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Original Investigation

The Impact of Surgical Timing on the Management of Aneurysms with Acute Hydrocephalus After Aneurysmal Subarachnoid Hemorrhage

Anevrizmal Subaraknoid Kanama Sonrası Akut Hidrosefali Bulunan Anevrizmaların Takibinde Cerrahi Zamanlamanın Etkisi

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ABSTRACT

AIM: To explore the feasibility and effectiveness of early microsurgical therapy for acute hydrocephalus resulting from a ruptured intracranial aneurysm.

MATERIAL and METHODS: Forty patients with Hunt-Hess grades II-III were assigned to group A; 27 patients with grades IV-V formed group B. The patients were also divided into 2 groups based on the time interval between the hemorrhage and surgery. Subjects in the early surgery group underwent aneurysm clipping within 3 days of subarachnoid hemorrhage (SAH), followed by intraoperative lateral ventricle puncture and third ventriculostomy. Subjects in the late surgery group underwent aneurysm clipping within 10 days of SAH, after initial treatment with lateral ventricular drainage. Three months after surgery, we used the Glasgow Outcome Scale (GOS) to compare the differences between the early and late surgery groups.

RESULTS: More patients benefited from early surgery than from late surgery in both groups: GOS4-5 was achieved by 75% and 73.3% of early-surgery patients compared to 37.5% and 25% of late-surgery patients from Groups A and B, respectively (both $p < 0.05$). Analysis of the relationship between surgical timing and outcomes with the Ridit method showed that outcomes of early surgery were better than those of late surgery ($p < 0.05$).

CONCLUSION: Aneurysmal SAH with acute hydrocephalus requires early surgery.

KEYWORDS: Hydrocephalus, Intracranial aneurysm, Subarachnoid hemorrhage, Surgical timing

ÖZ

AMAÇ: Rüptüre intrakranial anevrizmadan kaynaklanan akut hidrosefalinin erken mikrocerrahi tedavisinin uygulanabilirliğini ve etkinliğini araştırmak.

YÖNTEM ve GEREÇLER: Hunt-Hess derece II-III olan kırk hasta A grubuna atandı ve derece IV-V olan 27 hasta B grubunu oluşturdu. Hastalar aynı zamanda kanama ve ameliyat arasındaki zaman aralığına dayanarak 2 gruba ayrıldılar. Erken cerrahi grubundaki hastalara intraoperatif lateral ventrikül ponksiyonu ve üçüncü ventrikülostomiyi takiben subaraknoid kanamadan sonraki 3 gün içerisinde anevrizma kliplenmesi yapıldı. Geç cerrahi grubundaki hastalara lateral ventrikül drenajı ile ilk tedaviyi takiben, subaraknoid kanamadan sonraki 10 gün içinde anevrizma kliplenmesi yapıldı. Ameliyattan üç ay sonra, erken ve geç cerrahi gruplar arasındaki farklılıkları değerlendirmek için Glasgow Sonuç Ölçeğini (GSÖ) kullanıldı.

BULGULAR: Her iki grupta da geç cerrahiye nazaran daha fazla hasta erken cerrahiden yararlanmıştır: A ve B grupları için sırasıyla, erken ameliyat olan hastalarda %75 ve %73,3 ve geç hastalarda %37,5 ve %25 oranlarında GSÖ 4-5 değerlerine ulaşıldı (ikisi için de $p < 0.05$). Ridit yöntemi ile cerrahi zamanlama ve sonuçları arasındaki ilişkinin analizi erken cerrahinin sonuçlarının geç cerrahininkinden daha iyi olduğunu gösterdi ($p < 0,05$).

SONUÇ: Akut hidrosefali ile anevrizmal subaraknoid kanama erken ameliyat gerektirir.

ANAHTAR SÖZCÜKLER: Hidrosefali, İntrakranial anevrizma, Subaraknoid kanama, Cerrahi zamanlama

INTRODUCTION

Acute hydrocephalus is one of the most common complications faced by patients with aneurysmal subarachnoid hemorrhage (SAH) (14). Acute hydrocephalus can cause serious neurological deficits and accelerate disease progression. The incidence of acute hydrocephalus following aneurysmal SAH varies greatly in the literature (4). This variability may be associated with diversity of the selected cases and differences in the time and frequency of CT or MRI scans performed after the onset of the disorder. A previous study has reported an incidence of acute hydrocephalus at approximately 20% to 30% (3). Hydrocephalus that occurs within three days of a subarachnoid hemorrhage is defined as an acute hydrocephalus. This condition usually results from a ruptured aneurysm that bleeds into the ventricular system or basal cistern and directly obstructs the cerebrospinal fluid (CSF) circulation. Concurrently, erythrocytes block the arachnoid granules or, the granules become adhesive due to the impact of bleeding, thus diminishing the CSF absorption. The primary clinical manifestations of acute hydrocephalus include acute symptoms of elevated intracranial pressure and reduced levels of consciousness. An accurate diagnosis of aneurysmal SAH relies on a CT scan, which usually reveals enlargement of the third and fourth ventricles, or a ball-shaped expansion of the anterior horn of the lateral ventricle. Periventricular low-density areas may also appear and are often accompanied by varying amounts of blood in the ventricles. However, currently, there is no evidence that hydrocephalus can alone directly lead to aneurysm re-bleeding and vasospasm.

The clinical condition of a patient with aneurysmal SAH can be graded in accordance with the Hunt-Hess scale (8). Assigning a Hunt-Hess grade to a patient with aneurysmal SAH can assist in deciding the timing of surgery and the patient's prognosis. The Hunt-Hess scale describes a patient's condition by 5 grades: Grade I, the patient is asymptomatic or experiences minimal headache and slight neck stiffness; Grade II, the patient experiences moderate to severe headache and neck stiffness but exhibits no neurologic deficits except cranial nerve palsy; Grade III, the patient is drowsy and confused or exhibits mild focal neurologic deficits; Grade IV, the patient is presents with a dazed state and exhibits moderate to severe hemiparesis, early cerebrum malfunction and vegetative disturbances; Grade V, the patient is in a deep coma and exhibits cerebral rigidity or a declining mental status. If a patient has a serious systemic disease such as diabetes, hypertension, severe arteriosclerosis, chronic lung disease, or severe vasospasm revealed by angiography, the Hunt-Hess grade is then increased by a value of 1. The conventional treatment for acute hydrocephalus after aneurysm rupture is lateral ventricular drainage. At an early stage of the disorder, surgical exposure is limited because of intracranial hematoma, cerebral edema, brain swelling, cerebral vasospasm, and high intracranial pressure, resulting in a difficult separation. Therefore, early surgery is difficult and highly risky. Surgical treatment of a ruptured aneurysm is recommended after 10 to 14 days, when the patient's condition has stabilized (19). However, De Gans et al. (2) suggested that delaying surgery does not improve the overall treatment effectiveness for patients with a ruptured intracranial aneurysm, because a considerable portion die from a re-rupture, re-bleeding or cerebral vasospasm prior to the surgery. Patients such as these have been excluded from studies that attempted to characterize the association between the timing of surgery for a ruptured aneurysm and its influence on prognosis.

In the past, early surgery was not recommended for patients with severe aneurysmal SAH because of higher mortality after surgical treatment. There is however a high rate of recurrent aneurysm ruptures in patients with a poor Hunt-Hess grade. If early treatment of hydrocephalus allows the aneurysm to be clipped and provides a benefit, then it is worthy of investigation. In this study, the clinical data of 316 patients who experienced aneurysmal SAH between August 2010 and October 2011 was reviewed. Among 316 patients, 67 patients had acute hydrocephalus. Through careful analysis, the feasibility and outcomes of early surgery following aneurysm rupture in these patients was explored. The results of the present study suggest that when acute hydrocephalus occurs in cases of aneurysmal SAH, treatment of hydrocephalus with early surgical clipping of the aneurysm can reduce hemorrhage, lower intracranial pressure, eliminate the risk of re-rupture and reduce cerebral vasospasm. Timely prevention and treatment of the three major complications (symptomatic vasospasm, re-bleeding, and hydrocephalus) resulting from aneurysm rupture can improve the prognosis.

MATERIAL and METHODS

Clinical Data

This study was approved by the ethics committee of the Sichuan Provincial People's Hospital. Seventy recorded cases with aneurysmal SAH and acute hydrocephalus were reviewed. Three cases in the late surgery group could not undergo surgery due to re-bleeding. Consequently, 67 cases with aneurysmal SAH and acute hydrocephalus were included in the current study. On admission, all patients presented with severe headache, vomiting, meningeal irritation and varying degrees of impaired consciousness. The duration from the onset of the disorder to hospitalization was between 1 and 28 hours. All patients fulfilled the following criteria: concurrent hydrocephalus within 48 hours (acute hydrocephalus) of aneurysmal SAH; a CT scan showing anterior and posterior horn expansion in the lateral ventricle; enlargement of the third and fourth ventricles; a low-density area surrounding the ventricles; varying amounts of blood in the ventricle and intracranial aneurysms confirmed by CT angiography or Digital Subtraction Angiography. The exclusion criteria included: subacute and chronic hydrocephalus; SAH and concurrent hydrocephalus from other causes; intraventricular hemorrhage mold and posterior circulation aneurysms. On admission, each patient's clinical features were graded in accordance with the Hunt-Hess scale (8). No patients matched the requirements of Hunt-Hess Grade I. Group A included 21 patients in Grade II and 19 patients in Grade III; Group B consisted of 22 patients in Grade IV and 5 patients in Grade V. A single aneurysm was found in 63 patients and multiple aneurysms in 7 patients. This resulted in a total of 77 aneurysms assessed in this study.

Surgical Procedure

Thirty-nine patients with aneurysmal SAH underwent surgical clipping of the aneurysms and hydrocephalus treatment within 3 days of the onset of the disorder. These patients comprised the early surgery group. The 28 patients of the late surgery group were initially treated for hydrocephalus with external ventricular drainage or lumbar drainage and waited until their conditions stabilized to undergo clipping. All patients received common surgical treatments for intracranial aneurysms with subarachnoid hemorrhage and hydrocephalus. The surgeons used microneurosurgical technology and took a pterional approach with a frontal temporal incision. External ventricular drainage was performed through the anterior horn of the lateral ventricle. Subsequently, the Sylvian and suprasellar cisterns were separated to release cerebrospinal fluid and to reduce pressure on the brain tissue. The brain tissue was separated to fully expose the lamina terminalis, which is usually located at the rear of the optic chiasm and covered with a light blue, slightly bulging film. Fenestration of lamina terminalis was carried out in strict accordance with the midline incision on the endplate membrane to avoid injury to the blood supply of the optic nerve. The appropriate stoma was approximately 5mm in diameter. The clots in the subarachnoid space and the three ventricles were sufficiently evacuated, then the artery supplying blood to the aneurysm was blocked and the aneurysm was clipped. If brain swelling was significant, a decompressive craniectomy was performed. Postoperative drainage was maintained for 4 to 7 days, with an average of 5 days. Intracranial pressure was maintained at approximately 150 to 200 mmH_2O. Following removal of the drainage apparatus, continuous lumbar drainage was established or repeated lumbar punctures were performed until the CSF became clear and intracranial pressure returned to normal. Drugs that control or prevent vasospasm, such as nimodipine, were administered after SAH and after surgical clipping of the aneurysm. Treatments for blood dilution and blood volume expansion were also administered concurrently.

Evaluation of the Surgical Outcomes

Three months after surgery, follow-up interviews were conducted at outpatient visits or by telephone inquiries to the patients' families. Treatment efficacy was evaluated with the Glasgow Outcome Scale (GOS) (18): scores of 4-5 indicate a good outcome; scores of 2-3 indicate a poor outcome; a score of 1 indicates death. Postoperative complications including cerebral infarction, intracranial hemorrhage, respiratory infection, and hemiplegia were investigated as these may have affected the patients' outcome.

RESULTS

Of the 316 patients with aneurysmal SAH, 70 were diagnosed with acute hydrocephalus. The overall incidence of acute hydrocephalus following aneurysmal SAH was 22.2%. Thirty-one of the patients were men and 39 were women; their ages ranged from 31 to 77 years with an average age of 54 ± 23 years. As mentioned above, a deteriorated condition prevented 3 patients from undergoing surgery. As a result, 67 patients with aneurysmal SAH and acute hydrocephalus were analyzed. Surgical clippings were successfully performed for 77 aneurysms in 67 patients. Of the 40 patients in Group A, 24 underwent early surgery and 16 underwent late surgery. Of the 27 patients in Group B, 15 underwent early surgery and 12 underwent late surgery. Analysis revealed that in both Group A and Group B, the differences of demographic and baseline data between patients in the early surgery and late surgery groups were insignificant (Table I). Notably, patients who underwent early surgery had better outcomes than those treated later. Among Group A patients, 75% of those who underwent early surgery achieved a "good" GOS score,

Table I: Patient Characteristics

	Early Surgery Group n (%)	Late Surgery Group n (%)	P value[a]
Group A (Grades II-III)			.12
Grade II	15 (71.4)	6 (28.6)	
Grade III	9 (47.4)	10 (52.6)	
Age (years)	48.9 ±11.8	53.1 ±11.6	.27
Sex			
Male	16 (64.0)	9 (36.0)	.51
Female	8 (53.3)	7 (46.7)	
Aneurysm diameter (mm)	4.5 ±1.1	4.9 ±1.4	.23
Group B (Grades IV-V)			.82
Grade IV	12 (54.6)	10 (45.4)	
Grade V	3 (60.0)	2 (40.0)	
Age (years)	48.1 ±13.0	57.8 ±10.7	.0495
Sex			
Male	9 (60.0)	6 (40.0)	.60
Female	6 (50.0)	6 (50.0)	
Aneurysm diameter (mm)	4.9 ±1.0	5.5 ±1.6	.26

[a]*The demographics of the early surgery and late surgery groups were compared by using the Student's t test.*

Table II: The Efficacy of Surgical Timing for Treatment of Aneurysmal SAH and Acute Hydrocephalus

Outcomes	Early Surgery Group (n, %)	Late Surgery Group (n, %)	u value (early-late)[a]	P value (early-late)
Group A (Grades II-III)				
Good (GOS4-5)	18 (75.0)	6 (37.5)		
Poor (GOS3-2)	5 (20.8)	9 (56.3)		
Death (GOS1)	1 (4.2)	1 (6.3)	1.9566	.05
Complications				
Yes	3 (12.5)	9 (56.3)	8.7500	.003
No	21 (87.5)	7 (43.7)		
Group B (Grades IV-V)				
Good (GOS4-5)	11 (73.3)	3 (25.0)		
Poor (GOS3-2)	3 (20.0)	7 (58.3)		
Death (GOS 1)	1 (6.7)	2 (16.7)	2.1367	.03
Complications				
Yes	4 (26.7)	7 (58.3)		
No	11 (73.3)	5 (41.7)	2.7690	.10

[a]The efficacy of different surgical time intervals for the treatment of acute hydrocephalus following aneurysmal SAH was compared by using Ridit analysis.

while only 37.5% of those who had surgery later achieved this score (P < .05). A "good" GOS score was achieved by 73.3% of Group B patients who underwent early surgery, while only 25% of late-surgery patients in Group B achieved this score (P < .05). Patients in the early surgery group also experienced fewer postoperative complications than those in the late surgery group: 12.5% and 26.7% of the patients who underwent early surgery in Groups A and B, respectively, reported complications, while 56.3% and 58.3% of the late-surgery patients in Groups A and B, respectively, reported complications (Table II). The relationship between the timing of surgery and the patients' outcomes were assessed by using Ridit analysis, and the results showed that the prognoses of patients undergoing early surgery were significantly better than those of patients treated later (P < .05) (Table II).

DISCUSSION

There are various factors influencing the outcomes of aneurysmal SAH. Rosengart et al reported that unfavorable outcome of aneurysmal SAH was associated with increasing age, worsening neurological grade, ruptured posterior circulation aneurysm, larger aneurysm size, more SAH on admission computed tomography, intracerebral hematoma or intraventricular hemorrhage, elevated systolic blood pressure on admission, and previous diagnosis of hypertension, myocardial infarction, liver disease, or SAH (12). Similarly, it has been reported that the clinical severity of the SAH (7), and the high intracranial pressure and deterioration in neurological status (1) were independent factors related to unfavorable outcome aneurysmal SAH. In addition, Sviri et al showed severe basilar artery vasospasm was an independent prognostic factor highly associated with an unfavorable outcome in patients with clinically suspected severe vasospasm after aSAH (15). Collectively, these studies highlight the fact that apart from hydrocephalus, more variables are involved in the outcomes of SAH patients.

A number of studies have shown that patients with acute hydrocephalus following aneurysmal rupture tend to have higher Hunt-Hess grades (3). After surgical treatment of such patients, the mortality rate can still be as high as 50%. In the past, many physicians have been pessimistic about the therapeutic effectiveness of surgery for these patients (10). In recent years, the rapid advancement of endovascular techniques has provided a new treatment option for treatment of patients with SAH in higher Hunt-Hess grades by eliminating the risk of re-rupture. However, several important prognostic factors, such as high intracranial pressure, extensive cerebral vasospasm, and acute and chronic hydrocephalus, need to be resolved (17). Given the technological advances and increasing surgical expertise, a growing number of neurosurgeons have sought more aggressive treatment strategies for such patients (11). In this study, acute hydrocephalus occurred after widely distributed bleeding into the subarachnoid and ventricular spaces. The Hunt-Hess grades of patients were all II or greater and there were 27 (40.3%) in grades IV-V. In particular, 15 patients in whom ruptures bled into the ventricle showed acute hydrocephalus. Of the 27 patients with grades IV-V who were treated by surgery, 14 (51.9%) had a postoperative GOS score of 4 to 5 points. In the 15 patients undergoing early surgery, 11 recovered or suffered only mild disability, suggesting that successful early surgery is essential for a considerable number of patients with cerebral aneurysm in grades IV-V.

Patients with intracranial aneurysm rupture and acute hydrocephalus often have hematomas, cerebral edema, brain swelling and higher intracranial pressure. The lateral fissure and cistern are often difficult to separate in these patients, and surgical exposure of the aneurysm can be difficult. As a result, anatomical structure is often less clear in early surgeries than in late surgeries. In addition, highly skilled personnel and a rescue process are necessary, creating certain difficulties. In our experience, early surgery should focus on several factors: 1) Use dehydrating agents prior to surgery, adequately perform temporary hyperventilation, puncture the anterior horn and establish drainage after the craniotomy, etc. to reduce intracranial pressure. 2) When possible, perform a sharp dissection of the cistern and subarachnoid space, then perform the third ventriculostomy. When cerebral edema and brain swelling are severe, resect the anterior temporal lobe, or directly open the temporal horn to release CSF and reduce traction of the brain tissue. 3) After determining that the intracranial pressure is reduced, expose the parental artery and the aneurysm. Exposure avoids forcible separation, which can easily lead to aneurysm rupture. 4) Hematomas should first be cleared from the parental artery and aneurysm neck; to do this, temporary occlusion of the parental artery may be required. Hematomas attached to the aneurysm should be cleared after clipping. 5) When intraoperative bleeding occurs, avoid panic and blind clamping, absorb the blood quickly (with double suction) to allow identification of anatomical structures, then rapidly separate and clip the aneurysm.

It is generally believed that the risk of intraoperative aneurysm rupture is higher during early surgery than during late surgery, because of higher intracranial pressure, significant cerebral edema, traction of the brain tissue, and the vulnerable tissue of the ruptured aneurysm. Once an intraoperative rupture occurs, surgical exposure becomes difficult and the surgeon is often lead into a passive situation. In this study, 20% of patients in the early surgery group had intraoperative rupture. This percentage is higher than that of the late surgery group. However, the rates of disability, mortality, and complications were lower in the early surgery group, and patient rehabilitation was ideal. The risk of aneurysm rupture is present at all stages of surgery; however, gentle microsurgical manipulations by skilled neurosurgeons can minimize the risk of rupture and bleeding.

It has been noted that in cases of aneurysmal SAH, the therapeutic effect of surgery is not determined by the occurrence of re-rupture during the procedure; rather, it is determined by the experience and skills of the personnel who are treating the patients. It is believed that the substantial risk of re-bleeding and the difficulties experienced during early surgery in patients with a ruptured aneurysm should not be obstacles that lead to neglect of a treatment that may yield a superior outcome. In this study, we lost the opportunity to treat 3 patients, because they died from re-bleeding and cerebral vasospasm while waiting for surgical treatment. Although surgeries performed later may be less difficult, the condition of a considerable number of patients may deteriorate prior to surgery, and some may even die because of re-bleeding, resulting in lost opportunities for treatment.

Whether the timing of surgery effects a patient's prognosis has been debated (13). Some studies found no statistical difference of effectiveness between removal of the aneurysm within 3 days or within 14 days (6). The controversy over the timing of surgery has mainly stemmed from the occurrence of severe cerebral vasospasm secondary to SAH, because early surgery can reduce the risk of re-bleeding but cannot prevent cerebral vasospasm. Vasospasm is one of the most important prognostic factors for SAH. Its severity is not necessarily associated with the aneurysm site, bleeding time, or the amount of blood lost (16), and its occurrence cannot be predicted. Treatment includes early drainage of CSF and extensive, timely application of antivasospasm agents. In our experience, vasospasms are temporary and controllable as long as the surgeon pays great attention to detail. Therefore, when treating SAH caused by an intracranial aneurysm, there is no need to pay attention to the time window of intervention. Early surgery should be carried out as soon as the patient's condition allows. In fact, a recent study (5) has determined that early intervention reduces re-bleeding and control vasospasm, thus significantly improving a patient's long-term survival. Early treatment of an aneurysm is the most effective means to prevent re-bleeding and "triple-H" (hypertension, hypervolemia, and hemodilution). Acute hydrocephalus causes significant neurological impairment, accelerates the progression of the disease, and can even cause death. Therefore, timely treatment is imperative to reduce these events. Komotar and colleagues (9) demonstrated that in cases of hydrocephalus following aneurysmal SAH, microsurgical fenestration of the lamina terminalis during surgical clipping could reduce the rate of shunt placement by more than 80%. In addition, this procedure also reduced the amount of blood in the subarachnoid space, improved the circulation of CSF around the circle of Willis, and reduced the incidence of delayed vasospasm.

There are several limitations to this study. There is a lack of prospective randomized investigations and the time of follow-up results is short. In addition, the subarachnoid hemorrhage and severity of hydrocephalus was not quantified, and patient number in this study is low. In future studies, a larger prospective study with increased patient number and longer follow-up results will be included to verify this study.

In conclusion, when acute hydrocephalus occurs shortly after aneurysmal SAH, early surgical clipping of the ruptured aneurysm can reduce hydrocephalus and the accumulation of blood in the subarachnoid space, lower intracranial pressure, eliminate the risk of re-rupture, and reduce cerebral vasospasms. Timely prevention and treatment of the 3 major complications of a ruptured aneurysm may help to improve the prognosis. Early intervention to treat hydrocephalus is important to reduce disability and achieve comprehensive rehabilitation, and is of significance in the treatment of SAH. Therefore, patients with all grades of aneurysmal SAH and acute hydrocephalus should be diagnosed early and receive surgical treatment promptly.

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