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The risk factors of shunt-dependent hydrocephalus after subarachnoid space hemorrhage of intracranial aneurysms

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Abstract

Shunt-dependent hydrocephalus is a common complication of aneurysmal subarachnoid hemorrhage (aSAH) which indicated intensive care unit stay and unfavorable outcome. Our aim is to study the risk factors of shunt-dependent hydrocephalus after aneurysmal subarachnoid space hemorrhage. Patients with intracranial aneurysms treated in our department from January 2014 to October 2018 were included in the study. Patients' age, gender, history of hypertension and diabetes, location of aneurysms, Glasgow coma scale (GCS) score, Hunt–Hess grading, intraventricular hemorrhage, therapeutic option, shunt placement, clinical outcome, length of stay were analyzed. The follow-up period was 1 to 5 years. Statistics included Chi-squared, Student t test, 1-way analysis of variance, Pearson correlation coefficient, and multivariate logistic regression. About 845 cases with intracranial aneurysms treated in our department were included in the study. The mean age was 52.19 ± 9.51 years and the sex ratio was 317/528. About 14.3% (121/845) of the patients developed shunt-dependent hydrocephalus in the follow-up period. According to our results, older than 60, Hunt–Hess grading, GCS, coma, posterior circulation aneurysm, external ventricular drainage, and decompress craniotomy were risk factors of shunt dependency ($P < .05$). Moreover, older than 60, GCS 3 to 8, Hunt–Hess 3 to 5, and posterior circulation aneurysm were the independent risk factors of shunt dependency. Moreover, shunt dependency was related to longer hospital stay and unfavorable outcome ($P < .05$). In conclusion, patients older than 60, GCS 3 to 8, Hunt–Hess 3 to 5, and posterior circulation aneurysm need more strict observation and longer follow-up. Timely and appropriate treatment may benefit patients in recovery, while further exploration is still needed in the future.

Abbreviations: CSF = cerebrospinal fluid, DC = decompressive craniotomy, EVD = external ventricular drainage, GCS = Glasgow coma scale, GOS = Glasgow outcome scale, ICH = intracerebral hemorrhage, IVH = intraventricular hemorrhage, SAH = subarachnoid hemorrhage, VP = ventricle-peritoneal.

Keywords: intracranial aneurysm, risk factors, shunt-dependent hydrocephalus, ventricle-peritoneal shunt

1. Introduction

Hydrocephalus is a common complication of aneurysmal subarachnoid hemorrhage (aSAH). The incidence in an unselected series of patients is between 6.5% and 67%,[1–6] and the incidence of the permanent shunt is between 10% and 20%.[7,8]

The pathogenesis of shunt-dependent hydrocephalus involves obstruction of blood products or adhesions which blocks cerebrospinal fluid (CSF) circulation within the ventricular system, fibrillation of aseptic inflammation after aneurysmal subarachnoid hemorrhage which may cause CSF mal-absorption.[9–11] Besides, alterations of CSF dynamics may also affect the CSF circulation and absorption.[12]

Although the occurrence of hydrocephalus after aSAH has been well studied and some measures have been applied to prevent hydrocephalus, its potential risk factors are still unclear.[13–15] To our knowledge, there are few large sample studies examining characteristics of aSAH that may lead to symptomatic hydrocephalus requiring ventricle-peritoneal (VP) shunt. Thus, we conducted a retrospective review of a cohort of patients with aSAH to identify risk factors associated with the shunt-dependent hydrocephalus. Our study will assist neurosurgeons to manage patients with aSAH by suggesting potential risk factors for shunt dependency and furthering our understanding of hydrocephalus after aSAH.

2. Patients and methods

2.1. Participants

Patients with intracranial aneurysms treated in our department from January 2014 to October 2018 were included in the study. Inclusion criteria were patients with ruptured arterial aneurysm and subarachnoid hemorrhages. Exclusion criteria were patients

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with unruptured aneurysm or combined with other vascular diseases such as dural arteriovenous fistula, arteriovenous malformation, or Moyamoya disease. Patients with multiple aneurysms were also excluded from the analysis. The follow-up period is from 1 to 5 years. The study was approved by the Ethical Committee of Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology. As a retrospective review, all methods were carried out in accordance with relevant guidelines and regulations.

2.2. Patients management

Records of patients who met the inclusion criteria were examined for age, gender, history of hypertension and diabetes, location of aneurysms, Glasgow coma scale (GCS) score, Hunt–Hess grading, intraventricular hemorrhage, therapeutic option, shunt placement, clinical outcome, and the length of stay.

All cases displayed subarachnoid space hemorrhage according to the head CT examination upon admission to hospital and before the shunt surgery. Hydrocephalus was defined by radiologic proof and 2 experienced surgeons' diagnosis. The treatment options included expectant treatment, neurosurgical clipping, and endovascular coiling. The surgeons stated the advantages and disadvantages of the treatment sufficiently to patients or their family for them to make independent decisions. Some patients refused both neurosurgical clipping and endovascular coiling, so conventional drug treatment was adopted. Clinical outcome was categorized into 2 groups: unfavorable group (GOS score, 1–3) and favorable group (GOS score 4 or 5).

2.3. Statistical analysis

Statistical analysis using Student *t* test and 1-way analysis of variance was performed to determine characteristics that were statistically significant different between the 2 groups. Pearson correlation analysis was performed for the risk factors. Thus variables with $P<.05$ were deemed to have statistically significant associations. Variables with *P*-value <.05, as determined by univariate analysis, were included for multivariate analysis. Multivariate logistic regression analysis was employed to identify independent predictors of unfavorable outcome. Pearson correlation coefficient was conducted for the clinical outcome and the hospital stay of patient with shunt-dependent hydrocephalus. *P*-values <.05 were considered statistically significant.

3. Results

A total of 845 patients with intracranial aneurysms treated in our department from January 2014 to October 2018 were included in the study. Furthermore, 14.3% (121/845) of the patients developed shunt-dependent hydrocephalus in the follow-up period. The mean age was 52.19±9.51 years and the sex ratio was 317/528.

According to our results, age is not a factor of hydrocephalus. But when we subdivided the patients into groups younger than 60 and older than 60,[16] we find that the age of patients over 60 is a risk factor of hydrocephalus and also an independent factor of shunt ($P<.001$). Although more female patients with aneurysms are included in our study, female is not a risk factor of hydrocephalus according to our result ($P>.05$). Moreover, the history of hypotension and diabetes is also not related to hydrocephalus ($P>.05$) (Table 1).

We further evaluated the influence of GCS score on the outcome. Patients were categorized into 3 groups according to the GCS scores: mild (GCS 13–15), moderate (GCS 9–12), and severe (GCS 3–8). The patients were subdivided into 2 groups according to Hunt–Hess grading: mild (1–2) and severe (3–5).

The mean GCS were 8.94 in shunt group and 8.11 in no shunt group. The Hunt–Hess grading were 2.28±0.73 and 2.28±0.90 in the 2 groups. The GCS and Hunt–Hess grading were significantly related to the incidence of hydrocephalus ($P<.001$). According to our subgroup analysis, GCS 3 to 8 ($P<.05$) and Hunt–Hess grading 3 to 5 ($P<.001$) were independent risk factors of hydrocephalus. Unconscious state is also related to hydrocephalus and coma is a risk factor of hydrocephalus ($P<.05$) (Table 2).

We subdivided the aneurysms location into 3 types according to previous research[17]: the posterior circulation artery aneurysm (105, 12.4%), anterior circulation artery aneurysm (644, 76.2%), and other aneurysm (96, 11.3%). Ventricular hemorrhage can be found in 109 (12.9%) patients and 27 of them developed shunt dependency. Ventricular hemorrhage is also a risk factor of shunt-dependent hydrocephalus ($P<.05$) (Table 3).

Table 2

Factors between clinical symptoms and shunt-dependent hydrocephalus.

Factor	No shunt	Shunt	Univariate analysis	Multivariate analysis
GCS	8.94	8.11	$P<.01$	$P<.05$
3–8	258	49	$P<.01$	$P<.05$
9–12	214	31	–	–
13–15	252	41	–	–
Hunt-Hess grading	2.28±0.73	2.28±0.90	$P<.001$	$P<.01$
1–2	501	128	–	–
3–5	172	44	$P<.001$	$P<.01$
Coma	411	74	$P<.05$	–

Table 1

Factors between general condition and shunt-dependent hydrocephalus.

Factor	No shunt	Shunt	Univariate analysis	Multivariate analysis
Age, yr	51.95±9.41	53.67±10.05	–	–
>60	137	40	$P<.001$	$P<.001$
<60	587	81	–	–
Gender (M/F)	271/453	46/75	–	–
Hypotension	194	39	–	–
Diabetes	130	21	–	–

Table 3

Factors between aneurysms location and shunt-dependent hydrocephalus.

Factor	No shunt	Shunt	Univariate analysis	Multivariate analysis
Aneurysms location			–	–
Posterior circulation aneurysm	76	29	$P<.01$	$P<.01$
Anterior circulation aneurysm	563	81	–	–
Other aneurysm	85	11	–	–
Ventricular hemorrhage	109	27	$P<.05$	–

According to our results, neurosurgical clipping was performed in 598 patients, endovascular coiling was performed in 188 patients and 39 of them were only given drug therapy. Besides, the endovascular coiling failed in 20 patients and a neurosurgical clipping was performed accordingly. The therapeutic method was not a risk factor of shunt dependency in our study ($P<.05$). External ventricular drainage (EVD) was performed in 113 patients mostly because of acute hydrocephalus. At the same time, decompressive craniotomy (DC) was performed in 124 patients with severe cerebral edema. Both EVD and DC are risk factors according to our results ($P<.05$) (Table 4).

The total hospital stay was 17.03±10.05. The patients with and without hydrocephalus was 16.84±9.60 and 20.09±12.04, respectively. Shunt-dependent hydrocephalus was significantly related to hospital stay ($P<.01$) and outcome ($P<.05$) (Table 5).

4. Discussion

The incidence of shunt dependency after aSAH is influenced by many different factors such as patients' general conditions, their clinical symptoms, aneurysms conditions and therapeutic methods.[2] Some factors can be revised by our treatment choice and others have already been determined upon hospital admission. For the changeable factor, our study can help surgeons to make better decision; while for the irrevocable factors, our study provides more information for the focus of observation and prediction of prognosis.

4.1. General condition

According to our results, the incident rate was 14.3% which is a little lower than the baseline. Although 1 study demonstrated significant shunt dependency increase in male[14] and 2 studies indicated that females are related to shunt dependency,[1,18] most studies show no significant difference between different genders and our results also generate the same results.[4,13,19,20]

Previous research indicated that the incident rate of chronic hydrocephalus is higher in patients aged over 60. A meta-analysis reported that the overall incidence of shunt dependency in patients aged 60 to 69 and in patients aged over 70 is 19.5% and 30.5%, respectively.[16] When we subdivided patients aged over 60, it is an independent risk factor of hydrocephalus. It also consistent with the clinical knowledge that old age always associated with adverse clinical outcome and more complications, and more care should be given to patients over 60.

Some researchers reported that historical hypertension as an independent risk factor.[21,22] They speculated that hypertension indicated a large amount of intracranial hemorrhage and poor vascular condition which might be related with a higher incidence of hydrocephalus. Similarly, a history of diabetes also indicated more hemorrhage and more damage of CSF circulation pathway. Although they are not risk factors of hydrocephalus in our study, we still believe they are risk factors of unfavorable prognosis. According to our clinical experience, blood pressure and blood sugar control can effectively reduce complications and improve the prognosis.

Table 4

Factors between therapeutic method of aSAH and shunt-dependent hydrocephalus.

Factor	No shunt	Shunt	Univariate analysis	Multivariate analysis
No surgery	34	5	–	–
Clipping	521	77	–	–
Coiling	153	35	–	–
Combine	16	4	–	–
EVD	94	19	$P<.05$	–
DC	85	39	$p<0.05$	–

aSAH=aneurysmal subarachnoid hemorrhage, DC=decompressive craniotomy, EVD=external ventricular drainage.

Table 5

The correlation between patients' hospital stay, outcome, and hydrocephalus.

Factor	Shunt	No shunt	*P*-value
Hospital stay	20.09±12.04	16.84±9.60	<.01
Outcome	1.33±0.75	1.50±0.90	<.05

4.2. Clinical symptoms

According to our result, Hunt–Hess scale score and GCS score were risk factors with substantial supporting data in our study. It is similar to previous meta-analysis.[16] Hunt–Hess scale scores are widely used for the evaluation of patients with ruptured aneurysms.[23,24] GCS is also meaningful. It can not only evaluate patients' consciousness, but also predict the shunt dependency. When we subdivided the Hunt–Hess scale score and GCS score, we found that Hunt–Hess scale between 3 and 5 and GCS score between 3 and 8 are independent risk factors of hydrocephalus. Based on our clinical experience, conscious state is also related to the incidence of hydrocephalus. Therefore, we analyzed the relationship between hydrocephalus and the state of mind. According to our result, coma is also a predicting factor of a higher incidence of hydrocephalus and patients with coma should be paid more attention for the symptoms of hydrocephalus.

4.3. Aneurysms condition

The association of posterior circulation aneurysm location with shunt dependency was evaluated in some previous studies.[6,8,25–27] A meta-analysis indicated that a posterior circulation aneurysm increased the risk of shunt dependency nearly twice as much as much as the patients who had aneurysms elsewhere. It has been reconfirmed in our study. Anterior circulation aneurysm indicated more incidence of intracerebral hematoma while posterior circulation aneurysm bleed into ventricles and cisterns such as basal cisterns, sylvian fissure, and subdural space.[28]

However, more subarachnoid blood is associated with higher shunt-dependency rates.[1,5]

At the same time, intraventricular hemorrhage has been analyzed in our study and deemed to be a risk factor of hydrocephalus. Intraventricular blood is a well-recognized risk factor for shunt dependency. Some researchers pointed out some potential reasons such as blood increases CSF viscosity[29] and blood in the ventricles may cause obstruction in aqueduct or foramen of Monro. Moreover, too much blood can deposit in the CSF circulation and cause mal-absorption.[30] Additionally, posterior aneurysms are more likely to cause intraventricular hemorrhage than anterior aneurysms, which again confirmed the relationship between posterior aneurysms and hydrocephalus. According to our results, more attention should be paid to patients with extensive subarachnoid hemorrhage than intracerebral hematoma for potential hydrocephalus. Recently, quantitative blood amount assessment is served as a predictor for shunt-dependent hydrocephalus following aneurysmal subarachnoid hemorrhage.[31]

4.4. Therapeutic method

The comparison of the advantage and disadvantage between neurosurgical clipping and endovascular coiling is controversial in terms of the efficacy, safety, and complication.[32–34] Although, some researchers indicated that operations of endplate windowing in aneurysm microsurgery operations may lower the incident rate of hydrocephalus[35,36] of chronic hydrocephalus, a recent meta-analysis reported that shunt-dependent hydrocephalus did not differ significantly on techniques.[16] According to our result, different therapeutic options will not influence the incidence of hydrocephalus. We also find that the incidence of hydrocephalus would not change even no surgery is performed.

Intraventricular hemorrhage (IVH) and acute hydrocephalus often cause acute hydrocephalus and thus EVD is always needed. According to our result, EVD is not related to the incidence of hydrocephalus. As EVD indicates severe acute hydrocephalus, it could be a confounding factor of hydrocephalus. No subgroup analysis has been done in our study because of insufficient data at this time. But we still believe that EVD is a protecting factor of hydrocephalus. It can drain the inflammation factor, clotting and fibrosis material after the initial hemorrhage and prevent it from deposition in the CSF circulation pathway and cause CSF mal-absorption or obstruction of the circulation pathway. Another possible explanation is that draining a large amount of CSF during early stages after aSAH can induce lower intracranial pressure which can prevent hydrocephalus advancing into the shunt-dependent stage.[37,38] When the patient carried through the acute phase, the CSF circulation would recover and the potential hydrocephalus can be prevented. At the same time, lumbar drainage has also been reported in the prevention shunt-dependent hydrocephalus after the treatment of ruptured intracranial aneurysms.[39] Although lumbar drainage is not a routine application for aSAH patients, its potential to prevent hydrocephalus has been recognized in recent years. Previous meta-analysis indicated that IVH is a negative prognostic factor in intracerebral hemorrhage (ICH) and is associated with permanent shunt dependency in a substantial proportion of patients post-ICH and a combined approach of IVF plus lumbar drains treatment is feasible and safe and significantly reduces rates of permanent shunt dependency for aresorptive hydrocephalus post-ICH.[40]

The DC is a known risk factor for the development of posttraumatic hydrocephalus.[41] Our study also indicated the relationship between DC and hydrocephalus. DC is not a routine procedure after intracranial aneurysms surgery and it is always associated with malignant brain edema. Therefore, we believe that brain edema may deteriorate the CSF circulation pathway and also be a risk factor of hydrocephalus. Previous research also suggested the craniotomy size and surgical technique are also related to the incidence of hydrocephalus which suggested that improving surgical techniques and management may reduce the incidence of hydrocephalus.[42]

4.5. Outcome

It has also been demonstrated in our study the hydrocephalus increases morbidity, hospital stay, and intensive care unit stay.[4,18] In other words, hydrocephalus indicates unfavorable prognosis. Therefore, we should observe the patient with risk factor of hydrocephalus intensively and make a quick response to minimize the potential damage of hydrocephalus.

4.6. Limitations

Our study has several limitations. Firstly, it is not a RCT which will inevitably suffers from the bias of unmeasured factors and some unknown factors. Secondly, bias can also be caused by different surgery techniques. Independent prognosticators were unavailable because of the limited group size of the patients with a VP shunt. Thirdly, a recent meta-analysis of risk factors for shunt dependency aSAH was also published to identify the risk factor of hydrocephalus. It indicated that high Fisher grade, acute hydrocephalus, in-hospital complications, intraventricular blood, high Hunt–Hess scale score, rehemorrhage, posterior circulation aneurysm location, and older than 60 years were risk factors of hydrocephalus. However, our study based on a large amount of patients can provide more convincing proof on this issue.

5. Conclusion

Based on our results, hydrocephalus after aSAH is variable and difficult to predict. However, patients older than 60, GCS 3to 8, Hunt–Hess 3 to 5 and posterior circulation aneurysm need more strict observation and longer follow-up. Clinical and radiologic monitoring should be stricter and follow-ups should be prolonged in patients with these factors. Moreover, more well-designed exploration is still needed in the future.

Author contributions

Conceptualization: Hao Xu, Ding Wei.
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