Acta Neurochir (Wien) (2005) 147: 1181–1188
DOI 10.1007/s00701-005-0613-4

Acta Neurochirurgica
Printed in Austria

Illustrated Review

Cerebral vasospasm in patients with unruptured intracranial aneurysms

S. Paolini[1], **Y. Kanaan**[2], **A. Wagenbach**[2], **K. Fraser**[3], and **G. Lanzino**[2]

[1] Cattedra di Neurochirurgia, Università degli Studi di Perugia, IRCCS Neuromed, Pozzilli, Italy
[2] Illinois Neurological Institute, Department of Neurosurgery, University of Illinois College of Medicine at Peoria, Peoria, IL, USA
[3] Illinois Neurological Institute, Department of Radiology, University of Illinois College of Medicine at Peoria, Peoria, IL, USA

Received April 4, 2005; accepted July 15, 2005; published online August 29, 2005

Summary

Intracranial arterial vasospasm is a typical sequela of subarachnoid haemorrhage. The association between symptomatic vasospasm and unruptured aneurysms has been sporadically presented in the literature. The pathogenesis of this unusual entity is unclear. The published cases were collected in this review and analysed with regard to timing, clinical presentation and possible relationship with surgical factors. We also added an illustrative case which was recently observed in our department.

Keywords: Clipping; delayed vasospasm; middle cerebral artery; unruptured aneurysm.

Introduction

Cerebral vasospasm accounts for 10% to 15% of morbidity and mortality due to subarachnoid haemorrhage (SAH) [10]. In typical cases, the spasm begins in the first week after the initial haemorrhage and peaks in severity during the second week [10, 19]. Although the exact pathogenesis is still unknown, most studies point to a functional vasoconstriction triggered by blood breakdown products. A number of chemical agents have been investigated as possible mediators of vasospasm [10]. The blood-derived nature of the theorized vasoactive factors also confirms the relationship between the amount of the subarachnoid blood and the incidence of vasospasm [12, 16]. Cerebral vasospasm with unruptured aneurysms, either treated or untreated, is a reportedly rare association which challenges the aforementioned hypothetical mechanism. We report here on a patient developing delayed vasospasm after successful clipping of an unruptured middle cerebral artery (MCA) aneurysm. Previously reported cases were collected from the literature and reviewed. Clinical presentation, temporal profiles and possible relationship with surgery where analysed in the light of alternative theories on the pathogenesis of vasospasm.

Literature review

The results of our literature search yielded several cases of cerebral vasospasm occurring after clipping of unruptured aneurysms [2, 6, 20, 21, 25]. Indeed, as diagnostic and surgical tools have evolved over the years, a convincing documentation of this phenomenon has become increasingly rare.

Three cases described by Simeone and Peerless in 1975 belong to the pre-CT era [25]. All patients presented with headache, had no cerebrospinal fluid evidence of SAH and had angiographically documented vasospasm occurring after surgical clipping of unruptured aneurysms. Again in 1980, Peerless collected from the literature a series of 53 cases of vasospasm occurring in patients with unruptured aneurysms [20]. In his review, the author concluded that in most reported cases, the symptoms could be attributed to previous or misdiagnosed SAH, thromboembolic events, surgical trauma or other factors. Only eight cases, whose details where not documented, were regarded by the author as true expression of non-haemorrhagic vasospasm. In all of them, the onset of symptomatic vasospasm was within

hours of the surgical clipping and in more than one case, a spastic response of the arteries was noticed by the surgeon intraoperatively. In 1980 Fein reviewed a series of 14 patients with unruptured aneurysms and cerebral vasospasm [6]. Five of the fourteen patients had coexisting multiple aneurysms and a history of previous SAH. The only case illustrated in the article was that of a young woman who underwent surgical clipping of a right choroidal artery aneurysm, complicated by intraoperative rupture. The patient awakened from anaesthesia with right hemiparesis which lasted less than 6 hours. A vasospasm of the left anterior and middle cerebral arteries was angiographically demonstrated. Overall in three of the four patients with intraoperative aneurysmal bleeding, significant angiographic spasm was seen postoperatively. According with his previous experimental studies [7–9], the author concluded that intraoperative bleeding of a previously unruptured aneurysm can be complicated by postoperative vasospasm.

Raynor and colleagues reported the case of a young woman with clinical and angiographic evidence of vasospasm soon after uncomplicated clipping of a left

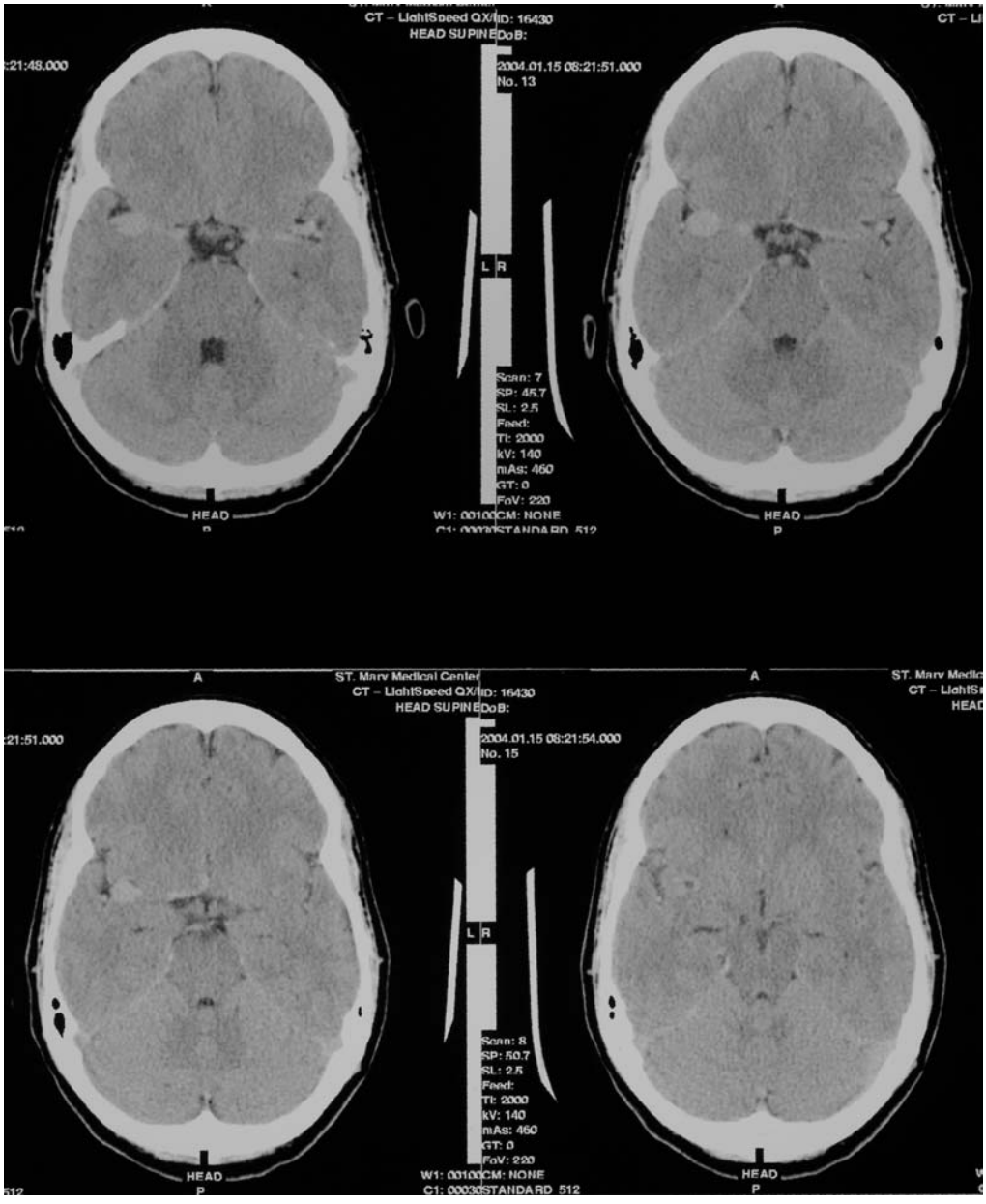

Fig. 1. Contrast enhanced CT scan showing a round mass effacing the right sylvian fissure. There is no evidence of subarachnoid haemorrhage

posterior communicating artery aneurysm [21]. Indeed, the patient had a history of severe headache and partial nerve palsy two days before admission and some evidence of ongoing vasospasm on the first angiographic scan. Preoperative lumbar puncture showed no xanthochromia and 16 red cells/mm^3.

In 1983, Friedman and colleagues described a unique case of vasospasm complicating an unruptured and untreated posterior communicating artery aneurysm [13]. Although the lumbar puncture showed no evidence of subarachnoid bleeding, five days before admission the patient had developed a complete third cranial nerve palsy, consistent with enlargement of the aneurysm.

Two years later, Bloomfield and Sonntag described the case of 54-year-old with incidental CT finding of a right MCA aneurysm [2]. The patient underwent successful and uncomplicated surgery but 9 days after surgery, developed a left hemiparesis. Three days later, angiography showed a diffuse spasm of the right MCA and ACA.

A search for cases of symptomatic vasospasm after treating an unruptured aneurysm after the early 1990's was exhaustive and unsuccessful.

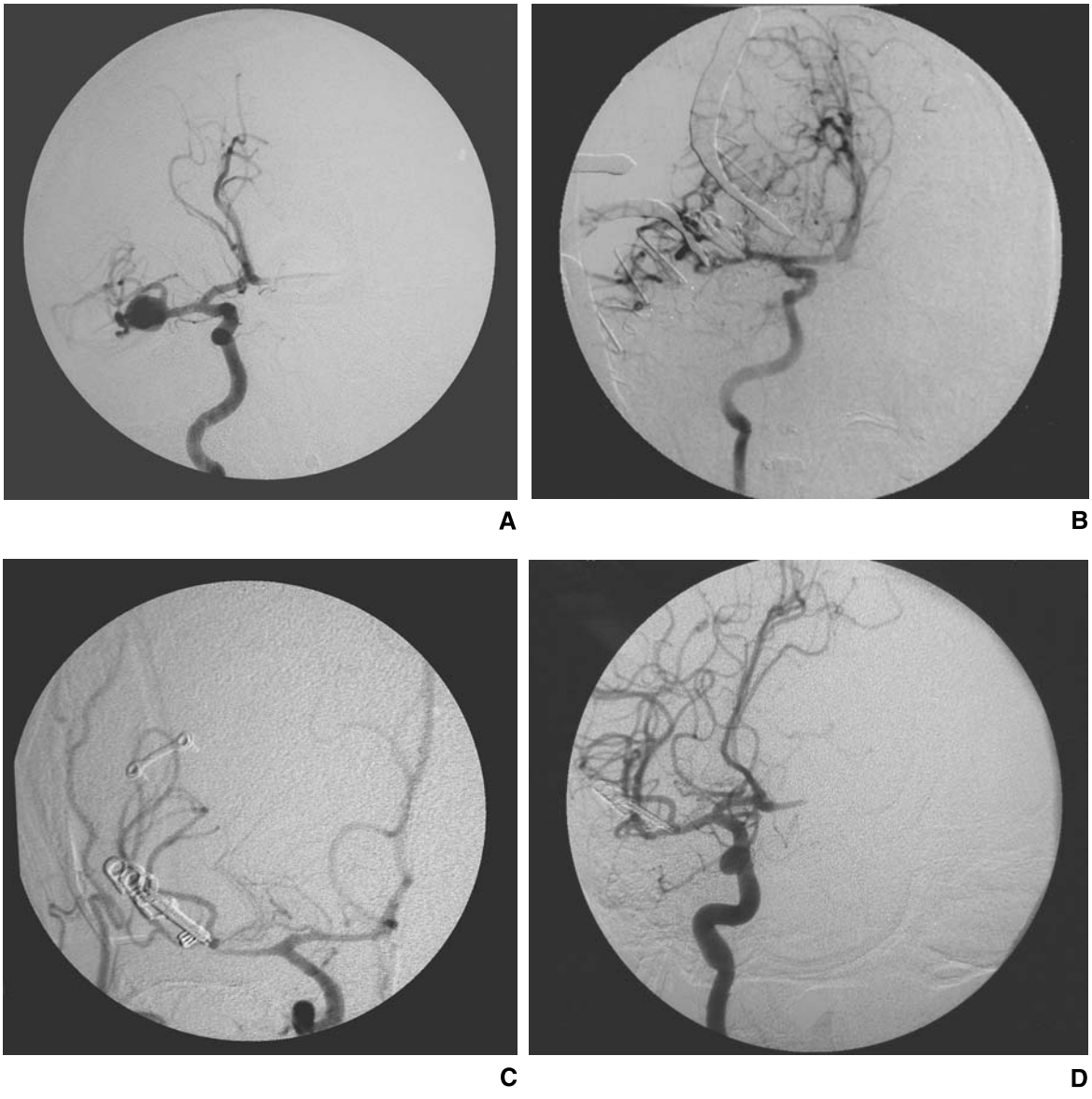

Fig. 2. (A) right internal carotid artery angiogram, oblique view, showing a large aneurysm arising at the bifurcation of the MCA. (B) intraoperative angiogram showing the aneurysm excluded and no arterial spasm along the MCA trunk. (C) the angiogram obtained 30 days after surgery discloses severe vasospasm along the M1 segment, reaching its highest degree close to the bifurcation. (D) 7-month follow-up angiogram showing a normal calibre MCA

Illustrative case

We report here the case of a 47-year-old woman who presented with symptomatic vasospasm 28 days after successful clipping of an unruptured middle cerebral artery aneurysm. Along with the absence of subarachnoid haemorrhage, the peculiarity of the case is the marked delay from the surgical intervention. The patient initially presented to the emergency room complaining of lightheadness, numbness of the extremities and faintness. There was no headache preceding or associated with the episode or afterwards. She had a smoking history of two to three packs a day. Computed tomography (CT) scan of the head revealed a lesion, consistent with an aneurysm, in the right Sylvian fissure. There was no evidence of SAH (Fig. 1). The patient was immediately transferred to our Institution, where a cerebral angiogram confirmed the presence of a large aneurysm of the right middle cerebral artery (MCA) bifurcation

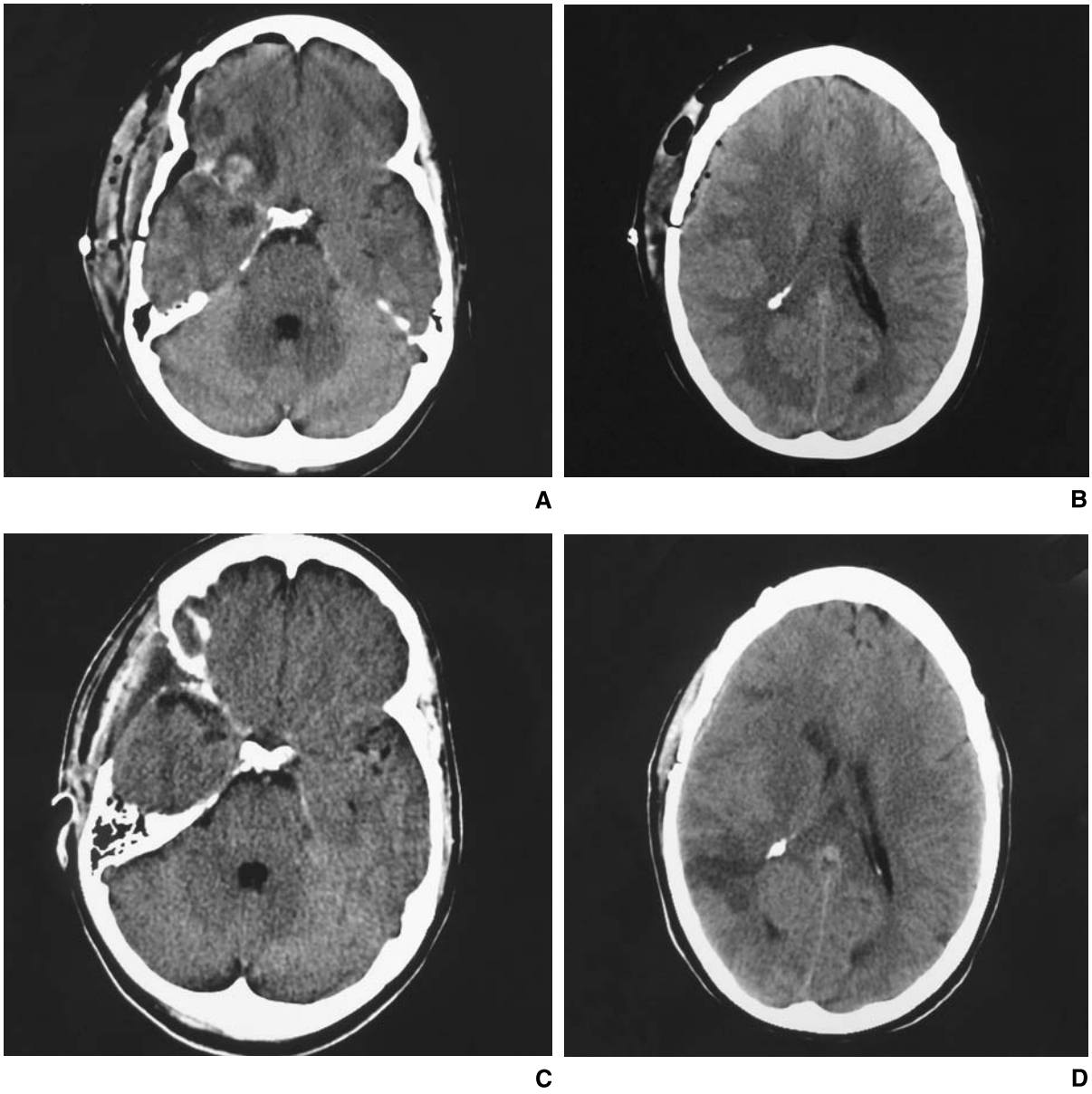

Fig. 3. (A) CT scan post-operative day two. Hypointense areas within the right juxta-sylvian brain tissue. On the frontal side there's a small intracerebral haemorrhage. (B) no ischemic lesions can be seen on a more cranial scan. (C) One month after surgery, at the time of delayed vasospasm, the CT show resolution of the juxta-sylvian abnormalities as well as (D) small lacunar infarcts within the right paraventricular white matter

(Fig. 2A). Four days after the onset of symptoms, the patient underwent surgery through a right frontotemporal craniotomy. On opening the Sylvian fissure and dissecting the aneurysm no signs of subarachnoid bleeding or of aneurysm rupture were found. The aneurysm was closed with two straight clips. An intraoperative angiogram confirmed exclusion of the aneurysm (2B). The postoperative course was uneventful. On the first postoperative day, a control CT showed hypointense areas in the brain parenchyma around the Sylvian fissure, with a small haemorrhage in the frontal side (Fig. 3A). The lesions, which were regarded as post-retraction oedema, remained asymptomatic. On the same CT scan, there was no evidence of ischemic lesions in the MCA territory (Fig. 3B). The patient was discharged 3 days later without complications. Twenty-eight days later the patient developed left lower facial droop and left upper extremity weakness requiring re-admission. A CT of the head showed resolution of the post-surgical oedema (Fig. 3C) and subacute infarctions in the right periventricular MCA territory (Fig. 3D). A new cerebral angiogram revealed significant vasospasm of the distal M1 segment (Fig. 2C). The patient was treated with volume expansion and antiplatelet therapy. She immediately responded to therapy with improvement of her symptoms. She returned to her previous neurological baseline within 12 hours. On a follow-up angiogram performed 7 months later, the right MCA had normal calibre (Fig. 2D).

Discussion

In this literature review, the first question that arises is whether all the reported cases could be accepted as truly non-haemorrhagic vasospasm. The occurrence of a SAH is generally suggested by typical symptoms and eventually confirmed by diagnostic examinations which include a CT scan and, in cases with typical presentation and negative CT, rachicentesis with spectrophotometric examination of the cerebrospinal fluid [27, 29]. In the case described here there was no clinical or radiological evidence of aneurysm rupture. The presenting symptoms were aspecific, though consistent with a possible neurological disease. In particular, neither headache nor other signs of acute intracranial hypertension were reported by the patient. The surgical exploration confirmed the absence of a SAH since it was performed a few days after the onset of symptoms. For this reason, we are prone to consider the CT finding of a MCA aneurysm an incidental finding. In the previously reported cases the criteria used to rule out an aneurysm rupture, were not always clear. Particularly in the first cases reported by Fein and in that reported by Raynor and Messer (Table 1), the symptoms preceding the diagnosis of vasospasm might be consistent with a minor aneurysmal leak which went undiagnosed. This possible sequence of events, according with recent experimental evidences [28], would question the commonly accepted relationship between the risk and the severity of vasospasm and the amount of the subarachnoid blood.

Alternatively, considering that all but one [13] of the reported cases underwent surgery, the occurrence of spasm could be theoretically related to the normal surgery-related blood extravasation. In particular, Fein argued the intraoperative aneurysmal bleeding was specifically associated with the development of vasospasm [6]. Neither the literature nor the daily practice have confirmed this hypothesis. Vasospasm typically complicates spontaneous SAH, rather than post-surgical blood collections, either subarachnoid or other. For

Table 1. *Summary of documented cases of symptomatic vasospasm occurring in patients with unruptured aneurysms. In all cases, the vasospasm was angiographically demonstrated*

Author	Aneurysm	Clinical presentation	SAH exclusion criteria	Surgery	Delay from surgery
Simeone [25], 1975	MCA, l	headache	rachicentesis	uncomplicated	hours
Simeone [25], 1975	ICA-PCoA, l	headache	rachicentesis	local spasm following clip application	hours
Simeone [25], 1975	ICA-OphA, l	headache	rachicentesis	uncomplicated	5 days
Fein [6], 1980	ICA-AChA, l	seizures	–	intraoperative rupture	no delay
Raynor [21], 1980	ICA-PCoA, l	headache, 3rd c.n. palsy	rachicentesis	uncomplicated	no delay
Friedman [13], 1983	ICA-PCoA, l	3rd c.n. palsy 5 days before admission	CT, rachicentesis	– (unoperated)	– (unoperated)
Bloomfield [2], 1985	MCA, r	– (incidental finding)	CT	local vasospasm following clip application	9 days

ICA Internal carotid artery, *PCoA* posterior communicating artery, *AChA* anterior choroidal artery, *MCA* middle cerebral artery, *l* left, *r* right.

the same reason, no role could be apparently played by the small frontal haemorrhage which, in our case, was seen on postoperative CT. The haemorrhage was intraparenchymal rather than subarachnoid and it likely occurred in the context of post-retraction oedema. Overall, it is conceivable that factors other than subarachnoid blood may occasionally be involved in the development of vasospasm.

In our case, as in others', the distribution of the spasm suggests that factors close to the aneurysm itself must be the source of the spasm. On a clinical and experimental basis [30, 31] an ''hypothalamic'' theory received attention about three decades ago. The hypothesis was that mechanical or vascular compromise of the hypothalamus could promote the release of vasospastic mediators. This mechanism was initially accepted as a possible cause of vasospasm in operations close to midline structure, i.e. clipping of anterior communicating artery aneurysms, but left unexplained the frequent association between vasospasm and more peripheral aneurysms.

The mechanical stress occurring over the arterial wall at the time of surgery has been investigated as another possible source of spasm [11, 14]. Schaller *et al.* provided instrumental evidence that dissection of the Sylvian fissure and manipulation of the MCA branches may induce a vasospastic response along these vessels, but the vasospasm was generally modest, clinically silent and reached its highest value at a mean interval of 7 days after surgery [23]. Hence, the mechanical theory leaves unexplained the long interval elapsing between surgery and the onset of vasospasm in our patient. Alternatively, because two long clips had been applied across the aneurysmal neck, one could speculate that late, spontaneous twisting of the clips produced a mechanical torsion of the parent vessel, eventually triggering a vasospastic reaction. It must be said that large MCA aneurysms are commonly repaired with a number of different clips and, to our knowledge, no association has been reported between the incidence of vasospasm and the number, size or weight of the clips.

While typical vasospasm develops with a constant 4 to 14 day latency after a SAH, the temporal profile of the spasm in unruptured aneurysms is quite heterogeneous. In the majority of the earlier reports, vasospasm developed within hours after surgical clipping of the aneurysm. A 9-day interval was reported by Bloomfield and Sonntag [2]. The 1-month delay observed in our case is strikingly unusual and hardly explainable. In commenting Raynor's report, De Long proposed an intriguing mechanism derived from the clinical observation that resecting, rather than simply closing, the aneurysm sac seems to be accompanied by a lower incidence of postoperative vasospasm. He hypothesized that spasmogenic blood breakdown products might diffuse into the arterial wall not only from the subarachnoid cisterns but also from the inside of the aneurysm once this has been secured [4]. This process could be very slow and, in our case, would account for the long delay between surgery and the onset of vasospasm. Although merely speculative, this theory draws attention to the fact that the subarachnoid clot is not the only conceivable source of a blood-derived spasm factor. A similar concept was addressed by Friedman and coll. in discussing their unique case of vasospasm associated with an unruptured and untreated aneurysm [13]. The aneurysm had undergone symptomatic enlargement a few days before admission. In their discussion, the authors hypothesized that ongoing enlargement of the aneurysm damaged the adjacent endothelium impairing its ability to produce prostacyclin, a substance with vasorelaxant properties. This would have resulted in unopposed vasoconstriction mediated by prostaglandin endoperoxide and thromboxane A2, substances normally present in the cerebrospinal fluid and antagonized by prostacyclin [13]. In the last years, the role of the endothelial damage in the genesis of vasospasm has been further investigated. The vasoactive properties of endothelium-derived substances such as the endothelin-1, have been extensively documented [22, 24, 26, 32]. Overall, there is a growing body of evidence documenting that, under particular circumstances, the source of spasmogenic factors might be the vessels themselves, regardless of the amount of subarachnoid blood around them [17, 28, 32]. According with other evidences, the adventitial nerves, rather than the endothelium, could initiate the spasmogenic mechanism. The so-called trigemino-cerebrovascular system (TCVS) is part of a complex nerve network surrounding the arteries of the circle of Willis [3, 5]. The axons of the TCVS reach the basal arteries via the ophthalmic and maxillary divisions of the trigeminal nerve [18] and may be responsible for the development of headache. Also, they seem to be involved in maintaining a normal vessel diameter by a constant release of vasodilatatory peptides such as substance P and calcitonin gene-related peptide. Experimental and clinical studies suggest an association between vasospasm following SAH and a TCVS-mediated reflex mechanism leading to marked release and late depletion of these vasodilatatory peptides [1, 5, 15]. Hypothetically, stimulation of the

TCVS nerve endings with secondary reflex vasospasm might be due not only to chemical factors, i.e. blood breakdown products, but also by a mechanical distention of the arterial wall following enlargement or, as in our patient, clipping of an aneurysm. Activation of the TCVS would also account for the headache observed in most cases reviewed here. The latency time of the vasospasm would be variable, based on the temporal pattern of vasoactive peptides depletion.

On the basis of these emerging concepts, most cases mentioned in this review might be consistent with a comprehensive pathogenesis in which powerful vasoactive substances following sudden enlargement or even simple surgical clipping of the aneurysmal sac.

Conclusions

The association between cerebral vasospasm and unruptured aneurysms is very rare. The ability of minimal or non-subarachnoid amount of blood or blood break-down products to provoke the vasospasm is uncertain. It is conceivable, however, that factors other than blood collections may trigger the vasospasm. A sudden change involving the patho-anatomy of the aneurysmal malformation may trigger the vasospasm in the neighbouring vessels. Such a change might be either spontaneous, e.g. enlargement of the aneurysm, or triggered by surgical clipping.

The temporal profile non-haemorragic vasospasm is highly variable, with symptoms manifesting from hours up to one-month after clipping of the aneurysm.

References

1. Arienta C, Balbi S, Caroli M, Fumagalli G (1991) Depletion of calcitonin gene-related peptide in perivascular nerves during acute phase of posthemorrhagic vasospasm in the rabbit. Brain Res Bull 27: 605–609
2. Bloomfield SM, Sonntag VK (1985) Delayed cerebral vasospasm after uncomplicated operation on an unruptured aneurysm: case report. Neurosurgery 17: 792–796
3. Buki A, Horvath Z, Kallo I, Liposits Z, Lengvari I, Doczi TP (1999) Peptidergic innervation of human cerebral blood vessels and saccular aneurysms. Acta Neuropathol (Berl) 98: 383–388
4. De Long (1980) Comment in: severe vasospasm with an unruptured aneurysm: case report. Neurosurgery 6: 92–95
5. Edvinsson L, Juul R, Jansen I (1994) Perivascular neuropeptides (NPY, VIP, CGRP and SP) in human brain vessels after subarachnoid haemorrhage. Acta Neurol Scand 90: 324–330
6. Fein JM (1980) Unruptured aneurysms and cerebral spasm. In: Wilkins RH (ed) Cerebral arterial spasm: Proceedings of the Second International Workshop, Baltimore, pp 499–504
7. Fein J, Boulos R (1973) Local cerebral blood flow in experimental middle cerebral artery vasospasm. J Neurosurg 39: 337–347
8. Fein JM (1976) Brain energetics and circulatory control after subarachnoid hemorrhage. J Neurosurg 45: 498–507
9. Fein JM, Flor WJ, Cohan SL, Parkhurst J (1974) Sequential changes of vascular ultrastructure in experimental cerebral vasospasm. Myonecrosis of subarachnoid arteries. J Neurosurg 41: 49–58
10. Findlay JM (2003) Cerebral vasospasm. In: Winn HR (ed) Youman's neurological surgery, 5th edn. WB Saunders, Philadelphia PA, pp 1839–1864
11. Findlay JM, Macdonald RL, Weir BK, Grace MG (1991) Surgical manipulation of primate cerebral arteries in established vasospasm. J Neurosurg 75: 425–432
12. Fisher CM, Kistler JP, Davis JM (1980) Relation of cerebral vasospasm to subarachnoid hemorrhage visualized by computerized tomographic scanning. Neurosurgery 6: 1–9
13. Friedman P, Gass HH, Magidson M (1983) Vasospasm with an unruptured and unoperated aneurysm. Surg Neurol 19: 21–25
14. Hosoda K, Fujita S, Kawaguchi T, Shose Y, Hamano S, Iwakura M (1999) Effect of clot removal and surgical manipulation on regional cerebral blood flow and delayed vasospasm in early aneurysm surgery for subarachnoid hemorrhage. Surg Neurol 51: 81–88
15. Juul R, Edvinsson L, Gisvold SE, Ekman R, Brubakk AO, Fredriksen TA (1990) Calcitonin gene-related peptide-LI in subarachnoid haemorrhage in man. Signs of activation of the trigemino-cerebrovascular system? Br J Neurosurg 4: 171–179
16. 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
17. Nishizawa S, Chen D, Yokoyama T, Yokota N, Otha S (2000) Endothelin-1 initiates the development of vasospasm after subarachnoid haemorrhage through protein kinase C activation, but does not contribute to prolonged vasospasm. Acta Neurochir (Wien) 142: 1409–1415
18. Nozaki K, Uemura Y, Okamoto S, Kikuchi H, Mizuno N (1990) Origins and distribution of cerebrovascular nerve fibers showing calcitonin gene-related peptide-like immunoreactivity in the major cerebral artery of the dog. J Comp Neurol 297: 219–226
19. Pasqualin A (1998) Epidemiology and pathophysiology of cerebral vasospasm following subarachnoid hemorrhage. J Neurosurg Sci 42: 15–21
20. Peerless SJ (1980) Postoperative cerebral vasospasm without SAH. In: Wilkins RH (ed) Cerebral arterial spasm: Proceedings of the Second International Workshop. William and Wilkins, Baltimore, pp 496–498
21. Raynor RB, Messer HD (1980) Severe vasospasm with an unruptured aneurysm: case report. Neurosurgery 6: 92–95
22. Roux S, Loffler BM, Gray GA, Sprecher U, Clozel M, Clozel JP (1995) The role of endothelin in experimental cerebral vasospasm. Neurosurgery 37: 78–85
23. Schaller C, Klemm E, Haun D, Schramm J, Meyer B (2002) The transsylvian approach is ''minimally invasive'' but not ''atraumatic''. Neurosurgery 51: 971–976
24. Seifert V, Loffler BM, Zimmermann M, Roux S, Stolke D (1995) Endothelin concentrations in patients with aneurysmal subarachnoid hemorrhage. Correlation with cerebral vasospasm, delayed ischemic neurological deficits, and volume of hematoma. J Neurosurg 82: 55–62
25. Simeone F, Peerless SJ (1975) Prolonged cerebral vasospasm without subarachnoid hemorrhage. In: Smith Robertson JT (ed) Subarachnoid hemorrhage and cerebrovascular spasm. Charles C Thomas, Springfield, IL, pp 206–225
26. Suzuki R, Masaoka H, Hirata Y, Marumo F, Isotani E, Hirakawa K (1992) The role of endothelin-1 in the origin of cerebral vasospasm in patients with aneurysmal subarachnoid hemorrhage. J Neurosurg 77: 96–100

27. Tsementzis SA, Hitchcock ER, DeCothi A, Gill JS (1985) Comparative studies of the diagnostic value of cerebrospinal fluid spectrophotometry and computed tomographic scanning in subarachnoid hemorrhage. Neurosurgery 17: 908–912
28. Tureyen K, Nazlioglu HO, Alkan T, Kahveci N, Korfali E (2005) Single or multiple small subarachnoid hemorrhages by puncturing a small branch of the rat basilar artery causes chronic cerebral vasospasm. Neurosurgery 56: 382–390
29. Vermeulen M, Hasan D, Blijenberg BG, Hijdra A, van GJ (1989) Xanthochromia after subarachnoid haemorrhage needs no revisitation. J Neurol Neurosurg Psychiatry 52: 826–828
30. Wilkins RH (1975) Hypothalamic dysfunction and intracranial arterial spasms. Surg Neurol 4: 472–480
31. Wilson JL, Feild JR (1974) The production of intracranial vascular spasm by hypothalamic extract. J Neurosurg 40: 473–479
32. Zimmermann M, Seifert V (1998) Endothelin and subarachnoid hemorrhage: an overview. Neurosurgery 43: 863–875

Comments

This work deals with a rare but very interesting and important clinical problem. The illustrative case presented is rather ''atypical'' as to the timing of development of postoperative vasospasm. The review of the literature and that of the existing theories makes the article to the clinicians very valuable and worth reading.

T. Doczi
Pecs

This is an excellent article. The authors present an interesting clinical case and a very good review of related cases and of possible mechanisms.

There is an additional potential mechanism which has not been described by the authors. It is now well established that, in the mammalian brain, the Circle of Willis receives rich sensory perivascular innervation from the trigeminal ganglion. An expansion of the aneurysm – without a rupture – could sensitize this ''trigeminovascular system'' (TGVS) and this could be responsible for the headache that all patients experienced.

The trigeminal ganglion and its projections contain potent vasodilatory peptides (substance P, Calcitonin generelated peptide). This trigeminal intervention of the Circle of Willis is not only sensory but also vasomotor, i.e. vasodilatory. This has been shown extensively in animals but also in humans [1]. These perivascular sensory fibres respond to changes or perturbations in their environment by axoral reflex-like mechanisms. Stimuli for their response may be either *mechanical* such as distension of the aneurysm and adjacent vessels or *chemical* such as release of blood by-products or other substances because of distension of the aneurysmal wall. A change in the perivascular environment of the Circle of Willis, such as hemorrhage, surgical manipulation or aneurysm enlargement – without rupture – could be interpreted as an imminent threat. This may sensitise the trigeminal perivascular sensory endings, activate the TGVS and lead to release or even depletion of potent vasodilatory peptides from the perivascular nerve endings. Under normal conditions, it is probable that the TGVS participates and contributes along with other mechanisms in maintaining normal vessel diameter. An amount of vasodilatory peptides may be released constantly in order to maintain vessel diameter [2]. Following the depletion of neuropeptides, this mechanism of maintaining vessel diameter is no longer active and vasospasm develops. This mechanism could be responsible for the variable latent period from the initial insult, i.e. the aneurysm expansion (headache) or the surgical manipulation to the manifestation of vasospasm.

References

1. Tran Dinh YR, Thurel C, Cunin G, Serrie A, Seylaz J (1992) Cerebral vasodilation after thermocoagulation of the trigeminal ganglion in humans. Neurosurgery 31: 658–663
2. Shiokawa Y, Delgado-Zygmunt TJ, Arbab MA-R, Svendgaard N-A (1992) Effect of unilateral pre- and postganglionic lesioning of the trigeminal nerve on the development of cerebral vasospasm in the squirrel monkey: angiographic findings. Brit J Neurosurg 6: 445–455

Damian Sakas
Athens

Correspondence: Giuseppe Lanzino, Illinois Neurological Institute, Department of Neurosurgery, University of Illinois College of Medicine at Peoria, 530 NE Glen Oak, Peoria, IL 61637, USA. e-mail: lanzino@uic.edu