could be increased production of fluid from the cyst wall after surgery. There are evidences that the component of fluid inside the ACs are different from CSF.[33] The fluid transport across the cyst wall may already reach a constant level. Once abruptly by trauma or surgery, fluid production from the cyst wall could change in the imbalance condition. ACs having rich microvilli in the luminal epithelium may be more likely to develop SH after surgery.[30]

To avoid this complication, marsupialization is now considered obsolete. But still, we find high re-operative SH rates in some recently published fenestration studies. We think there are two key points in preventing postoperative SH: 1) the larger the fenestration size the better: a small fenestration can create the turbulent CSF flow. It cannot effectively drainage the cystic fluid. Furthermore, a significant narrow fenestration will act as a slit-valve[35], aggravating the accumulation of extra-axial CSF; 2. The smaller the opening of the outer membrane the better: If there is a larger surgical opening of the outer wall than the fenestration into the cisterns, the fluid will readily accumulate in the subdural space because there is lower flow resistance. Our experience is that one should carefully dissect the dura before entering the cyst. This can not only keep the entrance as small as possible, but also secure the vessels on the cyst (Fig. 4). We advise keeping the other walls of the cyst (besides the entrance and fenestration site) intact during manipulation.

Another important non-surgical risk factor for SH is low age. Children less than 2 years old are more vulnerable to SH because of immature CSF drainage pathways.[23] Choi et.al. showed that 50% of infants who underwent MFAC fenestration required reoperation because of SH.[6] Similarly, Dong et.al. reported a 75% reoperation rate in children < 2 years old.[9] The logistic analysis in the present study also indicated that a lower age could be a risk factor for developing SH. As a result, we agree that infants and young children should not be subjected to surgery unless surgery is essential.

## **Cranial nerve and vessel protection**

The direct reason for immediate postoperative cranial nerve palsy and hemorrhage is accidental injury by the surgeon. We have emphasized the necessity for a large fenestration above. However, a larger

fenestration means there are more risks we need to bear. Here we describe the details of fenestration in three anatomic spaces.

The most accessible space for fenestration is the tentorial-oculomotor space. There is sparse vascularity and the space is usually large (Fig. 3A). The important structure is the underlying basilar artery and its branches. Using microscopy, one can elevate the membrane with suction or micro-forceps to keep it away from the underlying vessel, and open the membrane with micro-scissors. The risk of causing cranial palsy in this space is low because the surgeon usually does not need to retract the oculomotor nerve for more room. For Galassi II MFAC, the temporal lobe may block the surgical view for this space. One can slightly push the temporal lobe away using a small retractor. Do not cut the tentorial edge, as it will not only give rise to annoying hemorrhage, but also destroy the integrity of the cyst.

The second accessible space is the oculomotor-ICA space. The structures worth noticed are the branches of the communicating segment of ICA, namely the posterior communicating artery and anterior choroidal artery. Due to the longstanding compression of the cyst, these arteries are usually elongated and variant. They can be very close to the oculomotor nerve. Sometimes this space may be narrow. As the arteries are unmovable, the oculomotor nerve is the only structure that can be manipulated. This is the situation one could easily paralyze the nerve by accidentally poking it. To push the nerve posteriorly, we like to use suction rather than micro-forceps, because the water accumulated in this area frequently blurs the view. One should ensure that the suction has been turned down. Micro-scissors should only cut parallelly to the ICA and oculomotor nerve.

The ICA-optic space is the most challenging one for fenestration. As the ICA was pushed anteriorly and medially by the cyst, this space is usually very narrow. Although one can access the inner membrane of the cyst, the Liliequist membrane underneath is hard to reach. We suggest that one should only open this space if at least 5 mm fenestration can be done. As we have discussed above, making an incomplete fenestration (a one-way valve) is not beneficial or even harmful for the patients.

A total of 70.6% (12/17) of postoperative hemorrhage/hematomas are subdural hematomas. Chronic or traumatic subdural hematomas were excluded from the systemic review. Acute subdural hematoma following MFAC fenestration could result from the bleeding of the cyst wall. Subdural hemorrhage is not unusual during the manipulation of the cyst's wall. It particularly occurs in between the inner wall of the cyst and the tentorium cerebelli where the vasculatures are rich. In this situation, one should avoid using coagulation inside the cyst, as it increases the risk of neurovascular injury. Irrigation will be more appropriated. Significantly, do not use cold water irrigation after fenestration. It could contract basilar or carotid arteries[29], which induce rapid hemodynamic changes (e.g., tachycardia, hypertension) in pediatric patients.

## **Infection and CSF leak**

The reported PCNSI rate in MFAC surgery is comparable to the general neurosurgical procedure.[43] CSF leak is one of the risk factors for PCNSI.[43] The simple way to prevent both complications is water-tight

closure of the dura. As we cut the dura circularly and perform dura tenting around the opening, dural substitutes are demanded. We do not use the native dura because it tends to shrink after coagulation or dry in the air. In this situation, the native dura is of high tension and is easy to be torn during suturing. CSF may leak from the suture's pinhole in the dura as well. As such, we are fond of using a large, loose temporal fascia for duraplasty (Fig. 2C). One can also use fibrin glue to prevent leakage from the pinhole. [16] We did not use those supporting materials simply for cost-saving. To evacuate the air, filling the cranial cavity with warm water is required before the complete closure.

Unlike the endoscopic technique, we use a larger incision and bone flap, because we need to harvest temporal fascia and perform water-tight duraplasty. Usually, we only spend about 20 minutes on MFAC fenestration. The most time-consuming part is the closure of the dura and skin. One can use the running suture technique to save time. The surgery duration of our series is comparable to other studies. No prophylactic antibiotic was applied postoperatively. By using this technique, we have one PCNSI (2.6%) and no CSF leak in our series.

## The microscopic and endoscopic technique

Traditionally, Fenestration was performed under the microscope. The first endoscopic AC fenestration was performed in the 1990s.[31] Although the technique was primarily used in suprasellar AC, it had been rapidly spread in all kinds of AC. While endoscopic fenestration in suprasellar AC has stood the test of time, the question of which tool is more suitable in MFAC is still under debated. A meta-analysis published by Chen et.al showed that "endoscopic fenestration may be the best initial procedure in MFAC". [5] But we found that some data in this meta-analysis was not consistent with the result we found (for example, the complication rate in Levy et. al [20] study was over 10%, while Chen et.al recorded it as 0%). Therefore, we performed another systemic review for microscopic and endoscopic fenestration up to date.

In our review, we found no significant difference in complication rate between the microscopic and endoscopic techniques. Interestingly, it seems that institutes using both two techniques bear a higher complication rate (Supplemental table 2). Hitherto, there were two comparative studies for these two techniques, which showed that the complication rates were lower in the microscopic group.[4, 39]

We are fond of microscopic technique because: 1) Two-hands manipulation under the microscope can deal with the narrow gaps during fenestration; 2) In endoscopic technique, the illumination is non-uniform and highly directional. This makes it possibly overlook some small bleedings in the surgical field, especially in the extremely large cyst. Amelot et.al. had reported that the endoscopic group has more risk of developing SH.[4]

## Limitations

There are several limitations in our study: 1) we only investigated the short-term complications because the follow-up period was short; 2) we did not study patients' clinical outcomes (changes in the size of MFAC, symptoms and signs); 3) the sample size was relatively small.

This study focuses on introducing surgical techniques that can decrease the complication rate. To further reinforce our result, we are conducting a comparative study for MFAC fenestration in the next few years, with a longer follow-up period and larger series.

## Conclusions

The complication rate in MFAC fenestration is low in children. SH is the most common postoperative complication, and it is prone to occur in young children. The short-term postoperative complication rate between microscopic and endoscopic techniques was similar. The surgical techniques in preventing short-term postoperative complications are illustrated in detail.

## Declarations

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**Availability of data and material** Not applicable.

**Code availability** Not applicable.

**Authors' contributions** ZHENG and SHI independently assessed the full text of all included papers. GONG made the final decision for which study would be included. ZHENG composed the paper.

**Additional declarations for articles in life science journals that report the results of studies involving humans and/or animals** Not applicable.

**Ethics approval** This study is approved by the Beijing Tiantan Hospital Institutional Review Board.

**Consent to participate** All clinical data are collected in the cited literatures.

**Consent to publication** All authors are consent to publish in Neurosurgical Review.

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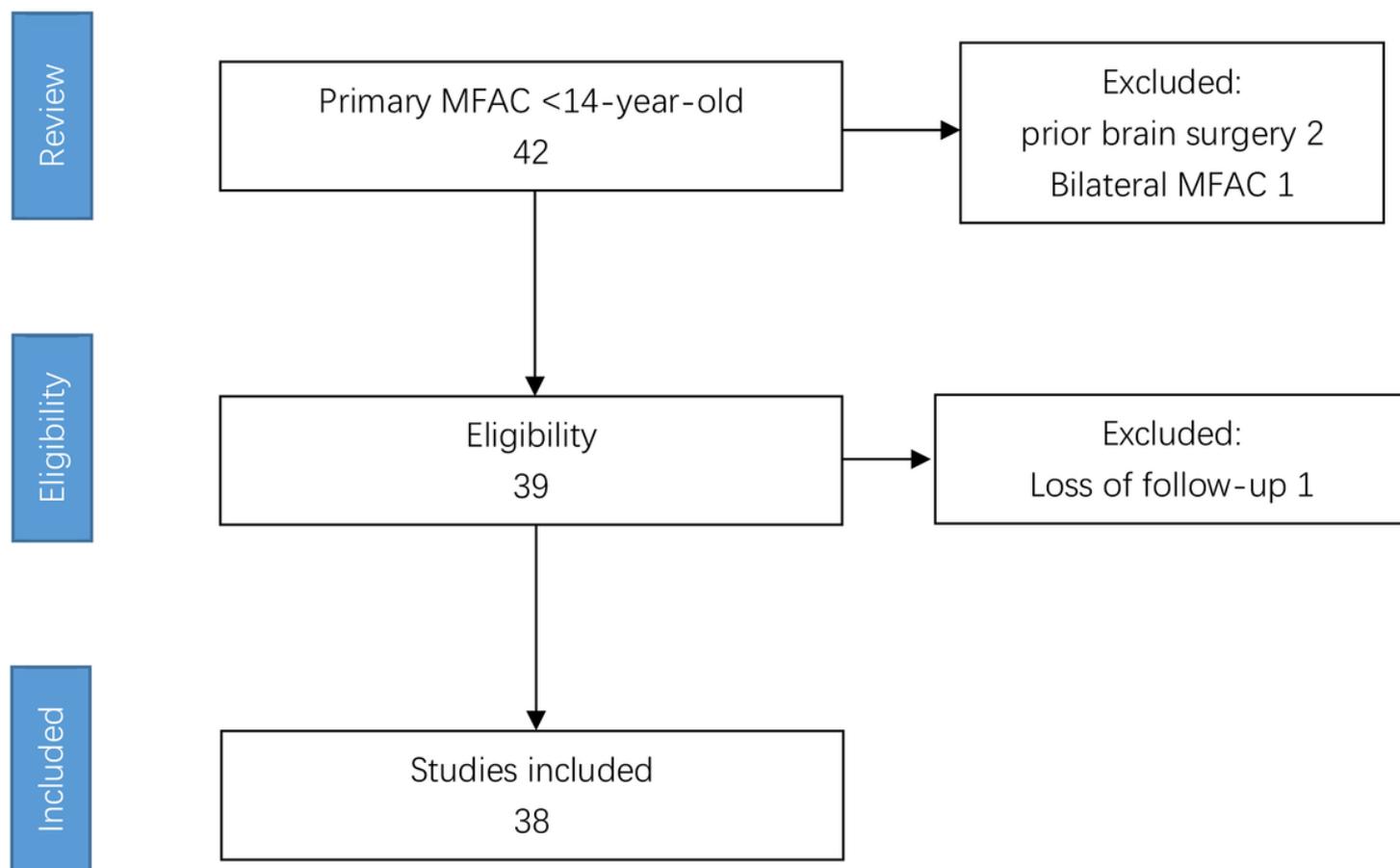
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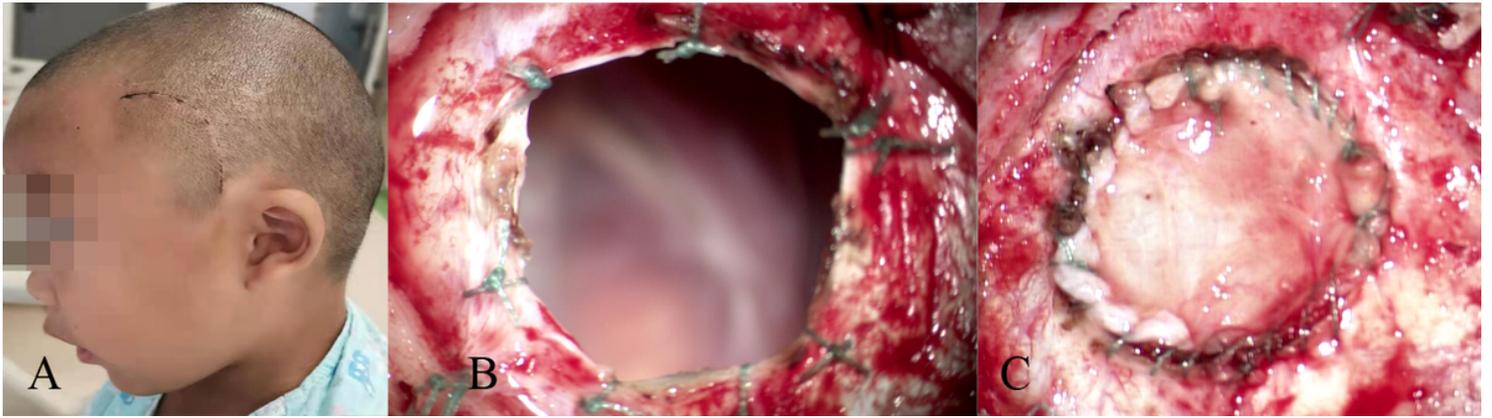
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## Figures



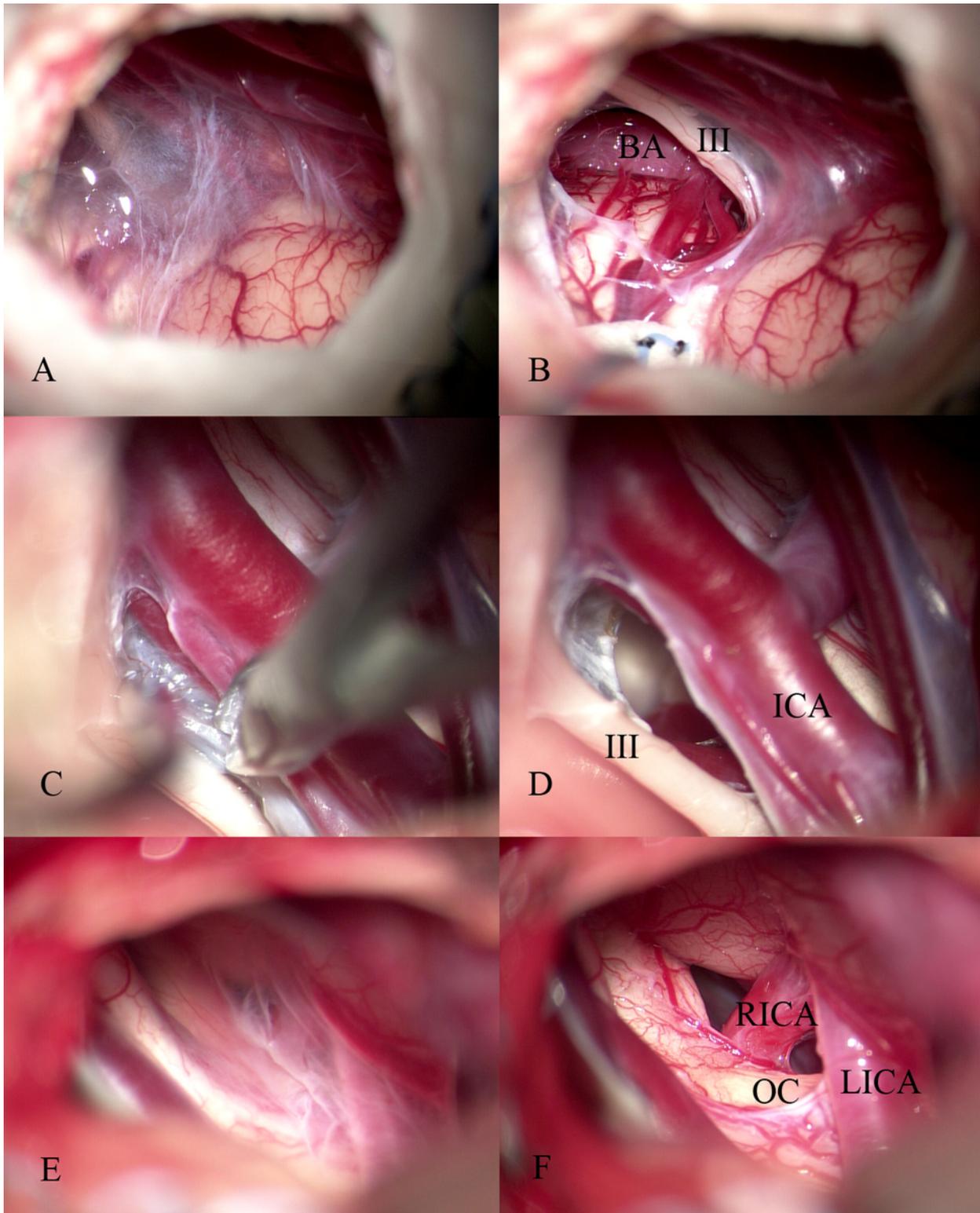
**Figure 1**

Flow diagram in patients' inclusion and exclusion.



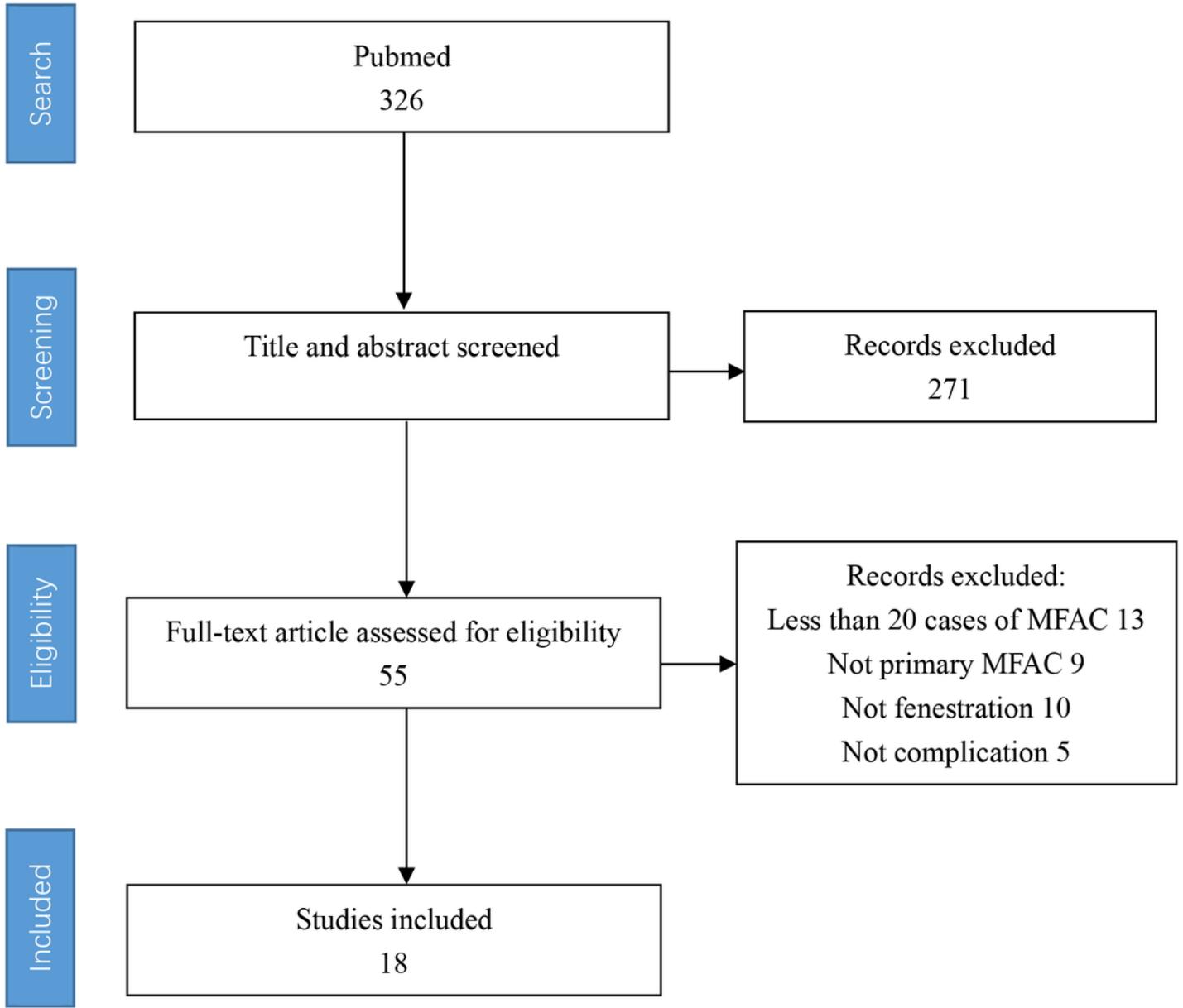
**Figure 2**

A. Frontotemporal incision for microscopic fenestration; B. Circular opening of dura; C. Water-tight duraplasty with temporal muscle fascia.



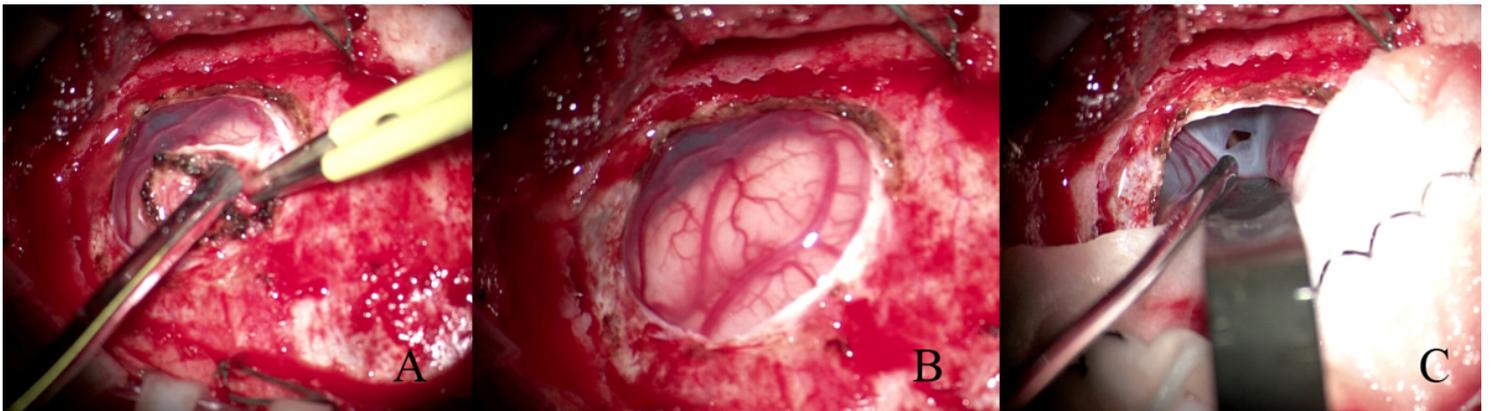
**Figure 3**

A. Tentorial-oculomotor space; B. Fenestration of Tentorial-oculomotor space. The diencephalic-mesencephalic leaf of Lilliequist's membrane is removed. The basilar artery (BA) and oculomotor nerve (III) are revealed; C, D. Oculomotor-ICA space. The oculomotor nerve is slightly pushed posteriorly by the suction to create more room for fenestration; E. A very narrow ICA-optic space is indicated; F. Lilliequist's membrane is removed after fenestration, demonstrating bilateral ICA and optic chiasm (OC).



**Figure 4**

PRISMA flow diagram in the systemic review.



**Figure 5**

Dural opening in MFAC microscopic fenestration. A. The dura is circularly dissected. One can feel free to use bipolar coagulators for hemostasis on the dura, as the dura was not needed for duraplasty; B. The subarachnoid membrane on the temporal lobe and the MFAC is exposed, showing that there are abundant vasculatures on the cyst's wall; C. A retractor is used to expose the MFAC. A small Entrance of the cyst is made on the avascular area.

## Supplementary Files

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