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Comparison of routine and selective use of intraoperative angiography during aneurysm surgery: a prospective assessment

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Object. Whether routine intraoperative angiography is necessary for cerebral aneurysm surgery is currently under debate. In this study the authors prospectively assessed the cerebrovascular surgeon's accuracy in predicting the need for intraoperative angiography.

Methods. Between January 2002 and January 2003, 200 consecutive patients (141 female and 59 male patients, mean age 52.8 years) with 235 aneurysms underwent routine intraoperative angiography. Before the operation, the surgeons indicated whether they believed that intraoperative angiography was necessary. Their responses were recorded as "intraoperative angiography necessary" or "intraoperative angiography unnecessary." Regardless of the response, all patients underwent intraoperative angiography after the aneurysm had been clipped. Changes in treatment resulting from intraoperative angiography were compared with surgeons' preoperative predictions of the need for intraoperative angiography.

Intraoperative angiography was predicted to be necessary in 41 cases (20%) and unnecessary in 159 cases (80%). Its use altered treatment in 14 patients. Seven of these patients were among the group in which intraoperative angiography was deemed necessary and seven were in the group in which it was considered unnecessary. In the latter group, two patients had residual aneurysms, three had parent vessel occlusion, and two had previously undiagnosed aneurysms. Only one patient (0.5%) sustained a major intraoperative complication attributed to angiography.

Conclusions. Given the frequency of significant disease that remains undetected if intraoperative angiography is used on a selective basis and the low complication rate associated with the procedure, the use of intraoperative angiography should be considered in the majority of aneurysm cases.

Key Words • **intraoperative angiography** • **aneurysm surgery**

Current convention holds that intraoperative angiography is used on a selective basis for complex aneurysms only. Consequently, it is used in a minority of aneurysm cases. Recently authors of a number of studies have evaluated the routine use of intraoperative angiography for cerebral aneurysm surgery.[1,3,4,9,10] In two of the most recent and largest studies the authors found that routine intraoperative angiography altered surgical treatment in 11 or 12% of cases and was associated with neurological morbidity in less than 0.5% of cases.[3,10] Based on these findings, some authors have suggested that intraoperative angiography should be used more frequently, if not routinely.

A key question that remains unanswered regarding the use of intraoperative angiography for aneurysm surgery is whether surgeons can accurately predict when intraoperative angiography is necessary. If surgeons can accurately predict cases in which this mode of imaging will most likely alter the surgical course, its use can be reasonably restricted. Conversely, if surgeons cannot accurately predict the need for intraoperative angiography, its routine use is justified. We hypothesized that an experienced cerebrovascular surgeon can accurately predict the need for intraoperative angiography, thus justifying its use on a selective basis only. At the outset of this study we believed very strongly that our hypothesis would hold true and that routine intraoperative angiography would be found to be entirely unnecessary. Our findings, however, failed to support this hypothesis.

Clinical Material and Methods

Study Design

This study was reviewed and approved by the Institutional Review Board of St. Joseph's Hospital and Medical Center and the Barrow Neurological Institute.

Between January 2002 and January 2003, intraoperative angiography was performed on all patients who underwent

Abbreviations used in this paper: SAH = subarachnoid hemorrhage; VA = vertebral artery.

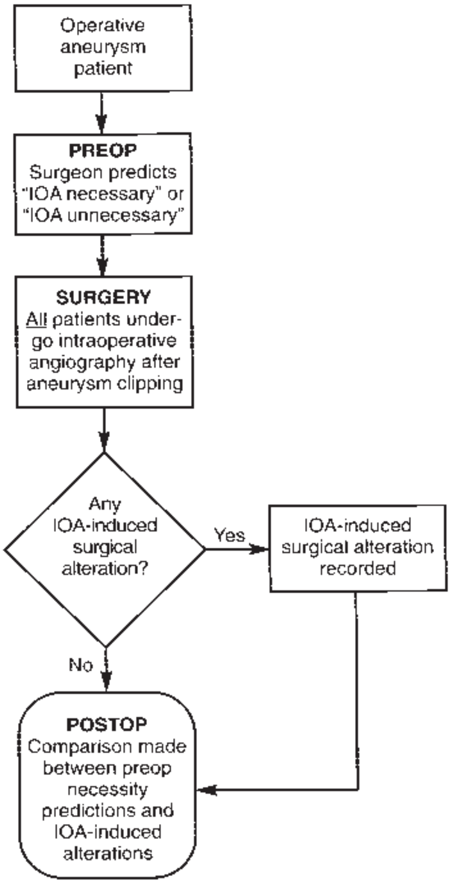

FIG. 1. Flow diagram summarizing the study protocol. An intraoperative angiography (IOA)–induced surgical alteration is any change in the surgical procedure that was made in response to the findings of intraoperative angiography.

aneurysm surgery at our institution (Fig. 1). Based on patients' preoperative angiograms, surgeons were asked before each case whether they believed that the aneurysm was sufficiently complex to necessitate intraoperative angiography. In other words, if intraoperative angiography was performed on a selective basis, would the surgeon suggest that the patient undergo intraoperative angiography? The surgeon's response was recorded as either "intraoperative angiography necessary" or "intraoperative angiography unnecessary." Regardless of the surgeon's prediction, all patients underwent intraoperative angiography at the time of surgery for their aneurysm. Any alteration in surgical treatment that resulted from the angiographic findings and the reason for the change were compared with the surgeon's preoperative predictions for the case.

Postoperative angiography was performed in a subset of the study population. Early in the series, all patients underwent postoperative angiography. As our comfort level with intraoperative angiography increased, however, we stopped performing postoperative angiography in elective cases and in patients with low-grade SAH. When intraoperative and postoperative angiography studies were performed, the results were compared to establish the rates of false-positive and false-negative findings associated with intraoperative angiography.

TABLE 1

*Distribution of 235 aneurysms in 200 patients**

Location of Aneurysm	No. of Lesions (%)
anterior circulation	208 (88.5)
ACoA	62 (26.4)
MCA bifurcation	41 (17.4)
PCoA	36 (15.3)
OphA	25 (10.6)
ICA terminus	13 (5.5)
distal ACA	8 (3.4)
SHA	7 (3.0)
distal MCA	3 (1.3)
carotid cave	3 (1.3)
posterior circulation	27 (11.5)
BA	10 (4.3)
PICA	5 (2.1)
SCA	5 (2.1)
AICA	4 (1.7)
PCA	2 (0.9)

* ACA = anterior cerebral artery; ACoA = anterior communicating artery; AICA = anterior inferior cerebellar artery; BA = basilar artery; ICA = internal carotid artery; MCA = middle cerebral artery; OphA = ophthalmic artery; PCoA = posterior communicating artery; PICA = posterior inferior cerebellar artery; SCA = superior cerebellar artery; SHA = superior hypophysial artery.

Patient Population

During the 12-month study period, 220 patients with aneurysms were studied. Twenty patients did not undergo intraoperative angiography and, therefore, were excluded from the study. The reasons why intraoperative angiography was not performed in those patients included problems with vascular access (eight patients), severe atherosclerosis (three patients), allergy to the contrast dye (two patients), cardiac standstill (two patients), an incidental aneurysm found at the time of hematoma evacuation (two patients), critical condition of the patient (one patient), angiography team unavailable (one patient), and stroke after a previous angiography session (one patient).

Intraoperative angiography was performed in the remaining 200 patients (141 female and 59 male patients). Eight of these patients underwent two procedures each. The mean age of the patients was 52.8 years (range 14–80 years). Subarachnoid hemorrhage was present in 110 patients (55%).

In all, 235 aneurysms were clipped (mean 1.2 aneurysms/patient; range one–five aneurysms/patient). In 24 patients (12%) two or more aneurysms were treated during a single operation; in the remaining patients one aneurysm was treated at each operation.

Most aneurysms (88.5%) were located in the anterior circulation, whereas 11.5% were located in the posterior circulation (Table 1). Four aneurysms (1.7%) were larger than 25 mm, 37 (15.7%) were between 10 and 25 mm, and 194 (83%) were less than 10 mm.

Intraoperative Angiographic Procedure

Often in patients with SAH, sheaths had already been placed in the right common femoral artery by our colleagues in the Division of Neuroradiology during the patients' initial diagnostic angiography. In patients who were undergoing elective aneurysm treatment, placement of sheaths was accomlished in the operating room. The pa-

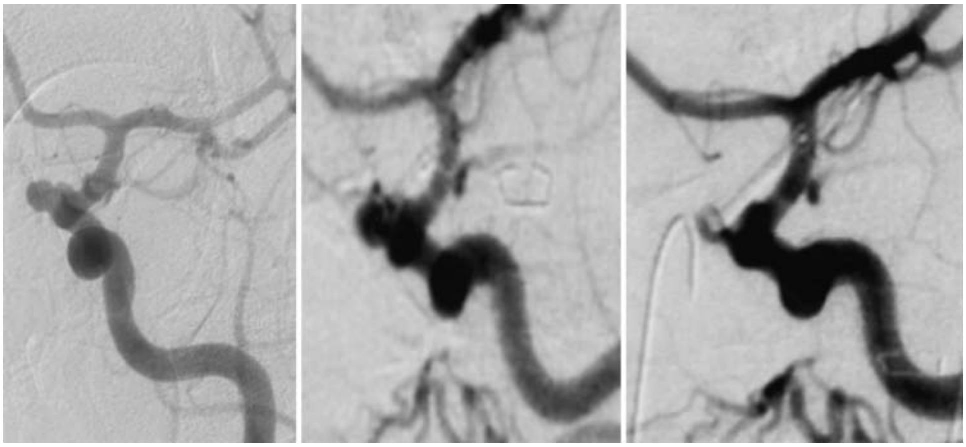

FIG. 2. *Left:* Preoperative angiogram obtained in a 59-year-old woman, revealing a left OphA aneurysm. *Center:* First intraoperative angiogram obtained after the initial clipping of the lesion, demonstrating the presence of a significant residual aneurysm. *Right:* Second intraoperative angiogram obtained after the clip had been repositioned, confirming obliteration of the aneurysm.

tients were placed supine and received a general endotracheal anesthetic agent. The groin was prepared and draped in a standard sterile fashion. A small nick incision was made in the right common femoral artery region by using standard landmarks to approximate placement over the femoral head. A 19-gauge, single-wall needle was placed into the right common femoral artery, and a Benson 0.035-in wire (Cook, Inc., Bloomington, IN) was placed through the needle. The needle was exchanged for a No. 5 French sheath, which was attached to a standardized flush solution of heparin. The sheath was then secured to the groin with a 2-0 silk suture. Following this, the craniotomy and clipping of the aneurysm was performed.

After the aneurysm had been treated, the neuroendovascular team performed intraoperative cerebral angiography. A C arm (OEC Medical Systems, Inc., Salt Lake City, UT) was used with road-mapping and digital subtraction angiographic technology. A No. 5 French University of California, San Francisco catheter or Weinberg catheter (Cook, Inc.) was used with a Benson wire or, if needed, a glidewire and torque device. Road-mapping techniques were used to access the right or left common carotid artery. If an aneurysm involved the posterior circulation, selective catheterization of the VAs was attempted. If that attempt failed, the subclavian artery was catheterized and used for angiography. Before intraoperative angiography was performed, the preoperative angiograms were reviewed to determine the appropriate angle of view to visualize the aneurysm and the proximal and distal vessels.

After angiography had been completed, all catheters were withdrawn from the patient and the angiograms were reviewed by the neurosurgical and neuroendovascular teams. The craniotomy was closed or the aneurysm clip was adjusted, and angiography was repeated. After the entire procedure had been completed, the patient was transferred to the recovery room. The sheath was usually removed the next day. If formal angiography in the biplanar angiography suite was thought to be indicated, the sheath was left in place until this procedure could be completed.

The far-lateral approach was indicated for aneurysms involving the posterior inferior cerebellar artery and the VA in a small group of patients. The sheaths were inserted in the manner described earlier, and the patients were placed in the modified park-bench position for surgery. If the patient's right side was down, the left common femoral artery was accessed for sheath placement; if the patient's left side was down, the right common femoral artery was accessed. A longer No. 5 French sheath was placed to enable easier access to the sheath by the angiography team.

TABLE 2

Summary of cases in which intraoperative angiography was deemed unnecessary, but surgical treatment was altered based on its findings

Case No.	Aneurysm Location	Aneurysm Size (mm)	Reason for Alteration in Surgery
1	ACoA	20	A_2 occlusion
2	AICA	6	AICA occlusion
3	ACoA	7	A_2 occlusion
4	OphA	5	residual aneurysm
5	PCoA	7	residual aneurysm
6	PCoA	6	new SHA aneurysm
7	ICA terminus	7	new MCA aneurysm

Statistical Analysis

The following variables were analyzed: 1) overall rate of positive findings on intraoperative angiography; 2) overall rate of change in surgical treatment resulting from findings of intraoperative angiography; 3) rates of change in surgical treatment in patients in whom intraoperative angiography was deemed necessary and patients in whom it was deemed unnecessary; 4) reasons for these changes in treatment; 5) the discrepancy rate between findings on intraoperative and postoperative angiography when both were performed; and 6) the complication rate associated with intraoperative angiography.

All data were recorded and stored in a confidential manner in computer spreadsheet format. Wherever applicable, the results were recorded as mean values ± standard errors of the means. Chi-square analysis was used to compare the surgeons' preoperative predictions about the need for intra-

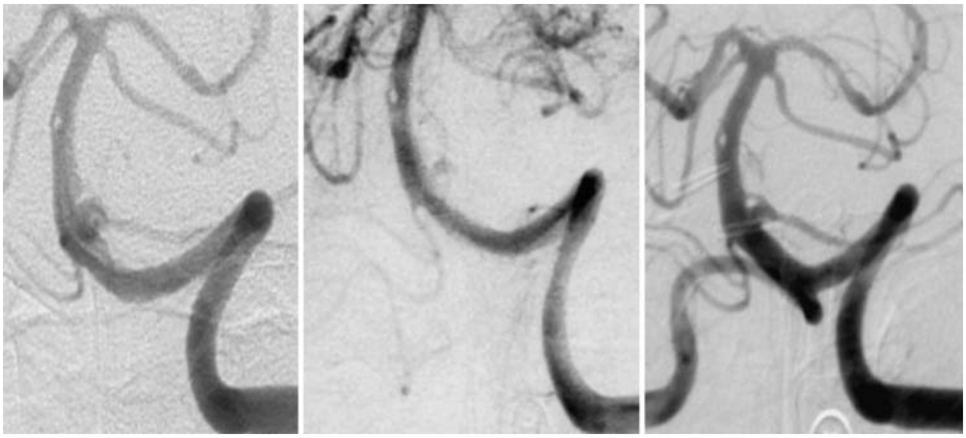

FIG. 3. *Left:* Preoperative angiogram obtained in a 77-year-old woman, revealing a left AICA aneurysm. *Center:* Intraoperative angiogram obtained after initial clipping of the lesion, demonstrating that the aneurysm is obliterated, but the AICA is occluded. *Right:* Postoperative angiogram obtained after the clip had been repositioned, confirming obliteration of the aneurysm and a patent AICA.

operative angiography and actual outcomes. Significance was set at a probability level lower than 0.05.

Results

Alterations in Surgical Treatment Attributable to Intraoperative Angiography

A surgeon's prediction that intraoperative angiography was necessary was recorded in 41 cases and the prediction that it was unnecessary was recorded in the remaining 159 cases. Overall, intraoperative angiography led to changes in surgical treatment in 14 cases (7%).

Intraoperative angiography led to an alteration in surgery in seven (17.1%) of the 41 patients in whom intraoperative angiography had been deemed necessary: two for a significant residual aneurysm, two for parent vessel occlusion, one for both a residual aneurysm and vessel occlusion, and two for new aneurysms identified on intraoperative angiography, which had not been detected on preoperative imaging studies.

In the 159 patients in whom intraoperative angiography had been deemed unnecessary preoperatively, intraoperative angiography led to changes in surgical procedure in seven patients (4.4%). Two changes were made for residual aneurysm, three for parent vessel occlusion, and two for previously undetected aneurysms (Table 2 and Figs. 2 and 3). None of the patients in whom alterations in the surgical procedure were made for vessel occlusions experienced infarcts in the territory of the occluded vessel. Changes in surgical treatment that were made on the basis of intraoperative angiography findings were significantly more likely ($p = 0.013$) to have occurred in patients in whom intraoperative angiography was deemed necessary (17.1%) than in those in whom it was considered unnecessary (4.4%).

Intraoperative Angiographic Findings and Accuracy

Of 200 intraoperative angiograms, 65 (32.5%) were interpreted as having positive findings of disease by the physician performing the study. These positive findings included 42 residual aneurysms, 22 instances of vessel stenosis or occlusion, and four previously undetected aneurysms. Of these 65 intraoperative angiograms with positive findings of disease, 14 (21.5%) were thought to reveal findings significant enough to warrant changes in surgical treatment. The findings in the remaining 51 patients (78.5%) were thought to be insignificant and led to no changes in treatment. A residual aneurysm that was demonstrated on one intraoperative angiogram was deemed insignificant, but hemorrhaged on postoperative Day 1. The patient required a repeated operation in which the aneurysm was reclipped.

Postoperative angiography was performed in 138 cases (69%) either to assess for vasospasm in patients with SAH or to confirm obliteration of the aneurysm. Based on the findings of the postoperative angiography there were 16 intraoperative angiograms (11.6%) with false-positive findings. The intraoperative angiographic findings not corroborated by postoperative angiography included nine residual aneurysms and six instances of parent vessel stenosis. One study showed both a residual aneurysm and an area of stenosis. None of the intraoperative angiograms with false-positive findings led to changes in surgical treatment.

There were 12 intraoperative angiograms (8.7%) with false-negative findings. The postoperative angiographic findings included eight residual aneurysms and four instances of vessel stenosis. Eleven false-negative findings were minor and associated with no sequelae. In one patient, however, a significant residual aneurysm discovered on postoperative angiography required reclipping of the aneurysm.

Complications of Intraoperative Angiography

No death, stroke, or neurological morbidity occurred in the study population. Overall, complications occurred in three patients (1.5%). There were two minor complications (1%), an asymptomatic VA dissection and an asymptomatic aortic dissection. There was one major complication (0.5%), a pseudoaneurysm of the femoral artery that required surgical repair. The source of the VA dissection was unclear and may have been related to the preoperative angiography. To be conservative, however, we included this case as a complication of intraoperative angiography. Both dissections were treated with antiplatelet agents and the patients recovered completely.

Discussion

The goal of this study was to address the accuracy of surgeons in predicting the need for intraoperative angiography and, in so doing, to determine whether intraoperative angiography is necessary for all aneurysm cases. Our findings were unexpected and have changed our opinion about the need for intraoperative angiography.

Accuracy of the Surgeon's Prediction of Intraoperative Angiographic Necessity

When intraoperative angiography is used on a selective basis, patients selected for intraoperative angiography were more likely to harbor significant disease following aneurysm clipping than those not selected for intraoperative angiography (17% compared with 4.4%; $p = 0.013$). This finding suggests that an experienced cerebrovascular surgeon is fairly good at evaluating preoperative angiograms and identifying patients likely to benefit from intraoperative angiography. The question, however, is not whether surgeons are good at performing this task, but rather whether their judgments are accurate enough to justify not using intraoperative angiography on a routine basis.

The answer lies in the rate at which intraoperative findings result in alterations in surgical procedures in cases in which the surgeons had predicted that intraoperative angiography would be unnecessary. In these cases, the 4.4% rate of alterations in surgical procedures indicated that postoperatively 4.4% of patients who do not undergo intraoperative angiography will harbor undetected pathological conditions in need of treatment. Perhaps more importantly, almost half of these cases (1.8%) involved parent vessel occlusions that likely would have led to stroke. These rates are significantly higher than we expected and we may infer that the surgeon's prediction of the necessity of intraoperative angiography is not accurate enough to justify its use on a selective basis only. Rather, these results indicate that intraoperative angiography should be used in the majority of aneurysm cases to detect the occasional, but significant postoperative diseases that can remain undetected when intraoperative angiography is used on a strictly selective basis. Exceptions to this rule are situations in which intraoperative angiography would lead to an unfavorable risk/benefit ratio. Examples of such scenarios include the presence of severe atherosclerosis; a difficult catheterization, which sometimes occurs when the patient is in a prone or park-bench position; allergy to the contrast dye; and the critical condition of the patient.

Alterations in the surgical procedure based on findings of intraoperative angiography are most likely to occur in relatively complex aneurysms, particularly ones that are large.[3,9,10] Nevertheless, among our patients in whom intraoperative angiography was considered unnecessary, but surgical treatment was changed because of the angiographic findings, all but one aneurysm were relatively small (< 1 cm). This pattern is inconsistent with the profile of cases whose surgical course is typically altered by findings on intraoperative angiography. The finding suggests that when intraoperative angiography is used selectively, a small subset of relatively small aneurysms, which were unlikely to be selected for intraoperative angiography will be associated with significant, undetected disease.

Complications of Intraoperative Angiography

A second important issue when considering whether intraoperative angiography should be used on a routine basis is the rate of complications associated with its use. In two of the largest series to date, Chiang and colleagues[3] and Tang and associates[10] found that the routine use of intraoperative angiography was associated with major morbidity rates ranging between 0.4 and 1.3% and neurological morbidity rates ranging between 0.3 and 0.4%. Our major morbidity and neurological morbidity rates of 0.5 and 0% are consistent with their findings. Two large studies in which cerebral angiography performed in the angiography suite was evaluated reported similar rates.[6,7] Consequently, morbidity rates do not appear to detract from the routine use of intraoperative angiography.

The use of both intraoperative and postoperative angiography creates an additive angiographic risk and thus increases the patient's overall risk. Nevertheless, we found that intraoperative angiography served as an excellent postprocedure study that could be used in lieu of postoperative angiography. Eliminating postoperative angiography reduces a patient's overall risk to that of intraoperative angiography alone. The exception is the need for postoperative angiography in patients with SAH in whom symptomatic vasospasm develops; otherwise, patients need only undergo intraoperative angiography.

Accuracy and Efficiency of Intraoperative Angiography

Two final issues to be considered in evaluating the routine use of intraoperative angiography are those of its accuracy and efficiency. Standard reporting of the accuracy of intraoperative angiography has focused primarily on the rates of false-negative findings, presumably because the rates of false-positive findings are inconsequential. False-negative findings have ranged in incidence from 0 to 8.3%;[1–4,8–11] our rate was only slightly higher at 8.7%. All but one of our false-negative findings were inconsequential. Undoubtedly, however, intraoperative angiography is slightly less accurate than postoperative angiography as evidenced by the false-negative finding in the patient with the residual aneurysm that required a repeated operation. Nonetheless, the overall accuracy of intraoperative angiography was excellent and supports its routine use.

To date, the best and most accurate alternative to intraoperative angiography for vascular assessment has been Doppler ultrasonography, but its use is limited to the assessment of vascular patency. Its value for assessing vessel stenosis is limited and it lacks any value for detecting residual or previously undetected aneurysms. We have found Doppler ultrasonography to be most useful when immediate real-time assessment of vascular patency is needed. From an empirical perspective, the value and accuracy of this imaging modality fall far short of intraoperative angiography and thus it does not provide a legitimate alternative. In this study we did not formally compare the efficacy of intraoperative Doppler ultrasonography and angiography. Nonetheless, it is interesting to note that, in one case in which Doppler ultrasonography indicated vascular patency, intraoperative angiography demonstrated a critical flow-limiting stenosis in the same vessel. Subsequently, the patient's clip was repositioned.

In this study we did not directly address the issue of efficiency. Authors of previous studies have indicated that an experienced team requires 20 to 30 minutes to perform intraoperative angiography. In fact, our early intraoperative angiographic procedures were cumbersome and lengthy. As our proficiency increased, however, intraoperative angiography only required approximately 20 minutes. Our anecdotal experience concurs that the steep learning curve of intraoperative angiography plateaus relatively quickly and the procedure rapidly becomes a routine part of the operation in aneurysm cases.

If intraoperative angiography is used in lieu of postoperative angiography, little, if any, additional expense is incurred. Furthermore, we believe that the theoretical prevention of disease offered by routine intraoperative angiography would reduce overall expenditures for the care of patients with aneurysm in general. Suffice it to say that the routine use of intraoperative angiography is unlikely to result in increased costs and may, in fact, have the opposite effect.

Overall Rate of Alterations in Surgery Based on Findings of Intraoperative Angiography

Overall intraoperative angiography resulted in an alteration in the surgical procedure in 7% of cases. This rate was significantly less than those reported in other studies of routine intraoperative angiography in which rates have ranged from 11 to 34%.[1,3,4,9,10] This discrepancy may reflect the fact that surgeons who use intraoperative angiography routinely may rely more on angiography than on visual inspection of the surgical field.[5] By eliminating the presumption that intraoperative angiography is necessary for all aneurysm cases, our study should have minimized the reliance on this imaging method over visual inspection. In other words, in cases in which the surgeon predicted that intraoperative angiography was unnecessary, the natural tendency would be to validate the prediction by a thorough inspection of the surgical field to ensure that no disease requiring a change in the surgical plan would be missed and later detected on intraoperative angiography. Theoretically, the tendency to overrely on intraoperative angiography would have been reduced. This dynamic may account for our overall lower rate of changes in surgical treatment related to findings on intraoperative angiography.

Conclusions

Despite our initial skepticism, the results of this study led us to conclude that routine intraoperative angiography is warranted for patients undergoing aneurysm surgery. Given the number and nature of the diseases that remain undetected when intraoperative angiography is only used on a selective basis, the relatively low complication rate associated with this imaging modality, and the relative accuracy and efficiency with which intraoperative angiography can be performed, its use should be seriously considered for the majority of aneurysm cases.

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