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Clinical and radiological outcomes following surgical treatment for intra-cranial arachnoid cysts

Samuel Hall[a,*], Alexander Smedley[a], Shivani Rae[b], Nijaguna Mathad[a], Ryan Waters[a], Aabir Chakraborty[a], Owen Sparrow[a], Vassilios Tsitouras[a]

[a] Department of Neurosurgery, Wessex Neurological Centre, Southampton General Hospital, Southampton, UK
[b] Faculty of Medicine, University of Southampton, Southampton, UK

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ABSTRACT

Objectives: Intra-cranial arachnoid cysts are benign lesions which are usually incidental, however can produce neurological symptoms due to mass effect as they enlarge. Controversy still exists regarding the optimal option for the surgical management of these cysts. These options are neuroendoscopic fenestrations, microsurgical fenestrations +/− marsupialisation and insertion of a cysto-peritoneal shunt.

Patients and methods: A retrospective case note review of all patients with intra-cranial arachnoid cysts treated surgically at a single UK neurosurgical centre over a 15 year period. Data on clinical presentations and outcomes was collected from the patient notes and the pre- and post-operative cyst volumes were calculated by creating 3-dimensional volumetric models.

Results: Eighty-two patients were identified of which 45 were treated endoscopically, 34 microscopically and 3 underwent cysto-peritoneal shunting. The most common cyst location was the middle fossa (n = 25). Amongst the symptomatic patients, improvement or resolution of symptoms was seen in 35 out of 40 cysts treated endoscopically (88%), 28 out of 32 treated microsurgically (88%) and 3 out of 3 treated by shunting (100%, p = 0.79). The reoperation rate was not significantly different between the endoscopic and microsurgical groups (24.4% vs 14.7%, p = 0.49). The endoscopic and shunted groups had a shorter length of stay than the microsurgical group (3.0 vs 3.0 vs 4.5 days, p = 0.04). All three treatment modalities had a similar percentage reduction in cyst volume after surgery (30.0 vs 41.7 vs 30.9%, p = 0.98).

Conclusions: This cohort series shows that endoscopic and microsurgical approaches to treat intracranial arachnoid cysts produce comparable clinical and radiological outcomes. Endoscopic fenestration is associated with a shorter length of stay as would be expected from a minimally invasive procedure.

1. Introduction

Arachnoid cysts are intra-arachnoid lesions which form due to splitting or duplication of the arachnoid membrane [1]. The prevalence of arachnoid cysts is estimated to be 1.4% [2] and their detection is becoming more frequent due to the widespread use of brain imaging. Surgical treatment is usually reserved for symptomatic patients who most commonly present with headaches, epilepsy, dizziness, or focal neurological deficits [3]. Paediatric patients may also present with macrocrania, vomiting, and behavioural disturbances [4] or may even be diagnosed on prenatal ultrasound.

Microscopic fenestrations +/- marsupialisation of the cyst was the mainstay of treatment until the application of neuroendoscopy became widespread. There is growing popularity and experience in the use of endoscopic fenestrations which has the advantage of being minimally invasive compared to microsurgical procedures. The third treatment option is cystoperitoneal (CP) shunting. Open surgery, endoscopic fenestrations and CP shunting have all been reported to show clinical improvement [5,6] however there are differing results on which treatment method is the most effective. Holst et al. [7] reported better results with microsurgical operations however, Shim et al. [8] and the meta-analysis by Chen et al. [6] concluded that there were no differences in clinical outcomes between open and endoscopic surgery. Gangemi et al. [9] provided an alternative approach to this issue with a literature review and analysis based on cyst location which found that the open approach is still preferred for cortical and interhemispheric cysts whilst endoscopic surgery produces better results in other locations.

* Corresponding author at: Department of Neurosurgery, Southampton General Hospital, Tremona Road, Southampton, SO16 6YD, United Kingdom.
E-mail address: Samuel.hall@doctors.org.uk (S. Hall).

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The series presented here provides a comparison of the surgical treatment options for intracranial arachnoid cysts. The comparison includes clinical and radiological outcomes for paediatric and adult patients and is presented in the context of the current literature on arachnoid cysts.

2. Materials and methods

2.1. Patient population

A database search of the hospital electronic records at a tertiary neurosurgical centre was conducted for all patients who were treated for an intracranial arachnoid cyst between January 2003 and December 2017 inclusive. All patients' notes, including clinic letters, discharge summaries and operation notes, were retrospectively reviewed for demographics, presenting symptoms, surgical treatment details, complications, further treatments and clinical outcomes. The diagnosis of arachnoid cyst for all patients was confirmed pre-operatively by a consultant radiologist and consultant neurosurgeon. The clinical outcomes recorded were the change in symptoms at most recent follow-up or prior to cyst re-operation and were classified as resolved, improved, unchanged or worse as described by the patient. Symptoms were classified as *resolved* if the patient was 100% symptom free at follow-up, *improved* if there was any degree of noticeable difference in symptoms compared to pre-operative levels and *unchanged* if the patient felt there was a 0% difference. More accurate quantification of symptom improvement was not possible due to the retrospective nature of the data collection.

Only primary treatment of the cyst was analysed with outcomes of repeat procedures being excluded. Both adult and paediatric patients were eligible despite their different natural histories because the focus of the study was surgical efficacy.

2.2. Cyst volumes

The hospital Picture Archiving and Communication System was reviewed and cross sectional imaging was selected for volume analysis. Volumes were calculated for pre-procedure scans and the most recent follow-up scan with a preference for MR high resolution sequences or T2 sequences if available. Volumetric data on cyst size was calculated by author SRH using the segmentation module of the open source DICOM analysing programme *3D Slicer* (Fig. 1) [10]. In order to maintain consistency between different cyst locations, the percentage reduction in cyst volume between the pre- and post-operative imaging was calculated and used for analysis. In patients requiring further treatment, the most recent scan before the second operation was used to calculate the post-operative volume.

2.3. Statistical analysis

The primary outcome measure was the percentage of patients with improvement or resolution of their symptoms. Secondary outcomes were change in cyst volume, complication rates, length of hospital stay and re-operation rates. Data were analyzed by descriptive statistics (mean, SD, etc.) and the outcomes were analyzed by chi-square or ANOVA tests as appropriate. All analysis was conducted on GraphPad Prism version 6 (GraphPad Software Inc., La Jolla, CA, USA).

3. Results

The database search returned 92 patients with an intracranial arachnoid cyst who were operated on during the 15-year eligibility period. Nine patients were excluded because their surgical treatment was not specifically targeting the cyst; foramen magnum decompressions for associated hindbrain hernias (Chiari I) (n = 3), VP shunt (n = 2), burr hole drainage of a chronic subdural haemorrhage (n = 2), endoscopic third ventriculostomy (n = 1) and Ommaya reservoir implantation (n = 1). A further patient was excluded because the medical records were unavailable.

3.1. Demographics

Of the remaining 82 patients, 46 (56.1%) were male and the average age was 27.8 years (SD ± 25.5). Thirty-nine (47.6%) patients were less than 18 years old. The most common location of the treated cysts was the middle fossa (n = 25). These were further classified using the Galassi system [11] into Galassi type 2 (n = 11) and Galassi type 3 (n = 14). The remaining locations were: retrocerebellar (n = 12), convexity (n = 11), suprasellar (n = 10), cerebellopontine angle (n = 9), quadrigeminal/supracerebellar (n = 7), intraventricular (n = 6), thalamus (n = 1) and *velum interpositum* (n = 1).

Seventy-six (92.7%) of the patients in this cohort were symptomatic with the remainder being operated on for enlarging cysts or progressive ventriculomegaly. The most common presenting symptoms were; headache (n = 36, 47.4%), nausea (n = 14, 18.4%), macrocephaly (n = 10, 13.2%), dizziness (n = 10, 13.2%), seizures (n = 6, 7.9%) and hemiparesis (n = 6, 7.9%).

Among the 82 eligible patients, the surgical treatments included 45 endoscopic fenestrations, 34 craniotomies and 3 CP shunts. Within the endoscopic fenestration group, seven patients were also treated with third ventriculostomy at the time of fenestration and three of the craniotomies incorporated evacuation of a subdural haematoma. The baseline characteristics were evenly matched for each treatment group but notably with cyst location in the posterior fossa, microsurgery was more frequently used than endoscopic treatment (Table 1). The decision on choosing the most appropriate treatment modality was done on a case-by-case basis based on factors including cyst location, depth and relationship to adjacent CSF spaces as determined by the surgeon's opinion and experience.

3.2. Hydrocephalus

Twenty-five patients (30.5%) had associated hydrocephalus. The cyst locations with associated hydrocephalus were: posterior fossa (n = 12), suprasellar (n = 6), middle fossa (n = 3), intraventricular (n = 2), cerebral convexity (n = 1) and thalamus (n = 1). Six of the patients managed with endoscopic fenestration had an associated third ventriculostomy. A further 6 patients, of which two were initially treated with craniotomy and 4 with endoscopic fenestration, required VP shunting due to persistent hydrocephalus following the first surgery.

3.3. Clinical outcomes

The average length of clinical follow-up was 40.6 (95% CI 28.5–52.8) months for the endoscopic group, 32.8 (95% CI 19.9–45.8) months for the craniotomy group and 10.3 (95% CI 0.0–31.8) months for the shunts (p = 0.28). Of the symptomatic patients who underwent endoscopic fenestration (n = 40), 35 (87.5%) had improvement in their symptoms (complete resolution n = 15, partial improvement n = 20). Of the remaining five patients in this group, four had no change in their symptoms and the other did not attend clinic follow-up.

In the symptomatic microsurgical group (n = 32), 28 (87.5%) patients had improvement in their symptoms (complete resolution n = 17, partial resolution n = 11). All of the CP shunts had improvement in their symptoms (Table 2).

When the clinical outcomes were dichotomised into improved/resolved and unchanged/worsened, there was no significant difference in the proportion of symptom improvement or resolution between the three treatment groups (p = 0.79). However, the endoscopic and shunt groups had a shorter length of stay than the microsurgical group (3.0 vs 3.0 vs 4.5 days respectively p = 0.04).

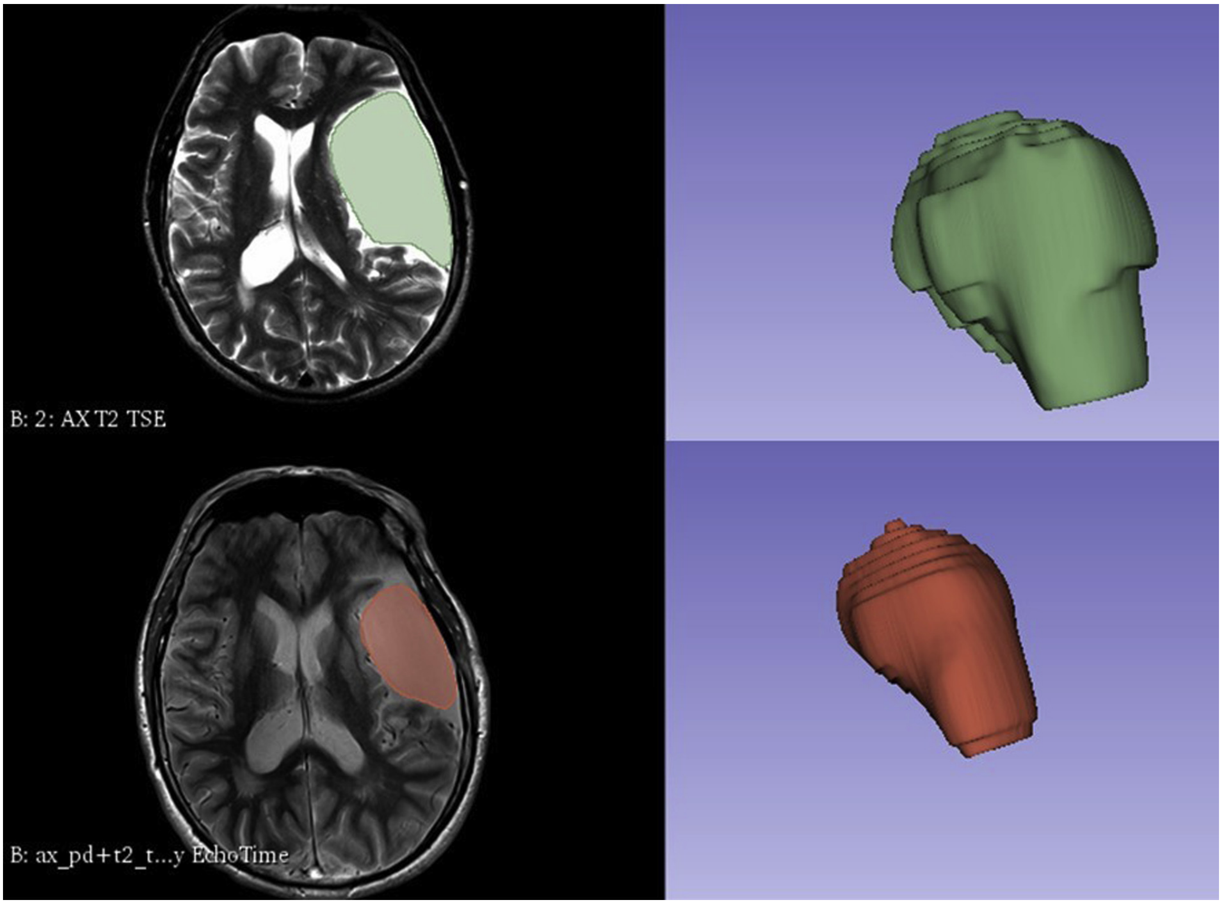

Fig. 1. 3-dimensional models of Galassi Type 3 Sylvian fissure cyst before (top) and after (bottom) endoscopic fenestration.

Table 1
demographics of patients in each treatment cohort. Statistical comparisons made between all three groups unless otherwise specified. (CI – confidence interval, CP – cystoperitoneal, CPA – cerebellopontine angle).

	Endoscopic (n = 45)	Open (n = 34)	CP shunt (n = 3)	p-value
Age in years (95% CI)	27.8 (19.5-36.3)	30.1 (22.4–37.8)	2.7 (0.0–14.1)	0.09
Male gender (%)	23 (51.1)	22 (64.7)	1 (33.3)	0.35
Cyst location (%)				0.002[a]
• Middle fossa	15 (32.0)	9 (26.5)	1 (33.3)	
• CPA	1 (2.1)	7 (20.6)	1 (33.3)	
• Suprasellar	8 (17.0)	2 (5.9)	0 (0)	
• Convexity	6 (13.0)	4 (11.8)	1 (33.3)	
• Retrocerebellar	2 (4.3)	9 (26.5)	0 (0)	
• Intraventricular	6 (12.8)	0 (0.0)	0	
• Other	7 (15.6)	3 (8.8)	0 (0)	
Hydrocephalus (%)	16 (35.6)	8 (23.5)	1 (33.3)	0.51
Symptomatic at presentation (%)	40 (88.8)	32 (94.1)	3 (100)	0.62

[a] shunt group not included due to too few numbers for chi-square.

Table 2
Rate of change in symptoms following different surgical methods.

	Endoscopic (n = 40)	Open (n = 32)	CP Shunt (n = 3)
Resolved (%)	15 (37.7)	17 (53.1)	1 (33.3)
Improved (%)	20 (50.0)	11 (34.4)	2 (66.6)
Unchanged (%)	4 (10.0)	2 (6.3)	0 (0.0)
Worse (%)	0 (0.0)	1 (3.1)	0 (0.0)
No follow-up (%)	1 (2.5)	1 (3.1)	0 (0.0)

3.4. *Cyst volumes*

Paired pre- and post-operative radiological imaging was available for 34 of the endoscopically treated patients, 26 of the microsurgical patients and 2 of the CP shunted patients. The remaining patients did not have available imaging because it was performed before the introduction of the hospital's electronic imaging database. The length of radiological follow-up for the three groups (endoscopic, open and shunts) was 29.9 (95%CI 16.9–42.9), 27.9 (95%CI 14.6–41.1) and 12.3 (95%CI 0.0–59.9) months respectively ($p = 0.59$).

Patients treated endoscopically had an average reduction in cyst volume of 30.0% which was not significantly different to those treated microsurgically who had a reduction of 41.7% or those with a CP shunt with a 30.9% reduction ($p = 0.98$). Subgroup analysis of Sylvian fissure cysts which were the most common location in this series also found that there was no significant difference in percentage cyst volume reduction between endoscopic and open surgery (30.1% vs 25.9%, $p = 0.83$).

Of the 75 symptomatic patients, there was pre- and post-operative imaging available for 56. In those with < 50% volume reduction (n = 27), 25 (92.6%) had symptom improvement/resolution compared to 26 out of 29 (89.7%) in the group with > 50% cyst volume reduction ($p = 0.99$).

3.5. *Re-operation and complication rates*

Eleven (24.4%) patients treated by endoscopic fenestration had a further surgical intervention which included VP shunts (n = 4), repeat fenestrations (n = 3), CP shunts (n = 2) and re-siting Ommaya reservoirs for migration (n = 2). The reoperation rate for microsurgical patients was 14.7% (repeat fenestrations n = 2, VP shunts n = 2 and CP shunt n = 1). One CP shunt patient required a further operation for burr hole drainage of a chronic subdural haematoma, which had been present on initial presentation but not been drained as part of the primary procedure. There was no significant difference in the re-operation rate between endoscopically and microsurgical treated patients (p = 0.49).

The craniotomy group had 4 (11.8%) recorded complications (CSF leak, blocked VP shunt, hypertrophic scarring and aseptic meningitis) which was comparable to the 8 (17.7%) in the endoscopic group (CSF leak n = 4, Ommaya migration n = 2, hygroma requiring diversion procedure n = 1 and post-operative seizures n = 1). There was no significant difference in the complication rates between the three groups (p = 0.58).

4. Discussion

Arachnoid cysts are a common and benign intracranial lesion which results from splitting of the arachnoid membrane [1] or from early childhood head trauma [12]. A large study into the natural history of arachnoid cysts has shown that the majority of cysts do not require surgical intervention [2]. It is not yet known how to predict which patients will subsequently become symptomatic however theories exist regarding the underlying pathological changes of cyst enlargement. One observed mechanism is the creation of a slit valve in the membrane adjacent to an artery which opens during the cardiac cycle through which there is unidirectional flow of CSF driven by arterial pulsations [13].

Most surgeons would agree that treatment should be reserved for symptomatic patients. The most well recognised and accepted symptoms are those due to intracranial hypertension as the cyst enlarges. However there is increasing understanding of the more subtle symptoms of cognitive deficits related to hypoperfusion in the cortex adjacent to the cyst [14]. The advanced perfusion imaging techniques such as MR arterial spin labelling may play a role in patient selection for surgery in the future.

The mainstay of surgical treatment has been craniotomy with microsurgical fenestration and/or cyst wall removal. A microsurgical approach allows for a wider operating corridor and the option for resection of the cyst wall; however it is a more significant undertaking for the patients, whereas endoscopic surgery is minimally invasive, less traumatic and thus has a faster recovery time. Endoscopic surgery is also better able to reach deeper midline cysts than open surgery and allows for third ventriculostomy to treat any associated hydrocephalus. Endoscopic procedures for deep midline cysts allow for a combined ventriculocystocisternostomy rather than simple fenestration which appears to have lower rates of repeat surgery [15,16]. Shunting procedures are also minimally invasive but carry with them the risks of over drainage and hardware associate complications such as infection and future revision procedures.

4.1. Clinical improvement

A recent literature review reported a clinical improvement rate of 79% [9] following open surgical treatment which was replicated in two separate series showing recovery rates of 76.5% [17] and 90.5% [18]. The series presented here demonstrates a rate of symptom improvement of 84.8% following open surgical treatment which is consistent with the previous literature reports.

A meta-analysis of 474 patients demonstrated no significant difference in the rate of symptom improvement between the three treatment modalities [6]. The results of our series of all patients treated at a single UK institution reproduce the finding that there is no significant difference in clinical improvement rates between open and endoscopic surgical treatment. However, the endoscopically treated patients had a shorter length of stay which is expected for a less invasive procedure and is a finding that has also been observed in other series [19].

4.2. Cyst volume reduction

Various methods have been used to determine cyst size including maximal diameter [17], AxBxC/2 [20] and 3-dimensional model creation [21,22]. The 3-dimensional model method was used in this study as it was felt to create the most accurate representation of the cyst volume. Regardless of the method used, there is a wide number of reports of cyst size reduction following all three methods of treatment [9,18,21,23–25]. Shunting procedures have been reported to result in a greater reduction in the cyst volume than the other surgical techniques [6,20]. To the best of our knowledge the results presented here are the first to use 3-dimensional volumetric models to compare treatment methods in arachnoid cysts. The results show cyst volume reduction following open, endoscopic and shunting procedures with no significant difference between them with regard to the percentage volume change. Li et al. [22] reported on volumetric changes using endoscopic fenestration of middle fossa arachnoid cysts and found a 31.1% average volume reduction which is comparable to the endoscopic group in this series.

There is uncertainty over whether the reduction in cyst volume correlates to symptomatic improvement [20,26] or not [19,24,27] which this series adds to by suggesting there is no relationship. However, this issue is limited by the lack of consensus regarding what degree of volume change constitutes a meaningful reduction and proposed criteria include a reduction of 10 cm^3 [19], 10% [26,28], 15% [22] and 50% [3,29,30]. Furthermore, meaningful volume reduction is variable depending of cyst location with Wang et al. [3] suggesting that greater reduction of cyst volume in midline and posterior fossa cysts correlates better with symptom improvement as they are more likely to present with focal neurological deficits.

4.3. Complication and re-operation rate

Complication and re-operation rates are a particular concern in the treatment of arachnoid cysts which, with the exception of associated hydrocephalus, are benign lesions. A recent meta-analysis of Sylvian fissure cysts by Chen et al. [6] demonstrated different complication profiles for the different treatments with open surgery having a high rate of short-term complications in the form of sub-dural hygromas whereas CP shunts have a higher rate of long-term complications due to shunt infections and dysfunction. Shunts in the treatment of arachnoid cysts are also at risk of shunt dependency [31,32] which carries a lifelong morbidity from shunt complications. In this series our rates of complications were comparable to those of the Chen et al. [6] review however, due to the small number of CP shunts, the long term complications may be under-represented. Larger series of CP shunts show reoperation rates of approximately 30% for complications or failures [29].

4.4. Limitations

There are several limitations with this case series that must be acknowledged. Firstly, it is a retrospective study which creates gaps in the data, particularly the radiological data where many images are missing due to inaccessibility with changing imaging software. Furthermore, as it is retrospective review patient numbers were fixed and so a power calculation was not conducted to determine the number of patients required to ensure significance. Secondly, this is a single centre experience and thus includes bias on treatment practices which may skew the results. Multi-centre, prospective clinical trials would be the best way to overcome these limitations. Lastly, this series is a mixed population both of adult and paediatric patients, and of cyst locations. Certain cyst locations, such as interhemispheric cysts, are more difficult to treat which may influence outcomes. It is likely that optimal treatment is not the same for the different locations, however without larger series this sub-group analysis is not feasible.

5. Conclusion

In summary this case series supports the use of both endoscopic and open fenestration in the treatment of intracranial arachnoid cysts. The comparable clinical improvement and complication rates are in line with the literature and with increasing numbers it may be possible to clarify the argument on treatment choices for specific cyst characteristics.

Conflict of interest

The authors have no conflicts of interest to disclose.

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