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ORIGINAL PAPER

Neurocognitive profile in children with arachnoid cysts before and after surgical intervention

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Abstract

Objectives Treatment indications for arachnoid cysts are not clear. Some surgeons take improvement in neurocognitive function into account as a surgical indication for arachnoid cysts. However, only a few studies have evaluated the relationship between arachnoid cysts and neurocognitive function. Furthermore, studies that analyze neurocognitive function as an effect of arachnoid cyst surgery are even rarer. The purpose of this study was to analyze the neurocognitive function scores of children with arachnoid cysts before and after surgery and to examine whether surgical treatment led to improved neurocognitive function.

Methods From June 2009 to August 2012, data for 24 children diagnosed with arachnoid cysts who underwent surgery at Seoul National University Children's Hospital were analyzed. Pre-operative and post-operative cyst volume was assessed and neurocognitive function was tested using the Korean version of the Wechsler Intelligence Scale for Children-Revised (WISC-R) and the Bender-Gestalt Test (BGT). Comparison of pre- and post-operative profiles by laterality of the arachnoid cyst was performed.

Results Patients had age-appropriate full-scale intelligent quotients (FSIQ), verbal IQ (VIQ), and performance IQ (PIQ) pre-operatively, which were maintained after surgery. Of the subtests, Block Design showed significant improvement post-operatively ($p = 0.021$). This means that visuo-spatial integration and mental construction abilities were improved after surgery. Patients with left or right arachnoid cysts did not show statistically significant changes in FSIQ, VIQ, or PIQ after surgery (110.21 versus 113.95, $p = 0.307$; 108.92 versus 111.54, $p = 0.368$; 107.88 versus 111.04, $p = 0.152$, respectively). Subanalysis showed that the pre- and post-operation VIQ mean scores of the patients with right arachnoid cysts were significantly higher ($p < 0.054$) than those of the patients with left arachnoid cysts, and there was no significant change after the surgery.

Interpretation There was no significant association among cyst volume reduction, laterality, and clinical neurocognitive function improvement. The present findings indicate a limited role for surgical intervention in improving the intellectual abilities of children with arachnoid cysts.

Keywords Arachnoid cyst · Neurocognitive profile · Children

Introduction

Arachnoid cysts (ACs) are well described as developmental anomalies. The prevalence ranges from 0.1 to 2.6% [1, 2]. ACs often manifest as headache, seizure, dizziness, or cognitive impairment. However, the link between ACs and these symptoms is not clear. Recently, ACs have been increasingly found incidentally due to the widespread use of imaging

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devices, such as computed tomography (CT), magnetic resonance (MR) imaging, and ultrasonography. Most ACs are observed in the middle cranial fossa, and surgery is usually not necessary when ACs are discovered incidentally. However, some studies suggest that ACs can affect brain development and cause neurocognitive dysfunction [3]. Several studies argue that the dysfunction can be reversed through surgical decompression [4–6]. This study was conducted to examine whether changes in neurocognitive function occurred before and after surgical decompression of ACs.

Materials and methods

Patients

From June 2009 to August 2012, 46 pediatric patients with ACs received surgical treatment at the Division of Paediatric Neurosurgery, Seoul National University Children's Hospital. Among surgically treated patients, 24 patients (19 boys and 5 girls; mean age at operation: 9.4 years) were administered a full matched set of pre- and post-operative neurocognitive function tests by psychologists at the Department of Child and Adolescent Psychiatry of Seoul National University Hospital. Pre- and post-operative cyst volume was calculated by multiplying the AC area measurement by the contour lines of each axial view and the slice thickness. Seventeen patients had left ACs, and seven patients had right ACs; twenty patients had temporal ACs, and four patients had frontal ACs. Neurocognitive tests were administered twice before and after surgery within a 1-year interval.

This study was approved by the institutional review board of Seoul National University Hospital.

Instruments

To examine the changes in neurocognitive function after surgery, the Korean version of the Wechsler Intelligence Scale for Children-Revised (KEDI-WISC-R) [7] and the Bender-Gestalt Test (BGT) [8] were individually administered to children with ACs by clinical psychologists before and after the operation.

KEDI-WISC-R

The KEDI-WIS-R is composed of 11 subtests: 5 verbal subtests (Information, Similarity, Arithmetic, Vocabulary, and Comprehension), and 6 performance subtests (Digit Span, Picture Completion, Picture Arrangement, Block Design, Object Assembly, and Coding). Full-scale intelligence quotient (FSIQ), verbal IQ (VIQ), and performance IQ (PIQ) are age-corrected standard scores based on 11 subtests, 5 verbal, and 6 performance subtests, respectively. These three standard scores have a mean of 100 and a standard deviation of 15.

BGT

The BGT consists of 9 geometric figures. It was used to evaluate visual motor coordination and visual memory. In the copy condition, a child is asked to draw each figure as presented by an examiner one by one, and then in the immediate recall condition, they have to draw as many figures as they can remember. The visual memory score for a child was the number of recalled figures.

Statistical methods

The performance scores of the KEDI-WISC and BGT were analyzed using SPSS version 18.0 (SPSS, Chicago, IL). To compare the significant differences between pre- and post-operation scores in neurocognitive tests, paired t tests were conducted. After classifying all children into two groups in terms of laterality (right-left AC), significant differences between two groups in neurocognitive tests were examined using repeated measures ANOVA. $p < 0.05$ was considered statistically significant.

Results

A total of 24 patients received surgical decompression, and they were tested using neurocognitive function tests. Pre-operative findings in the analyzed group of children was not different from age-matched norms. We fenestrated the ACs microscopically or endoscopically (Table 1). Seventeen patients had ACs of the left. Temporal fossa was the most frequent site of ACs (1 Galassi type I, 10 Galassi type II, 9 Galassi type III AC in the middle cranial fossa). No patients had hydrocephalus. ACs with subdural hygroma were present in one case. There was a difference between VIQ and PIQ in the pre-operative neurocognitive function test (mean difference, 16.3). The pre-operative AC volume was 75.5 cc, and the post-operative volume was 37.1 cc. There was a significant decrease in AC volume ($p < 0.05$), but there were no statistically significant changes using Pearson's correlation test in FSIQ ($r = 0.133$, $p = 0.536$), VIQ ($r = 0.259$, $p = 0.222$), and PIQ ($r = 0.253$, $p = 0.234$) after the surgery. There was no significant difference between pre- and post-VIQ-PIQ (mean 0.6, $p = 0.793$). Additionally, significant changes in various subtest scores except Block Design were not found after the surgery (Table 2). Actually, the verbal comprehension, attention and memory functions, and perceptual organization ability of the children with ACs were in the average to superior level for their age norms before the surgery. The post-operation mean score for the Block Design

Table 1 Demographic characteristics of the patients

Demographics	Mean/SD	No.
Mean age at operations	9.4 years/4.03	
Sex		
Male		19
Female		5
Laterality		
Right		7
Left		17
Location		
Frontal		4
Temporal		10
Frontotemporal		10
Type of operation		
Microscopic fenestration		20
Endoscopic fenestration		4
AC volume		
Pre-operation	75.5 cc/75.3	
Post-operation	37.1 cc/63.6	

subtest significantly improved compared to the pre-operation mean score ($t = -2.478$, $p < 0.05$). Improvement in the Block Design subtest suggested that children's visuo-spatial integration and mental construction abilities were slightly improved after the surgery. The children's visual memory tended to increase slightly after the surgery, but it did not reach a statistically significant level (Table 3). The pre- and post-operation mean numbers for recall were 4.13 and 4.94, respectively ($p = 0.06$). We analyzed the two age groups (one less than 7 years, and the other older than 7 years) separately. There was no significant changes in cyst volume reduction (mean = 55.7 cc vs 24.8 cc, $p = 0.062$). However, group aged less than 7 years showed a significant difference in neurocognitive profiles after surgery in measured in FSIQ, verbal comprehension subtest, and Block Design ($t = 2.49$, $p < 0.05$; $t = 3.75$, $p < 0.01$; $t = 3.94$, $p < 0.001$). Next, after classifying all children into left and right AC groups, we examined significant differences between the two groups in neurocognitive tests after the surgery. There were no statistically significant changes in FSIQ, VIQ, PIQ, and VIQ-PIQ between the left and right AC groups after the surgery. Additionally, significant changes in various subtest scores except the Information subtest were not found between the two groups after the surgery (Table 4). The pre- and post-operation VIQ mean scores of the children with right ACs were significantly higher ($p < 0.05$) than those of the children with left AC, and there was no significant change after the surgery (Fig. 1). The Information subtest score of the children with left ACs did not change after the surgery, while that of the children with right ACs tended to decrease after the surgery. However, the post-operation

Table 3 Mean difference between pre- and post-operation scores of children with arachnoid cysts in the Bender-Gestalt Test

	Pre		Post		*t*	*p*
Bender-Gestalt Test	M (SD)		M (SD)			
Number of recall	4.13	(2.45)	4.94	(1.84)	−2.09	.055

Table 2 Mean differences between pre- and post-operation scores of children with arachnoid cysts in the Korean Educational Developmental Institute-Wechsler intelligence scale for children ($n = 24$)

	Pre		Post		*t*	*p*
Wechsler Intelligent Scale for Children-Revised	M (SD)		M (SD)			
FSIQ	110.21	(16.19)	113.95	(16.96)	− 1.047	.307
VIQ	108.92	(17.69)	111.54	(18.82)	− .918	.368
PIQ	107.88	(17.50)	111.04	(17.64)	− 1.483	.152
VIQ-PIQ	16.33	(10.52)	15.75	(12.76)	.266	.793
Information	12.48	(4.14)	12.29	(4.29)	.347	.732
Similarity	11.96	(3.65)	12.46	(3.71)	− .551	.587
Arithmetic	10.44	(3.64)	10.46	(2.96)	− .206	.838
Vocabulary	11.52	(3.63)	12.25	(3.65)	− .965	.344
Comprehension	10.44	(2.33)	11.46	(3.13)	− 1.910	.069
Digit Span	10.40	(2.66)	10.92	(2.38)	− 1.061	.300
Picture Completion	9.00	(3.61)	9.42	(3.56)	− .449	.658
Picture Arrangement	10.44	(3.50)	10.21	(3.68)	.291	.774
Block Design	12.36	(3.48)	13.50	(3.08)	− 2.478	.021
Object Assembly	10.68	(3.38)	10.92	(3.67)	− .399	.693
Coding	12.84	(2.21)	12.88	(3.19)	0.000	1.000

FSIQ full-scale intelligent quotients, *VIQ* verbal intelligent quotients, *PIQ* performance intelligent quotients

Table 4 Mean differences between the left and right arachnoid cyst groups in the Korean Educational Developmental Institute-Wechsler intelligence scale for children after the surgery ($n = 24$)

	Left ($n = 17$)		Right ($n = 7$)		F (laterality)	F (*interaction*)
Wechsler Intelligent Scale for Children-Revised	Pre M (SD)	Post M (SD)	Pre M (SD)	Post M (SD)		
FSIQ	108.73 (14.98)	110.33 (16.98)	117.86 (16.53)	121.71 (15.21)	.208	.217
VIQ	104.65 (15.56)	106.82 (17.82)	120.14 (20.23)	123.00 (17.17)	4.851*	.014
PIQ	106.35 (18.11)	109.06 (17.67)	111.43 (18.15)	115.86 (17.93)	.598	.126
Information	11.06 (3.42)	11.59 (3.84)	16.14 (3.98)	14.00 (5.13)	5.568*	3.102
Similarity	11.65 (3.41)	11.53 (3.41)	13.14 (4.34)	14.71 (3.64)	2.693	1.289
Arithmetic	9.82 (3.78)	9.76 (3.09)	11.57 (3.36)	12.14 (1.86)	2.511	.216
Vocabulary	10.94 (3.21)	11.59 (3.64)	13.14 (4.56)	13.86 (3.39)	2.482	.002
Comprehension	9.94 (2.11)	10.82 (2.79)	11.86 (2.55)	13.00 (3.61)	3.760	.053
Digit Span	10.29 (2.95)	10.59 (2.24)	10.57 (2.23)	11.71 (2.69)	.483	.560
Picture Completion	8.65 (3.37)	8.94 (3.58)	10.29 (4.23)	10.57 (3.46)	1.297	.000
Picture Arrangement	10.18 (3.83)	10.35 (3.66)	10.86 (3.02)	9.86 (4.02)	.004	.865
Block Design	11.71 (3.37)	13.29 (3.02)	13.57 (3.74)	14.00 (3.42)	.871	1.096
Object Assembly	10.88 (3.86)	10.59 (4.03)	10.14 (2.34)	11.71 (2.69)	.017	1.905
Coding	13.00 (2.15)	12.29 (3.27)	12.57 (2.30)	14.29 (2.69)	.622	3.000

FSIQ full-scale intelligent quotients, *VIQ* verbal intelligent quotients, *PIQ* performance intelligent quotients

* $p < 0.05$

Information subtest score of the children with right ACs was still significantly higher than that of the children with left AC and was at a very superior level, suggesting that the children with right ACs had very high abilities in learning and long-term memory function before and after the surgery (Fig. 2). The visual memory of children with left ACs assessed by BGT tended to improve more than that of children with right ACs after the surgery, but the difference did not reach a statistically significant level (Table 5).

Discussion

The aim of this study was to examine whether changes in neurocognitive function occurred before and after surgical decompression of ACs. The results showed that the patients with ACs had no changes in FSIQ, VIQ, or PIQ after surgery. Only the mean Block Design score on the KEDI-WISC showed a significant difference between pre- and post-operations. Block Design is associated with visuo-spatial integration and mental construction abilities [7]. Therefore, it appears that there was an improvement in those abilities after surgery. However, it is difficult to localize the part of the brain related to this function because various areas of the brain are involved together in Block Design. There is controversy regarding whether ACs cause neurocognitive impairment. Some reports suggest that ACs interfere with brain development and cause cognitive deficits. They believe that neurocognitive impairment can be improved by surgery of ACs. However, in another article, there was no difference in neurocognitive function in AC patients compared to normal healthy patients [9]. In an assessment of 55 patients on four cognitive function tests conducted pre-operatively and 3 months post-operatively, there was an improvement in the patients' performance [4]. Wester et al. [10] even suggested that cognitive improvement should be considered a goal for AC surgery. They argued that ACs put

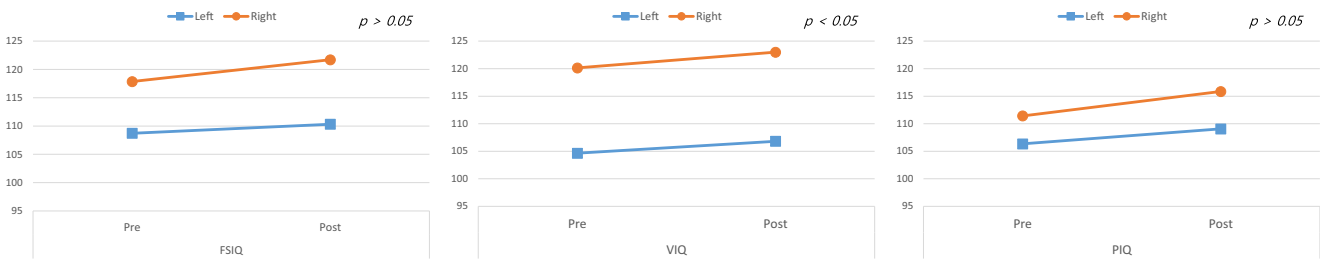

Fig. 1 Pre- and post-operation mean differences in scores on the Wechsler Intelligence Scale for Children-Revised. FSIQ, VIQ, and PIQ between the left and right arachnoid cyst groups

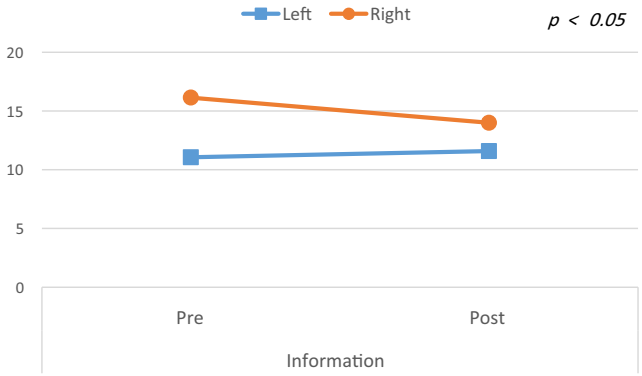

Fig. 2 Pre- and post-operation mean differences in scores on the Wechsler Intelligence Scale for Children-Revised. Information subtest between the left and right arachnoid cyst groups

pressure on the cortical surface of the brain, and by performing AC surgery to relieve their pressure, neurocognitive function could be reversed. These findings were not replicated by our study. However, the patient group aged under 7 years showed an improvement in FSIQ, verbal comprehension subtest, and Block Design, which might reflect the neuroplasticity of young developing brains. Wester et al. [6] documented post-operative improvement of cognitive function after surgery for ACs of the left temporal fossa. Interestingly, the results of the present study are in part similar to the findings of earlier studies. We observed that the patients with ACs on the left side had lower VIQ and Information scores than those with ACs on the right side. However, there was no significant change in those scores after surgery. In our study, compared to right-side ACs, left-side ACs might have affected VIQ and Information, a subset of verbal ACs, but surgery did not improve them. Generally, VIQ is known to be associated with left-hemisphere function. ACs might interrupt brain development, but it was not improved by surgical decompression of ACs in our study. In the present study, all of the left-side ACs except one case were located in the temporal lobe. Parts of the left temporal lobe are thought to be essential for normal language development, as is the posterior portion of the frontal lobe [11]. Although ACs do not invade the tissue, they could interfere with the normal brain development, which may lead to lower verbal IQ scores. However, another study suggested that the very early occurrence of ACs does not cause damage to the development of functional neuronal pathways, owing to the important plasticity of the central nervous system [12]. If surgery was done after brain development was complete, from this perspective, our results can be interpreted as no significant IQ difference before and after surgical intervention. Surgical treatment for ACs can cause many side effects or complications, such as subdural hematoma, subdural fluid collection, CSF (cerebrospinal fluid) leakage, intracranial hemorrhage, intracystic hemorrhage, and extradural hematoma. Therefore, we should strictly choose patients who have symptoms related to ACs [13].

The primary limitation of this study is that it is not a randomized controlled trial. The second limitation is the small number of patients. Third, VIQ and PIQ are generally known to be affected by different hemispheres [14–17]. Therefore, in our study, we enrolled patients with significant differences between VIQ and PIQ, but their FSIQ, VIQ, and PIQ were not below average for their age norms [16, 18]. Finally, we did not compare the results of the neurocognitive function test scores with those of healthy controls or patients with untreated ACs.

Conclusion

There were no significant changes in neurocognitive function after surgical decompression of ACs. Surgical treatment for ACs should be carefully considered, and the goal of the surgery should not be solely to improve cognitive function.

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Compliance with ethical standards This study was approved by the institutional review board of Seoul National University Hospital.

Conflict of interest The authors declare that they have no conflict of interest.

Table 5 Mean differences between the left and right arachnoid cyst groups in the Bender-Gestalt Test after surgery

	Left		Right		*F* (laterality)	*F (interaction)*
Bender-Gestalt Test	Pre M (SD)	Post M (SD)	Pre M (SD)	Post M (SD)		
Number of recall	3.80 (2.62)	5.00 (1.89)	4.67 (2.25)	4.83 (1.94)	.106	1.728

References

1. Al-Holou WN, Yew AY, Boomsaad ZE, Garton HJ, Muraszko KM, Maher CO (2010) Prevalence and natural history of arachnoid cysts in children. J Neurosurg Pediatr 5:578–585. https://doi.org/10.3171/2010.2.Peds09464
2. Clemenceau S, Carpentier A (1999) Intracranial arachnoid cysts. A review. Rev Neurol 155:604–608
3. Lang W, Lang M, Kornhuber A, Gallwitz A, Kriebel J (1985) Neuropsychological and neuroendocrinological disturbances associated with extracerebral cysts of the anterior and middle cranial fossa. Eur Arch Psychiatry Neurol Sci 235:38–41
4. Raeder MB, Helland CA, Hugdahl K, Wester K (2005) Arachnoid cysts cause cognitive deficits that improve after surgery. Neurology 64:160–162. https://doi.org/10.1212/01.Wnl.0000148724.61966.A4
5. Soukup VM, Patterson J, Trier TT, Chen JW (1998) Cognitive improvement despite minimal arachnoid cyst decompression. Brain Dev 20:589–593
6. Wester K, Hugdahl K (1995) Arachnoid cysts of the left temporal fossa: impaired preoperative cognition and postoperative improvement. J Neurol Neurosurg Psychiatry 59:293–298
7. Park K, Yoon J, Park H, Pakr H, Kwon K (1991) The manual of Korean educational development institute-wechsler intelligence scale for children-revised. Korean Educational Development Institute, Seoul
8. Bender L (1938) A visual motor gestalt test and its clinical use. Research Monographs, American Orthopsychiatric Association
9. Park YS, Eom S, Shim KW, Kim DS (2009) Neurocognitive and psychological profiles in pediatric arachnoid cyst. Childs Nerv Syst 25:1071–1076. https://doi.org/10.1007/s00381-009-0872-0
10. Wester K (2008) Intracranial arachnoid cysts–do they impair mental functions? J Neurol 255:1113–1120. https://doi.org/10.1007/s00415-008-0011-y
11. Stowe LA, Go KG, Pruim J, den Dunnen W, Meiners LC, Paans AM (2000) Language localization in cases of left temporal lobe arachnoid cyst: evidence against interhemispheric reorganization. Brain Lang 75:347–358. https://doi.org/10.1006/brln.2000.2358
12. Golaz J, Bouras C (1993) Frontal arachnoid cyst. A case of bilateral frontal arachnoid cyst without clinical signs. Clin Neuropathol 12:73–78
13. Choi JW, Lee JY, Phi JH, Kim SK, Wang KC (2015) Stricter indications are recommended for fenestration surgery in intracranial arachnoid cysts of children. Childs Nerv Syst 31:77–86. https://doi.org/10.1007/s00381-014-2525-1
14. Bornstein RA (1983) Verbal IQ–performance IQ discrepancies on the Wechsler Adult Intelligence Scale-Revised in patients with unilateral or bilateral cerebral dysfunction. J Consult Clin Psychol 51:779–780
15. Goldberg E, Podell K, Lovell M (1994) Lateralization of frontal lobe functions and cognitive novelty. J Neuropsychiatry Clin Neurosci 6:371–378. https://doi.org/10.1176/jnp.6.4.371
16. Iverson GL, Woodward TS, Green P (2001) Base rates of WAIS-R VIQ-PIQ differences in 1593 psychiatric inpatients. J Clin Psychol 57:1579–1587
17. Ryan JJ, Bartels JM, Morris J, Cluff RB, Gontkovsky ST (2009) WAIS-III VIQ–PIQ and VCI–POI discrepancies in lateralized cerebral damage. Int J Neurosci 119:1198–1209
18. Bornstein RA, Matarazzo JD (1982) Wechsler VIQ versus PIQ differences in cerebral dysfunction: a literature review with emphasis on sex differences. J Clin Neuropsychol 4:319–334