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Timing of Aneurysm Surgery

Comparison of Results of Early and Delayed Surgical Intervention

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Summary. In a retrospective study covering a period of 8 years and 403 surgically treated patients the results of microsurgical aneurysm treatment were compared between two groups. One group received surgical treatment within 72 h and the second were treated surgically after this time interval. The data indicated that patients receiving delayed surgery had a better outcome at 6 months as compared to patients receiving immediate surgical intervention. The location of the aneurysm and the preoperative neurological status imparted the most significant impact on the subsequent outcome and on the incidence of rebleeding. High risk patients with poor neurological status on admission seemed to have a considerable chance of gaining satisfactory functional recovery, especially with a more delayed surgical approach. Despite its superior results delayed surgery was burdened with a rebleeding rate and an incidence of ischemic deficits due to cerebral vasospasm twice as high as in patients receiving early surgery. The implications of these results on surgical timing are discussed and it is concluded that despite the fact that late surgery yields better results than early surgery, the considerable reduction of recurrent hemorrhage and additional possibility of aggressive treatment of incipient vasospasm makes early surgery a promising alternative for the treatment of patients with aneurysmal subarachnoid hemorrhage.

Key words: Subarachnoid hemorrhage – Aneurysm rupture – Early surgery – Delayed surgery

Introduction

The timing of aneurysm surgery remains a major topic of controversy among neurosurgeons. The advent of microneurosurgical techniques, sophisticated neuroradiological methods, and improvement in neuroanesthesiology, especially in pre- and postoperative monitoring has contributed to a significant decrease in the perioperative morbidity and mortality [5, 19, 21, 22, 37, 39, 40, 41, 42]. Despite these advances in operative management which have led to mortality rates below 5% in the hands of experienced neurosurgeons, the overall morbidity and mortality as a result of subarachnoid hemorrhage (SAH) remains high [4, 5, 22, 24, 33]. Only about 30% of patients suffering from SAH return to their premorbid state of health. A high percentage of morbidity and mortality in cases of intracranial aneurysm rupture is due to preoperative rebleeding and the occurrence of cerebral vasospasm with subsequent neurological deterioration [3, 4, 6, 7, 16, 26, 35, 36, 37].

It has been suggested that early aneurysm surgery within 72 h is preferable to late surgery because of the definitive prevention of recurrent hemorrhage and the additional possibility of aggressive treatment of incipient vasospasm [32, 36, 37, 41]. Late surgery on the other hand has been advocated as it allows patient recovery from the initial trauma of SAH by delaying surgery until it can be performed with only minimal injury to the brain. Outstanding operative results of microsurgical treatment of aneurysms have been achieved primarily by neurosurgeons performing late or elective surgery. However, their undoubtedly admirable results do not necessarily represent the daily problems of the experienced neurosurgeon in a community or university hospital. He/she is primarily concerned with the management of patients with SAH often delivered as emergency cases by ambulance or helicopter transport in all kinds of clinical grades.

The aim of this retrospective study was to present the surgical results of a clinical investigation comparing early versus delayed surgery in a university hospital with a major neurosurgical service and a 24-h emergency admittance service. This study was not performed as an epidemiological survey concerning the overall management of patients with SAH as this had been thorougly done by recent investigators [5, 20] but to analyze the results of surgery in two defined groups of patients assigned to different intervals of surgical intervention. The study covered a period of 8 years and 403 surgically treated patients.

Table 1. Clinical grading scale of aneurysm patients according to Hunt and Hess [18]

Grade 1:	asymptomatic, or minimal headache, and slight nuchal rigidity
Grade 2:	moderate to severe headache, nuchal rigidity, no neurological deficit other than cranial nerve palsy
Grade 3:	drowsiness, confusion, or mild focal deficit
Grade 4:	stupor, moderate to severe hemiparesis, possibly early decerebrate rigidity, and vegetative disturbances
Grade 5:	deep coma, decerebrate rigidity, moribund appearance

Clinical Material and Results

Between January 1979 and December 1986 526 patients with clinically suspected SAH were admitted to our clinic. As of 1979 it was our policy to accept all patients with typical neurological signs of SAH and clinical grade I–III Hunt and Hess [18], (Table 1). Policy concerning patients with grades IV and V has changed recently because of increasing experience with this patient group. Two major reasons have led to the change in our previous regimen which consisted of rejecting these patients until they had reached a more promising preoperative clinical grade. On one hand, a considerable percentage of referred patients were not in the prediagnosed semicomatose or comatose state upon arrival. This was probably because in many referring hospitals a lack of trained neurologists meant a thorough neurological examination was not made often resulting in false clinical grading with consecutive delay in patient referral [25]. On the other hand the admittance of these high risk patients to a neurosurgical intensive care unit as soon as possible offers some definitive advantages. The use of advanced neuroradiological techniques and neuromonitoring e.g., intracranial pressure recording and intraventricular drainage as well as the possibility of immediate surgical intervention in cases of complications (hydrocephalus, intracerebral hemorrhage) substantially improves their prognosis while awaiting surgery.

Following admission and neurological examination all patients were graded according to the criteria of Hunt and Hess [18]. A computerized tomography (CT) scan was performed followed by four-vessel angiography in all patients grade I–III. In 81 patients no vascular malformation could be found. The outcome of this group has been presented in part previously [14]. In 22 comatose patients who presented with decerebrate rigidity and additional intraventricular bleeding ventricular drainage alone was performed. In all of these cases the outcome was fatal.

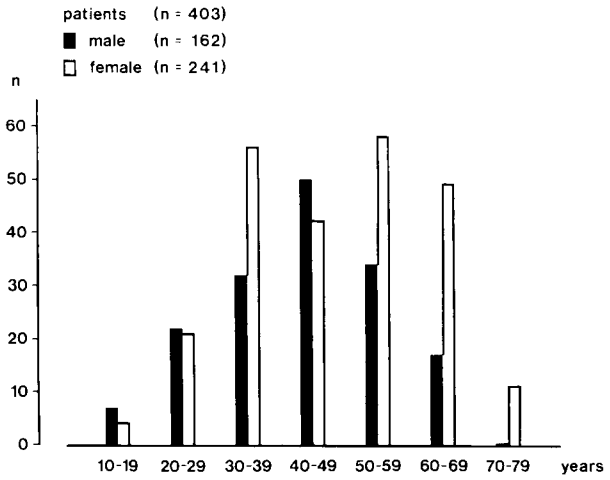

Fig. 1. Age and sex distribution of 403 patients with intracranial aneurysm treated by surgery

In 20 further patients the operation was delayed because of angiographic evidence of severe cerebral vasospasm. Of these patients, 12 cases proved fatal because of ischemic infarction and uncontrollable brain swelling, 6 deaths could be attributed to recurrent bleeding, and 2 patients survived in a vegetative state.

Of the 526 patients admitted with the diagnosis of SAH 403 patients had definitive treatment of their aneurysms. All patients underwent surgery using standard microneurosurgical techniques with clipping of the aneurysm. No wrapping or coating techniques were used. Surgery was performed under neuroleptic anesthesia. Intraoperative hypotension was occassionally found necessary during the final stage of dissection of the aneurysm. The age and sex distribution of the 241 women and 162 men is presented in Fig. 1. A total of 182 patients (45.2%) were operated upon within 72 h following SAH, and 221 patients (54.8%) underwent aneurysm clipping after the 3rd day. In all patients occlusion of the aneurysm was confirmed by

Table 2. Glagow Outcome Scale according to Jennett and Bond [20]

Grade 1.	
Good recovery:	patient can lead a full and independent life with or without minimal neurological deficit
Grade 2.	
Moderately disabled:	patient having neurological or intellectual impairment but is independent
Grade 3.	
Severely disabled:	consciuos patient but totally dependent on others to get through the activities of the day
Grade 4.	
Vegetative survival	
Grade 5.	
Dead	

control angiography between 3 and 8 weeks postoperatively. All surviving patients were reexamined after a minimum interval of 6 months following surgery according to the guidelines of the Cooperative Aneurysm Study using the criteria of the Glasgow Outcome Scale [20], (Table 2). Operative outcome in both groups with regard to the location of the aneurysm is demonstrated in Table 3a and b. In both groups receiving early and delayed surgery[1] the anterior cerebral artery represented the most common location of aneurysm at 35.7% (33.4%). This was followed by the internal carotid artery at 33.0% (25.7%) and the middle cerebral artery, 22.5% (23.5%). Only 1 aneurysm of the posterior circulation was operated on within 72 h corresponding to 1.1%, whereas these aneurysms comprised 7.2% of the late surgery group. Of the patients with multiple aneurysms (7.6%) were operated on early, and 22 (9.9%) were subjected to late surgery.

Patients with aneurysms of the carotid artery undergoing early surgery showed the best postoperative outcome with 73.3% good recovery or mild neurological deficit. This was followed by middle cerebral artery aneurysms with 70.7% and anterior cerebral artery aneurysms with a lower percentage of satisfactory outcome of 61.5%. Moreover, as the percentages of severely disabled and fatal cases were almost comparable among patients suffering from aneurysms of the carotid artery with 26.7% and the middle cerebral artery with 29.4% respectively, the outcome of patients with aneurysms of the anterior cerebral artery following early surgery with 38.5% disabled or fatal cases was definitely worse. The patient suffering from the posterior circulation aneurysm who underwent early surgery showed a good recovery. Early surgery in multiple aneurysms was followed by a good outcome in 50% of cases. In the group undergoing late surgery no difference in post-

[1] Results of delayed surgery in parenthesis

Table 3a. Location of aneurysm and postoperative outcome in 182 patients undergoing early surgery

	n	Good recovery	Disabled		Vegetative survival or fatal outcome
			Moderately	Severely	
Internal carotid artery	60 (9)	37 (2)	7 (3)	9 (2)	7 (2)
Middle cerebral artery	41 (6)	25 (4)	4	4 (1)	8 (1)
Anterior cerebral artery	65 (5)	33 (2)	7	7 (1)	18 (2)
Posterior circulation	2	1	–	1	–
Multiple aneurysms	14 (2)	6 (2)	1	–	7
Summary	182 (22)	102 (10)	19 (3)	21 (4)	40 (5)

( ) Recurrent hemorrhage

Table 3b. Location of aneurysm and postoperative outcome in 221 patients undergoing delayed surgery

	n	Good recovery	Disabled		Vegetative survival or fatal outcome
			Moderately	Severely	
Internal carotid artery	57 (17)	37 (9)	4 (1)	2	14 (7)
Middle cerebral artery	52 (13)	36 (5)	2	3 (2)	11 (6)
Anterior cerebral artery	74 (15)	52 (7)	6 (3)	3	13 (4)
Posterior circulation	16 (3)	12			4 (3)
Multiple aneurysms	22 (6)	12 (2)	5 (2)	1 (1)	4 (1)
Summary	221 (54)	149	17	9	46

( ) Recurrent hemorrhage

Table 4a. Preoperative grading and postoperative outcome in 182 patients undergoing early surgery

	n	Good recovery	Disabled		Vegetative survival or fatal outcome
			Moderately	Severely	
I	47 (7)	32 (5)	5 (1)	5 (1)	5
II	44 (2)	29	3 (1)	5 (1)	7
III	58 (2)	32 (1)	8	4	14 (1)
IV	20 (7)	6 (3)	2	6 (2)	6 (1)
V	13 (3)	3 (1)	1 (1)	1	8 (1)
Summary	182	102	19	21	40

( ) Recurrent hemorrhage

Table 4b. Preoperative grading and postoperative outcome in 221 patients undergoing delayed surgery

	n	Good recovery	Disabled		Vegetative survival or fatal outcome
			Moderately	Severely	
I	95 (14)	83 (11)	4	2 (1)	6 (2)
II	47 (8)	30 (2)	3 (2)	4	10 (4)
III	40 (12)	20 (6)	7 (2)	1	12 (4)
IV	29 (14)	13 (3)	3 (2)	2 (2)	11 (7)
V	10 (6)	3 (1)	—	—	7 (5)
Summary	221 (54)	149 (23)	17 (6)	9 (3)	46 (22)

( ) Recurrent hemorrhage

operative outcome in the above-mentioned locations was demonstrated. The percentage of patients in postoperative grades I and II with aneurysms of the carotid artery (71.7%) and middle cerebral artery (73.0%) as well as the percentage of severely disabled and deceased patients in these two locations were comparable. Aneurysms of the anterior cerebral artery fared better with 78.3% of the patients reaching a satisfactory postoperative state and 21.7% with disappointing results. The rate of 75.0% and 77.2% good postoperative outcome was almost the same in patients suffering from aneurysms of the posterior circulation as in those with multiple aneurysms.

As expected the rate of rebleeding was strikingly different between the two groups of early and delayed surgery. In all cases recurrent hemorrhage was confirmed by CT following the clinical suspicion that a rebleeding had occurred with a new onset of sudden and severe headache or rapid neurological deterioration of the patient. The overall rate of recurrent hemorrhage was 12.1% in the early group whereas the percentage increased to 24.4% in patients undergoing late surgery. In the group receiving surgery aneurysms of the carotid artery and the middle cerebral artery had a comparable rate of rebleeding with 15% and 14.6% respectively. The incidence of recurrent hemorrhage was substantially less frequent in anterior cerebral artery aneurysms with only 7.7%. It should be noted that patients with multiple aneurysms also had a considerable rebleeding rate. Although the overall rate of recurrent hemorrhage was higher a similar ratio concerning the incidence of rebleeding between the different locations was also demonstrated for patients undergoing delayed surgery. The rate of rebleeding was 29.8% for carotid artery aneurysms, 25% for middle cerebral artery aneurysms, and 20.3% for aneurysms of the anterior cerebral artery.

This study supports the fact that the preoperative neurological status of the patient with SAH determined to a large extent the postoperative outcome as shown in Table 4a and b. Of the patients undergoing early surgery, 50% were preoperatively classified as grades I and II, 31.8% were grade III, whereas 18.1% were grades IV and V. This compared to 64.3%, 18.1% and 17.6% in the late surgery group. Of 91 patients with preoperative grades I and II 69 (75.0%) experienced a good recovery following early surgery compared to 120 (84.5%) of 142 late surgery patients. Grade III patients had a satisfactory outcome in 68.9% and 67.5% respectively. Furthermore, grades IV and V patients showed good chances of a satisfactory postoperative outcome with 36.3% good or slightly disabled patients undergoing early surgery and 48.7% in the late surgery group. However, the rate of rebleeding was 7.4% in patients with grade I to III undergoing early surgery and 18.7% in

patients undergoing late surgery. In patients with grades IV and V the percentage of recurrent hemorrhage was even more pronounced with 30% rebleeding in the group undergoing early surgery versus 51.3% in the late surgery group.

Discussion

Rebleeding and cerebral vasospasm are responsible for approximately 75% of the morbidity and mortality of aneurysm patients admitted for neurosurgical treatment [3, 4, 5, 16, 24, 26]. It has been postulated that early surgery might be a promising approach for the prevention of these two devastating complications. Clipping of the ruptured aneurysm is the only method for definitive prevention of recurrent hemorrhage. Moreover, elimination of the aneurysm from the cerebral circulation represents an inevitable prerequisite for the most effective treatment of cerebral vasospasm to date which consists of induced hypertension and hypervolemia [12, 23, 28, 34]. Additionally, evacuation of subarachnoid blood clots during early surgery may inhibit the development of vasospasm by reducing the amount of spasmogenic substances which are thought to be released during posthemorrhagic clot lysis in the basal cisterns [4, 15, 27, 32, 35, 36].

Strong arguments against early operative intervention do however exist. Early surgery, despite the use of atraumatic microsurgical methods, unquestionably represents an additional insult to the brain already injured by the SAH, thus increasing the surgical risk. In contrast, dissection of the aneurysm may prove to be substantially easier some weeks after the hemorrhage due to the slackness of the brain which results in the reduced need for retraction during surgery. Furthermore, sealing of the leak of the aneurysm can be expected 2 or 3 weeks after the SAH minimizing the risk of a premature rupture during the surgical procedure.

However, accumulating data from several authors suggesting a possible advantage of early surgery supported the change in our policy towards aneurysm treatment which prior to 1979 consisted of delaying surgery up to several weeks after the SAH. Since 1979 the percentage of patients undergoing early surgery has gradually increased and in 1986 reached 68%. Gaining more experience we now believe that the difficulties of early surgery which have traditionally been feared by many neurosurgeons can be overcome with the advent of modern neuroanesthesiological methods, deliberate intraoperative drainage of CSF, and the routine use of microsurgical techniques. When our data are analyzed in terms of

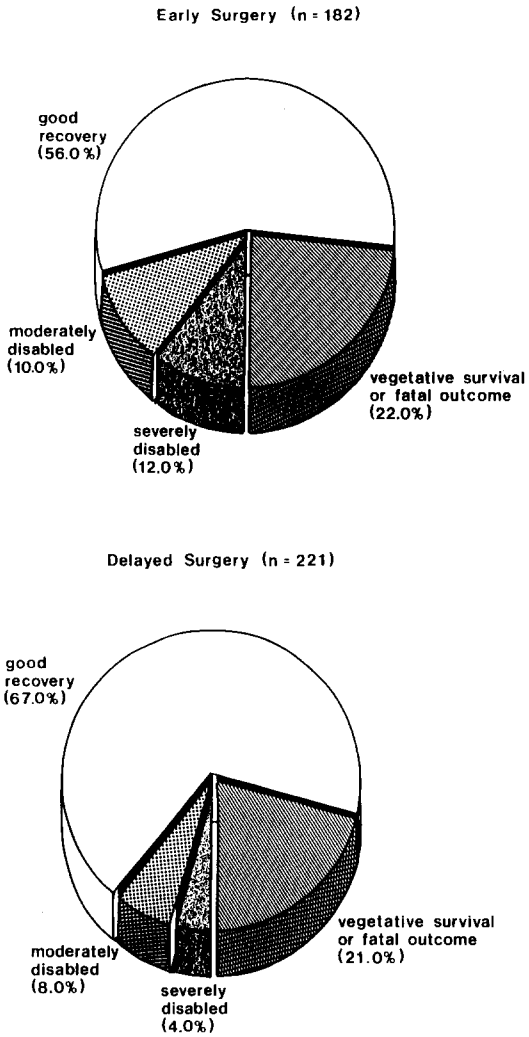

Fig. 2. Comparison of results between two groups of patients undergoing early ($n = 182$ patients) and delayed ($n = 221$ patients) surgical intervention

early and delayed intervention the outcome 6 months postoperatively indicates that late surgery had a better outcome than early surgery with more patients having a good recovery and less patients suffering fatal outcome or vegetative survival in the late surgery group (Fig. 2).

However entailed within these data are some important points which must be taken into consideration. The overall rate of rebleeding was twice as high in patients undergoing late surgery. Patients in preoperative grade I to III had a rebleeding rate of 18.7% in the late surgery group versus 7.4% in the group undergoing early surgery. This was even more the case in the high risk group. Of these patients in grades IV and V who according to our data had a considerable chance of gaining functional recovery even after a poor initial clinical status, 30.3% of those operated on early had suffered a recurrent

hemorrhage compared to 51.3% of the patients undergoing late surgery. Moreover, of 14 cases in the early surgery group with a fatal outcome or vegetative survival who were preoperatively in grades IV and V only 2 (14.2%) experienced rebleeding in contrast to 11 (61.1%) of 17 patients in the late surgery group.

Analyzing our results with regard to location of the aneurysm it is obvious that in both groups of early and delayed operative intervention surgery led to a comparable percentage of satisfactory results in patients with carotid artery and middle cerebral artery aneurysms. However, the outcome of aneurysms of the anterior cerebral artery was definitely worse in patients undergoing early surgery as compared to those experiencing delayed operation. this may reflect the difficult anatomical location of these aneurysms with close proximity to vital diencephalic structures and the danger of injury to small perforating vessels especially under the circumstances of acute SAH. In our experience these aneurysms seem to have a lower risk of recurrent hemorrhage as compared to other aneurysmal locations at the anterior circle of Willis.

The detection of cerebral vasospasm without the use of cerebral angiography which represents a considerable hazard to the patient with SAH is difficult to assess [2, 7]. The diagnosis of vasospasm is uncertain using clinical criteria alone [9, 19, 25]. Although the predictive value of CT for the development of vasospasm is well-established [8, 10, 12, 17, 20, 30], demonstration of hypodense areas on a CT scan may only serve as retrospective evidence of severe cerebral ischemia due to the possible occurrence of vasospasm. Transcranial Doppler seems to hold some promise for the bed-side evaluation of vasospasm [1, 38] but was not available during most of the course of this study. Based on occasional repeated angiograms, clinical diagnosis, and CT criteria, the occurrence of cerebral vasospasm was 30% in the late surgery group which was reduced to about 15% in the group undergoing early surgery. As no systematically pharmacological prevention or treatment of cerebral vasospasm was undertaken until 1986 we believe that this reduction was mainly achieved by extensive clot evacuation and postoperative volume loading and induced hypertension.

From the analysis of our data a definitive answer concerning the superiority of early or delayed surgery for the treatment of ruptured aneurysms cannot be given, a fact which is consistent with the results of the recently completed Cooperative Aneurysm Study [11]. In fact early surgery was not as convincing as we had initially thought whereas delayed surgery led to even better results than expected, even when the relatively small number of patients in whom surgery was delayed because of their bad neurological status or angiographic vasospasm and who died or became vegetative during the waiting period were added to the late surgery group. Despite the result that the anticipated strong trend in favor of early surgery was not demonstrable the efficacy of early surgery in preventing recurrent hemorrhage and allowing aggressive treatment of incipient vasospasm make it a useful alternative for the management of patients with aneurysmal SAH depending on the judgement of the individual neurosurgeon.

References

1. Aaslid R, Huber P, Nornes H (1984) Evaluation of cerebrovascular spasm with transcranial Doppler ultrasound. J Neurosurg 60:37–41
2. Adams ChBT, Fearnside MR, O'Laoire S (1978) An investigation with serial angiography into the evolution of cerebral arterial spasm following aneurysm surgery. J Neurosurg 49:805–815
3. Allen GS (1984) Cerebral arterial spasm. Clin Neurosurg 32:70–78
4. Ausmann JI, Diaz FG, Malik GM, Fielding AS, Son Ch S (1985) Current management of cerebral aneurysm: Is it based on facts or myths. Surg Neurol 24:625–635
5. Bonita R, Thomson S (1985) Subarachnoidal hemorrhage: Epidemiology, diagnosis, management and outcome. Stroke 16:591–594
6. Chyatte D, Sundt Th M (1984) Cerebral vasospasm after subarachnoid hemorrhage. Mayo Clin Proc 59:498–503
7. Cooper PR, Shucart WA, Tenner M, Hussain S (1980) Pre-operative arteriographic spasm and outcome from aneurysm operation. Neurosurgery 7:587–592
8. Eisentrout C, Tomsick TA, Tew JM (1980) Computed tomography findings as prognostic factor in subarachnoid hemorrhage for ruptured aneurysms. Stroke 11:124
9. Fisher CM, Roberson GH, Ojemann RG (1977) Cerebral vasospasm with ruptured saccular aneurysm – the clinical manifestations. Neurosurgery 1:245–248
10. Fisher CM, Kistler JP, Davis JM (1980) Relation of cerebral vasospasm to subarachnoid hemorrhage visualized by computerized tomography scanning. Neurosurgery 6:1–9
11. Flamm ES (1986) The timing of aneurysm surgery 1985. Clin Neurosurg 33:147–158
12. Fraser J, Johnson S, Ray M, Robertson JT (1980) Prediction of cerebral vasospasm with subarachnoid hemorrhage due to ruptured intracranial aneurysm by computed axial tomography. Neurosurgery 6:686–687
13. Gianotta SL, Frazee JG (1980) Treatment of cerebral vasospasm with intravascular volume expansion and induced hypertension. Contemp Neurosurg 2:1–6
14. Haensel-Friedrich G, Friedrich H, Herbold S, Vogelsang H (1985) Subarachnoid hemorrhage with negative panangiogrpahy. In: Auer LM (ed) Timing of aneurysm surgery. Walter de Gruyter, Berlin New York, pp 81–88
15. Hashi K, Aoyama I, Nin K, Shimotake K (1985) Further trial of cisternal clot removal for severe subarachnoid hemorrhage. In: Auer LM (ed) Timing of aneurysm surgery. Walter de Gruyter, Berlin New York, pp 373–380

16. Heros RC, Zervas NT, Varsos V (1983) Cerebral vasospasm after subarachnoid hemorrhage – an update. Ann Neurol 14:599–608
17. Higuchi H, Nagamine Y, Satoh H (1982) Direct operation on intracranial aneurysms within 48 hours of subarachnoid hemorrhage – Correlation between CT findings and vasospasm. In: Brock M (ed) Modern Neurosurgery. Springer, Berlin Heidelberg New York, pp 436–441
18. Hunt WE, Hess RM (1968) Surgical risk as related to time of intervention in the repair of intracranial aneurysms. J Neurosurg 28:14–19
19. Ito Z (1985) Microsurgery of cerebral aneurysms. Elsevier and Nishimura, Amsterdam Niigata
20. Jennett B, Bond M (1975) Assessment of outcome after severe brain damage. Lancet I:480–485
21. Kassell NF, Drake ChB (1978) Review of the management of saccular aneurysms. Neurol Clin 1:73–86
22. Kassell NF, Drake ChG (1982) Timing of aneurysm surgery. Neurosurgery 10:514–519
23. Kassell NF, Peerless SJ, Durward QJ, Beck DW, Drake ChG, Adams HP (1982) Treatment of ischemic effects from vasospasm with intravascular volume expansion and induced arterial hypertension. Neurosurgery 11:337–343
24. Kassell NF, Torner JC (1984) The International Cooperative Study on timing of aneurysm surgery – an update. Stroke 15:566–570
25. Dassell NF, Kongable GL, Torner JC, Adams HP, Mazuz H (1985) Delay in referral of patients with ruptured aneurysms to neurosurgical attention. Stroke 16:587–590
26. Kassell NF, Sasaki T, Colohan ART, Nazar G (1985) Cerebral vasospasm following aneurysmal subarachnoid hemorrhage. Stroke 16:562–572
27. Kawase T, Shiobara T, Toya S, Miyahara Y (1985) Scavengery surgery for subarachnoid hemorrhage (I) – Surgical technique of subarachnoid clot removal. In: Auer LM (ed) Timing of aneurysm surgery. Walter de Gruyter, Berlin New York, pp 357–364
28. Kindt GW, Mcgillicuddy J, Pritz M, Gianotta SL (1980) Hypertension and hypervolemia as therapy for patients with vasospasm. In: Wilkins RH (ed) Cerebral arterial spasm. Williams and Wilkins, Baltimore London, pp 659–664
29. Kistler JP, Crowell RM, Davis UR, Heros R, Ojemann RG, Zervas T, Fisher CM (1983) The relation of cerebral vasospasm to the extent and location of subarachnoid blood visualized by CT scan: A prospective study. Neurology 33:424–436
30. Ljunggren B, Säveland H, Brandt L, Zygmunt St (1985) Early operation and overall outcome in aneurysmal subarachnoid hemorrhage. J Neurosurg 62:547–551
31. Mizukami M, Takemae T, Tazawa T, Kawase T, Matsuzaki T (1980) Value of computed tomography in the prediction of cerebral vasospasm after aneurysm rupture. Neurosurgery 7:583–586
32. Mizukami M, Kawase T, Usami T, Tazawa T (1982) Prevention of vasospasm by early operation with removal of subarachnoid blood. Neurosurgery 10:301–307
33. Phillips LH, Whisnant JP, O'Fallow M, Sundt ThM (1980) The unchanging pattern of subarachnoid hemorrhage in a community. Neurology 30:1034–1041
34. Pritz MB, Gianotta SL, Kindt GW, Mcgillicuddy JE, Prager RL (1978) Treatment of patients with neurological deficits associated with cerebral vasospasm by intravascular volume expansion. Neurosurgery 3:364–368
35. Saito I, Ueda Y, Sano K (1977) Significance of vasospasm in the treatment of ruptured intracranial aneurysms. J Neurosurg 47:412–429
36. Sano K, Saito I (1978) Timing and indication of surgery of ruptured intracranial aneurysms with regard to cerebral vasospasm. Acta Neurochir 41:49–60
37. Sano K (1982) Cerebral vasospasm and aneurysm surgery. Clin Neurosurg 30:13–58
38. Seiler RW, Grolimund P, Aaslid R, Huber P, Nornes H (1986) Cerebral vasospasm evaluated by transcranial ultrasound with clinical grade and CT-visualized subarachnoid hemorrhage. J Neurosurg 64:594–600
39. Sugita K (1985) Microneurosurgical atlas. Springer, Berlin Heidelberg New York Tokyo
40. Sundt TM, Whisnant JP (1978) Subarachnoid hemorrhage from intracranial aneurysms: Surgical management and natural history of disease. N Engl J Med 299:116–122
41. Tanaeda M (1982) Effect of early operation for ruptured aneurysms on prevention of delayed ischemic symptoms. J Neurosurg 57:622–628
42. Yasargil MG (1984) Microneurosurgery II. Clinical considerations, surgery of the intracranial aneurysms and results. Thieme, Stuttgart New York

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