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Original Investigation

Factors that Affect Postoperative Hydrocephalus Development in Aneurysmal Subarachnoid Hemorrhage: A Clinical Study

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ABSTRACT

AIM: Factors affecting the development of postoperative hydrocephalus patients who underwent surgery after spontaneous subarachnoid hemorrhage were retrospectively assessed.

MATERIAL and METHODS: 201 cases, who underwent aneurysm surgery in our clinic after subarachnoid hemorrhage between 2008 and 2013, were retrospectively assessed. Twenty-one cases with hydrocephalus development were retrospectively examined according to their age, gender, history (hypertension, alcohol, and smoking), blood type, the number and size of aneurysms, aneurysm localization, the presence of ventricular hemorrhage, baseline-final neurological diagnosis, Fisher grading system, history of vasospasm and meningitis. The initial neurological course and Hunt-Hess, and also final neurological course of the patients were evaluated according to World Federation of Neurosurgical Societies (WFNS) Grading Scale.

RESULTS: Age, history of hypertension, aneurysm localization, Hunt-Hess grading, vasospasm, meningitis and Glasgow Outcome Scale (GOS) are determinative factors in hydrocephalus development due to subarachnoid hemorrhage. It was detected that gender, alcohol and tobacco use, blood group, the size and the number of aneurysm, the presence of intraventricular hemorrhage and Fisher grading were not the determinative factors in the patients.

CONCLUSION: In patients who underwent surgery for subarachnoid hemorrhage, risk factors for postoperative hydrocephalus should be determined and the patients with these risk factors should be closely monitored.

KEYWORDS: Aneurysm, Hydrocephalus, Subarachnoid hemorrhage

■ INTRODUCTION

Generally, arterial hemorrhage and rarely, venous hemorrhage into the subarachnoid space are called "subarachnoid hemorrhage" (SAH). Although 50-75% of the SAHs are caused by aneurysms, the reason for 13-25% of the cases are unknown (11,18).

Hydrocephalus following SAH due to aneurysm rupture can cause worsening of neurological course with the increase in intracranial pressure. The increase in intracranial pressure due to hydrocephalus is lowered with external ventriculostomy or ventricular shunt. Previous studies determined that the rate of hydrocephalus development following SAH was between 6% and 67% (29). It was found that communicating hydrocephalus is a well-defined and known complication (36). The patients with hydrocephalus following SAH have a worse prognosis than others without hydrocephalus.

The aim of our study is to detect the etiology of postoperative hydrocephalus in patients with aneurysm that follows SAH and to determine the primary factors that influence the development of hydrocephalus. Determining these factors is of great importance in terms of treatment strategies, patient mortality and morbidity. The identification of patients, who have the potential for developing hydrocephalus and giving extra-attention to this patient group, is also important.

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■ MATERIAL and METHODS

Two hundred and one patients who underwent aneurysm surgery in our clinic after subarachnoid hemorrhage between the years 2008 and 2013 were examined retrospectively. Of these 201 cases, 21 cases with hydrocephalus were investigated retrospectively according to their age, gender, history (hypertension, alcohol, smoking), blood type, the number and size of aneurysms, aneurysm localization, the presence of ventricular hemorrhage, initial-final neurological diagnosis, Fisher grading scores, history of vasospasm and meningitis. The initial neurological findings of the patients were evaluated using the World Federation of Neurosurgical Societies Grading Scale (WFNS) and Hunt-Hess grading, while initial-final neurological examinations were evaluated using the Glasgow Outcome Scale (GOS).

The data obtained in the study were analyzed using the SPSS (Statistical Package for Social Sciences) software for Windows. Descriptive statistical methods (numbers, percentage, mean, standard deviations) were used in the evaluation of the data. Chi-square analysis was performed between categorical variables. The results were assessed with 95% confidence intervals and at the 5% significance level.

■ RESULTS

The average age of patients with hydrocephalus (x=57.000) was significantly higher than those with no hydrocephalus (x=50.540) (p=0.03) (Table I).

A significant relationship was found between age and hydrocephalus. (X^2=14.928; p=0.001). Two of the patients with hydrocephalus (9.5%) were younger than 40 years of age. Seven patients (33.3%) ranged between 40 and 60 years. Twelve of the patients (57.1%) were older than 60 years of age. Thirty-five of the patients (19.4%) with no hydrocephalus were younger than 40 years, while 110 of the patients (61.1%) were between 40-60 years and 35 of the patients (19.4%) were older than 60 years (Table II) (Figure 1).

A significant relationship was found between hypertension and hydrocephalus (X^2=4.31; p=0.031). Hypertension history was determined in 15 of the patients with hydrocephalus (71.4%), whereas there was no hypertension history in 6 of the patients (28.6%). There was hypertension history in 85 of the patients with no hydrocephalus history (47.5%), whereas no hypertension history was determined in 94 of the patients (52.5%) (Table III) (Figure 2).

A significant relationship was found between localization and hydrocephalus. (X^2=30.42; p=0.01). In patients with

Table I: The Mean Age According to the Presence of Hydrocephalus

Groups	Positive (n=21)		Negative (n=180)		t	p
	Average	Standard deviation	Average	Standard deviation		
Age (years)	57.000	12.292	50.540	12.862	2.186	0.03

Table II: The Relationship Between Age and Hydrocephalus

Age (years)	Hydrocephalus						X^2/p
	Available		None		Total		
	n	%	n	%	n	%	
Younger than 40 years	2	9.5%	35	19.4%	37	18.4%	X^2=14.928 p=0.001
40-60 years	7	33.3%	110	61.1%	117	58.2%	
Older than 60 years	12	57.1%	35	19.4%	47	23.4%	
Total	21	100%	180	100%	201	100%	

Table III: The Relationship Between Hypertension and Hydrocephalus

Hypertension	Hydrocephalus						X^2/p
	Available		None		Total		
	n	%	n	%	n	%	
Available	15	71.4%	85	47.5%	100	50.0%	X^2=4.31 p=0.031
None	6	28.6%	94	52.5%	100	50.0%	
Total	21	100.0%	179	100.0%	200	100.0%	

hydrocephalus, 9 patients (42.9%) had anterior communicating artery (ACoA), 1 patient (4.8%) had anterior cerebral artery (ACA), 4 patients (19%) had middle cerebral artery (MCA), 1 patient (4.8%) had posterior circulation, 1 patient (4.8%) had posterior communicating artery (PCoA), 1 patient (4.8%) had ACoA+internal carotid artery (ICA), 1 patient (4.8%) had ACoA+MCA, 1 patient (4.8%) had PCoA+PCoA, and 1 patient (4.8%) had MCA+ICA. In patients with no hydrocephalus, 49 patients (27.2%) had ACoA, 12 patients (6.7%) had ACA, 66 patients (36.7%) had MCA, 9 patients (5.0%) had PCoA, 15 patients (8.3%) had ICA, 1 patient (0.6%) had ACoA+ICA, 6 patients (3.3%) had MCA+MCA, 13 patients (7.2%) had ACoA+MCA, 1 patient (0.6%) had ACoA+Posterior circulation, 2 patients (1.1%) had ACoA+ACA, 2 patients (1.1%) had MCA+ICA, 2 patients (1.1%) had MCA+PCoA, 1 patient (0.6%) had ACA+ACA, and 1 patient (0.6%) had ICA+ICA (Table IV).

A significant relationship was found between WFNS grading and hydrocephalus. (X^2=10.495; p=0.033). In patients with hydrocephalus, 6 of the patients (28.6%) were grade 1, 7 of the patients (33.3%) were grade 2, 5 of the patients (23.8%) were grade 3, and 3 of the patients (14.3%) were grade 4. In patients with no hydrocephalus, 100 patients (55.6%) were grade 1, 54 patients (30.0%) were grade 2, 12 patients (6.7%) were grade 3, 13 patients (7.2%) were grade 4, and 1 patient (0.6%) was grade 5 (Table V) (Figure 3).

A significant relationship was found between Hunt-Hess grading and hydrocephalus (X^2=17.501; p=0.002). In patients with hydrocephalus, 8 of the patients (38.1%) were grade 1, 2 of the patients (9.5%) were grade 2, 8 of the patients (38.1%) were grade 3, 3 of the patients (14.3%) were grade 4; in patients with no hydrocephalus, 114 patients (63.3%) were grade 1, 38 patients (21.1%) were grade 2, 21 patients (11.7%) were grade 3, 6 patients (3.3%) were grade 4, and 1 patient (0.6%) was grade 5 (Table VI) (Figure 4).

A significant relationship was found between vasospasm and hydrocephalus (X^2=11.725; p=0.001). Vasospasm was

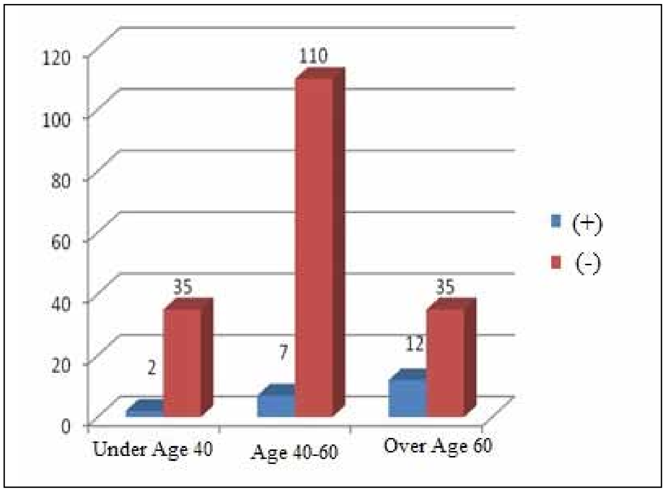

Figure 1: Distribution of the patients based on age groups.

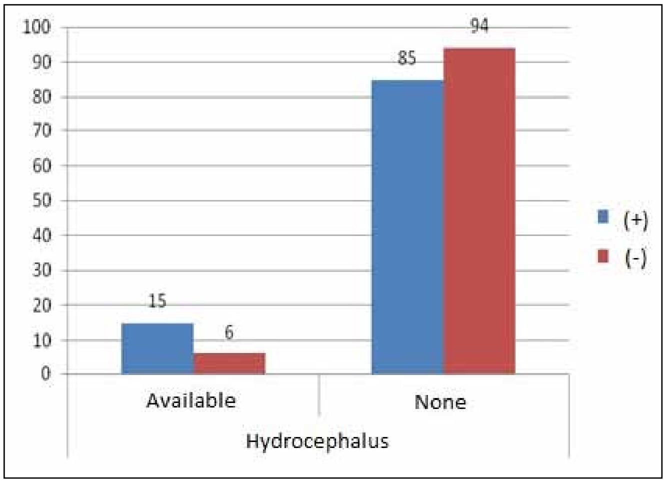

Figure 2: Distribution of the patients based on the presence of hypertension and hydrocephalus. Blue column represents patients with hypertension.

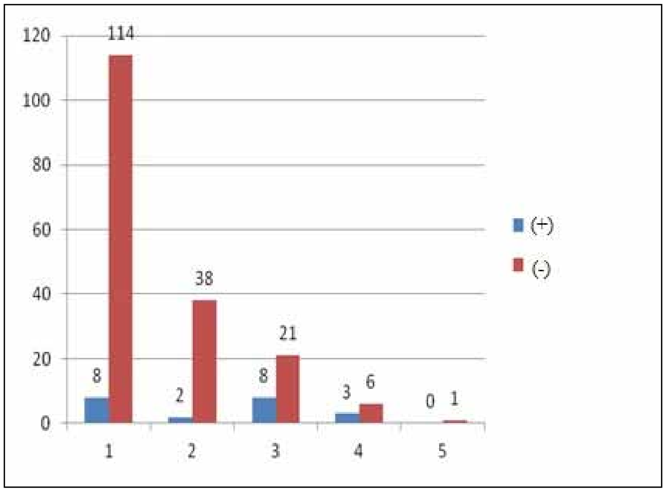

Figure 3: Distribution of the patients based on WFNS grading system.

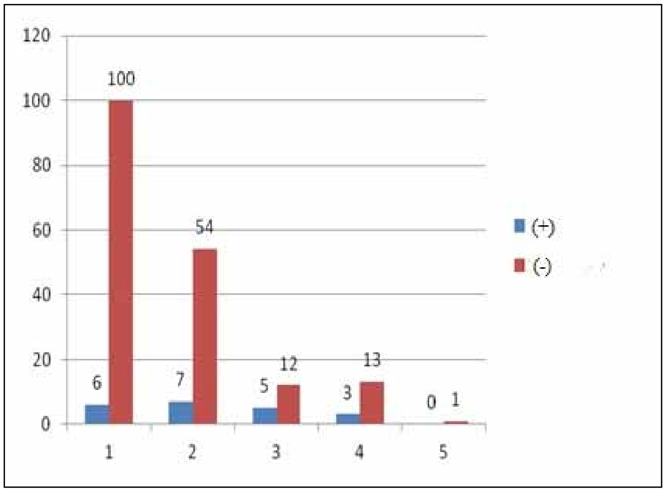

Figure 4: Distribution of the patients based on Hunt and Hess grading system.

determined in 14 of the patients with hydrocephalus (66.7%), whereas there was no vasospasm in 7 of the patients (33.3%). Vasospasm was detected in 53 of the patients with no hydrocephalus history (29.4%), while no vasospasm was determined in 127 of the patients (70.6%) (Table VII) (Figure 5).

A significant relationship was found between GOS grade and hydrocephalus (X^2=70.720; p=0.000). In patients with hydrocephalus, 7 of the patients (33.1%) were grade 1, 9 of the patients (42.9%) were grade 2, 4 of the patients (19.0%) were grade 3, 1 of the patient (4.8%) was grade 4. In patients with no hydrocephalus, 8 patients (4.4%) were grade 1, 7 patients (3.9%) were grade 2, 31 patients (17.2%) were grade 3, 40 patients (22.2%) were grade 4, and 94 patients (52.3%) were grade 5 (Table VIII) (Figure 6).

A significant relationship was found between meningitis and hydrocephalus. (X^2=23.426; p=0.000). Meningitis was de-

Table IV: The Relationship Between Localization and Hydrocephalus

Localization	Hydrocephalus						X^2/p
	Available		None		Total		
	n	%	n	%	n	%	
ACoA	9	42.9%	49	27.2%	58	28.9%	X^2=30.42 p=0.01
ACA	1	4.8%	12	6.7%	13	6.5%	
MCA	4	19.0%	66	36.7%	70	34.8%	
Posterior Circulation	1	4.8%	0	0.0%	1	0.5%	
PCoA	1	4.8%	9	5.0%	10	5.0%	
ICA	0	0.0%	15	8.3%	15	7.5%	
ACoA +ICA	1	4.8%	1	0.6%	2	1.0%	
MCA+MCA	0	0.0%	6	3.3%	6	3.0%	
ACoA +MCA	1	4.8%	13	7.2%	14	7.0%	
ACoA+Posterior Circulation	0	0.0%	1	0.6%	1	0.5%	
PCoA+PCoA	1	4.8%	0	0.0%	1	0.5%	
ACoA+ACA	0	0.0%	2	1.1%	2	1.0%	
MCA+ICA	1	4.8%	2	1.1%	3	1.5%	
MCA+PCoA	1	4.8%	2	1.1%	3	1.5%	
ACA+ACA	0	0.0%	1	0.6%	1	0.5%	
ICA+ICA	0	0.0%	1	0.6%	1	0.5%	
Total	21	100.0%	180	100.0%	201	100.0%	

Table V: The Relationship Between WFNS Grading and Hydrocephalus

WFNS grade	Hydrocephalus						X^2/p
	Available		None		Total		
	n	%	n	%	n	%	
1	6	28.6%	100	55.6%	106	52.7%	X^2=10.495 p=0.033
2	7	33.3%	54	30.0%	61	30.3%	
3	5	23.8%	12	6.7%	17	8.5%	
4	3	14.3%	13	7.2%	16	8.0%	
5	0	0.0%	1	0.6%	1	0.5%	
Total	21	100.0%	180	100.0%	201	100.0%	

termined in 12 of the patients with hydrocephalus (57.1%), whereas no meningitis was found in 9 of the patients (42.9%). Meningitis was found in 25 of the patients with no hydrocephalus history (13.9%), while no meningitis was determined in 155 of the patients (86.1%) (Table IX) (Figure 7).

Additionally, in our study, gender, blood type, alcohol and tobacco use, the number and size of the aneurysm, intraventricular hematoma and Fisher grade ventricular parameters were also examined as factors that may influence hydrocephalus development. However, no statistically significant results were obtained. In the current neurosurgical practice, the pathophysiology of hydrocephalus clinic developed following SAH is still not clearly known. Hydrocephalus may form due to one and/or several of the parameters mentioned above.

■ DISCUSSION

SAH incidence varies between 6 and 16 cases per 100,000 population in the literature (7,26). Intracranial aneurysms are responsible for SAH in approximately half of these cases. SAH is usually seen in adults and reaches to its highest incidence in the 40-60 age group (9,20). In our study, it was seen most commonly in this age group with a rate of 58.2% and the average age of the group, in accordance with the literature, was 51.2 years. The female/male ratio was approximately 2/3 (16) (Tables I, II) (Figure 1).

Table VI: The Relationship Between Hunt-Hess Grading and Hydrocephalus

Hunt-Hess grade	Hydrocephalus						X^2/p
	Available		None		Total		
	n	%	n	%	n	%	
1	8	38.1%	114	63.3%	122	60.7%	X^2=17.501 p=0.002
2	2	9.5%	38	21.1%	40	19.9%	
3	8	38.1%	21	11.7%	29	14.4%	
4	3	14.3%	6	3.3%	9	4.5%	
5	0	0.0%	1	0.6%	1	0.5%	
Total	21	100.0%	180	100.0%	201	100.0%	

Table VII: The Relationship Between Vasospasm and Hydrocephalus

Vasospasm	Hydrocephalus						X^2/p
	Available		None		Total		
	n	%	n	%	n	%	
Available	14	66.7%	53	29.4%	67	33.3%	X^2=11.725 p=0.001
None	7	33.3%	127	70.6%	134	66.7%	
Total	21	100.0%	180	100.0%	201	100.0%	

Table VIII: The Relationship Between GOS Grade and Hydrocephalus

GOS grade	Hydrocephalus						X^2/p
	Available		None		Total		
	n	%	n	%	n	%	
1	7	33.3%	8	4.4%	15	7.5%	X^2=70.720 p=0.000
2	9	42.9%	7	3.9%	16	8.0%	
3	4	19.0%	31	17.2%	35	17.4%	
4	1	4.8%	40	22.2%	41	20.4%	
5	0	0.0%	94	52.3%	94	46.8%	
Total	21	100.0%	180	100.0%	201	100.0%	

Significant developments have been achieved in the surgical and medical treatment of SAH following aneurysm rupture in the last 25 years. In spite of all these developments, aneurysm hemorrhage is still an important health issue with 10-67% mortality and 10-20% morbidity risks. Aneurysm and associated SAH development is one of the most current and important subjects of neurosurgical discussions. In the literature, many experimental studies were conducted and the development of SAH and the natural course of the disease was investigated in addition to angiographic studies related to the development and growth of aneurysm and studies on aneurysm pathology (1,2,10,24,28,30,32).

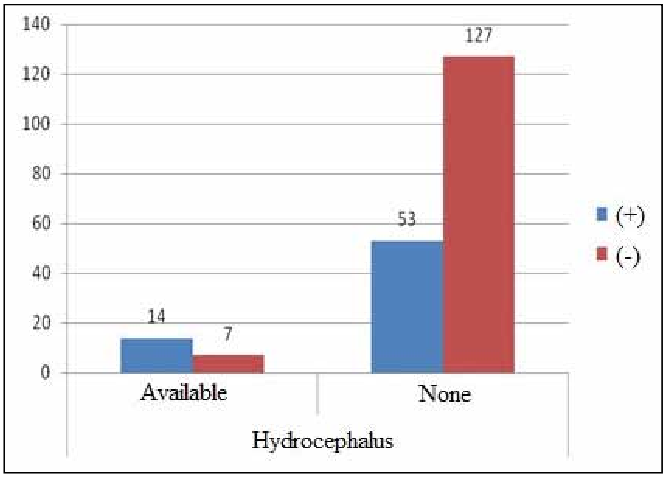

Figure 5: Relationship between the presence of hydrocephalus and vasospasm. Blue column represents patients with vasospasm.

In the literature, the post-SAH hydrocephalus rate was reported as 18-16% (4). This was reported as 18.8% in a series of 3120 cases (25). This rate was 10.4% in our series. This was associated with the fenestration of lamina terminalis and Liliequist membranes.

According to Stivaros and Jackson, the real problem in communicative hydrocephalus is the reduction of compliance of the walls of large cerebral vessels and subsequently, a larger amount of the transmission of the systolic wave to the brain. Whatever the cause is, the systolic-diastolic pressure difference is less compensated by the vessel. The increase in capillary pulsatility causes a further enlargement of the brain in systole and consequently, a subarachnoid pressure difference between the subarachnoid area and the ventricular system. This causes a superficial vein occlusion and a decrease in cerebrospinal fluid (CSF) absorption and leads to hydrocephalus development. Decreased venous compliance due to increased pressure changes the pulse pressure distribution throughout supratentorial space. In order to meet the incom-

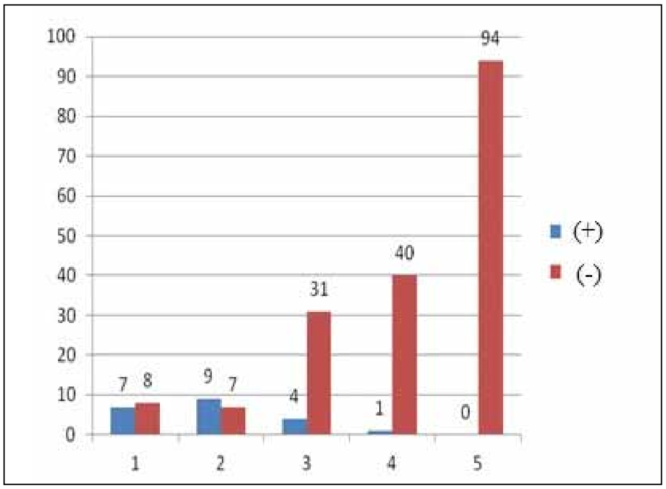

Figure 6: Relationship between the GOS grade and hydrocephalus. Blue column represents the presence of hydrocephalus.

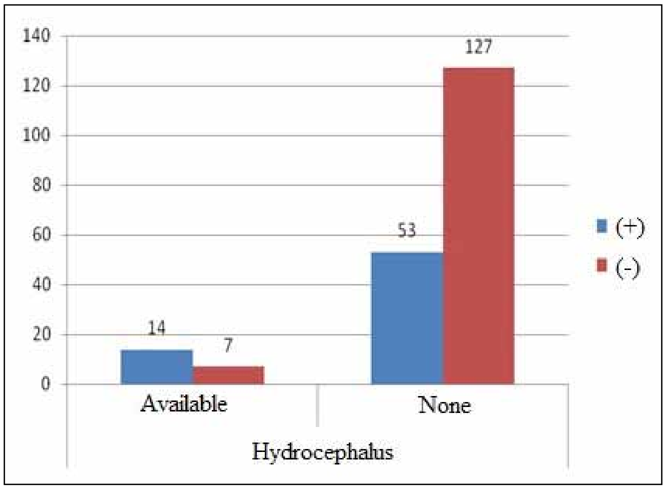

Figure 7: Relationship between the presence of meningitis and hydrocephalus. Blue column represents the presence of meningitis.

Table IX: The Relationship Between Meningitis and Hydrocephalus

Meningitis	Hydrocephalus						X^2/p
	Available		None		Total		
	n	%	n	%	n	%	
Available	12	57.1%	25	13.9%	37	18.4%	X^2=23.426 p=0.000
None	9	42.9%	155	86.1%	164	81.6%	
Total	21	100.0%	180	100.0%	201	100.0%	

ing blood in the systole, aqueduct flow increases up to 192%. This was associated with the possible improvement of compliance reduction in cortical veins after the implementation of shunt and this suggests that the compliance changes in the vessels are not structural but functional (31).

Hamlat et al. suggested that normal pressure hydrocephalus can develop with different mechanisms and it is not a homogeneous group. Accordingly, the craniospinal compartment can be considered as a semi-closed sphere rather than a closed one. These two systems are in a relationship with each other: While one absorbs CSF, the other stores it. Intracranial pressure is determined by the amount of stored CSF with the compliance of craniospinal space. Normal pressure hydrocephalus emerges with the increase in craniospinal compliance or the deterioration of CSF absorption-arachnoid villi in the sagittal sinus complex. Whatever the cause and the type is, CSF accumulation which exceeds spinal compliance causes a normal pressure hydrocephalus (14).

In the experimental study by Kanat et al., which allegedly changed the basis of post-SAH acute hydrocephalus pathophysiology, it has been proposed that CSF production increases in order to clean the blood products in the subarachnoid and intraventricular distance within the acute period and consequently, hydrocephalus develops. In this study, it was proposed that acetazolamide, furosemide, recurrent lumbar puncture, external ventricular drainage (EVD) and early surgical intervention would be the ideal treatment approaches (19).

There have been some experimental studies conducted for the prevention of hydrocephalus development. In their study, Brinker et al. created SAH in 19 cats with autologous fresh blood and implemented tissue plasminogen activator to a group. The researchers monitored the intracranial pressure (ICP) of the experimental animals and determined that ICP did not increase in the animals that received tissue plasminogen activator but increased in those that did not receive tissue plasminogen activator. This result suggests the possibility of using intrathecal fibrinolytic therapy (6).

In some series, it was reported that advanced age was one of the most important factors that negatively affect the SAH prognosis (5,26). In a study consisting of 299 patients, the mortality rate was 29% for the under-60 age group, while it was 33% in the 60-70 age group and 55% in over-70 age group. In another study, the mortality rate of SAH in patients aged 18-29 was 7%, while the rate of full recovery was 86%. In the same study, the mortality rate in patients aged over 70 was 49%, while the rate of full recovery was 26% (20).

Several studies have shown the relationship between hypertension and hydrocephalus (12,29). Graff-Radford et al. and Mehta et al. reported that hypertension is closely related to acute hydrocephalus development (12,23). However, Tapaninaho et al. did not detect a similar relationship (33). A statistically significant relation was detected between hypertension and hydrocephalus ($p<0.05$) (Table III) (Figure 2).

In some studies, it was reported that there were no positive correlations between aneurysm age and localization, and aneurysm age and smoking (36). In our study, significant relations were found between age (Table II) (Figure 1), localization (Table IV) and hydrocephalus. However, no significant relation was found between smoking and hydrocephalus ($p>0.05$).

In some articles, it was reported that intraventricular hemorrhage and accompanying acute hydrocephalus can be frequently seen in the first 24 hours (22,34). It was stated that hydrocephalus is more common following ACoA or basilar apex aneurysms induced SAH (26,33). Some studies suggested that there was no positive correlation between aneurysm localization, and hydrocephalus (36). In our study, it was detected that patients with ACoA aneurysm have a higher risk of hydrocephalus ($p<0.05$) (Table IV). The patients with basilar apex aneurysm were excluded from the study due to endovascular treatment applications.

The relationship among WFNS, Hunt-Hess and hydrocephalus is not very clear in the literature. In our study, 76.2% of the patients with hydrocephalus were Hunt-Hess grade 1 and grade 3. Also, 61.9% of the patients with hydrocephalus were grade 1 and grade 2 according to the WFNS grading system, and this was statistically significant ($p<0.05$), ($p<0.05$) (Tables V, VI) (Figures 3,4).

The pathogenesis of vasospasm is not entirely known. Substances that cause long-term arterial narrowing and suppress vasodilation, immunoreactive or inflammatory events and mechanical factors (stretching of the arachnoid fiber, direct compression of the clot, platelet aggregation) are held responsible for vasospasms. Substances that are associated with vasospasm are oxyhemoglobin, iron, norepinephrine, prostaglandins and free radicals (21). In our study, an increase was observed in the incidence of vasospasm in patients with hydrocephalus and it was statistically significant ($p<0.05$) (Table VII) (Figure 5).

In most of the studies, no significant relationship was found between GOS and hydrocephalus development (12,29). In their study consisting of 897 cases, Sheehan et al. detected that GOS was the factor that showed a significant correlation (29). In our study, 76.2% of the patients were GOS grade 1 and grade 2, and this result was statistically significant ($p<0.05$) (Table VIII) (Figure 6).

It was shown that acute hydrocephalus and intraventricular hemorrhage, severe clinical course, hypertension, alcoholism, gender, large aneurysm size and infections such as pneumonia and meningitis were important factors in the development of chronic hydrocephalus (12,13,22,29). In our study, an increase was observed in the incidence of hydrocephalus in patients with meningitis and it was statistically significant ($p<0.05$) (Table IX) (Figure 7). However, no statistically significant relation was found between intraventricular hemorrhage, ($p>0.05$), the size of the aneurysm ($p>0.05$) and hydrocephalus.

Alcoholism facilitates fibrinolysis and causes an increased amount of and recurrent bleeding. In the studies, a significant relation was detected between alcoholism and post-SAH hydrocephalus development (12). In our study, no statistically significant relation was detected between alcohol use and hydrocephalus ($p>0.05$).

No statistically significant relation was found between the number of aneurysms ($p>0.05$), blood type ($p>0.05$) and hydrocephalus.

In our study, the time of hydrocephalus emergence was the acute period in 9 patients and the chronic period in 12 patients. According to the literature, the incidence of acute hydrocephalus was reported as 6-30%, while the incidence of chronic hydrocephalus was 8-20% (3,8,15,35). In our study, acute hydrocephalus was detected at a rate of 4.5% and chronic hydrocephalus at 6%.

In acute hydrocephalus, it was reported that EVD was the most appropriate treatment method, especially in situations in which the patient's level of consciousness is poor. Some of the patients significantly benefit from ventricular drainage (22,34). Nevertheless, if the aneurysm is not closed, it should be kept in mind that ventricular drainage can facilitate rebleeding by reducing the intramural pressure. In this case, it would be suitable to prevent excessive drainage by adjusting the drainage level to 10 cm above the external ear canal (27). It was shown in surgical studies that intraventricular blood clean up or infusion of urokinase were not effective (22).

If the neurological course worsens or no improvement is observed as expected, ventriculomegaly treatment is required in these patients even if CSF pressure does not show an increase. In another study, it was reported that excessive CSF accumulation in the choroid plexus due to SAH was effective in acute hydrocephalus development (30). It was suggested that EVD, serial lumbar punctures and ventriculostomy with lamina terminalis fenestration during surgery can reduce the hydrocephalus risk (19). However, installing a ventriculoperitoneal or lumboperitoneal shunt can be necessary where this method proves inadequate.

■ CONCLUSION

Age, hypertension history, aneurysm localization, WFNS and Hunt-Hess grading, vasospasm, meningitis and CSF were determinative in hydrocephalus development following intracranial aneurysm rupture. All the concerned studies suggest that there are multiple etiological factors in the development of hydrocephalus. Knowing the risk factors will be a very important guide to brain surgeons for long-term follow-ups and treatments of the patients. The patients carrying these risk factors should be closely monitored for these factors and should be rapidly treated. Ventriculoperitoneal or lumboperitoneal shunt should be considered a lifesaver for properly selected patients and the follow-up and treatment of these patients should be approached in a multi-disciplinary manner. Timing of the surgical intervention should be valued as one of the most determinant factors and the necessary infrastructure should be prepared accordingly and moreover, the caretaking team should be dynamic and active. In the light of all these information, multi-centered prospective studies with broader participations are required for the determination of factors that affect the aneurysm-associated hydrocephalus development.

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