Blister Aneurysms of the Internal Carotid Artery: Microsurgical Results and Management Strategy

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ABSTRACT

BACKGROUND: Blister aneurysms of the supraclinoid internal carotid artery (ICA) are challenging lesions with high intraoperative rupture rates and significant morbidity. An optimal treatment strategy for these aneurysms has not been established.

OBJECTIVE: To analyze treatment strategy, operative techniques, and outcomes in a consecutive 17-year series of ICA blister aneurysms treated microsurgically.

METHODS: Seventeen patients underwent blister aneurysm treatment with direct clipping, bypass and trapping, or clip-reinforced wrapping.

RESULTS: Twelve aneurysms (71%) were treated with direct surgical clipping. Three patients required bypass: 1 superficial temporal artery to middle cerebral artery bypass, 1 external carotid artery to middle cerebral artery bypass, and 1 ICA to middle cerebral artery bypass. One patient was treated with clip-reinforced wrapping. Initial treatment strategy was enacted 71% of the time. Intraoperative rupture occurred in 7 patients (41%), doubling the rate of a poor outcome (57% vs 30% for patients with and without intraoperative rupture, respectively). Severe vasospasm developed in 9 of 16 patients (56%). Twelve patients (65%) were improved or unchanged after treatment, and 10 patients (59%) had good outcomes (modified Rankin Scale scores of 1 or 2).

CONCLUSION: ICA blister aneurysms can be cautiously explored and treated with direct clipping as the first-line technique in the majority of cases. Complete trapping of the parent artery with temporary clips and placing permanent clip blades along normal arterial walls enables clipping that avoids intraoperative aneurysm rupture. Trapping/bypass is used as the second-line treatment, maintaining a lowthreshold for bypasswith extensive or friable pathology of the carotid wall and in patients with incomplete circles of Willis.

KEYWORDS: Aneurysm, Blister, Bypass, Internal carotid artery, Pseudoaneurysm

INTRODUCTION

Blister aneurysms, or blood blister-like aneurysms, involving the supraclinoid internal carotid artery (ICA) are defined as small, sessile aneurysms at nonbranching sites on the dorsal wall of this arterial segment with fragile walls. These rare aneurysms were first described by Sundt and Murphey[1] in 1969 and more thoroughly described in the modern microsurgical era by Nakagawa et al[2] in 1986.

A dissecting etiology for these aneurysms has been suggested, consistent with their localization at nonbranching, high shear stress segments of the ICA.[3,4] Despite decades of advances in microsurgical and endovascular techniques, they remain formidable lesions without an established and reliable management strategy. Diagnostic angiography images the aneurysm lumen rather than its wall, making it impossible to determine preoperatively the extent of arterial injury or the aneurysmal tissue that might be incorporated into the microsurgical reconstruction. Their small size, broad base, and thin or nonexistent walls make them difficult to treat conventionally with microsurgical clipping or endovascular coiling. Microsurgical clipping

has been associated with increased risk of intraoperative rupture. Other microsurgical techniques for these aneurysms include clip reconstruction[5-7] of the arterial wall, clip-reinforced wrapping,[3,6] revascularization and trapping,[8,9] and primary suture repair.[10] Endovascular techniques, including balloon- or stent-assisted coiling,[11-15] parent artery occlusion,[8,13,14] and flow diversion with a pipeline embolization device (PED) (ev3 Neurovascular, Irvine, California),[16-19] have met with limited success because aneurysm morphology is unfavorable for conventional coiling, stent-assisted coiling has high residual and recurrence rates, and flow diverters often have delayed aneurysm obliteration, high re-treatment rates, and require dual antiplatelet therapy in the setting of subarachnoid hemorrhage. Therefore, the optimal treatment strategy for these lesions has not been established. We retrospectively examined our 17-year microsurgical experience to attempt to define a working management strategy for blister aneurysms.

METHODS

The study was approved by the Institutional Review Board and conducted in compliance with Health Insurance Portability and Accountability Act regulations. The prospectively maintained database for the VascularNeurosurgery Service at the University of California, San Francisco was searched for patients with blister or dissecting aneurysms of the ICA between December 1997 and December 2014.Medical records, radiographic studies, operative reports, intraoperative photographs, and clinical follow-up evaluations were reviewed retrospectively.

All patients were treated microsurgically with direct clipping, clip reinforcement of a muslin wrap, extracranial-to-intracranial or intracranial-to-intracranial bypass and trapping, or trapping alone. All but 1 patient underwent postoperative angiography. Angiographic outcomes were determined by a neuroradiologist not involved in the study. Operative records were used to determine the intraoperative rupture rate and the success or failure of the initial microsurgical strategy (clip reconstruction in all but 2 cases). Clinical outcomes were determined using the modified Rankin Scale score at the last follow-up visit.

RESULTS

Patient Characteristics

During the 17-year study period, 3600 aneurysms were treated in a single-surgeon series of 2748 consecutive patients by the senior author (MTL). Of those, 17 patients (0.6%) were found to have blister aneurysms of the supraclinoid ICA (Table 1). Fifteen blister ICA aneurysms were ruptured, representing 1.2% (15/1235) of patients with ruptured aneurysms and 1.0% (15/1574) of all ruptured aneurysms treated during the study period. No blister aneurysms were referred for endovascular treatment. A female predominance was observed, with 11 women and 6 men having a mean age of 46 years (range, 27-63 years). All but 2 patients (88%) presented with subarachnoid hemorrhage (SAH). Five patients (33%) presented with Hunt-Hess grade 2 SAH, 5 (33%) were grade 3, 3 (20%) were grade 4, and 2 (13%) were grade 5. All patients with SAH were either Fisher grade 3 or 4. Two patients with initial Hunt-Hess grades of 2 and 3 reruptured before surgery, and both deteriorated to grade 4. Four patients (24%) had multiple coexisting aneurysms, and 1 patient was found to have an extracranial vertebral artery dissection at the time that he presented with his ruptured ICA blister aneurysm.

Microsurgical Treatment

Patients were treated through a pterional craniotomy. In 3 cases, the exposure was augmented by an orbital osteotomy. In 6 cases, the anterior clinoid process was removed for proximal control. Twelve aneurysms (71%) were treated with direct clipping, 3 patients (18%) underwent bypass and trapping, and 1 patient, the first in this series, underwent wrapping with a clip reinforced muslin sling.

Clip Reconstruction

Of the 12 aneurysms treated with primary clip reconstruction, 7 were reconstructed with an angled clip with the tips oriented parallel to the parent ICA (Figure 1, case 14). Multiple tandem clipping (Figure 2, case 5) or additional stacked clips were used in 3 of these cases (Figure 3, case 9). The aneurysms in 4 other cases were clipped using curved clips with the convexity of the clip blade down against the carotid wall. The aneurysms in 3 of these 4 cases required multiple, usually understacked clips to obtain aneurysm obliteration.

Bypass

Three patients underwent bypass and trapping. One patient experienced a Hunt-Hess grade 3 SAH from a blister aneurysm along an elongated and dysplastic dilation of the supraclinoid ICA extending from the posterior communicating artery (PCoA) to the anterior choroidal artery (AChA). He was treated with a superficial temporal artery to middle cerebral artery (MCA) bypass and trapping of the diseased ICA segment (Figure 4, case 8). One patient was taken to the operating room for treatment of a presumed ruptured AChA aneurysm and was found to have a previously unrecognized dorsal ICA blister aneurysm at surgery. The aneurysm ruptured intraoperatively and was treated with trapping of the ICA segment, with good cross-filling from the anterior communicating artery and stable electrophysiological potentials. Vasospasm and hypoperfusion of the ipsilateral hemisphere later developed, and the patient was returned to the operating room for a high-flow external carotid artery to MCA rescue bypass using a radial artery graft (case 4). One patient had a medially projecting ICA blister aneurysm that ruptured early during dissection, and the distal ICA segment was trapped. Although indocyanine green angiography demonstrated adequate cross-filling via the anterior communicating artery, revascularization with a supraclinoid ICA-to-MCA bypass with a short-segment radial artery graft was performed to augment his perfusion, given the high risk of vasospasm (Figure 5, case 6).

Wrapping

Only 1 patient, the first in this series, underwent wrapping with a clip-reinforced muslin sling. The aneurysm was successfully treated; however, the patient experienced severe vasospasm and a resultant MCA distribution infarct.

Intraoperative Rupture and Success of Initial Treatment Strategy

Intraoperative aneurysm rupture occurred in 7 patients (41%), 4 of which occurred during final dissection and 3 during clip application. In 2 of these patients, the diagnosis of a blister carotid aneurysm was not recognized preoperatively. As described previously, the blister aneurysm in case 4 was discovered during dissection of what was thought to be an AChA aneurysm. Surgical clipping of a presumed ruptured MCA aneurysm was performed in case 10. During routine post-clipping exploration of the supraclinoid ICA, a thin-walled ICA dissection ruptured and was initially clip reconstructed using stacked vertical “picket fence” clips to close the hole in the ICA. This repair failed, the aneurysm reruptured during closure of the craniotomy, and that ICA segment was trapped without bypass. Four patients (57%) who experienced an intraoperative rupture had a poor outcome (modified Rankin Scale score>2) compared with 30% of patients who did not. Primary clip reconstruction was the initial treatment strategy in all but 2 patients (clip-reinforced wrapping in 1 patient and planned bypass trapping in 1 patient). The initial treatment strategy was successful in 12 of 17 cases (71%). Contingency plans were used in 5 cases, including 2 attempted clip reconstructions requiring subsequent trapping bypass (cases 4 and 6, described previously); 1 clipped aneurysm that rebled during craniotomy closure and was trapped without bypass (case 10, described previously); 1 clip solution that failed and was reclipped with an alternate clip configuration; and 1 patient who reruptured in the early postoperative period after clip reconstruction. Each case of failed initial strategy involved an intraoperative aneurysm rupture. Poor outcome occurred in 60% of patients in whom the initial treatment strategy failed compared with 25% of those with initial treatment success.

Sixteen patients underwent postoperative angiography, and 14 (82%) had complete obliteration of the aneurysm. One patient had a small residual aneurysm, and 1 demonstrated aneurysm occlusion but persistent dilation of the supraclinoid ICA.

Clinical Outcome

Severe vasospasm developed in 9 of 15 patients (60%) with SAH. Four patients experienced MCA strokes attributable to severe vasospasm, including 1 ICA-MCA bypass patient, 1 rescue bypass patient, and 1 clip-reinforced wrapping patient. There were 3 postoperative deaths (17.6%) in this series: 1 patient died after severe vasospasm and extensive bilateral cerebral infarction developed; another experienced a fatal rerupture the evening after surgery; and 1 patient who underwent successful clip reconstruction of his ICA aneurysm experienced an iatrogenic basilar artery rupture during angioplasty for severe vasospasm. Overall, 10 patients (59%) in this series had a good outcome with a modified Rankin Scale score of 1 or 2. Good outcomes were observed in 8 of 15 patients presenting with SAH (53%), and SAH patients accounted for all of the complications in this series. Two patients were worse (new permanent neurological deficits [11.7%]), including 1 patient who was severely disabled.

DISCUSSION

ICA blister aneurysms are technically challenging lesions and, thankfully, quite rare, accounting for just 0.6% of our total aneurysm experience and 1.2% of our ruptured aneurysm experience. These are deceptive aneurysms because they are small, located at a surgically accessible site, and mimic simpler aneurysms like PCoA and AChA aneurysms. The unsuspecting neurosurgeon may mistakenly expect a straightforward clipping procedure. Our clinical experience and that of many others in the literature (Table 2) demonstrate that ICA blister aneurysms are anything but straightforward.[2,5-10,20-25] They had an intraoperative rupture rate that was 6 times that of saccular aneurysms as reported in our previous publication (41% vs 7%).[26] Our experience revealed that intraoperative aneurysm rupture was a bad prognostic sign, doubling the risk of a poor outcome (57% vs 30% for patients with and without intraoperative aneurysm rupture, respectively). Conventional clipping was only possible in 71% of blister aneurysms, and contingency plans were enacted in nearly one third of patients. Contingency plans often involved bypass techniques and often were implemented after intraoperative rupture under duress, which increased the procedure's technical difficulty and decreased the likelihood of a good outcome. These factors make the blister aneurysm a unique aneurysm with a difficulty out of proportion to its size and location. Furthermore, the diagnosis of a blister aneurysm is easy to miss (as in 2 of our cases), and this failure can compromise preparations for proximal control, alternative reconstructive clipping, and a possible bypass.

Microsurgical Technique

Successful microsurgical treatment of ICA blister aneurysms begins with accurate diagnosis preoperatively. Any atypical aneurysm involving the dorsal wall of the supraclinoid ICA that is small, sessile, and at nonbranching sites should trigger the diagnosis, and digital subtraction angiography should be used to confirm and also evaluate collateral circulation from the anterior communicating artery and PCoA, which might be critical during temporary occlusion of the parent ICA during clipping or an intraoperative rupture, when determining the need for a bypass and while performing the anastomosis.

The projection of the blister should be carefully noted on the 3-dimensional angiogram reconstruction. Laterally directed domes are liable to rupture during early dissection within the carotid cistern. Superiorly directed domes may adhere to the frontal lobe, precluding subfrontal retraction and sometimes necessitating subpial dissection to reach the medial portion of the neck safely and establish complete control of the ICA. Medially directed domes may be less prone to early intraoperative rupture but may require clip reconstruction with fenestrated clips transmitting the ICA. In addition, medially directed aneurysms project away from the surgeon with a limited view of the diseased segment and the neck.

Bojanowski et al[27] recently proposed a classification system with 4 distinct morphological subtypes: classic, berry-like, longitudinal, and circumferential. We were able to recognize these morphological subtypes in our experience, and we agree with the proposed clipping strategy of these authors, but found little correlation between the blister aneurysm's morphology and clippability. The fragility of tissues, more than morphology, determined clippability, and this fragility could not be reliably predicted on the preoperative angiogram. Our case 6 (Figure 5) demonstrates a berry-like blister aneurysm that should be clippable, according to the proposed classification, but it ruptured during clip application due to a friable neck and instead required trapping and bypass.We found that classic and berry-like aneurysms were more likely to be clippable (Figures 1, 2, and 3), whereas longitudinal and circumferential aneurysms were less likely to be clippable (Figure 4). Therefore, the classification system of Bojanowski et al might serve as a crude indicator of clippability, with longitudinal and circumferential blister aneurysms suggesting more extensive dissection with a higher likelihood of intraoperative rupture during clipping and the need for high-flow bypass as an initial treatment strategy. However, the classification system has an inherent bias favoring clipping strategies, which may be dangerous.

ICA blister aneurysms call for contingency planning intraoperatively. The possibility of a bypass using the radial artery requires preoperative assessment of the palmar arch with an Allen test with Doppler ultrasonography. Muslin cloth should be available for clip-reinforced wrapping, the bypass instruments should be in the operating room, the forearm should be prepared for possible radial artery harvest, and the neck should be prepared or opened before beginning the craniotomy. In many cases, anterior clinoidectomy may obviate the need for cervical ICA exposure, providing proximal control intracranially along the clinoidal ICA segment. If anterior clinoidectomy is preferred, the arachnoid overlying the carotid cistern is left intact until after clinoidectomy to protect the optic nerve and the delicate thrombus capping the rupture site on the aneurysm or carotid wall. This thrombus must be meticulously avoided during the dissection steps, resisting the temptation to evacuate the clot.

Direct clip application is attempted only after completely trapping the supraclinoid ICA with distal and proximal temporary clips and a clip on the PCoA. Temporary clipping is performed in anticipation of intraoperative aneurysm rupture, but also to soften these friable tissues. In our experience, application of an angled or slightly curved clip with the blades parallel to the supraclinoid ICA was the best reconstruction. The clip blades are applied to the normal arterial wall, which usually means incorporating some tissue adjacent to the aneurysm base and deliberately stenosing the carotid artery slightly (<20%). A clip applied only on the blister might tear into the aneurysm's base. The sessile morphology of blister aneurysms can sometimes cause the clip to slide upward toward the dome, in which case the initial clip can act as an anchoring clip for a second understacked clip that secures the base of the aneurysm without any upward slide. Intraoperative aneurysm ruptures occurred during final dissection steps, typically when manipulating the thrombus cap to visualize the aneurysm or when applying clips. This situation is much easier to deal with when the aneurysm has already been temporarily trapped. The bleeding site is typically a gaping hole in the ICA, and intraoperative rupture should be viewed as an opportunity to carefully inspect the integrity

of the tissues intraluminally and around the base, resisting the temptation to place a permanent clip quickly (see *Video, Supplemental Digital Content* 1 which demonstrates dissection and clipping of a left ICA blister aneurysm). Premature permanent clipping can avulse any remaining arterial wall and eliminate potential clipping options. Holes in the carotid wall are best closed with curved or right-angled clips parallel to the artery's axis, advanced onto normal tissue, with some stenosis of the lumen. Alternatively, "picket fence" clipping can be used, with multiple straight clips applied with their blades perpendicular to the artery's axis and their tips advanced onto normal tissue. This technique allows the reconstruction to proceed along the tear bite by bite with the tips of each clip. If needed, cotton wisps between the clip blades can increase the traction of the blades against the arterial tissue and improve the closure of the defect. When clip reconstruction fails, the surgeon should proceed immediately to highflow bypass.

One of the learning points from our experience is to have a low threshold for bypass, based on the dramatically increased rate of intraoperative aneurysm rupture and the difficulties of performing a bypass under duress or as a rescue procedure later. Our threshold for bypass could have been lower. Our supraclinoid ICA-MCA bypass was designed to be quick: the length of harvested radial artery is short, and cervical carotid exposure is not necessary. However, the anastomosis to the ophthalmic ICA segment is difficult, with a short length of donor artery, a deep surgical corridor, and trapping clips crowding the field.

Our rescue external carotid artery to MCA bypass was easier,but was performed after clinical signs of ischemia. Both types of bypass require 2 anastomoses. Our case of planned superficial temporal artery to MCA and trapping had a good outcome. Preemptive exposure of the cervical carotid artery and preparation of the forearm for radial artery harvest minimize ischemia time, but a lower threshold for bypass is probably more important. After the bypass is completed, the aneurysm trapping must exclude all of the diseased carotid segment while preserving important branch vessels. Blister aneurysms are commonly located opposite the origins of the PCoA and AChA, and the distal clip must allow retrograde flow to the distal ICA to supply the AChA (Figure 4F). Preservation of the PCoA is not required unless it is a fetal posterior cerebral artery.

Endovascular Treatment

Endovascular therapy for blister carotid aneurysms continues to evolve (Table 3).[8,11-17,20] Treatment with stent-assisted coiling is associated with unacceptably high rates of incompletely treated aneurysms and early recanalization, with concordant complications related to rehemorrhage.[11-13] Other endovascular series indicate some improvement in outcome with dual "stent within a stent" techniques,[12,13] suggesting a role for flow-diverting stents in these lesions. Ashour et al[19] describe balloon-assisted embolization with Onyx liquid embolic agent (ev3 Neurovascular) in 3 cases. Recent small series with the PED demonstrated significantly higher rates of complete aneurysm obliteration, [15,16,28] although there is evidence from a meta-analysis that patients undergo PED treatment later in their hospital course,[29] requiring that they endure a waiting period after SAH during which they are vulnerable to rehemorrhage and complications from vasospasm and its treatment with an unsecured aneurysm. Furthermore, many PED series on blister aneurysms include patients without SAH; 50% of patients treated by Chalouhi et al[16] were unruptured aneurysms. Yoon et al[17] reported significant rates of both thromboembolic and remote hemorrhagic complications. One recent series describes hybrid treatment with clip-reinforced wrapping for immediate control of the ruptured aneurysm, followed by delayed definitive treatment with PED.[18] With a paucity of patients reported thus far in the literature, flowdiverting stents for ruptured carotid blister aneurysms represent a potential therapeutic advance, but with an incompletely understood and unpredictable side-effect profile.

Management Strategy for Blister ICA Aneurysms

The ruptured carotid blister aneurysm poses a therapeutic conundrum, and no clear management strategy has emerged (Table 2). Many authors have reported success with clipping or clip-reinforced wrapping[5-7,20,24] as well as a high rate of intraoperative aneurysm ruptures, which indicates wide variations in the vascular integrity of these blister aneurysms. Baskaya et al[8] used exclusively bypass and trapping, and, more recently, Kazumata et al[9] reported success with the use of pre-emptive superficial temporal artery to MCAbypass, even in cases that were ultimately amenable to clip reconstruction, and advocated for prophylactic bypass before aneurysm exploration. However, Murai et al[23] noted that even technically successful bypass did not prevent significant ischemic events from occurring in patients undergoing trapping. The endovascular literature has not offered convincing evidence that stenting or flow diversion is an acceptable alternative to microsurgical therapy (Table 3).

Based on our experience, we favor primary clip reconstruction as the first-line treatment because it is simple and effective in the majority of cases. Cautious exploration of the blister aneurysm can be done safely as described previously. Blister aneurysms with favorable anatomy, meaning necks that have substantive walls that can hold a clip, can be clipped with complete control proximally and distally and with liberal use of temporary clipping. Blister aneurysms with unfavorable anatomy, meaning necks that appear thin, friable, or weakened, should not be clipped in order to avoid intraoperative aneurysm rupture, and trapping/bypass should be used as the second-line treatment. Maintaining a low threshold for bypass is recommended. This cannot be based on preoperative angiography because this test provides no information about the integrity of the arterial wall. However, longitudinal and circumferential morphology suggest an unclippable blister aneurysm. Intraoperative inspection that suggests excessive fragility or friability of tissues is the most important factor in revising the surgical strategy from clipping to trapping/bypass; heeding surgeon intuition will avoid intraoperative ruptures that might require carotid sacrifice and a bypass under duress. Resorting to a bypass procedure represents a significant escalation in case complexity, and there can be reluctance to do this, but the extra effort seems justified after the primary clipping option has been eliminated and after considering the dangers of intraoperative aneurysm rupture.

Limitations

Trapping without bypass is only advisable when patients have tolerated a preoperative balloon test occlusion and are outside the window for vasospasm. Collateral circulation alone is rarely sufficient to protect against ischemia if vasospasm occurs, as demonstrated by the delayed ischemic deficits that developed in case 4 of this series. Therefore, the coincidence of blister aneurysms and SAH makes balloon test occlusion and trapping without bypass of limited value. Trapping the ICA segment complicates the endovascular treatment of vasospasm postoperatively because it eliminates direct catheter access to deliver intra-arterial vasodilators or mechanical angioplasty. Wrapping with a sling secured with an aneurysm clip may provide some immediate protection, but diseased tissue remains in the circulation, and the long-term efficacy and durability of clip-reinforced wrapping are unproven. Therefore, we consider this an option of last resort.

CONCLUSIONS

Blister aneurysms of the supraclinoid ICA can be successfully treated with direct surgical clipping in the majority of cases. Complete trapping of the arterial segment with temporary clips and placing the permanent clip blades along normal arterial walls are key to successful clip reconstruction that avoids intraoperative aneurysm rupture. Despite proper microsurgical technique, disintegration of the arterial wall can occur. Trapping with revascularization is an important contingency plan that requires a low threshold for implementation and advance preparations.

Disclosure

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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FIGURE LEGENDS

FIGURE 1. Case 14. **A**, preoperative 3-dimensional angiographic reconstruction (right ICA) demonstrated a dorsal ICA blister aneurysm. **B**, the ICA blister aneurysm was clipped with 2 stacked right-angled clips with the blades paralleling the axis of the ICA. **C**, postoperative 3-dimensional angiographic reconstruction showed the stacked angled clips and aneurysm occlusion. ICA, internal carotid artery; ON, optic nerve.

FIGURE 2. Case 5. Preoperative 3D angiographic reconstructions (right ICA) in anteroposterior (**A**) and medial (**B**) orientations demonstrated a broad-based blister aneurysm with medial and dorsal projection. **C**, intraoperative view showing the broad-based right ICA blister aneurysm under the optic nerve with a cap of thrombus over the dome. **D**, proximal control with a temporary clip enabled safe application of a 45◦-angled fenestrated clip. **E**, the distal portion of the neck required a second curved clip applied behind the carotid terminus (**F**) with its blades beneath the AChA (between the no. 6 dissector and sucker) and beneath the heel of the fenestrated clip. **G**, postoperative 3-dimensional angiographic reconstruction demonstrated the fenestrated clip transmitting the distal ICA and occlusion of the aneurysm. ACA, anterior cerebral artery; An, aneurysm; MCA, middle cerebral artery; ON, optic nerve.

FIGURE 3. Case 9. Preoperative right ICA angiogram, anteroposterior **A** and lateral **B** views demonstrate a blister aneurysm of the supraclinoid ICA. **C**, this medially projecting blister aneurysm was barely visible underneath the optic nerve, and minimal manipulation precipitated its rupture. **D**, temporary clips on the proximal and distal ICA and PCoA controlled the aneurysm completely, and the rupture site was visualized **arrow**. **E**, there was enough tissue at the neck to clip with a side-angle clip, followed by several curved clips **F**. **G**, postoperative angiography (anteroposterior view) showed the clip reconstruction of the supraclinoid ICA and obliteration of the aneurysm. ICA, internal carotid artery; ON, optic nerve.

FIGURE 4. Case 8. Preoperative right ICA angiogram (anteroposterior view) **A** and 3-dimensional angiographic reconstruction **B** demonstrated a blister aneurysm on the dorsal

surface. **C**, the blister aneurysm was thin-walled, capped with thrombus, and deemed unclippable. **D**, an STA-MCA bypass was performed initially. The aneurysm was then trapped with permanent clips on the proximal ICA and PCoA **E** and the distal ICA, proximal to the AChA seen at the tip of the no. 6 dissector **arrow F**. **G**, postoperative angiography (left internal carotid injection, anteroposterior view) demonstrated trapping of the ICA aneurysm with cross-filling of the distal ICA **arrow** via the anterior communicating artery and filling of the MCA territory via the STA-MCA bypass **arrowheads** (right common carotid injection, anteroposterior view) **H**. ACA, anterior cerebral artery; An, aneurysm; MCA, middle cerebral artery; ON, optic nerve; PCoA, posterior communicating artery; STA, superficial temporal artery.

FIGURE 5. Case 6. Preoperative computed tomography angiogram (superior view) **A** and ICA angiogram (anteroposterior view) **B** demonstrating a right ICA blister aneurysm just proximal to the ICA terminus projecting medially. **C**, the aneurysm ruptured during the final dissection and was controlled by trapping the supraclinoid ICA proximally and distally and with a temporary clip on the PCoA. An arteriotomy was made on the proximal supraclinoid ICA **arrowheads**, and the deep anastomosis of the ICA-MCA bypass was completed **D**. **E**, the other end of the radial artery graft was anastomosed to the M2 MCA segment, and the distal parent ICA was trapped with permanent clips. **F**, indocyanine green videoangiography demonstrated patency of the graft. ACA, anterior cerebral artery;ICA, internal carotid artery; MCA, middle cerebral artery; ON, optic nerve; PCoA, posterior communicating artery; RAG, radial artery graft.