Comparing Surgical Treatment Options for Intracranial Arachnoid Cysts; Radiological, Clinical and Histopathological Outcomes of the Operated Patients

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Abstract

Aim: This study was designed to examine patients who underwent surgery for arachnoid cysts and compare surgical treatment options in terms of clinical, radiological and histopathological outcomes.

Methods: Data obtained from 47 patients who underwent surgery for arachnoid cysts at 3 neurosurgery institutions between November 2002 and January 2020 were retrospectively reviewed.

Results: The mean age of the patients was 12.7 ± 11.3 years. In the study group, 32 patients (68%) underwent fenestration with craniotomy, while 15 patients (32%) underwent cystoperitoneal shunt application. The mean reduction rates of the cyst volume were determined as 51.4%. The group with the highest reduction rates was detected as convexity cysts treated with fenestration with a rate of 73.9%. The rate of complete resolution of symptoms was found to be statistically significantly higher in the fenestration group (p=0.01). Postoperative mass effect reduction was also found statistically significant in the patients with edema positivity (p=0.024) and thickening of basal lamina negativity (p=0.002).

Conclusions: The present study revealed that fenestration with craniotomy seems to be a favorable technique as the first step in the treatment of arachnoid cysts. The rate of complete resolution of symptoms was higher in the fenestration group and complication rates were higher in the cystoperitoneal shunt group. We also found that the membrane thickness of arachnoid cysts and the amount of collagen increases as the patients' age increases and tissue edema increases in younger patients. Preoperative mass effect, and postoperative reduction in mass effect correlated positively with tissue edema and negatively with basal lamina thickness.

Keywords: Arachnoid cyst; fenestration; cystoperitoneal shunt; hydrocephalus; histopathology

1. Introduction

Arachnoid cysts are benign developmental anomalies that occur between layers of the arachnoid membrane and contain cerebrospinal fluid (CSF) like fluid. They are usually detected incidentally and remain asymptomatic. They constitute approximately 1% of all intracranial lesions.[1-4] Arachnoid cysts do not usually enlarge and are very likely to remain the same. Regression in cyst size may be observed in some patients. However, bleeding into the cyst or expansion of the cyst can also be seen. Surgery may be required for persistent headache, nausea, vomiting, or neurological symptoms secondary to neural or vascular compression in these patients.[1-4]

A definitive treatment protocol has not yet been established for surgical applications. In addition, there is limited information in the literature on arachnoid cyst regression rates or brain parenchymal changes after surgery. In this study, we aimed to examine 47 patients who underwent surgery for arachnoid cysts and to determine whether there were differences in the clinical and radiological outcomes of the patients between the different surgical approaches.

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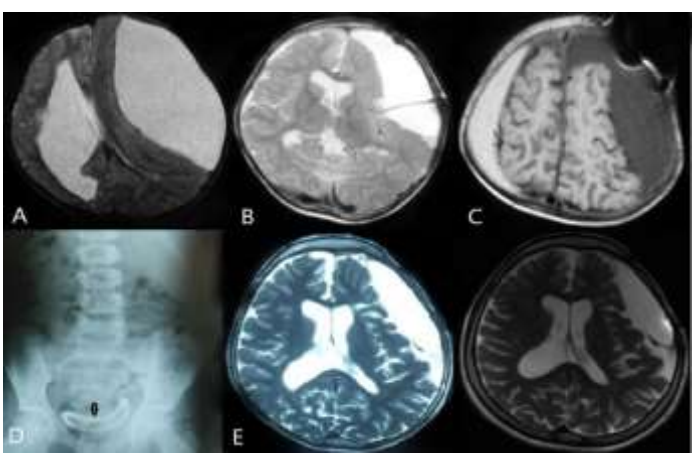
2. Materials and Methods

The research was conducted in accordance with the principles of the World Medical Association Declaration of Helsinki "Ethical Principles for Medical Research Involving Human Subjects" (amended in October 2013) and Institutional Review Board approval was obtained. This study included 47 patients with arachnoid cysts who were operated upon at 3 neurosurgery institutions between November 2002 and January 2020. Patient data that includes age, gender, symptoms, preoperative and postoperative neurological conditions, localization of the arachnoid cysts, preoperative and postoperative cyst volume, whether there is a mass effect of the cysts, surgical methods applied, length of hospital stay, postoperative complications, follow-up periods, and the final status of the patients were recorded.

Neuroimaging of the patients was performed by applying magnetic resonance imaging (MRI) of the brain preoperatively, postoperatively at 6 months, 1 year, and once a year in the subsequent follow-up visits. The final status of the cysts was included in the biostatistical analysis based on the last brain MRI values at which their cyst volumes reached a constant value. The preoperative and postoperative arachnoid cyst volumes were measured using the modified MacDonald ellipsoid criteria.5 As the surgical interventions, two methods were used on the patients; cyst fenestration(Fig 1) with craniotomy, and cystoperitoneal (CP) shunt.(Fig 2, 3)

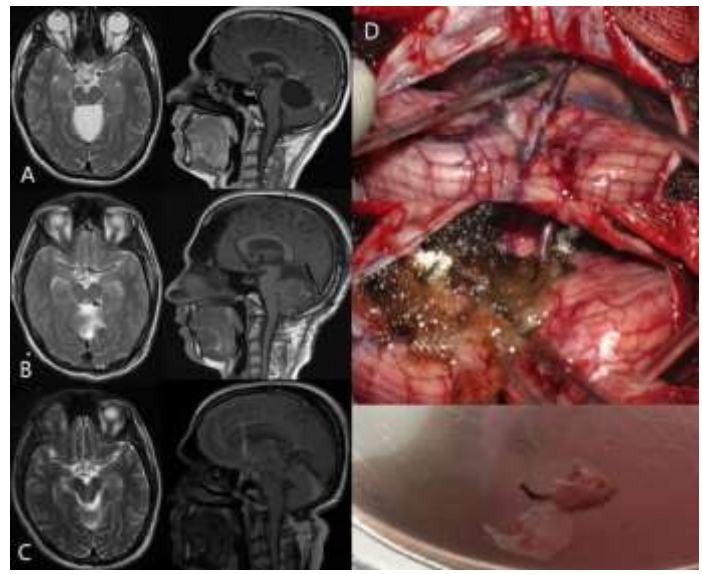
In order to examine the detailed histopathological parameters of the patients' arachnoid cysts, the specimens of 22 patients could be accessed and detailed examinations were performed on these patients. In the detailed histopathological examination; materials fixed with formalin and then embedded in paraffin blocks were microtomed to 6-micron thickness and treated with alcohol and xylol solutions, and routinely stained with hematoxylin and eosin. The examination was carried out with a light microscope. In addition, histochemical staining evaluated the development of fibrosis with Masson Trichrome and basement membranes with Periodic Acid-Schiff. The histopathological parameters including edema, collagen increase, and thickening of the basal lamina were recorded.

Figure 1



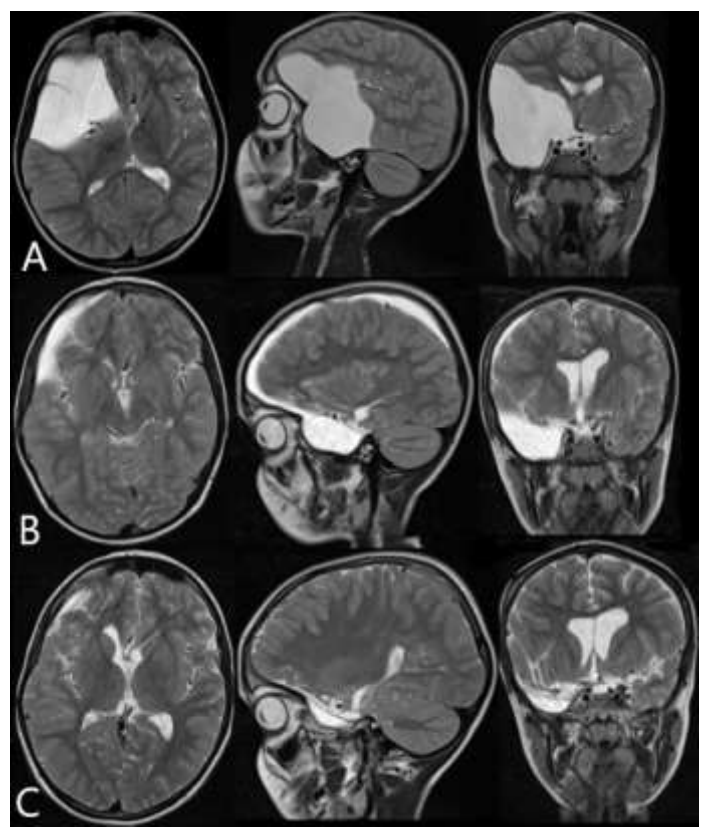
*Preoperative axial magnetic resonance imaging scan revealing a large left middle fossa arachnoid cyst **(A)**. Postoperative axial magnetic resonance image showing cystoperitoneal shunt placement **(B)**. Postoperative 1st year follow-up axial magnetic resonance image showing subdural effusion on the contralateral side **(C)**. Abdominal radiography revealing migration of the distal tip to the abdomen (black arrow) **(D)**. Postoperative 4th year follow-up axial magnetic resonance image showing reduction of the arachnoid cyst **(E)**.*

Figure 2



*Preoperative axial and sagittal magnetic resonance imaging scans revealing quadrigeminal cistern arachnoid cyst of a 16-year-old patient who underwent cyst fenestration with craniotomy **(A)**. Postoperative 6th month **(B)** and 2nd year **(C)** follow-up axial and sagittal magnetic resonance images showing reduction of the arachnoid cyst. Peroperative images of the quadrigeminal arachnoid cyst **(D)**.*

Figure 3



*Preoperative axial, sagittal and coronal magnetic resonance imaging scans revealing middle fossa arachnoid cyst of a 5-year-old patient who underwent cyst fenestration with craniotomy **(A)**. Postoperative 6th month **(B)** and 2nd year **(C)** follow-up axial, sagittal and coronal magnetic resonance images showing reduction of the arachnoid cyst.*

2.1. Statistical Analysis

SPSS software version 25.0 (IBM Corporation, Armonk, New York, USA) was used to analyze the variables. Quantitative variables were presented as mean ± SD (standard deviation) and range (maximum-minimum) and categorical variables as n (%). Pearson's chi-square test and Fisher's exact test were used when comparing categorical variables. Data conformance to normal distribution was evaluated by the Shapiro–Wilk test. The Mann–Whitney U test was used with the Monte Carlo results to compare categorical variables quantitatively. The variables were examined at a 95% confidence level and $p<0.05$ was considered statistically significant.

3. Results

A total of 47 patients were included in the study. The mean age of the patients was 12.7 ± 11.3 (2 months to 72 years). 40 patients were in the pediatric age group, 7 patients in the adult age group. 18 patients (38.3%) were female and 29 patients (61.7%) were male. The arachnoid cysts of 24 patients were located in the middle fossa, 7 patients were cerebellopontine angle (CPA) cisterns, 7 patients were convexity, 3 patients were suprasellar, 3 patients were intraventricular, and 3 patients were quadrigeminal (Table 1). The most common symptom was headache (72.3%). Other symptoms noted were dizziness (36.2%), increased head circumference (19.1%), nausea (19.1%), seizure (17%), consciousness disorder (12.8%), vision deficit (10.6%), and tinnitus (4.2%), respectively. Eight of 47 patients had hydrocephalus and all of these patients were in the pediatric age group (Table 1).

Table 1

Demographic data of the patient groups

Characteristics		Study cohort n=47	Fenestration group n=32	Shunt group n=15	P value
Age (years)		12.7 ± 11.3	15.2 ± 14.4	9.9 ± 7.2	0.09
Gender (n/%)	Female	18 (38.3)	12 (37.5)	6 (40)	0.46
	Male	29 (61.7)	20 (62.5)	9 (60)	
Cyst location (n/%)					
Middle fossa		24 (51)	18 (56.2)	6 (40)	0.12
Convexity		7 (14.9)	3 (9.4)	4 (26.6)	
CPA cistern		7 (14.9)	6 (18.7)	1 (6.7)	
Quadrigeminal		3 (6.4)	2 (6.3)	1 (6.7)	
Intraventricular		3 (6.4)	-	3 (20)	
Suprasellar		3 (6.4)	3 (9.4)	-	
Hydrocephalus at presentation (n/%)		8 (17)	-	8 (53.3)	0.03

In the study group, 32 patients (68%) underwent fenestration with craniotomy, while 15 patients underwent CP shunt application. CP shunt was applied to all patients with hydrocephalus. When the patients were measured preoperatively, the mean arachnoid cyst volume was 111.2 ± 75.9 cm^3 (8.75 - 372 cm^3 interval). The mean postoperative arachnoid cyst volume was 52.8 ± 42.7 cm^3 (2.8 - 161.7 cm^3 interval). The mean reduction rates of the cyst volume were determined as 51.4%. When comparing the surgeries performed, no statistically significant difference was found between the reduction rates ($p>0.05$). Considering the reduction rates of arachnoid cysts according to their locations; the convexity cysts shrunk the most with the rate of 62.4%, and the intraventricular cysts shrunk the least at 30.8% (Table 2).

Considering the subgroups according to the surgical interventions performed, the group with the highest reduction rates was detected as convexity cysts treated with fenestration with a rate of 73.9% (Table 2).

When the arachnoid cysts of the patients are evaluated in terms of creating a mass effect; there was a mass effect in 42 patients and there was no mass effect in 5 patients in the preoperative period. As a result of neuroradiological evaluation of these 42 patients in the postoperative period; it was observed that the mass effect decreased in 35 patients (83%) and there was no change in 7 patients (17%) (Table 2).

Comparing the surgeries performed, it was found that the rate of reduction of the mass effect was 85% in patients with fenestration, and 80% in patients with CP shunt. When comparing the surgeries performed, no statistically significant difference was found ($p>0.05$). When symptom progression was evaluated, the symptoms of 29 patients (62%) completely resolved, while the symptoms of 14 patients (30%) improved. Symptoms did not change in 3 patients (6%), and worsening was observed in 1 patient (2%) (Table 2). When comparing the surgeries performed, the rate of complete resolution of symptoms was found to be statistically significantly higher in the fenestration group ($p=0.01$) (Table 2). The patients' median hospital stay was 5.1 ± 2.5 days (range 2-12 days).

The mean follow-up period of the patients was 3.3 ± 2.9 years (1-18 years). A total of 6 patients had complications (12.8%). Complications developed in 3 patients (20%) who underwent CP shunt application and 3 patients (9.4%) who underwent fenestration with craniotomy. Among the patients who underwent CP shunt application, mortality was detected in 1 patient, shunt over drainage in 1 patient and shunt dysfunction in 1 patient. Among these patients, mortality developed in the patient who was 2-month-old, on the 7th day following the operation, due to the progress of his complaints and the general deterioration. Shunt revision was performed on the patient with shunt dysfunction. In the patient, who underwent CP shunt when she was 4 years old, subdural effusion on the contralateral side developed due to shunt overdrainage at the 1st year follow-up. The patient was followed conservatively because there was no parenchymal compression. At the 2nd year follow-up, regression was detected in the effusion and abdominal radiography showed that the distal end of the shunt migrated to the abdomen and the shunt integrity was disrupted. After 6 months of follow-up, the shunt was removed due to the arachnoid cyst regression. On the 4th year follow-up, 61% reduction in the size of the arachnoid cyst was detected (Figure 1). Among the patients who underwent fenestration, re-fenestration was performed on 2 patients, one after 2 years, and the other after 5 years. In the last patient who developed a complication, re-fenestration was performed in the 3rd postoperative year and CP shunt application was performed in the postoperative 5th year due to the symptoms continued.

Table 2

Comparison of surgical methods

Characteristics		Study cohort n=47	Fenestration group n=32	Shunt group n=15	P value
Cyst volume preoperative (cm^3)		111.2 ± 75.9	92.4 ± 60.3	151.1 ± 91.5	0.09
Cyst volume postoperative (cm^3)		52.8 ± 42.7	40.4 ± 33.4	79.3 ± 49.1	0.12
Cyst volume reduction rate (%)	Total	51.4	53.2	50.6	0.28
	Convexity	62.4	73.9	45	
	Quadrigeminal	54.9	51	62.6	
	Suprasellar	54.3	54.3	-	
	Middle fossa	54	53.2	56.2	
	CPA cistern	41.6	42.9	33.8	
	Intraventricular	30.8	-	30.8	
Mass effect* (n/%)	Reduced	35 (83)	23 (85)	12 (80)	0.38
	Unchanged	7 (17)	4 (15)	3 (20)	
Change in symptoms (n/%)	Resolved	29 (62)	22 (68)	7 (46)	0.01
	Improved	14 (30)	8 (26)	6 (40)	
	Unchanged	3 (6)	2 (6)	1 (7)	
	Worse	1 (2)	-	1 (7)	
Complications (n/%)		6 (12.8)	3 (9.4)	3 (20)	0.01

** There were 42 patients with mass effect in the preoperative period. There was no mass effect in 5 patients in the study cohort.*

Table 3

Comparison of age, gender, edema, increase in collagen and thickening of basal lamina parameters of the patients

Patient	Age	Gender	Edema	Increase in collagen	Thickening of basal lamina
1	2M	M	+++	+	-
2	6M	F	+++	-	-
3	1	M	+++	+	-
4	2	M	+++	+	-
5	6	M	+++	-	-
6	6	M	+++	-	-
7	12	M	++	-	-
8	14	M	+	+	-
9	15	F	+	++	-
10	16	M	+	+	-
11	16	F	+	+	-
12	17	M	+	+	-
13	18	M	+	+	-
14	19	M	+	+	-
15	19	M	+	++	-
16	21	F	+	+	-
17	23	M	+	++	+
18	35	F	-	++	++
19	43	F	-	+++	+++
20	46	M	-	+++	+++
21	50	M	-	+++	+++
22	70	M	-	+++	++

Table 4

Comparison of histopathologic parameters of the patients

Characteristics		Edema		P	Increase in collagen		P	Thickening of basal lamina		P
		Negative	Positive		Negative	Positive		Negative	Positive	
Age (Median / Min-Max)		46 (35-70)	15 (1-23)	0.001	6 (6-12)	18.5 (1-70)	0.041	14.5 (1-21)	44.5 (23-70)	0.001
Cyst volume preoperative (cm^3 / Min-Max)		65,75 (8,75-109,9)	88,6 (43,8-247,5)	0,108	144,35 (43,8-247,5)	75 (8,75-200,8)	0,307	93,3 (43,8-247,5)	57,25 (8,75-109,9)	0,055
Cyst volume postoperative (cm^3 / Min-Max)		22 (4,5-38,4)	41,8 (3,1-152)	0,031	31,05 (5,6-152)	36,45 (3,1-95,2)	0,865	42,3 (3,1-152)	22,3 (4,5-38,4)	0,046
Cyst volume reduction rate (% / Min-Max)		48,5 (0,45-82,8)	45,3 (0,59-87,2)	0,667	74,5 (38,5-87,2)	43,4 (0,45-82,8)	0,074	46,2 (0,59-87,2)	45 (0,45-82,8)	0,941
Mass effect preoperative (n/%)	Negative	3 (60)	0 (0)	0,006	0 (0)	3 (16,7)	0,603	0 (0)	3 (50)	0,013
	Positive	2 (40)	17 (100)		4 (100)	15 (83,3)		16 (100)	3 (50)	
Mass effect postoperative (n/%)	Reduced	2 (40)	16 (94,1)	0,024	4 (100)	14 (77,8)	0,554	16 (100)	2 (33,3)	0,002
	Unchanged	3 (60)	1 (5,9)		0 (0)	4 (22,2)		0 (0)	4 (66,7)	
	Resolved	3 (60)	13 (76,5)		3 (75)	13 (72,2)		13 (81,3)	3 (50)	
Change in symptoms (n/%)	Improved	2 (40)	3 (17,6)	0,654	1 (25)	4 (22,2)	0,631	3 (18,8)	2 (33,3)	0,234
	Unchanged	0 (0)	1 (5,9)		0 (0)	1 (5,6)		0 (0)	1 (16,7)	

3.1. Histopathology

In the detailed histopathologic examination; it was found that as the age of the patients increased, the positivity of edema decreased and, levels of collagen and thickening of basal lamina increased (Table 3). There was no statistically significant difference in the preoperative cyst volumes. However, postoperative cyst volumes were found higher in the patients with edema positivity (p=0.031) and thickening of basal lamina negativity (p=0.046) (Table 4). Preoperative mass effect was found statistically significant in the patients with edema positivity (p=0.006) and thickening of basal lamina negativity (p=0.013). Postoperative mass effect reduction was also found statistically significant in the patients with edema positivity (p=0.024) and thickening of basal lamina negativity (p=0.002) (Table 4).

4. Discussion

Although the first discovery of arachnoid cysts dates back to the 17th century, Bright was first to describe the term as arachnoid cyst in 1831.[6,7] Arachnoid cysts constitute approximately 1-1.5% of all intracranial lesions. They are generally seen in children and 75% of all arachnoid cysts are detected in childhood.[8-10] They are more common in male patients, and their frequency is higher in the left cerebral hemisphere.[10] The most common regions are the middle fossa, posterior fossa, sellar, and parasellar regions, convexity, and the intraventricular region.[2,5,10,11] In our series, the middle fossa (51%) was found to be the most common location.

It is generally accepted that they are congenital, but trauma and infection have also been reported to play a role in some cases.[12,13] It is believed that congenital arachnoid cysts are formed during the fetal period (between the 6th and 8th weeks) during the hemispheric folding and separation of the arachnoid membranes.[1,14,15] Differences between arachnoid membranes and cyst walls have been described in the literature.[10,12,15,16] The presence of a thick collagen layer in the cyst wall, the absence of cross-trabecular structure in the cyst, and the presence of hyperplastic arachnoid cells involved in collagen production in the cyst wall are the main differences.[10,12,15,16] It has been determined that arachnoid cysts occur after a latent period between 10 months and 6.2 years following trauma.[12,16]

Various theories have been described on the development and growth mechanisms of arachnoid cysts. It is believed that with the osmotic gradient and one-way valve mechanism, the cyst expands after active fluid release from the cells in the cyst walls.[1,17-19] According to another theory, the CSF entering the cyst becomes trapped and cannot escape, and it expands due to the increase in pressure inside the cyst.[20,21] Arachnoid cysts can be associated with

diseases such as Marfan syndrome, neurofibromatosis, glutaric aciduria type 1, myotonic dystrophy, neural tube defects, and cavernous hemangioma.[22-25] It is useful to screen children with bilateral and multiple cysts for type 1 glutaric aciduria.[23]

While they can remain asymptomatic for life, symptoms may develop at any age, especially in childhood and adolescence. Expansion rates are higher in arachnoid cysts detected in the early period.[26] Their symptoms are related to the size and localization of the cysts. Symptoms occur due to reasons such as cortical irritation, parenchyma compression, and increased intracranial pressure due to impaired CSF circulation. Headache, nausea, vomiting, seizures, hemiparesis, increased head circumference, and consciousness disorders are among the symptoms that can be detected.[1,4,20,21] Studies have been conducted in the literature on the development of epilepsy and arachnoid cysts, but no significant relationship has been found.[27,28]

60-90% of arachnoid cysts may become symptomatic in early childhood.[20,21,26] In the study performed by Al-Holou et al., brain MRI was performed in 11738 pediatric patients in an 11-year period and arachnoid cysts were detected in 309 patients. The prevalence of arachnoid cyst was 2.6%. After a mean follow-up of 3.5 years, 11 arachnoid cysts increased in size, 13 decreased, and 87 remained stable. Younger age at presentation was significantly associated with cyst enlargement and the need for surgery. No patient older than 4 years of age at the time of initial diagnosis had cyst enlargement, demonstrated new symptoms, or underwent surgical treatment.[26]

Ultrasonography in the prenatal period, brain computerized tomography (CT), and MRI in the postpartum period are frequently performed as radiological diagnostic examinations.[29] Arachnoid cysts are detected as extra-axial cystic lesions with smooth borders and the contents of cysts are observed isodense with CSF in CT examinations. The optimal method used in a detailed examination of arachnoid cysts is MRI. MRI has many advantages such as multiplanar imaging of arachnoid cysts, determination of their relationship with the surrounding basal cisterns and subarachnoid distance, and detailed detection of accompanying hydrocephalus or other developmental anomalies.[30-32] Arachnoid cysts are hypointense on T1-weighted MR images and hyperintense on T2-weighted MR images, similar to CSF. No staining is detected on the cyst walls after contrast application and brain edema is not detected around arachnoid cysts. The relations of the cysts with CSF spaces can be determined with cine MRI.[33] The differential diagnosis of an arachnoid cyst includes leptomeningeal cyst, subdural hygroma, enlarged CSF spaces such as mega cisterna magna, epidermoid cyst, porencephalic cyst, and anterior temporal lobe giant perivascular spaces. Arachnoid cysts are differentiated from epidermoid cysts with diffusion-weighted MRI. While diffusion limitation is observed in epidermoid tumors in DWI, it is not observed in arachnoid cysts.[34,35]

There is no definite and clearly defined protocol in the literature for the treatment of arachnoid cysts. The first step in treatment is the conservative method. The patients who are followed conservatively are checked clinically and radiologically at regular intervals. Spontaneous resolution can be observed in some of the patients who are followed conservatively.[36,37] However, in some cases, enlargement of arachnoid cysts and signs of increased intracranial pressure may be observed. In these patients, symptoms such as severe headaches that do not respond to medical treatment, severe nausea-vomiting, hemiparesis, and seizures due to parenchymal compression may develop. In addition, sometimes spontaneous or post-traumatic bleeding into the cyst or subdural hematoma ipsilateral to the cyst may develop.[4,21,38,39] Surgical treatment protocols should be applied in such patients.

In the surgical treatment of arachnoid cysts, cyst excision with craniotomy and fenestration with adjacent areas, cyst excision with neuroendoscopy and fenestration, and CP shunt application are the options. Craniotomy with cyst excision and fenestration method is the most commonly used method in the literature.[2,4,11,21,40-42] The neuroendoscopy method, which has been increasingly used in the neurosurgery practice in recent years, is also becoming more important in the treatment of arachnoid cysts. The advantages of this method are small incisions and minimal damage to the tissues.[1,2,19,43,44] However, the disadvantages such as insufficient surgical exposure, insufficient fenestration, need for reoperations, and insufficient intervention for complications that develop during surgery should also be considered. Although used as the first application according to some authors, CP shunts are generally applied in cases such as the association of arachnoid cyst with hydrocephalus and failure after multiple fenestration applications.[3,21,45] As in all shunts, these patients have disadvantages such as lifelong shunt dependence, shunt dysfunction, and the risk of developing shunt infection.

5. Conclusion

The surgical treatment of cranial arachnoid cysts is controversial. Cyst fenestration with craniotomy and CP shunt placement both appear to be effective techniques. In the present study, we found that convexity cysts treated with fenestration are the group with the highest reduction rates. The rate of complete resolution of symptoms was higher in the fenestration group and complication rates were higher in the CP shunt group. However, we think that the patients with coexistence of arachnoid cyst and hydrocephalus should be treated with CP shunt application. Fenestration with craniotomy seems to be a favorable technique as the first step in the treatment of arachnoid cysts. We also found that the membrane thickness of arachnoid cysts and the amount of collagen increases as the patients' age increases and tissue edema increases in younger patients. In the detailed histopathological examination of these patients; preoperative mass effect, and postoperative reduction in mass effect correlated positively with tissue edema and negatively with basal lamina thickness.

Statement of ethics

The study received approval from the Cukurova University Faculty of Medicine Non-Interventional Clinical Research Ethics Committee on October 3, 2025 (159/6).

genAI

No artificial intelligence-based tools or generative AI technologies were used in this study. The entire content of the manuscript was originally prepared, reviewed, and approved by both authors.

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Conflict of interest statement

The authors declare that they have no conflict of interest.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Author contributions

KO is the major contributor in writing the manuscript. KO, EG and AG are involved in the design and conception of the study. KO, EG, FA, IS, AIO, KB, MKD and AG are involved in the collection of the data

and clinical follow-up of the patients. All authors read and approved the final manuscript.

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