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Clinical Article

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Predisposing Factors Related to Shunt-Dependent Chronic Hydrocephalus after Aneurysmal Subarachnoid Hemorrhage

Objective : Hydrocephalus is a common sequelae of aneurysmal subarachnoid hemorrhage (SAH) and patients who develop hydrocephalus after SAH typically have a worse prognosis than those who do not. This study was designed to identify factors predictive of shunt-dependent chronic hydrocephalus among patients with aneurysmal SAH, and patients who require permanent cerebrospinal fluid diversion.

Methods : Seven-hundred-and-thirty-four patients with aneurysmal SAH who were treated surgically between 1990 and 2006 were retrospectively studied. Three stages of hydrocephalus have been categorized in this paper, i.e., acute (0-3 days after SAH), subacute (4-13 days after SAH), chronic ($\geqq$14 days after SAH). Criteria indicating the occurrence of hydrocephalus were the presence of significantly enlarged temporal horns or ratio of frontal horn to maximal biparietal diameter more than 30% in computerized tomography.

Results : Overall, 66 of the 734 patients (8.9%) underwent shunting procedures for the treatment of chronic hydrocephalus. Statistically significant associations among the following factors and shunt-dependent chronic hydrocephalus were observed. (1) Increased age ($p < 0.05$), (2) poor Hunt and Hess grade at admission ($p < 0.05$), (3) intraventricular hemorrhage ($p < 0.05$), (4) Fisher grade III, IV at admission ($p < 0.05$), (5) radiological hydrocephalus at admission ($p < 0.05$), and (6) post surgery meningitis ($p < 0.05$) did affect development of chronic hydrocephalus. However the presence of intracerebral hemorrhage, multiple aneurysms, vasospasm, and gender did not influence the development of shunt-dependent chronic hydrocephalus. In addition, the location of the ruptured aneurysms in posterior cerebral circulation did not show significant correlation of development of shunt-dependent chronic hydrocephalus.

Conclusion : Hydrocephalus after aneurysmal subarachnoid hemorrhage seems to have a multifactorial etiology. Understanding predisposing factors related to the shunt-dependent chronic hydrocephalus may help to guide neurosurgeons for better treatment outcomes.

KEY WORDS : Subarachnoid hemorrhage · Ventriculoperitoneal shunt · Chronic hydrocephalus · Related factor.

INTRODUCTION

It is known that hydrocephalus is a relatively common complication in aneurysmal subarachnoid hemorrhage (SAH) patients. The prognosis is poor in SAH case complicated by hydrocephalus, and the potential factors affecting the development of hydrocephalus in SAH patient still remain incompletely understood.

Relating factors that have been suggested are the age of patient, sex, intraventricular hemorrhage, Fisher grade, clinical vasospasm, initial mental status, history of hypertension, and site of ruptured aneurysm, and so on[8,18,22,28].

As there are still many opinions posed for possible risk factors associating the development of hydrocephalus, this study was designed to analysis various factors in aneurysmal SAH cases, particularly in cases requiring shunt operation and not requiring it, and forecast potential factors affecting the development of hydrocephalus to provide certain indices helpful for treatment of hydrocephalus cases.

MATERIALS AND METHODS

A total of 734 patients were treated with surgical clipping from 1990 to 2006 were surveyed. They were diagnosed by brain computerized tomography (CT) with 3-dimensional angiography and digital substraction angiography (DSA). Patients with unruptured cerebral aneurysm and patients treated with intra-vascular intervention procedure were excluded in this study.

Digital substraction angiography before operation and brain CT before and after operation

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Table 1. Factors related to shunt dependent hydrocephalus

	Shunt (+)	Shunt (−)	total	%	*P* value
Age					$p<0.001$
10−19	0	2	2	0%	
20−29	0	14	14	0%	
30−39	3	72	75	4%	
40−49	9	186	195	4.6%	
50−59	21	201	222	9.4%	
60−69	26	157	183	14.2%	
70−79	7	36	43	16.2%	
80−89	0	1	1	0%	
Gender					$p=0.410$
Male	18	218	236	7.6%	
Female	48	450	498	9.6%	
Hunt and Hess grade					$p=0.003$
I	3	74	77	3.8%	
II	31	375	406	7.6%	
III	10	124	134	7.5%	
IV	19	86	105	18%	
V	3	9	12	25%	
IVH					$p<0.001$
Yes	34	102	136	2.5%	
No	32	566	598	5.6%	
ICH					$p=0.087$
Yes	76	11	76	14%	
No	658	55	658	8.3%	
Fisher grade					$p<0.001$
I	0	31	31	0%	
II	8	258	266	3%	
III	24	231	255	9.4%	
IV	34	140	174	19.5%	
Acute hydrocephalus					$p<0.001$
Yes	43	113	156	27.5%	
No	23	555	758	3.9%	
Location of ruptured aneurysm					$p=0.587$
ACA	29	208	237	12.2%	
MCA	8	149	157	5.1%	
ICA	10	156	166	6.0%	
Vertebrobasilar A.	4	24	28	14.2%	
Multiple A.	15	129	144	10.4%	
Clinical vasospasm					$p=0.837$
Yes	6	67	73	8.2%	
No	60	601	661	9.0%	
Meningitis					$p<0.001$
Yes	7	6	13	53.8%	
No	59	662	721	8.1%	
Total	66	668	734	8.99%	

IVH : intraventricular hemorrhage, ICH : intracerebral hemorrhage, ACA : anterior cerebral artery, MCA : middle cerebral artery, ICA : internal carotid artery, A : artery

were taken. Fisher grade, presence of IVH and ICH were checked by pre-operative brain CT. Hunt and Hess grade was measured with initial neurological examination.

This study classified hydrocephalus to acute (0-3 days after SAH), subacute (4-13 days after SAH) and chronic ($\geq$14 days after SAH) by brain CT[26]. The criteria indicating hydrocephalus was the presence of significantly enlarged temporal horns or ratio of frontal horn to maximal biparietal diameter more than 30% in brain CT.

The site of ruptured aneurysm was detected by pre-operative DSA. We compared various factors to confirm statistical significance in operated cases and non-operated cases. Those factors are as follows ; (1) age, (2) gender, (3) initial Hunt and Hess grade, (4) initial IVH, (5) initial ICH, (6) initial Fisher grade I, II or III, IV, (7) radiological hydrocephalus at the time of admission, (8) location of ruptured aneurysm, (9) presence of multiple aneurysms, (10) presence of clinical vasospasm and (11) presence of post operation meningitis.

We analyzed the data statistically with Chi-square test, independent-samples t-test and logistic regression analysis, and used SPSS for windows version 15.0.

RESULTS

During research period, a total of 734 cases were treated with surgical clipping, 8.9% of them needed shunt operation. Several patients who showed no improvement of symptoms after LP shunt operation were treated again with VP shunt operation.

Eleven factors were compared and analyzed between cases requiring shunt operation and not requiring it, and the results are outlined as follows.

Age

The mean age of the patients was 53 (ranging from 17 to 82). It was found that the mean age of shunt operation cases was 58.4, while that of control was 52.3. That indicates, shunt operation cases were older than control ($p<0.001$). The older age groups were treated with shunt operation more often (Table 1).

Gender

Female group (498 cases) comprised significantly higher ratio of all cerebral aneurismal SAH cases treated with operation than male group (236 cases). Fourty-eight female (9.6%) and 18 male (7.6%) patients were treated with shunt operation. The female group comprised higher ratio of shunt operation cases than the male group ($p=0.410$) (Table 1).

Hunt and Hess grade

Hunt and Hess grade IV or V group had an shunt operation more frequently than Hunt and Hess grade I or II group ($p=0.003$) (Table 1).

Table 2. Factors related to shunt dependent hydrocephalus (Logistic regression analysis)

Factors related chronic hydrocephalus		Odd ratio	Confidence interval (95%)	
	Categories		Lower	Upper
Age	≦ 50	1		
	> 50	1.035*	1.004	1.060
Gender	Male	1		
	Female	1.024	0.523	2.006
Hunt and Hess	Grade I	1		
	Grade II	0.853	0.229	3.182
	Grade III	0.280	0.060	1.317
	Grade IV	0.594	0.134	2.628
	Grade V	0.870	0.118	6.387
Intraventricular hemorrhage	No	1		
	Yes	2.826	0.778	10.260
Intracerebral hemorrhage	No	1		
	Yes	1.099	0.450	2.684
Fisher	Grade I	1		
	Grade II	0.000	0.000	0.000
	Grade III	0.588	0.064	5.377
	Grade IV	2.362	0.321	17.378
Acute hydrocephalus	No	1		
	Yes	5.256*	0.170	1.547
Posterior circulation	No	1		
	Yes	0.773	0.159	3.768
Clinical vasospasm	No	1		
	Yes	1.099	0.416	2.898
Meningitis	No	1		
	Yes	14.143*	0.019	0.285

*Statistical significance at 95% confidence interval

On the other hand, 3.9% of patients without hydrocephalus were treated with shunt operation ($p < 0.001$) (Table 1).

Site of ruptured aneurysm

The number of shunt operation according to the location of the aneurysms detected by pre-operation DSA are as follows ; 4 cases (14.2%) located in posterior circulation, 29 cases (12.2%) located in anterior cerebral artery including anterior communicating artery, 8 cases (5%) located in middle cerebral artery, 10 cases (6%) located at internal carotid artery were requiring shunt operation, and 15 cases (10.4%) located in multiple sites. The 15 cases of aneurysms at multiple sites were excluded in this study because we couldn't detect ruptured sites clearly (Table 1).

There was no significant relationship between location or presence of multiple aneurysms and the requirement of shunt operation in statistical analysis (p=0.587) (Table 1).

Intraventricular hemorrhage in initial brain CT

Twenty-five percent of patients with intraventricular hemorrhage (IVH) in initial brain CT were treated with shunt operation. In comparison, 5.6% of patients without IVH in initial brain CT were treated with shunt operation (p<0.001) (Table 1).

Intracerebral hemorrhage in initial brain CT

Fourteen percent of patients with intracerebral hemorrhage (ICH) in initial brain CT were treated with shunt operation. On the other hand, 8.3% of patients without ICH were treated with shunt operation (p=0.087) (Table 1).

Fisher grade in initial brain CT

The Fisher grade I, II group underwent shunt operation by 0% and 3% compared to the Fisher grade III, IV group by 9.4% and 19.5%. This indicates the Fisher grade III, IV group underwent shunt operation much more than the Fisher grade I, II group ($p < 0.001$) (Table 1).

Hydrocephalus in initial brain CT

Twenty-seven-and-five percent of patients with hydrocephalus on initial brain CT were treated with shunt operation.

Clinical vasospasm

Seventy-three patients who clinical vasospasm were treated with 3H (hypertension, hypervolemia, hemodilution) therapy and 6 cases (8.2%) were treated with shunt operation (p= 0.837) (Table 1).

Meningitis after clipping surgery

Meningitis diagnosed by cerebrospinal fluid examination was detected in 13 patients during research period and 7 cases (53.8%) were treated with shunt operation ($p < 0.001$) (Table 1).

The logistic regression analysis showed that only three factors, age of patient, initial acute hydrocephalus, and postoperative encephalitis, have statistical significance in needing shunt operation (Table 2).

DISCUSSION

The previous studies have shown that patients with aneurysmal SAH with ruptured cerebral aneurysms developed hydrocephalus after clipping operation from 6% to 67%[5,26]. In this study, 8.9% were treated with shunt operation due

to chronic hydrocephalus. It was reported that the potential risk factors inducing hydrocephalus after SAH includ old age, posterior circulation aneurysm, IVH, hypertension, poor Fisher grade, poor Hunt and Hess grade, symptomatic vasospasm, female sex, low Glasgow coma scale score, focal ischemia, previous use of anti-fibrinolytic agents, and so on[8,18,22,28].

This study analyzed potential factors affecting the development of hydrocephalus after aneurysmal SAH by allowing for these factors.

First, we found that the age of patients as a factor for the development of hydrocephalus. As shown in Table 1, the older age led to the higher ratio of shunt operation, which was comparable to the former findings from the analysis on 300 cases[22]. In addition, Graff-Radford et al.[2,8] analyzed age as a potential factor of hydrocephalus after rupture of cerebral aneurysm, and also showed findings similar to those above.

Second, we found though results from more shunt operation was required in female group than in male group. Other previous studies have been controversial[4,16, 20,27]. It is estimated that these differences would be associated with higher onset of SAH in older female group[1,7,12,16,20].

The findings of previous studies have shown that Hunt-Hess grade at admission may work as a potential factor for the development of hydrocephalus, and another previous study showed that mentality of patient at admission may work as a potential factor affecting the development of hydrocephalus[8]. This study also observed a finding which supports that the poorer Hunt-Hess grade would be more likely to work as potential factor of hydrocephalus with statistical significance. However, this results can be influenced by Hunt-Hess grade V which did not need shunt operation because of their low long-term survival rate.

The presence of IVH on CT at admission may work as a potential factor of hydrocephalus, as reported in many studies[2,8,10,17,28]. It is estimated that this result possibly attributed to IVH-induced disturbance and obstruction of CSF circulation, and our study also showed results comparable to those found in previous studies.

The cases complicated with ICH on CT at admission showed higher onset rate of hydrocephalus requiring shunt operation. But, there was no statistical significance. One study on 47 spontaneous ICH cases found that the rate of hydrocephalus might depend on the site of ICH[23], but we didn't analyze the site of ICH.

Many previous studies showed that low initial Fisher grade may be a risk factor for the development of hydrocephalus in aneurysmal SAH cases[4,8,9,14,26]. In this study, we noted a finding similar to studies previously conducted. But, another study on 897 cerebral aneurysm rupture cases reported that low initial Fisher grade was not a risk factor influencing shunt operation[21].

Since hydrocephalus was classified to acute and chronic by Foltz & Ward[5,10,27] in 1956, there have been a series of studies on possible mechanisms of hydrocephalus depending on the onset time after SAH. It is suggested that acute hydrocephalus results mainly from hemorrhage-induced obstruction of forth ventricle and basal cistern[5,10,27]. In our study, SAH cases with acute hydrocephalus showed higher frequency of chronic hydrocephalus later requiring shunt operation, contrary to SAH cases without acute cerebral hydrocephalus. Another study reported that ferritin level in CSF may be useful index to predict the development of ocases at admission showed higher CSF ferritin level than other cases[24,25].

The site of ruptured aneurysm can also affect the development of hydrocephalus. According to several previous studies, it seems that ruptured aneurysm in posterior circulations required shunt operation more often[5,10,27]. This study showed similar result, but there was no statistical significance.

In our study, cases that had clinical vasospasm showed more requirements for shunt operation, but there was also no statistical significance. According to a report on 718 cases by Dorai et al.,[5], it was found that 152 cases (21.2%) were treated with shunt operation. One-hundred-and-two cases showed vasospasm symptoms, and 36 cases of them (35.3%) were treated with shunt operation[5] and other previous studies reported similar findings[3,6,11].

In this study, 13 cases were complicated with meningitis, and 7 cases of them (54%) required shunt operation. It suggested that meningitis was associated with the duration of indwelling catheter due to acute hydrocephalus, and there have been many similar reports[13,29,30].

CONCLUSION

There have been a series of studies that are on potential risk factors of hydrocephalus after SAH caused by ruptured cerebral aneurysm requiring shunt operation. It has been often reported that those cases requiring shunt operation show worse in prognosis than other cases that didn't require shunt operation. In this study, we found several statistically significant factors the onset of hydrocephalus. Understanding and awareness of these factors related to and forecasting long-term disease course, it is expected that treatment of SAH will make prognosis better.

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