Childs Nerv Syst (2016) 32:1257–1263
DOI 10.1007/s00381-016-3064-8

ORIGINAL PAPER

Surgery for intracranial arachnoid cysts in children—a prospective long-term study

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Received: 19 December 2015 / Accepted: 13 March 2016 / Published online: 21 March 2016

Abstract
Purpose Intracranial arachnoid cysts are cystic malformations found in both adults and children. While many are asymptomatic, some cause symptoms and warrant surgical treatment. In this prospective population-based study, we aimed to study the short- and long-term outcome after surgical intervention in children with arachnoid cysts referred to our centre.
Methods Twenty-seven pediatric patients (13 f. 14 m, mean age 9.4 years) with de novo cysts were consecutively included during a 5-year period. The presenting symptoms were headache (n = 12), balance disturbance and dizziness (n = 6), seizures (n = 6), hydrocephalus (n = 5), and macrocephaly (n = 1). Twenty-two patients underwent surgical treatment with either microsurgical (n = 17) or endoscopic fenestration (n = 5) of the cyst wall. Cyst volume was measured with OsiriX® software pre- and postoperatively. Short-term and long-term follow-up of all patients was conducted 3 months and 8.6 years (7–10.5 years) postoperatively.
Results Three months after surgery, 59 % of the patients were improved regarding at least one major complaint, and average cyst volume was reduced to 33.3 ml (0–145 ml). At the long-term follow-up of 8.6 years, 77 % of the patients were improved regarding at least one symptom but subjective symptoms remained in 59 %. There was no permanent postoperative morbidity. We found no association between radiological reduction of cyst volume and clinical improvement.
Conclusion Our findings support a restrictive attitude to surgery for intracranial arachnoid cysts, in the absence of objectively verified symptoms and signs or obstruction of CSF pathways.

Keywords Arachnoid cysts · Long-term outcome · Cyst volume · Radiological versus clinical improvement

Introduction

Arachnoid cysts (ACs) are common cystic malformations [1]. The symptoms and signs of intracranial ACs range from symptoms of elevated intracranial pressure and hydrocephalus to unspecific and multifactorial symptoms, such as headache, dizziness, seizures, and developmental delay [2]. ACs may also be asymptomatic or found as incidental findings without associated symptoms [1]. Several authors have described both an increase and a decrease in cyst size over time, as well as rupturing into the subarachnoid space and the subsequent disappearance of the ACs [1, 3, 4]. Neurosurgeons are divided on the issue of surgical treatment of ACs but most agree that surgical treatment should be strictly limited to symptomatic cases [3, 5]. However, the evaluation of symptoms can be challenging, especially when facing symptoms that are common in the general population and may have other causes [1, 3].

The relationship between a postoperative decrease in cyst volume and clinical improvement has shown diverging results, but in most reports the imaging has been subjectively evaluated [3, 6].

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Our study is a prospective population-based long-term series on the clinical effect of surgical treatment of intracranial ACs in pediatric patients. We also aimed to investigate, using volumetry, whether the clinical outcome is related to a decrease in cyst volume.

Methods

Study population

The study was conducted as a prospective study between October 2004 and October 2009. During this time, 27 children (13 females and 14 males) with de novo cysts were referred to our neurosurgical department from the western region of Sweden, and were consecutively included in the study. The patients were between 2 months and 17 years old (mean age 9.4 years).

All the patients were evaluated for symptoms, including the occurrence and characteristics of headache, imbalance and/or dizziness, cognitive function, seizures, endocrine function, visual disturbance, and neurological deficits. Three patients were considered to be asymptomatic after the initial evaluation, and one patient who suffered from headaches declined further investigation. These four patients were followed by a pediatric neurologist and/or family practitioner. One patient was found to have a desmoplastic infantile ganglioglioma and was excluded from the study. The demographics of the study population and cyst locations are presented in Table 1.

Table 1 Patient demographics

	Operated	Non operated	*p* value
Number	22	4	
Sex	11 m, 11	3 m, 1 f	
Age mean (range)	8.5 years (0.2–17)	15 years (9–17)	0.08
Location			
Temporal	9	3	
Occipital	0	1	
Multi lobular[a]	3	0	
Posterior fossa	3	0	
Suprasellar	3	0	
Intraventricular	3	0	
Ambient cistern	1	0	
Cyst volume mean (range)	60.6 ml (5.3–225.2)	6.4 ml (1.3–14.1)	0.01

For comparison between groups, Fisher's exact test was used for dichotomous variables, Chi-square exact test was used for non-ordinal categorical variables, and the Mann-Whitney *U* test was used for continuous variables

[a] One frontotemporal and two frontotemporoparietal

All patients who exhibited symptoms that could be related to the AC were offered surgery. The procedure of choice was endoscopic fenestration for intraventricular cysts and open microsurgical fenestration for other locations. In case of a recurrent cyst, refenestration was the first-hand choice. Shunt surgery was only reserved for cases of postoperative development of hydrocephalus or postoperative persistent and symptomatic hygroma. All patients underwent MRI including FLAIR-, diffusion-, and T1-weighted sequences for excluding differential diagnoses and determining the cyst volume [7].

All 22 investigated patients were considered to be symptomatic and were offered surgical treatment. Seventeen patients were operated on with open microsurgical fenestration and 5 patients with endoscopic fenestration. In two cases, the fenestration procedure (one endoscopic and one open fenestration) was combined with shunt placement occasioned by concomitant hydrocephalus.

The study was approved by the local ethical committee (registration number 380–09). Informed consent for study participation was given by the patients' parents.

Short-term and long-term follow-up

All the patients were available for short- and long-term evaluation. The short-term follow-up was carried out by the outpatient clinic 3 months postoperatively. Patients were re-examined regarding headache, including headache characteristics, imbalance and/or dizziness, cognitive function, seizures, endocrine function, visual disturbances, and neurological deficits. Complete disappearance of at least one preoperative symptom was considered as clinical improvement.

A long-term follow-up was conducted during 2015 through standardized interviews with the patients' parents and/or the patients if they had reached adulthood. In 11 cases, the parents of the patients were interviewed; in 5 cases, both the children and the parents were interviewed; and in 6 cases, only the patients were interviewed. The interviews were conducted 8.6 years (7–10.5 years) after surgical treatment by author KR, who was not involved in the surgical treatment or short-term follow-up of the patients. The interview included detailed questions about the same symptoms as those identified in the preoperative examination and the 3-month follow-up. In addition, we asked about present occupation or study performance, functional improvement after surgery, worries about the cyst, and a personal estimation of whether the surgery had been worthwhile. The whole interview lasted up to 30 min per patient.

The four conservatively managed patients were followed up with the same standardized interview, with the exception of questions directly related to the surgery.

Cyst volume measurement

The cyst volume was measured on MRIs performed preoperatively, 3 to 4 months after surgery and 1 year postoperatively. The measurements were done on FLAIR sequences of 1.5T MRI using the OsiriX® software version 6.5 [8, 9]. The region of interest was manually outlined on each MRI slice by authors RDM and KR collectively, and the cyst volume was measured by the software. Both examiners were blinded to the clinical information on the patients at the time of the volume measurement.

Statistical analysis

The Sign test was used to compare pre- and postoperative data. The Wilcoxon signed-rank test was used for the comparison of volume measurements. For comparison between groups, Fisher's exact test was used for dichotomous variables. The Chi-square exact test was used for non-ordered categorical variables, and the Mann-Whitney *U* test was used for continuous variables. All tests were two-tailed and conducted at the 5 % significance level. The data were analyzed using version 9 of the SAS System for Windows.

Results

Preoperative symptoms and signs

At the preoperative evaluation, headache was found in 12 patients, imbalance and/or dizziness in 6, cognitive impairment or developmental delay in 3, seizures in 5, endocrine dysfunction in 2, visual disturbance in 3, hydrocephalus in 5, and macrocephaly in 1 patient. Two patients exhibited signs of elevated intracranial pressure; one with headache, vomiting, and visual disturbance caused by a suprasellar cyst, and one with headache and decreased level of consciousness due to a chronic subdural hematoma 2 weeks after a head trauma. The latter patient was operated on with evacuation of the chronic subdural hematoma and fenestration of the cyst at a later stage. The patients' symptoms and signs, before and after surgery, are presented in Tables 2 and 3.

Surgical complications

There were four postoperative complications (18 %): one case of transient oculomotor palsy, one case of subgaleal fluid collection, and one case of temporary CSF leakage that did not require surgical intervention. One patient (patient 1, Table 3) developed functional paralysis and was wheelchair-bound postoperatively. She was treated with cognitive therapy by pediatric psychiatry. At the time of the 3-month follow up, she was walking with a remaining functional balance disturbance and eventually made a full recovery within 6 months.

There were three reoperations during the entire study period and long-term follow-up. The patient with the subgaleal fluid collection became lethargic and exhibited signs of raised intracranial pressure. He was subsequently reoperated on 2 weeks after the initial surgery with a cystoperitoneal shunt. One other patient was reoperated on 9 months after the initial endoscopic fenestration with ventriculoperitoneal shunting due to hydrocephalus. The third patient was reoperated on with open microsurgical fenestration 5.5 years after the initial fenestration surgery, due to recurrent therapy-resistant headaches and an increase in cyst size (patient 13, Table 3).

At the time of the 3-month follow up with MRI, five patients had an asymptomatic hygroma. After 1 year, only two had an asymptomatic hygroma without radiological mass effect.

Outcome at the 3-month follow-up

At the 3-month follow-up, 13 out of 22 patients (59 %) who had undergone surgery had a complete recovery with regard to at least one preoperative symptom (Tables 2 and 3).

Operated cysts had a mean preoperative volume of 60.6 ml (5–225 ml), which, at the 3-month follow-up, had been reduced, on average, by 56 %, to 33.3 ml (1–145 ml) (Table 4). There was no association between the postoperative volume reduction and reduction in symptoms (Mann-Whitney *U* test $p = 0.12$). The cyst volume 1 year after the surgery was 38 ml in average (0–202 ml) (Table 4).

Outcome at the long-term follow-up

At the time of the long-term follow-up, 77 % (17/22) of the operated children had complete recovery of at least one preoperative symptom. Thirteen patients had remaining subjective symptoms (Tables 2 and 3). There was no significant difference in improvement between the short- and long-term follow-up.

Balance and gait disturbances were not present at the long-term follow-up in any of the patients who suffered from these symptoms preoperatively ($p < 0.05$). Visual disturbances, endocrine dysfunction, seizures, and symptoms of hydrocephalus were not present in any of the patients at the long-term follow-up; however, two patients who had entered precocious puberty remained of short stature, and two patients had abnormal head shapes, according to their parents. The patients and their symptoms are presented in Tables 2 and 3.

Out of 15 patients who were in school at the time of surgery, 8 were affected by their symptoms to a degree that it affected their participation in school. Seven of these patients reported improvement in school participation and/or results after the surgery. All patients had been attending regular

Table 2 Symptoms and signs in children operated for intracranial cyst before and after surgery

	Preoperative complaints (n = 22)	3 months postoperative (n = 22)	p value preoperative to 3-months	Long-term follow up (n = 22)	p value preoperative to long-term	p value 3 months to long-term
Headache	12	7	0.13	8	0.22	1
Dizziness and imbalance	6	2	0.22	0	0.03	0.5
Cognitive impairment/ developmental delay	3	2	1.0	4	1.0	0.6
Visual disturbance	3	0	0.25	0	0.25	
Seizures	5	2	0.25	1	0.13	1.0
Endocrine dysfunction	2	2	1.0	0	0.5	0.25
Hydrocephalus	5	1	0.13	0	0.06	1.0
Number of remaining symptoms			0.001		<0.001	0.34
N = 0	0	7		9		
N = 1	11	13		13		
N = 2	8	2		0		
N = 3	3	0		0		

One patient can have several symptoms and signs

For comparison over time, Sign test was used for categorical variables

school. Seven patients were top school students or were studying at the university. These patients were not experiencing cognitive disturbances at the time of the investigation and were operated on based on other symptoms. Cognitive problems remained in four patients, two of whom were suffering from a cognitive disturbance at the time of the investigation. Ten patients functioned normally and were either in school or working. One patient was unemployed. Twelve patients still worried about reoccurrence of the cyst. In 21 of the 22 operated patients, the surgery was considered worthwhile by the patients and/or their parents, based either on improvement of their symptoms or relief from worries about the cyst. Only one patient still suffering from headaches regrets undergoing surgery.

Conservatively managed patients

The four patients who were not operated on were still asymptomatic in two cases. The other two patients suffered from headaches but both experienced an improvement in their headache. All four were doing well and were studying or working.

Discussion

This prospective population-based long-term follow-up shows improvement in operated children with no long-term morbidity, few reoperations, and a high functioning level. However, as in most previous studies, the small sample size and uncontrolled design are obvious limitations. Objectively verified symptoms and signs, such as visual disturbances, endocrine dysfunction, seizures, and hydrocephalus, disappeared in most cases. We found a favorable outcome in 13 operated patients (59 %) after 3 months, and in 17 patients (77 %) at the long-term follow-up (mean 8.6 years, range 7–10.5 years). One or several subjective symptoms remained in 59 % of the patients at the time for the long-term follow-up. The volume of the ACs decreased significantly after surgical decompression.

At a first glance, these results seem to justify surgical intervention, but despite the improvement, many of the patients had residual symptoms. Furthermore, we do not know whether their symptoms would have improved at long term with conservative management; the few patients with small cysts who were managed conservatively remained stable and did not need surgical intervention. Symptoms caused by ACs could be explained by either obstruction of the CSF pathways or direct compression of neural structures and/or adjacent tissues [2, 5]. In the first case, the prognosis after surgery is generally accepted to be excellent and, subsequently, all five patients improved significantly.

In the case of ACs with presumed local compression, the surgical indication is much more debatable [3, 10]. The most common symptoms of headache, imbalance/dizziness, and cognitive disturbances are fully or partially subjective symptoms, frequent in general population, and multifactorial [11, 12]. Furthermore, the natural history of these symptoms in untreated ACs is poorly known. Al-Holou followed 111 patients with ACs and found only 3 patients with new symptoms who underwent surgery, over an average follow-up of 3.5 years [1]. Headache is the most common symptom found

Table 3 Patient and cases

Nr	Age at surgery	Age at longterm follow up	Sex	Cyst location	Cyst volume preoperative (ml)	Cyst volume 3 months follow up (ml)	Cyst volume 1 year follow up (ml)	Preoperative symptoms	Symptoms at 3 months follow up	Symptoms at longterm follow up
1	13	20	F	Temporal	23	9	7	Headache	Functional paralysis	None
2	9	17	M	Temporal	33	5	–	Seizures[a]	None	None
3	2	11	M	Temporal	35	37	47	HC, gait disturbance, developemental delay	None	Astheno-emotional disorder
4	6	14	F	Temporal	106	54	26	Seizures, cognitive disturbance	Seizures, headache	Seizures, cognitive disturbance
5	17	28	M	Temporal	117	21	12	Headache, chronic subdural hematoma	Paresthesias	None
6	13	22	M	Temporal	30	20	16	Cognitive disturbance	Cognitive disturbance	Cognitive disturbance, mild headache
7	1	10	M	Temporal	153	14	0	Seizures[a]	Seizures	Mild headache
8	9	17	M	Temporal	23	13	10	Mild headache, dizziness	Mild headache	Mild headache
9	15	25	F	Temporal	49	22	15	Headache, seizures[a]	Headache (unchanged)	Headache (unchanged)
10	8	16	M	Temporal	17	6	7	Headache, fatigue and astheno-emotional disorder	Fatigue and asheno-emotional disorder	None
11	4	13	M	Frontotemporal	148	112	93	Macrocephaly	Macrocephaly	Cognitive disturbance
12	11	19	F	Frontotemporoparietal	225	143	138	Headache, syncope	Headache	Mild headache
13	7	16	F	Suprasellar	6	5	–	Headache, visual disturbance, endocrine dysfunction	Headache, endocrine dysfunction	Headache
14	8	16	F	Suprasellar	34	14	11	HC, headache, nausea, visual disturbance	Precious puberty	Short stature
15	9	17	F	Suprasellar	20	14	11	Precocious puberty	Remainig precocious puberty	Short stature
16	0,2	8	M	Intraventricular	121	45	49	HC, seizures	None	None
17	0,5	8	F	Intraventricular	114	145	203	HC, increased head circumference	None	None
18	17	27	F	Intraventricular	12	3	3	Headache, balance disturbance	Balance disturbance	None
19	1	9	F	Ambient cistern	5	1	0	HC, increased head circumference, balance disturbance/unsteady gait, visual disturbance	None	Mental fatigue, cognitive problems, abnormal head shape
20	10	19	M	Posterior fossa	18	18	–	Headache, balance disturbance	Headache	Mild headache
21	17	24	F	Posterior fossa	36	29	32	Headache	Headache	Headache
22	10	19	M	Posterior fossa	8	2	–	Headache, balance disturbance	None	Mild headache

HC hydrocephalus

[a] Partial seizures. Seizures were generalized if not specified as partial

Table 4 Preoperative and postoperative cyst volume.

	Preoperative volume	*p* value
Preoperative cyst volume	60.6 ml (5.3–225.2)	
3-months postoperative volume	33.3 ml (1–145)	<0.001
1-year postoperative volume	37.8 ml (0–202.6)	0.13[a], 0.004[b]

[a] Compared to the volume at 3 months follow up

[b] Compared to preoperative volume, Wilcoxon signed rank test

in patients with AC but is also one of the most common conditions in the general population [2, 13]. Headache in children can be caused by various factors, including social stress [11, 14–16]. This could explain why headache in patients with ACs may persist despite adequate surgical decompression [1, 3, 17]. A review of 64 different studies in children and adolescents found an overall mean prevalence of 54.4 % for any type of headache [16, 18]. In our series, 54.5 % (12/22) of the patients suffered from headache at the initial evaluation, and only half of them experienced improvement after surgery. Balance disturbances and/or dizziness is the second most common symptom, equally difficult to quantify [12] and questioned by some authors as a surgical indication [3]. In our series, balance disturbance and or dizziness had a good outcome, but five of six patients with this symptom had concomitant hydrocephalus. No patient suffered from these symptoms at the long-term follow-up. Cognitive and behavioural problems are also commonly described in patients with AC. Some authors even go as far as suggesting prophylactic surgery to avoid development of these problems [6, 19]. Interestingly, a study in children with AC and healthy controls failed to prove that children with ACs suffer from cognitive decline [20]. Functional MRI studies do not support interference of ACs with the normal functions of the cortex [21]. In our series, the cognitive impairment persisted despite surgery.

The causative relationship between ACs and epileptic seizures is controversial [22]. Similar to our results, some studies find a complete resolution of seizures in some patients, while other patients experience either a reduced or an unchanged frequency of seizures [23].

Since the goal of surgery is to reduce a space-occupying lesion, one would anticipate an association between a decrease in cyst volume and clinical improvement. Previous studies report vastly differing results regarding the relationship between a radiological reduction in cyst volume and clinical improvement [3, 6]. The methodology of volume evaluation in these studies has mostly been subjective evaluation of MRI images and categorisation of MRI findings into different groups. Volumetry for AC has, to our knowledge, not been performed in previous studies. We chose to measure the numeric cyst volume in preoperative as well as two postoperative MRI examinations, and we defined clinical improvement as the disappearance of at least one preoperative symptom in order to avoid recall bias. We did not find clinical improvement to be related to a radiological reduction in cyst volume.

ACs are common incidental findings. In a hospital-based study by Al-Holou et al., ACs were found in 2.6 % of the examined children [1]. In our study, surgery was offered to all patients with any symptom that could be related to an AC. Consequently, with these rather broad indications, the rate of surgery was twice as high (three children per million inhabitants per year) as the national average in Sweden, according to the Swedish National Board of Health (The National Board of Health and Welfare, www.socialstyrelsen.se/english, accessed on April 10, 2015).

Finally, the cost-benefit ratio of surgery must be questioned if the patients only show moderate improvement of subjective symptoms. The rate of complications and treatment failure associated with the surgical treatment of ACs is quite high [2, 3, 24], even in studies by those in favor of surgery based on broad indications [6]. Considering the benign nature and the scarce natural history of this condition in most cases, serious surgical complications, such as hemorrhage, infarction, meningitis, and neurological deficits, are hard to accept [1, 2, 25]. Despite our findings of good long-term functional outcomes, with no permanent morbidity after surgery, the objective improvement is often difficult to quantify and validate. Hence, fenestration of an AC in the absence of obstructed CSF pathways, and/or verified objective symptoms/signs, remains debatable.

Conclusion

Our findings support a restrictive attitude to surgery for intracranial arachnoid cysts, in the absence of objectively verified symptoms and signs or obstruction of CSF pathways.

Acknowledgments Bengt Bengtsson at Statistiska Konsultgruppen for statistical analysis. Funding was received from Göteborg Foundation for Neurological Research (ISNF), Edit Jacobson's Foundation, Rune and Ulla Amlövs Foundation, and John and Brit Wennerström Foundation. The funders had no role in the study design, the collection and analysis of the data, data interpretation, or the writing of the paper.

Compliance with ethical standards

Conflict of interest None of the authors report any conflict of interest in relation to this study.

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