ORIGINAL ARTICLE

Aneurysmal Surgery in the Presence of Angiographic Vasospasm: An Outcome Assessment

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ABSTRACT: ***Background and Purpose:*** The timing of aneurysmal surgery for patients presenting within the period at risk for vasospasm (VS) is controversial. The goal of this study is to review our experience of surgically treated patients in the presence of angiographic VS. ***Materials and Methods:*** From 1990-2004, 894 consecutive patients presented with an aneurysmal subarachnoid hemorrhage (SAH) and were treated with a policy of early surgery. We retrospectively analyzed the patients that had pre-operative angiographic VS. In this study, symptomatic VS was diagnosed when a decreased level of consciousness and/or focal deficit occurred after SAH in the presence of angiographic VS without confounding factors. Functional outcome was assessed three months after SAH using the Glasgow Outcome Scale. ***Results:*** Of the 40 patients studied, 62.5% were in good clinical grade Hunt & Hess (H&H 1-2) on admission; 25%, intermediate grade (H&H 3); 12.5%, poor grade (H&H 4-5). Surgery was performed 24 hours or less after initial angiography in 87.5% of patients and less than 48 hours in 97.5%. Pre-operative symptomatic VS was diagnosed in 25%. Post-operatively, angiographic VS was documented in 87.2%. Of the 30% of patients that presented post-operative symptomatic VS, 66.7% also demonstrated pre-operative symptomatic VS. The functional outcome was favorable in 92.5% of the studied patients. Two deaths occurred in patients presenting pre-operative early radiological and symptomatic VS. ***Conclusion:*** Aneurysmal surgery, especially between 3-12 days following SAH, in the presence of asymptomatic pre-operative angiographic VS can be associated with a good outcome. Early surgery is not contra-indicated and might enable optimal treatment of VS.

RÉSUMÉ: Chirurgie anévrismale en présence de vasospasme angiographique: Analyse du pronostic. ***Contexte et objectif:*** Chez les patients qui consultent pour une hémorragie sous-arachnoïdienne (HSA) due à un anévrisme pendant la période à risque de vasospasme (VS), le moment de la ligature de l'anévrisme demeure controversé. Le but de cette étude est de réviser notre expérience chez des patients traités chirurgicalement en présence de VS angiographique. ***Matériel et Méthode:*** De 1990 à 2004, 894 patients consécutifs ont été admis pour une HSA due à un anévrisme et ont été traité par une chirurgie précoce. Nous avons analysé de façon rétrospective les patients présentant du VS angiographique pré-opératoire. Dans cette étude, un diagnostic de VS symptomatique était posé en présence d'une altération de la conscience ou d'un déficit focal survenant après une HSA en présence de VS angiographique et en l'absence de facteurs confondants. Le pronostic fonctionnel fut évalué selon l'échelle de Glasgow (GOS) 3 mois suivant l'HSA. ***Résultats:*** Parmi les 40 patients étudiés, 62,5% étaient en bon grade clinique de Hunt&Hess (H&H 1-2) à l'admission; 25% en grade intermédiaire (H&H 3); 12,5% en mauvais grade (H&H4-5).La chirurgie était réalisée 24 heures ou moins après l'angiographie initiale chez 87,5% des patients et 48 heures ou moins chez 97,5% des patients.Un VS symptomatique pré-opératoire fut diagnostiqué dans 25% des cas. En post-opératoire, un VS angiographique fut documenté dans 87,2% des cas. Parmi les 30% qui présentaient un vasospasme symptomatique post-opératoire, 66,7% avaient également présenté un VS symptomatique avant la chirurgie. Le pronostic fonctionnel était favorable chez 92,5% des patients étudiés. Deux décès sont survenus chez des patients qui présentaient un VS radiologique et symptomatique précoce. ***Conclusion:*** La ligature d'un anévrisme rompu, particulièrement entre le 3e et 12e jours suivant une HSA, en présence de vasospasme angiographique asymptomatique pré-opératoire, peut être associé à un pronostic favorable. La chirurgie précoce n'est pas contre-indiquée et pourrait favoriser un traitement optimal du VS.

The timing of ruptured aneurysm surgery has been a controversial subject in neurosurgery. Several studies have demonstrated that early surgical treatment after aneurysmal subarachnoid hemorrhage (SAH) is technically feasible[1,2] reduces the risk of rebleeding[1,2] and appears to be associated with improved outcome in particular for patients in good clinical condition on admission.[1,3-5] Some patients, however, delay seeking medical attention, are initially misdiagnosed, or present after a second hemorrhage, and in these patients diagnosis of SAH can come at a time when cerebral vasospasm (VS) is already present.

Some authors expressed their opinion to refrain from operating cerebral aneurysms during the period at risk for VS regardless of the presence or absence of angiographic VS and

others have reported an increased frequency of delayed cerebral ischemia and poor outcome in patients undergoing aneurysm clipping during this period.[2,4,6-9] On the other hand, it has also been argued that immediate aneurysm repair even in the presence of VS is warranted in order to prevent aneurysm rebleeding and to allow for optimal vasospasm treatment, including induced hypertension.[3]

To help inform this controversy, we reviewed our experience with a large series of patients who underwent early surgical aneurysm repair in the presence of angiographic VS.

MATERIAL AND METHODS

Patient population

From 1990 to 2004, 894 consecutive patients were surgically treated for an aneurysmal SAH. During this period, patients with aneurysmal SAH and angiographic VS who underwent surgical treatment at the Centre Hospitalier de l'Université de Montréal were collected for retrospective study. SAH was diagnosed by computed tomography (CT) scan or lumbar puncture. Digital substracted angiography (DSA) was performed soon after arrival to confirm the aneurysmal origin of the hemorrhage and document the presence of VS. Patients were divided in three groups accordingly to delay between SAH and surgery: Group 1: 0 to 2 days; Group 2: 3 to 12 days and Group 3: more than 12 days. Ten patients with VS on initial angiography were excluded because they reported a history suggestive of recent prior bleeding.

Initial management

Patients were admitted to the intensive care unit for close monitoring of neurological and hemodynamic status. Their clinical state was assessed according to the grading system of Hunt and Hess (H&H). A good clinical grade was considered for H&H grades 1-2, an intermediate clinical grade for H&H grade 3 and a poor clinical grade for H&H grades 4-5. Before cerebral angiography, normovolemia was maintained. The systolic arterial pressure was kept between 100-160 mmHg. No hypotensive episode occurred pre-operatively. When required a ventriculostomy was inserted.

Radiological assessment of VS

Complete four-vessel digital substracted angiography with antero-posterior, lateral and oblique views was performed soon after arrival. At our center, all angiographs are analyzed separately by the endovascular and neurosurgical team. Angiographic VS was diagnosed by both teams who followed the same evaluation protocol for evaluation of vessel narrowing. The consensus was noted in the patients' charts. On the initial angiography, the narrowed segment was assessed by comparing it to its proximal and distal vessel component. The spastic segment was also evaluated in relation to the intracranial extradural internal carotid artery diameter on both sides. Angiographic VS was characterized in terms of vessel narrowing by less than 50% or by 50% or more, an established criterion used in many other studies.[10,11] Angiographic VS was also described in terms of distribution - whether VS involved single or multiple arteries. Pre-operative angiographies were compared to post-operative angiographies to evaluate the progression of

VS and exclude normal hypoplastic vessels and arteriosclerotic changes. We qualified post-operative angiographic VS as worsened if vessel narrowing passed from less than 50% narrowing to 50% or more and/or if VS increased its distribution from a single to multiple vessels. Decreased angiographic VS was defined as vessel narrowing passing from 50% or greater to less than 50% and/or if VS restrained its distribution from multiple vessels to a single artery.

Assessment of symptomatic VS and cerebral infarction

Symptomatic VS was defined as the onset of a decreased level of consciousness and/or focal deficit occurring after SAH in the presence of angiographic VS without confounding factors.[12] Symptomatic VS, presenting pre-operatively or post-operatively, was confirmed by cerebral angiography which served diagnostic and therapeutic goals.

Cerebral infarction related to VS was defined as a persistent hypodensity on CT scan occurring in the corresponding vasospastic territory. When cerebral infarction appeared on post-operative CT scan, angiography was done to rule-out post-operative vessel occlusion.

Surgical management

Patients with newly diagnosed aneurysmal SAH were treated with a policy of early surgery, within 48 hours of their admission, regardless of the time elapsed since SAH and the presence of angiographic or symptomatic VS. Surgery was performed more than 48 hours after admission if supplementary imaging was required as for patients of Group 3. Maximum duration of temporary clip usage was assessed by reviewing operative reports. Systolic arterial blood pressure was maintained between 100-120 mmHg during surgery, even at the time of temporary clipping of cerebral vessels. An hypotensive episode was avoided throughout surgery. However, systolic arterial pressure decreased below 90 mmHg for more than five minutes in three patients, of which none developed post-operative symptomatic vasospasm or cerebral infarct. Thorough, gentle irrigation of basal cisterns was routinely done to remove the subarachnoid clot and papaverine was topically applied on the manipulated arteries.

Post-operative management

Post-operatively all patients were admitted to the intensive care unit for close monitoring of neurologic and hemodynamic status. Nimodipine was administered orally 60 mg every four hours in the post-operative period, except in one patient who received intravenous nicardipine. All patients had a central line installed after the induction by the anesthesiologist. However a pulmonary-artery catheter was not systematically used at our center since the routine use of this catheter in non-cardiac surgery is controversial.[13] Also, its usefulness in the context of vasospasm as a guide for maximum hydration, as suggested by Corsten and colleagues, must be validated by further studies.[14,15] Hypervolemic hypertension was induced with a combination of crystalloids and colloids such as human albumin solution. The hematocrit level was measured at admission and daily throughout hospitalization. Since the optimal hematocrit level in ischemia has not been established,[16] the absolute hematocrit

Table 1: Population characteristics

Sex	Male: 14	Female: 26	
Age	Mean: 48.6	Range: 16 to 75	
Hunt & Hess	**Surgical group**		
Grade	**1** (n=12)	**2** (n=25)	**3** (n=3)
1 (n=16)	0	13	1
2 (n=14)	4	6	1
3 (n=13)	3	6	1
4 (n=6)	4	0	0
5 (n=1)	1	0	0

level did not guide hypervolemic therapy adjustment. The mean hematocrit value at admission was 0.417, varying between 0.300 and 0.510 and the lowest level measured during hospitalization was 0.274, varying between 0.200 and 0.385. Pressor agents such as neosynephrine and dopamine, were used in four patients when systolic arterial pressure fell below 120 mmHg in the presence of an optimal hyperdynamic therapy. No hypotensive episode occurred in the post-operative setting. Angioplasty was performed in two patients of Group 2 for severe symptomatic vasospasm manifest in the post-operative period.

Outcome assessment

The functional outcome was assessed three months after surgery using the Glasgow Outcome Scale. The information was collected through chart revision. Good recovery and mild disability were considered as a favorable outcome.

Statistical analysis

The frequency of symptomatic VS and cerebral infarct in the three surgical groups was analyzed using the Fisher exact test. Separate Fisher exact tests were performed for pre-operative and post-operative events. In addition to testing the differences between the three groups, we also tested the difference between Groups 1 and 2, i.e. the two largest groups. The same approach was used to compare the frequency of favorable functional outcome. Significance level was defined as $p \leq 0.05$.

RESULTS

During the study period, 894 consecutive patients were surgically treated for an aneurysmal SAH. Angiographic VS on admission was documented in 50 patients of which ten were excluded because of a history suggestive of a recent prior bleeding. Therefore, 40 patients were retained for the present study. Patients were operated two days or less after SAH onset in 12/40 (30%), between 3 to 12 days in 25/40 (62.5%) and after more than 13 days in 3/40 (7.5%). Patient characteristics are presented in Table 1.

Pre-operative symptomatic VS was diagnosed in 10/40 (25%) of the patients of which two were in Group 1, seven in Group 2, and one in Group 3. Nine of these 10 patients were in good or intermediate clinical grade on admission.

Pre-operative CT showed evidence of SAH in 12/12 (100%) patients of Group 1; in 21/25 (84%) patients of group 2; in 1/3 (33%) patient of group 3. A focal cerebral brain infarct related to VS was present on admission CT scan in two patients of group 2.

The time elapsed between initial angiography and aneurysm clipping as well as the description of pre-operative angiographic VS are presented in Table 2. Aneurysm clipping was performed 24 hours or less after initial angiography in 35/40 (87.5%) patients and 48 hours or less after initial angiography in 39/40 (97.5%). Pre-operative angiographic VS involved most frequently single vessels in Group 1 and multiple vessels in Groups 2 and 3. Vessel narrowing was less than 50% in 21/40 patients (52.5%) of the studied population. Multiple aneurysms were present in 12/40 (30%): four presented bilateral aneurysms and eight ipsilateral aneurysms to the ruptured aneurysm. Of these eight patients, more than one aneurysm was clipped in five patients. Distribution of aneurysm responsible for SAH in regards to location is shown in Table 3. In two cases of multiple aneurysms the exact origin of SAH could not be determined. For these patients both aneurysms were tabulated totaling 42 aneurysms. Aneurysms were small ($\leq$ 1cm) in 38/40 (95%) patients, intermediate size in 1/40 (2.5%), and giant ($\geq$ 2.5cm) in 1/40 (2.5%).

Temporary clipping was noted in the operative reports of 30/40 (75%) patients. The maximum duration of clipping was specified in 15 cases. A favorable outcome was achieved in

Table 2: Description and timing of initial angiography

Description of pre-operative VS			
Characteristic	**Surgical group**		
	1 (n=12)	**2** (n=25)	**3** (n=3)
Distribution			
Single vessel	7	5	0
Multiple vessels	5	20	3
Severity			
Less than 50% narrowing	8	13	0
50% narrowing or more	4	12	3
Delay (in hours) between initial angiography and aneurysm clipping			
[0, 24]	12	21	2
]24, 48]	0	4	0
]48, ∞	0	0	1

Table 3: Location of aneurysms responsible for SAH

Location of aneurysm	No. of aneurysms
ACA[1]	2
AcoA[2]	15
PcoA[3]	8
MCA[4]	14
IC[5]	2
VB[6]	1

[1] ACA: Anterior cerebral artery, [2] AcoA: Anterior communicating artery, [3] PcoA: Posterior communicating artery, [4] MCA: Middle cerebral artery, [5] IC: Internal carotid artery, [6] VB: Vertebro-basilar arteries

12/15 (80%) patients who had temporary clipping for 15 minutes or less.

Post-operative CT scan was performed in 38/40 (95%) patients. A focal cerebral infarct due to VS was diagnosed in six patients: three of Group 1 and three of Group 2. A post-operative angiography was performed during hospitalization in all patients

Table 4: Description and timing of post-operative angiography

Description of post-operative VS			
Characteristic	Surgical group[1]		
	1 (11)	**2** (25)	**3** (3)
Absence of VS	1	4	0
Distribution			
Single vessel	1	5	0
Multiple vessels	9	16	3
Severity			
Less than 50% narrowing	3	10	2
50% narrowing or more	7	11	1
Delay (in days) between initial symptomatology and first post-operative angiography			
[0, 2]	1	0	0
]2, 7]	6	3	0
]7, 12]	3	15	0
]12, 21]	1	6	1
]21, ∞	0	1	2

[1]Numbers in parentheses represent patients that underwent a post-operative angiography.

except for one of Group 1. The delay between initial symptomatology and first post-operative angiography as well as the description of post-operative angiographic VS are described in Table 4. Initial post-operative angiographies were performed prior to 13 days after SAH in 28/39 (71.8%) patients. Post-operative angiographic VS was present in 34/39 (87.2%) patients. It concerned most frequently multiple vessels in 28/34 (82.3%) and consisted most commonly in a narrowing of 50% or more in 19/34 (55.9%). In comparison with pre-operative angiographic images, post-operative angiographies revealed that VS had worsened after aneurysmal clipping in 15/34 (44.1%) patients: seven patients of Group 1 and eight patients of Group 2. Angiographic VS had decreased or reversed post-operatively in 16/34 (47%) patients: 2 of Group 1, 12 of Group 2 and 2 of Group 3. The other patients had similar pre- and post-operative angiographic VS.

Post-operative symptomatic VS was diagnosed in 12/40 (30%) patients: three were in Group 1; seven in Group 2; two in Group 3. Clinical grade on admission was good or intermediate in 10/12 (83.3%) of these patients. Post-operative symptomatic VS was also present pre-operatively in 8/12 (66.7%) patients. The post-operative angiographies of these patients demonstrated increased VS in five patients, similar VS in two patients and diminished VS in one patient. Five patients presented de novo post-operative symptomatic VS, four of which showed increased VS on post-operative angiography that was treated by angioplasty in two cases.

The frequency of symptomatic VS and cerebral infarct due to VS in relation to timing of surgery are presented in Table 5. Of the three patients that developed a cerebral infarct in Group 1, one presented an increase in vessel narrowing and two presented an increase of VS distribution. Of the three patients that developed a cerebral infarct in Group 2, one presented an increase in vessel narrowing in a multiple vessel distribution similar pre- and –post-operatively. The second patient showed a decrease in vessel narrowing involving multiple arteries and the third a similar pattern in terms of vessel diameter and distribution. There are no statistically significant differences between the four groups regarding the proportion of subjects who manifested symptomatic VS (p=0.22 for Fisher exact test in the pre-operative period and p=0.49 for the post-operative period) or who developed cerebral infarct (p=0.99 for the pre-operative period and p=0.66 for the post-operative period).

Figure 1 illustrates the example of a patient included in the present study. This was a 63-year-old woman with no prior medical history who presented for a persisting headache that had begun six days before. On admission, the patient's vital signs and neurological exam were normal. Initial CT-scan showed no evidence of a SAH nor cerebral infarction. However, the lumbar puncture was positive for SAH. The cerebral angiography revealed the presence of a single aneurysm of the anterior communicating artery as well as the presence of vessel narrowing greater than 50% on multiple vessels (Figure 1 a,b). Within 24 hours of admission, the patient was brought to the operating room (OR) for surgical treatment of the aneurysm. Post-operative CT-scan showed no complications related to the VS and the intra-hospital follow-up angiography revealed complete exclusion of the aneurysm and improvement of the VS

in comparison to pre-operative period (Figure 1 c). Three months after surgery, the patient had regained her normal activities.

The functional outcome assessed three months after surgery was favorable in 37/40 (92.5%) of patients with aneurysmal SAH and associated pre-operative angiographic VS, regardless of Hunt and Hess grade at admission. However, a favorable outcome was significantly more likely in patients operated between 3 to 12 days after SAH than those operated in the first 48 hours following SAH (p=0.03). Table 6 compares the frequency of favorable clinical outcomes for the three groups. For patients with pre-operative symptomatic VS, only 70% presented a favorable outcome. Of the three patients who evolved towards an unfavorable outcome, the initial effect of SAH was the cause in one patient and VS in the two others. The mortality rate was 4% (2/50). These two patients presented pre-operative clinical VS without cerebral infarct on pre-operative CT scan. They underwent surgery within 48 hours of the hemorrhagic event. Both deaths were related to severe post-operative VS.

Table 5: Radiological and clinical findings due to vasospasm in relation to timing of surgery

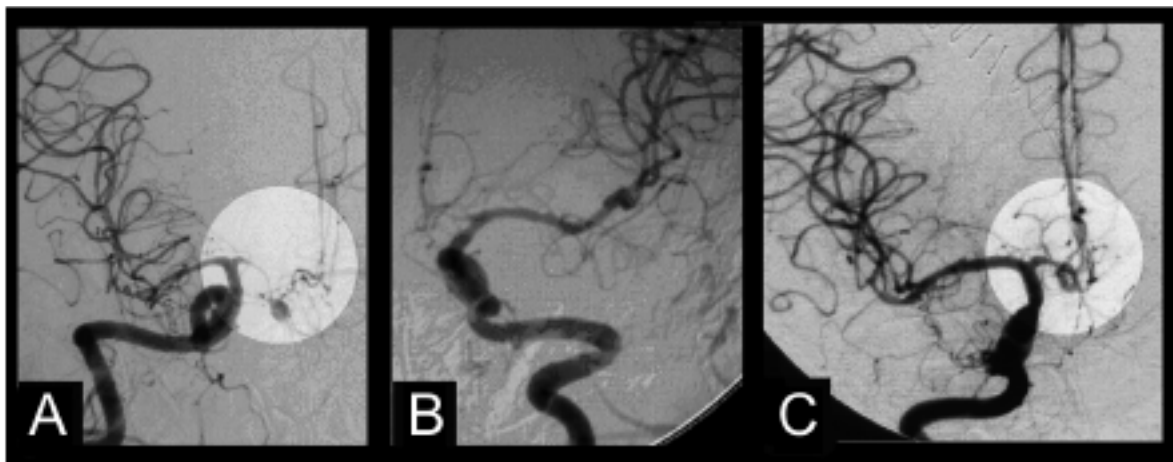|	Surgical group			
	1	2	3	Total
PRE-OPERATIVE PERIOD				
Angiographic vasospasm	12	25	3	40
Symptomatic vasospasm	2	7	1	10
Cerebral infarct	0	2	0	2
POST-OPERATIVE PERIOD				
No vasospasm on angiography	1	4	0	5
Angiographic vasospasm	10	21	3	34
Symptomatic vasospasm	3	7	2	12
Cerebral infarct	3	3	0	6

Figure 1: A 63 year-old woman presented for a persisting headache that began 6 days ago. A&B) Initial angiography with an anterior communicating aneurysm and vessel narrowing greater than 50% on multiple vessels. C) Post-operative angiography 10 days after initial hemorrhage with complete exclusion of the aneurysm and improvement of VS.

Table 6: Functional outcome in relation to surgical group

Surgical Group	Glasgow Outcome Scale	
	Favorable	Unfavorable
1	9	3
2	25	0
3	3	0
Total	37	3

DISCUSSION

The optimal timing of surgical treatment for ruptured intracranial aneurysms remains controversial. Recently authors of a meta-analysis on timing of aneurysm surgery suggested that both early and intermediate surgical treatments improved outcomes in all clinical grades.[3] Many clinicians will agree that most ruptured aneurysms should be treated as early as possible by surgical or endovascular means. The conclusion concerning intermediate surgical treatment might be less widely accepted since most clinicians have the impression of an increased incidence of ischemic complications. Our series does not support this belief. Surgery performed in the presence of angiographic VS can be associated with a good outcome. Patients operated on within 48 hours after SAH had a favorable outcome in 75% (9/12); those operated on between the 3rd and 12th day after SAH had a favorable outcome in 100% (25/25) of cases as those did operated more than 12 days after SAH.

Some series have suggested that delayed cerebral ischemia, post-operative VS, and poorer outcomes occur more frequently in patients operated during the period at risk of VS, regardless of its angiographic documentation.[2,7-9,17] An hypothesis explaining reported unfavorable results is that surgery, by dissection and manipulation of arteries already irritated by subarachnoid blood, might precipitate or exacerbate arterial narrowing.[18-20]

In an experimental study, Findlay et al[18] induced bilateral SAH in primates. Operative manipulation and temporary clip placement did not result in worsening of the VS documented on follow-up angiography. In our series, temporary clipping in the presence of vasospastic cerebral arteries was not associated with an unfavorable outcome.

In a clinical study Macdonald et al[21] measured arterial diameter on angiographies performed before and after aneurysm clipping in 56 patients: 34 were operated on by day three of SAH, 20 between SAH day 4 – 12, and two after SAH day 13. They found that neither surgery itself nor its timing, had an effect on angiographic VS. Qureshi et al[22] analyzed 296 consecutive patients diagnosed with SAH of whom 37 had angiographic evidence of early VS at admission. Of these, 24 underwent early surgery which did not aggravate the risk of symptomatic VS and poor outcome. Saito et al[23] analyzed 96 consecutive patients that presented with VS during their clinical course. Of the 68 patients with angiographic pre-operative VS, 29 underwent aneurysmal clipping, usually more than a week after documentation of VS. Given the delay between diagnosis of angiographic VS and surgery, the conclusion that subsiding or stable VS was not aggravated by surgery must be critically analyzed. In our series, 39/40 (97.5%) patients were operated on 48 hours or less after angiographic documentation of VS and all patients presenting pre-operative clinical VS had a stable neurological deficit prior to surgery. First post-operative angiography was performed prior to 13 days following SAH, therefore including the period most at risk of VS, in 28/39 (71.8%) patients.

Experimental and clinical evidence support the fact that VS is not aggravated by surgical procedure. Early aneurysm clipping might enable better treatment of existing delayed ischemic neurological deficits and prevent or limit the formation of cerebral infarcts. Solomon et al[8] prospectively studied 145 patients admitted within seven days of SAH and operated on within 24 hours of admission. Symptomatic VS and cerebral infarcts due to VS occurred in 16% and 4% of patients respectively, operated on the same day or the day after the SAH; 22% and 10% of those operated on day 2-3 after SAH; 28% and 11% of those operated on between day 4-7 after SAH. Unfavorable outcome due to delayed cerebral ischemia occurred in 2% of patients operated on the same day or the day after the SAH, 3% of those operated on day 2-3 after SAH, and 3% of those operated between day 4-7 after SAH.[8]

Chyatte et al[1] studied 244 patients admitted within 3 days of aneurysmal SAH. Patients operated on within 3 days of SAH presented a statistically significant increase in the post-operative ischemic symptoms balanced by a similar rate of pre-operative complications in patients undergoing delayed surgery. Moreover, the increased incidence of complications due to VS in the early surgical group did not result in statistically significant increase in morbidity as most were reversible.[1] Surgery seems to have little influence on bad clinical outcome due to VS.[1,8]

Post-operative clinical deterioration and unfavorable functional prognostic might not be due to VS.[24] Surgical complications, less frequently sought systematically, might be an important contributor of unfavorable outcome.[25-29] Altered cerebral blood perfusion and dysautoregulation occurring in the acute setting of SAH might also contribute to poorer results.[30]

Experimental and clinical studies have demonstrated that SAH induces an acute global decrease in cerebral blood flow (CBF) and cerebral metabolic rate of oxygen $(CMRO_2)$[31-35] which are correlated with higher clinical grades.[34,36-38] Also, cerebral autoregulation is impaired following aneurysmal SAH and during VS.[39-41] Parenchymal vessels distal to vasospastic arteries might be unable to dilate in response to reduced local perfusion pressure.[41] However, some studies suggest that surgery improves CBF patterns[36,37] partly due to better intracranial pressure control. Neuroanesthetic techniques, large opening of the sylvian and basal cisterns, and hematoma drainage contribute to minimizing the need for brain retraction, reducing the occurrence of focal insults in brain tissue rendered sensitive to changes in local pressure due to altered autoregulation. Once the aneurysm is secured, optimal medical management for VS might be securely optimized and might attenuate the effects of dysautoregulation and VS.

The decision to delay aneurysm clipping for patients with an aneurysmal SAH and angiographic VS must weigh the risk of rebleeding during the waiting period and the risk of presenting neurological ischemic deficits related to VS. Early VS, occurring within 48 hours of aneurysmal rupture, is present in approximately 10-13% of SAH patients.[22,42] It represents a significant predictor of neurological deterioration and cerebral infarction and of unfavorable outcome.[22,42] Interestingly, in our series, early angiographic VS (Group 1) was documented in 12/40 (30%) patients of which 7/12 (58.3%) presented a good or intermediate clinical grade at admission. Although 7/11 (63.6%) patients of Group 1 presented worsened angiographic VS post-operatively, symptomatic post-operative VS was not significantly more common than in other groups. An unfavorable outcome was found in 25% of Group 1. On the other hand, 12/25 (48%) patients of Group 2, which covers the interval most at risk for VS, showed a decrease in post-operative angiographic VS and symptomatic post-operative VS was not significantly more frequent. All Group 2 patients evolved towards a favorable outcome at three months after SAH.

Early VS is independant of delayed VS which suggests that these phenomena have a different eotiology. It has been shown that early vasospasm is associated with worse neurological grade, thicker SAH on CT-scan, larger aneurysms and intracranial hemorrhage.[42] Increased intracranial pressure and stretching of intracranial arteries by adjacent parenchymal hematomas, thick subarachnoid clots or the culprit aneurysm itself, may contribute to vessel narrowing seen in the presence of early VS.[42] These associated conditions might partially explain the worse prognosis of patients of Group 1 in comparison to patients of Group 2, presenting delayed VS. More studies are necessary to elucidate factors contributing to the difference in outcome observed between patients presenting angiographic VS either early after SAH onset or during the period most at risk for VS.[22,42]

There are some limitations to the present study. Although this is a retrospective study as most series analysing aneurysm

surgery in the period of vasospasm, there was no patient selection. All patients consecutively treated during the study period were included in the study if they answered the inclusion and not the exclusion criteria. The small number of patients is representative of the frequency of angiographic vasospasm prior to surgical treatment in a tertiary neurosurgical center's practice.

A consensus regarding the description of VS is lacking. Scales, spasm indexes, and measurements techniques have been proposed as instruments to standardize the evaluation of VS. However, their use in clinical practice is not widespread and most authors use personalized classifications. To minimize inter-observer variability, we used bimodal variables to describe the diameter of spastic vessels and their distribution.

Not only does radiological definition of vasospasm differ between studies but also the definition of clinical vasospasm. The main factor varying between studies is the onset of neurological symptoms anywhere between 3-5 to 12 days. Precise definitions allowed objective assessments of clinical charts by independent observers. In other studies, exclusion of early clinical vasospasm might have clinical significance in conclusions drawn.

Furthermore, an endovascular treatment securing the ruptured aneurysm and dilating vasospastic arteries either mechanically or pharmacologically could be considered a good option for patients with symptomatic VS on admission. Recent studies have shown that the incidence of angiographic and symptomatic vasospasm and the associated overall clinical outcome does not significantly differ between patients treated with craniotomy and clip application and those treated by embolization.[43-46] However, only case reports and small series have assessed the safety and effectiveness of combined embolization and angioplasty in a single session for the treatment of ruptured aneurysms associated with symptomatic VS.[47,48] In the light of these data, a prospective analysis of the outcome of patients with aneurysmal SAH presenting angiographic VS prior to aneurysmal treatment, either by surgical or endovascular means, might be warranted.

In summary, aneurysmal surgery, especially between 3-12 days following SAH, in the presence of asymptomatic pre-operative angiographic VS can be associated with a good outcome. Early surgery is not contra-indicated and might enable optimal treatment of VS. However, clinical VS on admission, especially within 48 hours after SAH, might be associated with a less favorable outcome.

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