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Role of angiography following aneurysm surgery

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✓ The postoperative angiograms in 66 patients who underwent craniotomy for clipping of 78 cerebral aneurysms were reviewed. Indications for urgent postoperative angiography included neurological deficit or repeat subarachnoid hemorrhage. Routine postoperative angiograms were carried out in the remaining patients. Postoperative angiograms were reviewed to determine the incidence of unexpected findings such as unclipped aneurysms, residual aneurysms, and unforeseen major vessel occlusions. Logistic regression analysis was used to test if the following were factors that predicted an unexpected finding on postoperative angiography: aneurysm site or size; the intraoperative impression that residual aneurysm was left or a major vessel was occluded; intraoperative aneurysm rupture; opening or needle aspiration of the aneurysm after clipping; or development of a new neurological deficit after surgery. Kappa values were calculated to assess the agreement between some of these clinical factors and unexpected angiographic findings.

Unexpected residual aneurysms were seen in three (4%) of the 78 occlusions. In addition, three aneurysms were completely unclipped (4%); these three patients were returned to the operating room and had their aneurysms successfully obliterated. There were nine unexpected major vessel occlusions (12%); six of these resulted in disabling stroke and two patients died. Of six major arteries considered to be occluded intraoperatively and shown to be occluded by postoperative angiography, two were associated with cerebral infarction. Logistic regression analysis showed that a new postoperative neurological deficit predicted an unforeseen vessel occlusion on postoperative angiography. Factors could not be identified that predicted unexpected residual aneurysm or unclipped aneurysm.

The inability to predict accurately the presence of residual or unclipped aneurysm suggests that all patients should undergo postoperative angiography. Since a new postoperative neurological deficit is one factor predicting unexpected arterial occlusion, intraoperative angiography may be necessary to help reduce the incidence of stroke after aneurysm surgery. With study of more patients or of factors not examined in this series, it may be possible to select cases more accurately for intraoperative or postoperative angiography.

Key Words · **aneurysm rest** · **cerebral angiography** · **postoperative angiography** · **vascular occlusion**

About 10% of the morbidity and mortality following subarachnoid hemorrhage (SAH) from ruptured cerebral aneurysms is due to surgical complications.[8] One potentially remediable problem is major vessel occlusion, which occurs after clipping of aneurysms in up to 22% of cases.[2,11,15] Intraoperative angiography or Doppler ultrasound assessment may detect major vessel occlusions and allow clip repositioning before permanent sequelae develop. However, since many surgeons do not even perform postoperative angiography, it seems unlikely that intraoperative angiography will become widely used unless some criteria for increasing the awareness of unexpected problems can be found or the procedure can be greatly simplified. Another problem following surgery for aneurysms is recurrent SAH, sources of which may be rupture (with or without regrowth) of a portion of unclipped aneurysm, possibly a slipped clip, or a second rupture from a completely unclipped aneurysm.[6,10,14] Intra- or postoperative angiography would detect these events and possibly prevent their sequelae.

We have reviewed 88 patients who underwent surgery for clipping of cerebral aneurysms with a preoperative plan for postoperative angiography. The purpose was to find the incidence of unexpected residual aneurysm, unclipped aneurysm, and unforeseen major vessel occlusion on postoperative angiograms. We attempted to identify factors that might predict unexpected find-

ings on angiograms in the hope of defining subgroups of patients in whom postoperative angiography is unnecessary or those in whom intra- or postoperative angiography is essential.

Clinical Material and Methods

Patient Population

A consecutive series of 88 patients were operated on for 92 cerebral aneurysms between July 1, 1988, and December 30, 1991. These included all of the aneurysms operated on by the senior author (M.C.W.) during this time. It was decided *a priori* to obtain a postoperative angiogram in all cases and this was done in 66 patients who underwent clipping of 78 aneurysms. These included 43 women and 23 men, with a mean age of 49 ± 13 years.

Each aneurysm clipping was recorded as a separate event, although some patients were operated on twice. A prospective record was kept of surgical procedures, intraoperative findings, and impressions about the adequacy of clipping and patency of adjacent major cerebral arteries. These records, as well as hospital charts and pre- and postoperative cerebral angiograms, were reviewed. The following data were collected: aneurysm location and size, presence or absence of intraoperative aneurysm rupture, the intraoperative impression that residual aneurysm was left or that a major vessel was occluded, whether or not the aneurysm was decompressed after clipping by incision or needle aspiration, and whether or not the patient awoke postoperatively with a new focal or global neurological deficit.

Definition of Terms

A giant aneurysm was defined as one larger than 2.5 cm based on its largest diameter on computerized tomography (CT) or cerebral angiography. Intraoperative rupture of the aneurysm was recorded as present if major rupture of the aneurysm occurred prior to clip application. Minor, easily controlled bleeding during clip application or during the final stages of dissection was not classified as intraoperative rupture. Note was made of whether the aneurysm was decompressed by inserting a needle into the sac or by incising the sac. The intraoperative impression about whether residual aneurysm was left proximal to the clip blades and whether any major vessels were thought to be included in the clip blades was obtained from the prospective aneurysm log and from operative reports dictated prior to postoperative angiography.

Major vessel occlusion was defined as occlusion of the internal carotid, posterior communicating, anterior communicating, vertebral, posterior inferior cerebellar, anterior inferior cerebellar, superior cerebellar, basilar, or first and second parts of the posterior, middle, or anterior cerebral arteries. Residual aneurysm was defined on angiography as a portion of the aneurysm, usually at its origin from the fork between two vessels, proximal to the clip blades, and still filling with contrast medium on angiography. To differentiate residual aneurysm from adjacent arteries, residual aneurysm had to be seen on two angiographic views. A new focal neurological deficit (other than cranial nerve palsy) was considered present if it persisted until at least 6 hours postoperatively. Similarly, global neurological deficit was considered present postoperatively if the patient had a Glasgow Come Scale[13] score more than 2 points lower than preoperatively, at least 6 hours postoperatively. Timing of postoperative angiography was defined as early after surgery if it was performed on the first 3 postoperative days. Possible indications for angiography after aneurysm clipping were recorded, including development of a new neurological deficit (either immediately or days after surgery), recurrent SAH, and evidence of cerebral infarction on a CT scan in a distribution other than that of small perforating arteries. In a few instances when the senior author (M.C.W.) recorded concern about the adequacy of aneurysm clipping, this also constituted an indication for postoperative angiography. Severe vasospasm was defined as greater than 50% reduction in diameter of at least one major vessel of the circle of Willis.

TABLE 1

*Clinical and radiographic features entered into logistic regression analysis**

Feature	Description
site	location of aneurysm
size	giant (> 2.5 cm diameter) or not giant
rupture	presence or absence of substantial intraoperative rupture
needled or opened	whether or not aneurysm was cut open or aspirated with a needle after clipping
residual aneurysm	surgeon's intraoperative impression about whether or not residual aneurysm was present following aneurysm clipping
major vessel occlusion	surgeon's intraoperative impression about whether or not a major artery was occluded by the clip blades
focal neurological deficit	new postoperative focal neurological deficit, other than cranial nerve palsy, present for at least 6 hours after surgery
global neurological deficit	new postoperative decrease in Glasgow Coma Scale[13] score of more than 2 points, for at least 6 hours after surgery

* Features tested in an attempt to predict results of angiography after aneurysm surgery.

Statistical Analysis

Data were collected, coded, edited, and entered into a desktop computer. Analysis was performed using commercially available statistical software. To attempt to identify a group of factors (Table 1) that would predict the unexpected findings on angiography (unexpected residual or unclipped aneurysm or unexpected major vessel occlusion), a logistic regression analysis was performed. Kappa values were calculated in order to assess the amount of agreement (beyond chance) between the clinical factors and the postoperative angiogram findings.[9] Chi-squared analysis was performed when appropriate. Data are presented as the mean ± standard deviation. The level of significance was p less than 0.05.

TABLE 2

Clinical grade on admission of 88 patients presenting with symptomatic or asymptomatic aneurysms

Grade*	No. of Cases
I	28
II	17
III	13
IV	12
symptomatic, no SAH	9
asymptomatic	9

* World Federation of Neurological Surgeons[4] grading scale. SAH = subarachnoid hemorrhage.

TABLE 3

Location and size of 78 aneurysms in 66 patients

Location of Aneurysm	Aneurysms	
	Total	Giant
posterior communicating artery	9	0
anterior choroidal artery	1	0
ophthalmic artery	7	5
carotid termination artery	2	1
middle cerebral artery	18	2
anterior communicating artery	21	0
pericallosal artery	2	0
basilar termination artery	9	2
posterior inferior cerebellar artery	4	0
other posterior circulation	5	2

Results

Postoperative Angiography

The clinical grade of patients according to the World Federation of Neurological Surgeons classification[4] and mode of presentation are summarized in Table 2. The location and size of each aneurysm are indicated in Table 3. Giant aneurysms comprised 15% of the aneurysms, and 23% of the aneurysms arose from vessels in the posterior circulation. Fifty percent of patients underwent surgery within 3 days of SAH (Table 4). Angiography was performed an average of 6 ± 5 days postoperatively (Table 4) and, for 22 aneurysms, within 3 days of surgery. Four-vessel angiography was not generally used; the number of vessels injected (mean 2 ± 1) was guided by the indication for the angiogram. There were no neurological complications due to angiography. One patient developed shortness of breath and nausea after injection of contrast medium and angiography was terminated; it was repeated without incident 2 days later, after the patient was premedicated with corticosteroid and antihistamine agents. In 17 patients, postoperative angiography was not performed. Eight patients died or were moribund postoperatively, two underwent craniotomy but their aneurysms were not clipped, and 12 patients refused angiography or were perfectly well postoperatively.

TABLE 4

Delay from subarachnoid hemorrhage (SAH) to surgery and from surgery to postoperative angiography in 78 aneurysm clippings in 66 patients

No. of Days	SAH to Surgery	Surgery to Angiography
1	14	7
2	14	9
3	5	6
4	8	5
5	4	12
6	3	10
7	2	10
> 8	16	19
total	66	78

TABLE 5

*Results of unexpected major vessel occlusions in nine patients**

Aneurysm Location	Artery Occluded	Infarction	Clinical Outcome
PCoA	PCoA	no	good recovery
ophthalmic	ICA	no	good recovery
MCA	M_2	yes	good recovery
ACoA	ACoA	yes	death
ACoA	A_2	yes	moderate disability
ACoA	A_2	yes	moderate disability
basilar apex	P_1	yes	good recovery
basilar apex	P_1	yes	death
PICA	PICA	no	good recovery

* PCoA = posterior communicating artery; MCA = middle cerebral artery; ACoA = anterior communicating artery; PICA = posterior inferior cerebellar artery; ICA = internal carotid artery; M_2 = insular segment of the MCA; A_2 = pericallosal segment of the anterior cerebral artery; P_1 = precommunicating segment of the posterior cerebral artery.

Major Vessel Occlusions

Unexpected major vessel occlusion occurred in nine (12%) of 78 occlusions (Table 5 and Fig. 1). In six cases, the patients developed cerebral infarction and two died as a result. Among eight patients who were thought to have major vessels occluded intraoperatively, this was confirmed angiographically in seven cases and stroke resulted in two cases. There were no deaths. Deficit due to major vessel occlusion was apparent immediately after surgery, although not all immediate postoperative deficits were due to major vessel occlusions. There was moderately good agreement between the intraoperative impression that a major vessel was occluded and the presence of major vessel occlusion on postoperative angiography (Table 6, kappa = 0.56).[9]

Residual and Unclipped Aneurysms

Three unexpected residual aneurysms were detected by postoperative angiography. These were portions of aneurysms at the middle cerebral artery bifurcation, the anterior communicating artery complex, and a vertebral artery dilation near the posterior inferior cerebellar

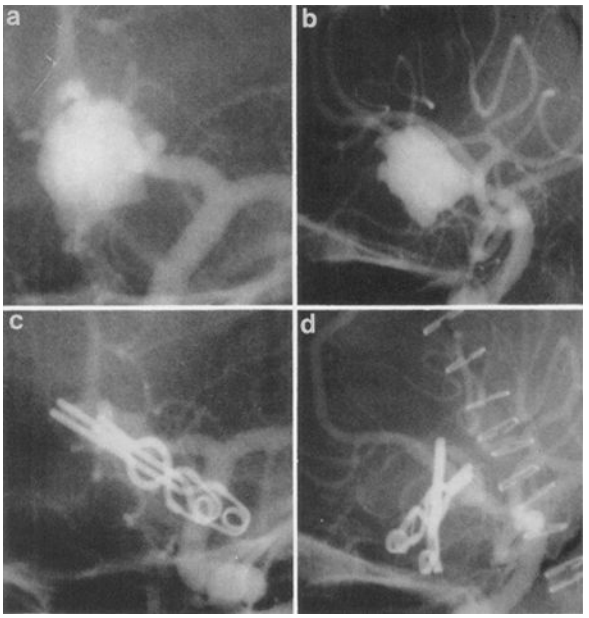

FIG. 1. a and b: Preoperative left internal carotid artery angiograms, anteroposterior (a) and lateral (b) views, showing a large aneurysm arising at the anterior communicating artery. Both pericallosal arteries fill from the left precommunicating anterior cerebral artery. c and d: Postoperative left internal carotid artery angiograms, anteroposterior (c) and lateral (d) views, showing that the aneurysm is obliterated but that the left pericallosal artery is occluded near the tip of one of the aneurysm clips. Intraoperatively, the clip blades were seen to pass anterior to the pericallosal arteries and the occlusion was thought to be due to kinking of the artery.

TABLE 6

*Relationship between intraoperative impression that a major artery was occluded and finding of major vessel occlusion on postoperative angiogram**

Finding at Surgery	Postoperative Angiographic Findings	
	Occlusion	No Occlusion
vessel occluded	7 (2 strokes)	1
no occlusion	9 (6 strokes, 2 deaths)	61

* Kappa = 0.56.

TABLE 7

*Relationship between angiographic findings and the operative impression that residual aneurysm was left**

Operative Impression	No. of Cases	Postoperative Angiographic Findings			
		Residual or Unclipped Aneurysm		No Residual, No Unclipped Aneurysm	
		No.	Location	No.	Location
residual	11	5	3 ophthalmic 1 MCA 1 ACoA	6	4 MCA 1 PCoA 1 ACoA
no residual	67	6	3 unclipped (ACoA, MCA, ophthalmic) 3 residual (ACoA, MCA, VA dissection)	61	

* Kappa = 0.38. MCA = middle cerebral artery; ACoA = anterior communicating artery; PCoA = posterior communicating artery; VA = vertebral artery.

artery in a patient who underwent vertebral artery occlusion for vertebral artery dissection and SAH. Of 11 aneurysms in which residual sacs were thought to be left intraoperatively, postoperative angiography confirmed this in five, including three intracavernous portions of carotid-ophthalmic aneurysms, one at the middle cerebral artery bifurcation, and one at the anterior communicating artery complex. Residual aneurysms thought to be left at the middle cerebral artery bifurcation (four cases), posterior communicating artery origin (one case), and anterior communicating artery complex (one case) were not visualized postoperatively on angiography.

Three aneurysms were completely unclipped on postoperative angiography (Fig. 2). One patient underwent a craniotomy for clipping of anterior communicating, middle cerebral, and giant carotid bifurcation aneurysms. An angiogram 5 days after surgery showed an aneurysm at the anterior communicating artery complex, which was found to be a separate aneurysm at a second operation. Another patient had two middle cerebral artery aneurysms, one successfully clipped and the other found to be remote from the second aneurysm clip on postoperative angiography. This aneurysm was also obliterated successfully at a second surgery. The third case was a patient who had a carotid-ophthalmic aneurysm clipped and opened widely to decompress the optic nerve. Two days later, he developed decreased vision in the ipsilateral eye and a CT scan showed new SAH. Angiography revealed filling of the aneurysm sac with the clip lying across the body of the aneurysm with the blades open. The aneurysm was reclipped with two large clips and the patient recovered uneventfully. Subsequent angiography showed complete obliteration of the aneurysm. The agreement between these angiographic findings (presence of unexpected residual aneurysm or unclipped aneurysm on postoperative angiography) and the intraoperative impression that residual aneurysm was left behind was only fair (Table 7, kappa = 0.38).[9]

Logistic Regression Analysis

Logistic regression analysis showed that none of the factors listed in Table 1 were significant independent predictors of whether or not postoperative angiography would show unexpected residual or unclipped aneurysm. A new postoperative focal neurological deficit was a significant independent predictor of an unexpected major vessel occlusion on the postoperative angiogram (odds ratio 2.06).

Other Findings

An angiogram performed within 3 days of surgery was more likely to disclose unexpected findings (resid-

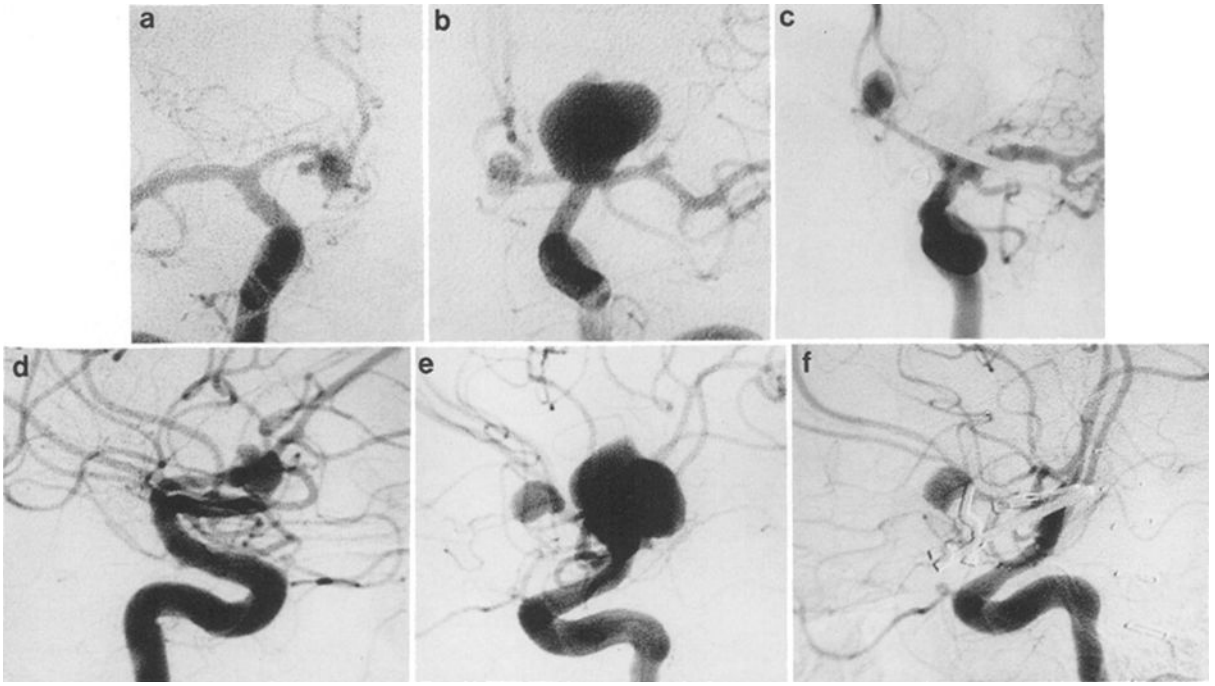

FIG. 2. a, b, d, and e: Preoperative angiograms from a patient with two aneurysms arising at the anterior communicating artery, a giant internal carotid artery bifurcation aneurysm, and a small proximal middle cerebral artery aneurysm. Right carotid artery injection (a and d), anteroposterior and lateral views, respectively, and left internal carotid artery injection (b and e), anteroposterior and lateral views, respectively. Only one of the anterior communicating artery aneurysms was recognized prior to surgery. c and f: Postoperative left internal carotid artery angiograms, anteroposterior (c) and lateral (f) views, showing obliteration of three aneurysms. There is still angiographic filling of an aneurysm at the anterior communicating artery. At a second operation, the clip was across one of the anterior communicating artery aneurysms.

ual or unclipped aneurysm or major vessel occlusion) than one done 4 or more days after surgery (chi-squared test = 4.4, $p < 0.05$). This is not surprising, as angiography was carried out early because of unexplained neurological deterioration (17 cases), recurrent SAH (one case), and concern about the adequacy of clipping (three cases). Postoperative angiography was considered to be indicated in 37 cases. Indications included new postoperative neurological deficit, recurrent SAH, and intraoperative concern about the adequacy of clipping or about major vessel occlusion. There was moderate agreement between an indication for angiography and unexpected residual or unclipped aneurysm, major vessel occlusion, or severe vasospasm on postoperative angiography (Table 8, kappa = 0.41).[9] In other words, 41 angiograms were obtained without clinical indication for postoperative study, and yet six (15%) showed an unexpected finding. There was fair agreement between new postoperative focal or global neurological deficit and unexpected major vessel occlusion on postoperative angiography (kappa = 0.33).

In 60 aneurysm clippings, the aneurysm was either needled or opened or clip application stopped intraoperative bleeding from the aneurysm, indicating that the aneurysm sac beyond the clip blades was isolated from the circulation. There was no agreement between this procedure and the presence or absence of residual or unclipped aneurysm on postoperative angiography (kappa = 0.03).

Discussion

Many neurosurgeons experienced in surgery of intracranial aneurysms do not perform angiography routinely after aneurysm clipping.[6] There is a small risk of complications and it is sometimes difficult to know what to do about small residual portions of aneurysms or artery occlusions, particularly when detected days later in asymptomatic patients. This study found that angiography was safe and that it frequently revealed unclipped aneurysms (4%), unexpected residual portions of aneurysms (4%), and unexpected major vessel occlusions (12%). Three unclipped aneurysms were successfully obliterated at subsequent operations and one residual aneurysm was clipped after it was found to have enlarged on angiography performed 1 year after the first postoperative angiogram. Based on these data, a new postoperative focal neurological deficit seemed to be predictive of unexpected postoperative major vessel occlusion as seen on angiography. The odds ratio of 2.06 implies that a patient with such a new focal deficit is about twice as likely to have an unexpected major vessel occlusion as a patient without a new focal

TABLE 8

*Relationship between indication for angiography and postoperative angiographic findings**

Indication for Angiogram	Postoperative Angiographic Findings	
	Unexpected Finding, Severe Vasospasm	Nothing Unexpected, No Severe Vasospasm
angiogram indicated	20	17
angiogram not indicated	6	35

* The presence of unclipped aneurysm, major vessel occlusion, or severe vasospasm on postoperative angiography (kappa = 0.41).

deficit. These results revealed that the site or size of the aneurysm, presence of intraoperative rupture, whether or not the aneurysm was decompressed after clipping, whether or not the surgeon thought he left residual aneurysm or occluded a major vessel, and whether or not the patient awoke with a new global deficit were not particularly helpful in predicting untoward findings on subsequent angiography.

Residual Aneurysms

Angiography after aneurysm clipping may reveal residual portions of aneurysm proximal to the aneurysm clip, or occasionally that the aneurysms are totally unclipped.[2,5,6,10–12] Feuerberg, *et al.*,[6] identified aneurysm rests in 4% of a series of 715 consecutive patients studied by postoperative angiography. In other series, the incidence of aneurysm rests in patients subjected to postoperative angiography has ranged from 4% to 18%.[2,5,10–12] Incomplete obliteration may occur in up to 17% of giant aneurysms.[12] Aneurysm rests may undergo spontaneous thrombosis, which may explain the failure of postoperative angiography to identify a residual sac in some patients in this series where a rest was thought to be left at surgery. It is important to identify these rests as there is some danger of rupture of residual aneurysms, usually accompanied by regrowth of the aneurysm. Feuerberg, *et al.*, found that residual aneurysms rebled at a rate of about 0.5% per year. They considered that this statistic warranted reoperation for aneurysm rests in younger patients.

Major Arterial Occlusions

The incidence of unexpected major arterial occlusion in this series seems high, although it is entirely consistent with previous series in which patients have been subjected to routine postoperative angiography after aneurysm clipping. Allcock and Drake[1] found major vessel occlusions in 9% of 70 cases, and other series document similar findings in 11% to 22% of patients undergoing aneurysm surgery.[3,14] Among 63 consecutive patients who died after surgery for aneurysm clipping, Karhunen[7] found major vascular complications in 28; there were seven (11%) major vessel occlusions. Operation on basilar aneurysms was significantly more likely to be associated with complications. Intraoperative angiography in 119 patients from two series[2,11] shows that suboptimal clip placement and arterial occlusions are detected in about 9% of patients following aneurysm obliteration using microsurgical technique. In 1% to 2% of cases, residual aneurysms not seen intraoperatively are observed on angiography obtained following surgery. Based on their experience, Martin and colleagues[11] recommended intraoperative angiography following clipping of giant aneurysms or those arising at sites such as the basilar artery termination, anterior communicating artery, or middle cerebral artery.

Value of Opening the Aneurysm

Incising or inserting a needle into the aneurysm after clipping did not predict unexpected findings on the postoperative angiogram. This practice indicates that the sac distal to the clip blades is isolated from the circulation. In two patients in our series, this was of value because bleeding occurred which stopped following advancement of the clip. Decompressing the sac, however, does not reveal what may be entrapped in the clip blades beyond the aneurysm; a portion of the aneurysm proximal to the blades might also still fill with blood. Therefore, routine opening of the aneurysm, apart from cases where neural compression must be relieved, is not valuable for predicting major vessel occlusion or residual aneurysm.

Conclusions

Major arterial occlusions and residual aneurysms can be detected unexpectedly on routine postoperative angiography. In this series, a new focal deficit after surgery was associated with unexpected major arterial occlusion on subsequent angiography. The presence of residual or unclipped aneurysms could not be predicted. The inability to predict these events suggests that all patients should have angiography after aneurysm surgery. In addition, since neurological deficit from major vessel occlusion can probably best be prevented by immediate clip repositioning,[15] a strong argument can be made for using intraoperative angiography or, possibly, intraoperative Doppler ultrasound studies to check clip placement. Further experience may help to narrow the indications for use of intra- and postoperative angiography after intracranial aneurysm surgery.

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