# Strategies to Minimize Complications During Intraoperative Aneurysmal Hemorrhage: A Personal Experience

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**Key words**
- Cerebral aneurysm
- Clip ligation
- Complications
- Intraoperative rupture

**Abbreviations and Acronyms**
CARAT: Cerebral Aneurysm Rerupture After Treatment Study
IOR: Intraoperative rupture
MCA: Middle cerebral artery

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BACKGROUND: **The occurrence of intraoperative rupture (IOR) of an aneurysm is one of the most precarious moments in microsurgery, and the management of IOR profoundly affects operative outcomes.**

METHODS: **The authors describe their personal experiences during the past decade with managing intraoperative aneurysm rupture for microsurgical treatment of complex cerebral aneurysm procedures.**

RESULTS: **Steps to avoid and manage IOR depend on the stage of the operation or phase of dissection and on aneurysm location and configuration. The point at which IOR occurs dictates the management options available. The rupture of the aneurysm itself usually does not cause death or disability, but the subsequent actions performed by the surgeon can make the difference between a good and poor outcome. Major complications are caused by the surgeon's premature reaction placing a permanent clip in the face of torrential bleeding without adequate visualization, leading to vascular and cranial nerve injuries. Short videos are provided to illustrate the technical nuances to minimize complications.**

CONCLUSIONS: **Accurate knowledge of the anatomy of the aneurysm and surrounding vasculature is the keystone to prevention and treatment of IOR. Most importantly, the surgeon must not rush prematurely to apply a permanent clip blindly in an effort to stop the hemorrhage.**

## INTRODUCTION

With advances in endovascular therapy for intracranial aneurysms, patients with increasingly complex aneurysms are being referred for microsurgical procedures. As a result, the skills and outcomes of the neurovascular surgeon are under close scrutiny. Microsurgical treatment of aneurysms has the advantages of durability and wide applicability. Using modern microsurgical and revascularization techniques, neurovascular surgeons can devise a therapeutic option for virtually all aneurysms. For this treatment modality to remain an acceptable and competitive feasible option in the presence of endovascular alternatives, neurovascular surgeons must reexamine their patients' outcomes and refine their techniques to minimize complications. Microsurgical treatment of aneurysms is not minimally invasive, but it should be minimally disruptive.

One of the most dramatic and potentially devastating complications during aneurysm microsurgery is intraoperative rupture (IOR). Containment of IOR and its sequelae can make an important contribution toward minimizing complications from microsurgery. The incidence of IOR has been reported in 7%–35% of cases (2, 4, 5, 8, 12). Factors associated with IOR include the surgeon's experience, aneurysm size, aneurysm morphology, and history of rupture (7, 12). The effect of IOR on patient outcomes is not well understood. Some series show no difference in outcomes, whereas others demonstrate poorer outcomes in patients who experience IOR (10, 11). Batjer and Samson (2) reported an 88% favorable outcome in patients without IOR; this decreased to 62% in patients with IOR. In a review of the CARAT (Cerebral Aneurysm Rerupture After Treatment) study, periprocedural death and disability increased from 18% to 31% in patients who experienced IOR (3).

Intraoperative aneurysm rupture during surgery bears some similarities to and some major differences from intraprocedural aneurysm rupture during endovascular treatment. The rates of intraprocedural rupture are significantly lower for endovascular therapy, with studies estimating an incidence of 1%–9% (13). However, management of IOR may be more difficult through endovascular routes. The CARAT study reported a 64% rate of death and disability in patients experiencing an intraprocedural rupture, more than double compared with the rate for microsurgery (3). This increased risk of poor outcomes makes logical sense because bleeding often cannot be controlled and decompressed in a timely fashion during endovascular procedures as it can during microsurgery.

IOR is potentially avoidable, but it nonetheless occurs in some cases and must be managed successfully to achieve good results. IOR can occur at several distinct time points during surgery. Steps to avoid IOR depend on the stage of the operation or phase of dissection and aneurysm

location and configuration. The point at which the complication occurs dictates the management options available.

## MATERIALS AND METHODS

We describe the personal experiences of 2 senior surgeons (D.L.B. and A.A.C.-G.) during the past decade with managing IOR for microsurgical treatment of 2500 complex cerebral aneurysm procedures. Because the related technical tenets can be difficult to describe, short videos complement the details mentioned in the text.

## RESULTS

### IOR During Exposure

Although the occurrence of an aneurysm rupture during exposure is uncommon and associated with <10% of all cases of IOR, the outcomes from this event can be catastrophic. Batjer and Samson (2) found that fewer than 1 in 4 patients survive the event. Giannotta et al. (5) found that only 20% of patients with IOR in this stage had a good outcome. Schramm and Cedzich (11) reported that IOR caused only poor outcomes in the early exposure stage. During this stage of surgery, the surgeon has not yet had an opportunity to identify the anatomy of the relevant vasculature and the aneurysm and in some cases has not even begun microdissection.

This early stage of surgery commences from the moment the patient enters the operating room to the onset of vascular microdissection. There are numerous potential causes of rerupture during this time. Inadequate anesthesia during intubation and pin placement can lead to wide variations in blood pressure, leading to IOR. The operator should notify the anesthesia team, especially an inexperienced team, to pay special attention to relevant details. The surgeon should exercise care during bone removal. Excessive use of the drill, especially during removal of the lesser sphenoid wing, can transmit vibrations to the aneurysm dome, precipitating rupture. Finally, excessive drainage of cerebrospinal fluid may change the transmural pressure of the aneurysm, leading to destabilization of its wall.

Aggressive early retraction on the lobe attached to the dome of the aneurysm should be avoided. Specifically, in the case of posterior communicating and anterior choroidal artery aneurysms, early retraction on the medial temporal lobe may lead to IOR by placing traction on the aneurysm dome. Middle cerebral artery (MCA) aneurysms often point laterally and are attached to the surface of the temporal lobe, and gentle and dynamic frontal lobe mobilization using the suction apparatus is a safe strategy to expose the proximal aneurysm neck and M2 branches before temporal lobe retraction is contemplated. In patients with sizable hematomas, such as an MCA aneurysm with a frontotemporal clot, care must be taken when decompressing the hematoma. Excessive removal of the clot can destabilize the aneurysm sac, leading to rupture. If too little clot is removed, the surgeon may have to retract excessively on the brain; this maneuver can also destabilize the aneurysm (**Video I**, available at http://youtu.be/SsvfsvfoJJs).

Options available to the surgeon are limited in the case of rupture before exposure of aneurysm or proximal control. In these instances, the surgeon must reduce the hemorrhage and clear the surgical field to allow for rapid dissection to the aneurysm; this can sometimes be accomplished by using a large-bore suction to follow the hemorrhage to its source (**Video I**, available at http://youtu.be/SsvfsvfoJJs). Intravenous administration of adenosine can be dramatic and lifesaving by providing temporary cardiac arrest, although this maneuver often provides only 30–60 seconds of relief. Profound lowering of the blood pressure may place the patient at high risk for cerebral infarction (5). If the aneurysm is on the anterior circulation, cervical carotid compression may slow bleeding and allow some control over the hemorrhage. Ultimately, the surgeon's goal is to gain proximal vascular control by placing a temporary clip on the proximal arterial supply to the aneurysm (9). This temporary clip provides cessation of torrential hemorrhage to allow microdissection of the aneurysm neck and clip application. Brain protection with burst suppression provided by propofol or barbiturates may be useful. Rapid closure with no attempt to find proximal control with the hope of intracranial tension tamponading the bleeding is not recommended and is likely to result in a poor outcome.

If the surgeon can follow the jet of blood to its source, he or she may control bleeding by placing a loose cotton ball over the bleeding site on the aneurysm. A self-retaining retractor can be placed gently on the cotton to tamponade the bleeding and free up the surgeon's hands to deal definitively with the aneurysm. The surgeon must take care not to exert too much retractor pressure on the aneurysm because this could worsen the tear (**Video IIA**, available at http://youtu.be/Dd1NtQNIJEE, and **B**, available at http://youtu.be/BxFTs_907Dk).

### IOR During Dissection without Proximal Control

Rupture of an aneurysm before dissection, as described previously, can be associated with many factors outside the immediate control of the operating neurosurgeon. When an aneurysm ruptures during dissection, the complication is likely caused by a problematic operative maneuver performed by the surgeon (2, 7). At this stage of the operation, more options are available that allow for improved outcomes compared with IOR during exposure.

The most likely cause for IOR at this stage is *the operator's incomplete understanding of the relevant vascular anatomy*—the location of the aneurysm dome, neck, and important arterial branches. Wide opening of the sylvian fissure by sharp dissection through a frontotemporal approach exposes most anterior circulation aneurysms safely, drains cerebrospinal fluid from the cisterns, relaxes the brain, minimizes the risk of IOR, and reduces or eliminates the need for fixed retractors.

Batjer and Samson (2) discovered that 75% of IORs occurred because of blunt, as opposed to sharp, dissection techniques. They reported good outcomes of IORs with sharp dissection, but a good outcome occurred in only 50% of IORs with blunt dissection. Sharp dissection is one of the hallmarks of microsurgery to minimize complications. Giannotta et al. (5) found that the method of controlling rupture, through either temporary clipping or direct tamponade, did not affect outcomes. They reported worsened outcomes with hypotension.

Management options for IOR at this stage of surgery require skill and decisive operative maneuvers. Good outcomes are possible if the surgeon remains calm, stays in control, and executes calculated and deliberate maneuvers (7). In our opinion, the operator's thoughtful technical reactions, rather than the IOR, are the