Intraoperative Angiography Evaluation of the Microsurgical Clipping of Unruptured Cerebral Aneurysms

Kiyoyuki YANAKA, Hiroyuki ASAKAWA, Shozo NOGUCHI, Yuji MATSUMARU, Akio HYODO, Izumi ANNO*, Kotoo MEGURO**, and Tadao NOSE

Departments of Neurosurgery and *Radiology, Institute of Clinical Medicine, University of Tsukuba, Tsukuba, Ibaraki; **Department of Neurosurgery, Tsukuba Medical Center, Tsukuba, Ibaraki

Abstract

Intraoperative angiography evaluation of the clippings of cerebral aneurysms was investigated in a series of 38 consecutive patients with unruptured cerebral aneurysms to determine any favorable impact on the outcome. Unexpected findings including major arterial occlusion or residual aneurysm were identified. Specific variables such as the size and site of aneurysm were analyzed to determine the impact on clinical outcome and the incidence of clip modification. There were 11 large and 27 small aneurysms in this series. Mortality and permanent morbidity after microsurgical clipping were 0.0% and 2.6%, respectively. Unexpected angiographic findings necessitating clip repositioning consisted of residual aneurysm in two cases and distal branch occlusion or parent vessel stenosis in four. The need for clip modification was significantly higher for large than for small aneurysms ($p = 0.007$), and the rate of clip adjustment increased with increasing aneurysm size ($p = 0.008$). Intraoperative assessment prior to wound closure allows for the recognition and correction of defects and decreases the risk of postoperative complications. Intraoperative angiography may become important in the microsurgical clipping of unruptured cerebral aneurysms, especially large aneurysms.

Key words: cerebral aneurysm, digital subtraction angiography, intraoperative angiography

Introduction

Prevention of hemorrhage from cerebral aneurysms is the most effective strategy for reducing mortality, but the optimal management of patients with unruptured cerebral aneurysms remains controversial. Aneurysm management decisions require an accurate assessment of the risks of various treatment methods, but the reported ranges of mortality and morbidity after surgery for unruptured cerebral aneurysms vary widely from 0% to 7% and 4% to 15.3%, respectively. Recently, the International Study of Unruptured Intracranial Aneurysms (ISUIA) reported rupture rates of 0.05%/yr in patients with aneurysms $<$ 10 mm in diameter and 1%/yr in those with aneurysms $\geq$ 10 mm in diameter. This study found that aneurysm size was the best predictor of future rupture. The Stroke Council of the American Heart Association then developed guidelines for the management of unruptured cerebral aneurysms, and concluded that treatment cannot be generally advocated for incidental small ($< 10$ mm) aneurysms because of the apparent low risk of hemorrhage, whereas surgery is strongly indicated for aneurysms of $\geq 10$ mm in diameter. There is no question that these reports will have a considerable impact on clinical practice, and neurosurgeons must make special efforts to treat larger aneurysms.

The goal of aneurysm surgery is to clip the aneurysm so that there is no residual filling of the aneurysm, distal branch occlusion, or stenosis of the parent vessel. The outcome of aneurysm surgery may be severely compromised by two factors: Focal cerebral infarction caused by the inadvertent occlusion of surrounding vessels by the aneurysm clip; and failure to achieve complete aneurysm closure resulting in regrowth and hemorrhage. Therefore, optimized clip placement in situ is necessary to
reduce the complication rates. Intraoperative angiography is useful in the treatment of cerebrovascular diseases.1-3,6,7,8,11,16-19,21,28,32,34-37 However, the value of intraoperative angiography in the treatment of unruptured cerebral aneurysms is unknown. We have employed digital subtraction angiography during the intraoperative assessment of various cerebrovascular procedures including microsurgical clipping of cerebral aneurysms, resection of arteriovenous malformations, and cerebral revascularization.34-37 Here, we report on our experience with intraoperative angiography in a series of 38 consecutive cases of unruptured cerebral aneurysms to determine whether the use of intraoperative angiography has a favorable impact on the outcome after surgical treatment of unruptured cerebral aneurysms.

**Materials and Methods**

I. **Patient population**

Thirty-eight consecutive patients, 18 men and 20 women aged 46 to 78 years (mean 60.8 years), were treated for unruptured cerebral aneurysms between April 1, 1997 and March 31, 2000. All surgical procedures were performed or supervised by the senior author (K.Y.). The lesions were predominantly located in the anterior circulation (n = 37) with one lesion in the posterior circulation. Eleven patients had lesions larger than 10 mm in sac diameter. Follow-up period ranged from 12 to 45 months (mean 21.3 months) (Table 1).

II. **Intraoperative angiography**

Informed consent was obtained from all patients. Intraoperative angiography used a portable digital subtraction angiography unit (Mobile Imaging System Series 9600; OEC Medical System Inc., Salt Lake City, Utah, U.S.A.) consisting of a C-arm fluoroscope, a digital image processor and storage unit, and a video monitor for intraoperative assessment. This unit can provide real time subtraction images in the operating room. After induction of general anesthesia, the right femoral artery was cannulated with a femoral sheath and a 4-F heparin-coated catheter (Anthron; Toray, Tokyo). The patient’s head was fixed with a radiolucent carbon frame (Multipurpose radiolucent frame; Mizuho Ika, Co., Tokyo) to allow imaging in every direction. This system allows rapid positioning of the surgical x-ray unit and reduces interruptions during the operation. The initial angiogram was performed prior to the dural incision for comparison with the intraoperative angiogram after clipping. Multiple views of each aneurysm were taken by rotating the patient, fluoroscope, or both to confirm the optimal surgical approach.

A 5-F double-lumen balloon catheter was used if intraoperative interventional techniques such as suction decompression were anticipated. Before opening the dura, a balloon catheter with a coaxial lumen was positioned and tested in the internal carotid artery, then the microsurgical exposure was completed, including intradural clinoid drilling and optic canal decompression if necessary. The lesion was trapped by inflating the balloon and placing a temporary clip beyond the aneurysm neck. The catheter was gently aspirated to achieve suction decompression and to facilitate clip application. Afterwards real-time intraoperative angiography was performed.

Conventional postoperative angiography was performed in the initial 20 patients and compared with the results of the intraoperative study.

III. **Statistical analysis**

Intraoperative and postoperative angiographic findings were reviewed by the neurosurgeons and/or a neuroradiologist to detect any residual filling of the aneurysm, distal branch occlusion, and parent vessel stenosis. The patient’s age, sex, aneurysm size and location, complications due to intraoperative angiography, and clinical outcome were recorded. The maximum diameter of each aneurysm was measured and classified as giant (≥ 25 mm; n = 0), large (10-25 mm; n = 11), or small (<10 mm; n =

<table>
<thead>
<tr>
<th>No. of patients</th>
<th>Clip adjustment (+)</th>
<th>Clip adjustment (-)</th>
<th>Total</th>
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<tr>
<td>Site of aneurysm</td>
<td>IC-PCA</td>
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<td>8</td>
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<tr>
<td>ICA</td>
<td>2</td>
<td>3</td>
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<td>2</td>
</tr>
<tr>
<td>MCA</td>
<td>2</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>VA-PICA</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Age* (years)</td>
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<td>60.9±9.5</td>
<td>60.8±9.3</td>
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<tr>
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<td>18:20</td>
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<tr>
<td>Diameter* (mm)</td>
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<td>6.9±4.6</td>
<td>8.1±5.5</td>
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<tr>
<td>Size (large:small)</td>
<td>5:1</td>
<td>6:26</td>
<td>11:27</td>
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<tr>
<td>Follow up* (months)</td>
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<td>20.6±8.1</td>
<td>21.3±8.4</td>
</tr>
</tbody>
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Results

Intraoperative angiography was successfully performed in every patient. Intraoperative angiography prompted clip modification due to residual aneurysm in two cases and distal branch occlusion or parent vessel stenosis in four as summarized in Table 2. Intraoperative endovascular procedures were performed in three patients: suction decompression in one patient with a large internal carotid artery aneurysm, and proximal control in two with internal carotid artery (paraclinoid) aneurysms. Intraoperative angiography caused no complications.

The rate of clip modification was similar for men and women (p = 0.761). Neither age nor aneurysm location had a significant effect on the rate of clip modification (p = 0.929, p = 0.388, respectively). Five of the six patients who underwent clip adjustment had large aneurysms (mean 14.7 ± 5.7 mm). A chi-square test with Yates’ correction demonstrated that the rate of clip modification was significantly higher for large than for small aneurysms (p = 0.007). ANOVA also demonstrated that the rate of clip adjustment increased significantly with increasing aneurysm size (p = 0.008). Logistic regression analyses of multiple factors showed that the only significant predictor of clip repositioning was large aneurysm (p = 0.021, odds ratio = 21.667), whereas sex (p = 0.448), age (p = 0.9266), and site of aneurysm (p = 0.3543) were not significant.

Clinical mortality after surgery was 0.0%. One patient (Case 6) with a large internal carotid artery aneurysm who underwent suction decompression had hemiparesis after surgery. The patient made a prompt recovery but slight hemiparesis persisted at 1 year after surgery. Therefore, the permanent morbidity was 2.6%.

Representative Case Reports

Case 5: A 55-year-old woman was referred to our hospital with a 3-week history of visual disturbance in the right eye. Computed tomography (CT) demonstrated a cystic mass in the right paracclinoid region. Right carotid angiography demonstrated a large aneurysm arising from the bifurcation of the internal carotid and the ophthalmic arteries (Fig. 1). Three-dimensional CT clearly demonstrated the aneurysm and the bleb (Fig. 2). Her symptom was considered to result from the mass effect to the right optic nerve caused by the aneurysm. Microsurgical clipping of the aneurysm with intraoperative angiographic evaluation was conducted. Before opening the dura, a double lumen balloon catheter was in-
Case 5: A 54-year-old woman was referred to our hospital for treatment of an incidental unruptured cerebral aneurysm. Right carotid angiography demonstrated a large aneurysm arising from the internal carotid artery (Fig. 4). Three-dimensional CT demonstrated that the aneurysm had a broad neck (Fig. 5). Microsurgical clipping of the aneurysm with intraoperative angiographic evaluation was conducted. Before opening the dura, a double lumen balloon catheter was introduced into the right internal carotid artery for suction decompression. After inflation of the balloon and temporary clipping, the aneurysm was aspirated and collapsed to facilitate further dissection. Two fenestrated clips were then placed to occlude the aneurysm neck (Fig. 6). Intraoperative angiography showed occlusion of the A1 portion of the anterior cerebral artery (Fig. 7 left). The clips were repositioned and repeat intraoperative angiography confirmed the patency of the A1 portion and complete disappearance of the aneurysm with bleb formation on its top.

Fig. 1 Case 5. Preoperative right carotid angiograms (left: anteroposterior view, right: lateral view) showing a large aneurysm arising from the bifurcation of the internal carotid and ophthalmic arteries.

Fig. 2 Case 5. Three-dimensional computed tomography scan showing the aneurysm with bleb formation on its top.

Fig. 3 Case 5. Intraoperative right carotid angiograms showing complete disappearance of the aneurysm and occlusion of the ophthalmic artery after first clipping (left), and patency of the ophthalmic artery after clip modification (right).

Fig. 4 Case 6. Preoperative right carotid angiograms (left: anteroposterior view, right: lateral view) showing a large aneurysm arising from the internal carotid artery.

Fig. 5 Case 6. Three-dimensional computed tomography scan showing the aneurysm with bleb formation on its top.

Fig. 6 Case 6. Intraoperative right carotid angiograms (left: anteroposterior view, right: lateral view) showing a large aneurysm arising from the internal carotid artery.
Fig. 5 Case 6. Three-dimensional computed tomography scan showing the broad-based aneurysm.

Fig. 6 Case 6. Intraoperative photograph captured from a video recorder showing the expanded aneurysm (left), and shrinkage of aneurysm after suction decompression (right). ACA: anterior cerebral artery, AN: aneurysm, ICA: internal carotid artery, MCA: middle cerebral artery, OP: optic nerve.

Fig. 7 Case 6. Intraoperative right carotid angiograms showing complete disappearance of the aneurysm and occlusion of the A1 portion of the anterior cerebral artery (left), and patency of the A1 portion after clip modification (right).

Intraoperative Angiography for Unruptured Aneurysms

Discussion

This study clearly demonstrated that intraoperative angiography is of particular value in the microsurgical clipping of unruptured cerebral aneurysms, especially large aneurysms. Intraoperative angiography was also effective in conjunction with interventional techniques such as temporary balloon occlusion for proximal control or suction decompression of large aneurysms. This technique was safe and effective for preventing postoperative neurological sequelae, and helped achieve better clinical outcomes.

Aneurysm clipping should obliterate the lumen of the aneurysm without occluding the parent or branch vessels. The compromise of normal vasculature is not apparent during microsurgical clipping of aneurysms, but may lead to serious permanent neurological sequelae. Permanent ischemic injury can develop prior to wound closure, so postoperative evaluation may be too late. Therefore, intraoperative vascular assessment will help to reduce the incidence of ischemic stroke following aneurysm surgery. Intraoperative angiography resulted in revision in six of this series of 38 operations. Clip adjustments restored flow in four cases of major arterial compromise and complete obliteration in two cases of persistently filling aneurysms. Therefore, intraoperative angiography detected unexpected arterial occlusions and residual aneurysms in a total of 15.8% of cases, resulting in probable reduction of mortality and morbidity in this series. Intraoperative angiography has been used in the surgical treatment of cerebral aneurysms in various series, including ours, consisting of 1073 aneurysms (Table 3).1–3,6,7,9,11,16,17,19,21,22,28,32) Clip adjustment was performed in 13.8% of cases: residual aneurysms and arterial
compromises were found in 7.3% and 6.9%, respectively. The intraoperative findings from 837 aneurysms were further evaluated by conventional postoperative angiography. Unexpected postoperative findings were detected in 1.7% of cases, indicating that the intraoperative assessment was highly correlated with the postoperative assessment. Therefore, clip adjustment may have improved the clinical outcome in more than 10% of all patients. The size and location of the aneurysm are correlated with the need to reposition the aneurysm clip after intraoperative angiography.1,7,22) The subgroup of patients with giant or large aneurysm, and basilar apex, posterior communicating artery, or superior hypophyseal artery aneurysms had a significantly higher incidence of clip adjustment.1,7,22) Although our study found that aneurysm location appeared to have no effect on the rate of clip repositioning, the rate of clip adjustment increased significantly with

including 3877 aneurysms demonstrated residual aneurysms and arterial compromise in 5.3% and 3.9% of cases, respectively (Table 4).5,8,14,15,17,23,25,27,31)  

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increasing aneurysm size. The ISUIA study showed that the natural history of smaller aneurysms is more benign than previously believed and that smaller aneurysms are less likely to bleed than larger ones.\(^1\)\(^2\)

The guidelines for the management of unruptured cerebral aneurysms developed by the Stroke Council of the American Heart Association concluded that factors that favor surgery include a young patient with a long life expectancy, previously ruptured aneurysms, a family history of aneurysm rupture, large aneurysms, symptomatic aneurysms, observed aneurysm growth, and established low treatment risks.\(^3\)\(^4\)

Surgical experience with unruptured cerebral aneurysms found morbidity of <3% for aneurysms of 5 mm, <7% for 6 to 15 mm aneurysms, and 14% for 16 to 24 mm aneurysms.\(^5\)\(^6\) Meta-analysis showed that aneurysm size correlated with morbidity and mortality, with smaller aneurysms associated with better outcomes.\(^7\)\(^8\) Obviously surgical difficulty increases with increasing aneurysm size. We found that the rate of clip repositioning was significantly higher for large than for small aneurysms. Therefore, neurosurgeons should concentrate their efforts on treating larger aneurysms. Intraoperative angiography may become important as an adjunct to reduce complications in the microsurgical clipping of unruptured cerebral aneurysms, especially large aneurysms.

**References**


Address reprint requests to: K. Yanaka, M.D., Department of Neurosurgery, Institute of Clinical Medicine, University of Tsukuba, 1–1–1 Tennodai, Tsukuba, Ibaraki 305–8575, Japan.
e-mail: kyanaka@md.tsukuba.ac.jp.

Commentary on this paper appears on the next page.
**Commentary**

This study extends the applicability of intraoperative angiography in the previously rather neglected group of unruptured aneurysms. Although surgery for these is generally considered less difficult than after a recent hemorrhage, clip adjustment was necessary in over 15% of the 38 cases, comparable with the proportions seen in a large review. A significant correlation with aneurysm size was noted even in this rather small series, as well as in the larger numbers, presumably of mostly ruptured aneurysms, in the authors' review. Setting up for intraoperative angiography carries the added advantage of the ability to use a double-lumen balloon catheter, for proximal occlusion/suction decompression if needed for large aneurysms. It is apparent from this study that if this facility is available, its use is equally justified for surgery on intact or ruptured aneurysms. It should be noted that, not surprisingly, this technique may not show occlusion of tiny perforators as presumably occurred in Case 6. I agree with the use of a 10 mm diameter to distinguish small from large aneurysms. This has always seemed more logical than 15 mm from the point of view of surgical difficulty, and it equates better with the cutoff of 10 mm in natural history studies such as the ISUIA. An interesting exercise is to extract from Tables 3 and 4 those reports where both complications, residual aneurysm and vessel compromise were mentioned. With intraoperative angiography (Table 3), this was seen in 125/885 cases or 14.4%, compared with 102/1078 (9.5%) with postoperative angiography in Table 4. This difference would be highly significant statistically if it were valid to test it. Does it suggest that surgeons are more careful with clip application, or with visual or ultrasound checks, if intraoperative angiography is not available? In any case, the small proportion, 1.7%, of unexpected findings when angiography is repeated postoperatively is impressive.

Nicholas W. C. Dorsch, M.D., F.R.C.S., F.R.A.C.S.
Department of Surgery
Westmead Hospital
Sydney, Australia

The benefit of using intraoperative angiography (IA) during the intracranial aneurysm surgery is still controversial in the aspect of its efficacy and complications (ref. 32 of this article). It is effective for the detection of residual aneurysm, distal branch occlusion and parent artery stenosis. Special concerns should be focused on the malpositioning of clips compromising the patency of important perforating vessels due to postoperative brain replacement. Another important factor is the abnormal weakness of the closing power of aneurysm clips resulting in reopening of the clipped aneurysm and possible fatal subarachnoid hemorrhage especially in large–giant aneurysms with broad necks.2) Preoperative 3-D CT angiography and 3-D magnetic resonance angiography have major roles in the accurate positioning of aneurysm clips.3) The application of IA for the proximal control and suction-decompression of large aneurysms may be another benefit of this procedure.

**References**


Dae Hee Han, M.D.
Department of Neurosurgery
Seoul National University Hospital
Seoul, R.O.K.