Causes of Death in a Consecutive Series of 390 Surgically Treated Ruptured Intracranial Aneurysms

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Summary: *Objective:* To identify the main causes of death in a contemporary series of surgically treated patients with subarachnoid hemorrhage (SAH) and angiographically proven aneurysm. *Methods:* Since August 1989, 390 patients with aneurysmal SAH underwent surgery. Early surgery within 72 hours was possible in 309 patients, who had been admitted in time. In all patients, the outcome was assessed at discharge and after six months. Cases with a fatal outcome were studied in detail with respect to the clinical state pre- and postoperatively, the incidence of cerebral vasospasm as measured by transcranial Doppler sonography (TCD), and the postoperative neuroradiological investigations to identify the cause of death. *Results:* Thirty-three of the 390 surgically treated patients died during the follow-up period of six months, accounting for a post-operative mortality rate of 8.4%. The main cause of death was the effect of the initial hemorrhage in 18 patients (4.6%), followed by surgical complications in 6 patients (1.5%), vasospasm in 4 patients (1%), and medical complication in 4 patients (1%). In one patient, the available records did not allow to identify the cause of death. *Conclusion:* In the past two decades, re-rupture and vasospasm had been the leading causes of death in patients with aneurysmal SAH. Today, the effect of the hemorrhage is the main reason for a fatal outcome, which could be explained by the current policy to perform early surgery in good- as well as in poor-grade patients.

Key words:

- aneurysm
- mortality
- cerebral vasospasm
- clinical grade
- re-rupture
- early surgery

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Introduction

Still in the 1960s, postoperative mortality rates between 28% and 53% raised the question if aneurysm surgery is of benefit at all.¹⁸⁾²⁵⁾ In the 1970s, the main cause of death among hospitalized patients with aneurysmal SAH was the re-hemorrhage, which could be explained by the management policy to delay the operation to the 11th to 14th day.⁵⁾¹⁹⁾ The concept of delayed surgery was abandoned at the beginning of the 1980s, and early surgery within the first 72 hours post-SAH became the procedure of choice in good-grade patients.¹⁾⁷⁾¹⁷⁾¹⁹⁾ In this decade, cerebral vasospasm was identified as the major cause of poor and lethal outcome.¹²⁾¹⁴⁾ New drugs for intravenous as well

as intrathecal use and endovascular techniques have been developed recently for prevention and treatment of cerebral vasospasm.¹⁾³⁾⁶⁾⁸⁾ Furthermore, the concept of early surgery, which was limited to good-grade patients in the 1980s, has been extended to poor-grade patients.¹⁵⁾²¹⁾²⁴⁾ We analyzed the fatal cases of a consecutive series of 390 patients with surgically managed ruptured aneurysms to identify the predominant causes of death in the times of these new developments.

Patients and Methods

Patients

Between August 1989 and August 1996, 422 patients with a proven, ruptured intracranial aneurysm came to

Table 1 Summary of the demographic data

No. of patients	390
Age (range)	16–80 years
Gender (M/F)	134/256
No. of aneurysms	
-single	310
-multiple	80

Table 2 Clinical grade (according Hunt/Hess, 10) at admission and timing of surgery

	Hunt/Hess grade					total
	I	II	III	IV	V	
No. of cases	68	104	122	60	36	390
Early surgery	35	90	101	51	32	309 (79.2%)
Late surgery ¹	33	14	21	9	4	81 (20.8%)

¹delay of the operation predominantly because of delayed referral (72 patients, 18.5%)

admission. Thirty-two patients were not considered to be surgical candidates because of signs of severe brain stem damage on arrival, or poor Hunt/Hess grade¹⁰⁾ in association with life-limiting internal diseases and advanced age. The remaining 390 patients underwent aneurysm clipping. There were 134 men and 256 women, and the age ranged between 16 and 80 years. Multiple aneurysms were found in 80 of the 390 patients (20.5%). Ninety-six of the 390 patients (24.6%) came to admission in Hunt/Hess grade IV or V. A summary of the demographic data and the clinical state at admission of these patients is given in the **Tables 1 and 2**.

Management protocol

All patients in Hunt/Hess grades I to IV, if admitted in time, were subjected to early surgery within 72 hours after SAH. Poor grade patients demonstrating aneurysmal intracerebral hematoma underwent immediate surgery. Poor grade patients with severe ventricular enlargement initially were treated by ventriculostomy, and, if improving neurologically, by early operation. Late operation was performed in patients in Hunt/Hess grade V without neurological improvement following external CSF drainage. Early operation was performed in 309 of the 390 patients (79.2%). The remaining 81 patients (20.8%) underwent delayed operation. In 72 of the 81 patients (18.5%), delayed referral did not allow early surgery. Intraoperatively, the surgical field was rinsed with nimodipine solution. The intraoperative Doppler sonography was routinely used to evaluate the patency of the vessels following clip placement. All patients received nimodipine intravenously for 14

Table 3 Causes of death

Cause	No.	%
Initial SAH	18	4.6%
Surgical complications	6	1.5%
-premature rupture	1	
-occlusion of perforating artery	5	
Vasospasm	4	1%
Medical complications	4	1%
Unknown	1	0.3%
Post-operative mortality	33	8.4%

days, and underwent daily transcranial Doppler (TCD) investigations for early detection of cerebral vasospasm.

In cases of proven vasospasm, hypertension, hypervolemia, and hemodilution (triple-H therapy) was initiated. Patients with a significant amount of intraventricular blood received recombinant-tissue plasminogen activator (rt-PA) via an external ventricular catheter. Intracisternal rt-PA was not given, and angioplasty was not performed. The outcome of all patients was assessed at discharge from the hospital and after six months using the Glasgow Outcome Scale (GOS).¹¹⁾

Results

Thirty-three of the 390 surgically treated patients died during the follow-up period of six months, accounting for a post-operative mortality rate of 8.4%. In 18 patients, the death was caused by the severity of the hemorrhage alone or by the severity of the SAH and medical complications (4.6%). Medical complications (sepsis, esophageal bleeding, ileus and renal failure, pneumonia and renal failure) alone led to death in 4 patients (1%).

The death of 6 patients was believed to be related to surgery, because their clinical state deteriorated immediately after the operation (1.5%). In five patients, ischemia due to inadvertent clip occlusion of perforating arteries was believed to be the cause of death. In one patient, premature rupture before the visualization of the aneurysm occurred. The prolonged temporary clipping of the parent vessel, which was necessary to control the bleeding, caused a space-occupying and finally lethal cerebral infarction. Four patients developed severe cerebral vasospasm and subsequent lethal cerebral infarctions in spite of adequate triple-H-therapy (1%). In one patient, the cause of death remained unclear (**Table 3**).

Discussion

Postoperative mortality

Since 1989, surgery was performed in 390 patients

with aneurysmal SAH. Thirty-three of the 390 patients died during the follow-up period of six months, accounting for a postoperative mortality rate of 8.4%. The postoperative mortality rates in most studies of similar design (early surgery, inclusion of poor-grade patients) was slightly higher, but mortality rates as low as 5.4% have also been reported.⁷⁾¹⁴⁾¹⁷⁾²⁰⁾²³⁾ Smaller numbers of poor-grade patients and follow-up periods limited to the hospital stay might explain these good results. In an additional three patients (0.7%), fatal re-rupture occurred before the scheduled operation on the next day.

Causes of Death: Vasospasm

By the introduction of early aneurysm surgery at the beginning of the 1980s, the risk of fatal re-rupture had been reduced significantly, but the problem of endangering cerebral vasospasm remained largely unsolved. Cerebral vasospasm was considered to be the most important cause of death or disability after operation for ruptured aneurysms.¹²⁾¹⁴⁾¹⁶⁾ The introduction of nimodipine for prophylaxis,³⁾⁸⁾ daily transcranial Doppler (TCD) sonography for early detection⁹⁾ and induced hypertension, hypervolemia and hemodilution (triple-H therapy) for treatment¹³⁾ reduced the mortality related to cerebral vasospasm to rates between 3.3% and 7.8% at the end of the last decade.⁴⁾²²⁾ We routinely irrigated the surgical field with nimodipine, administered nimodipine intravenously for 14 days, performed daily TCD investigations and began with the triple-H therapy in all cases with Doppler sonographical flow velocities exceeding 120 cm/sec. Fatal vasospasm occurred in only 1% of our cases, which underlines the efficacy of the already available antiischemic therapies. Additional investigations are required to evaluate, if intracisternal application of recombinant tissue plasminogen activator (rt-PA), endovascular dilatation of vasospastic arteries, and intraarterial papaverin injections could contribute to a further reduction of the vasospasm-associated mortality rate.

Causes of death: Surgery

By the introduction of the operating microscope and the development of removable clips, the rate of fatal surgical complications could be reduced significantly since the 1960s. Even in early surgery, which had been considered to be technically more challenging because of the swollen, vulnerable brain, the incidence of fatal surgical complications did not exceed 4% in most larger series⁷⁾¹⁴⁾¹⁶⁾ In our series, six of the 390 surgically treated patients deteriorated immediately after surgery and finally died, accounting for a surgical mortality rate of 1.5%. In

five patients, ischemia due to inadvertent clip occlusion of perforating arteries was believed to be the cause of death. In spite of the routine use of intraoperative Doppler sonography, we failed to recognize this perforator occlusion. Recently, similar experiences had been reported by Bailes and coworkers.²⁾ Somatosensory evoked potentials are of value to detect major vessel occlusion, but small vessel occlusion could still remain undetected.²⁾ It seems, that a further reduction of the incidence of fatal surgical complications can hardly be achieved with the present day technical armamentarium.

Causes of death: Severity of SAH

In the present study of 390 surgically treated patients, 18 patients with severe SAH in a poor clinical state did not survive the bleeding in spite of aggressive surgical therapy accounting for an SAH-related mortality rate of 4.6%. In our series, the severity of the initial SAH alone or in conjunction with complicating internal disease replaced re-rupture and vasospasm, which contributed most to fatal outcomes in the last two decades, as the main cause of death. Similar results have recently been published by LeRoux *et al.* and Spetzger *et al.*¹⁵⁾²⁴⁾ At the beginning of the 1990s, the management policy of poor-grade aneurysms changed, and an increasing number of neurosurgeons did not exclude patients in Hunt/Hess grade IV or V any longer from early surgery, which could explain that the severity of the initial SAH became the main cause of death at least in series with a high percentage of poor-grade patients.

Summary

The main cause of death in our series of surgically treated patients with aneurysmal SAH was the traumatization of the brain by the initial bleeding, followed by surgical complications, medical complications and vasospasm. Fatal re-rupture of the aneurysm was a less frequent cause of death among our hospitalized patients with aneurysmal SAH. Because of the rare occurrence of lethal surgical complications and fatal vasospasm, improvements in the treatment of vasospasm and operative techniques only could contribute insignificantly to a further reduction of the postoperative mortality rate. Substantial reduction of the postoperative mortality seems only be possible by refraining from surgery in those patients with severe SAH, who will not benefit from the operation, but reliable indicators of lethal outcome are lacking in most instances.

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