The Use of Bypass Surgery in the Flow-Diverter Era to Treat Complex Intracranial Aneurysms in the Anterior Circulation

Divya Chauhan*

Department of Life Sciences, Graphic Era (Deemed to be) University, Uttarakhand, India

*Corresponding Author**

Divya Chauhan
Department of Life Sciences, Graphic Era (Deemed to be) University, Uttarakhand, India
E-mail: divyachauhan5234@gmail.com

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Abstract

Even though Flow Diverters (FDs) are becoming more and more common as an endovascular treatment for cerebral aneurysms, treating complicated aneurysms remains difficult. In certain circumstances, combined techniques utilizing a flow-preservation bypass may be taken into account. In this study, a group of patients who had complicated cerebral aneurysms and undergone bypass surgery were looked at. During the period of January 2015 to May 2022, 23 patients were chosen. We found 6 (26.1%) ACA aneurysms, 6 (26.1%) MCA aneurysms, and 11 (47.2%) ICA aneurysms. Eight were categorized as enormous, nine were fusiform, eight had intraluminal thrombosis, ten had wall calcification, and eighteen involved significant branches or perforating arteries. The mean maximal diameter was 12.16 mm. In 23 patients, 25 bypass surgeries were carried out (2 EC-IC bypasses with radial artery graft, 17 single-barrel or double-barrel STA–MCA bypasses and 6 IC-IC bypasses in anterior cerebral arteries). With a mean follow-up of 28 months, the long-term bypass patency rate was 94.5% and the total aneurysm exclusion was 95.6%. The median KPS values at the most recent follow-up were 90, and 87% of the cases had good results. When a simpler direct approach, including the use of FD, is deemed to be impractical, the use of bypass procedures can be a viable therapeutic alternative in the therapy of complicated anterior circulation aneurysms in some circumstances.

Keywords: Complex intracranial aneurysms • ICG videoangiography • Combined treatment • Fluorescein

Introduction

Unruptured Intracranial Aneurysms (UIAs) require proper management and treatment, which is a subject of extreme importance. The prevalence of UIAs diagnosis has increased from 2% to 8.8% as a result of the wide diffusion of neuroimaging modalities. Even while prediction models based on several risk factors predicted a 3-year to 5-year probability of aneurysm rupture ranging from>1% to 15%-20%, a precise evaluation of a patient's lifetime risk of UIAs rupture is still not practical. Therefore, choosing the optimal management options for patients with UIAs is particularly challenging. According to the most recent European Stroke Organization (ESO) guidelines on the management of unruptured intracranial aneurysms, preventive treatment should be recommended for adult patients whose estimated 5-year risk of aneurysm rupture is higher than the risk of doing so, taking into account the most efficient and secure treatment option for that specific aneurysm. When weighing conservative versus preventive treatment, the authors recommended taking aneurysm form and intricacy into consideration. In reality, vascular neurosurgeons and interventional neuroradiologists still face major challenges when treating complicated intracranial aneurysms despite advancements in surgical and endovascular procedures. Size, shape, the presence of intraluminal thrombus, wall calcification or atherosclerosis, and the involvement of main branches or perforators in the aneurysm sac are some of the variables that affect an aneurysm's complexity. A straightforward endovascular or surgical occlusion may not be possible when treating such aneurysms. Although Flow Diverters (FDs) have grown in favor as an endovascular treatment option for cerebral aneurysms, there is a larger risk of problems when treating more complicated aneurysms. In these situations, various strategies might be taken into account. A bypass method could be utilized in particular to save one or more cerebral areas that can be secondarily entirely or partially occluded using a surgical or endovascular approach and are distal to the aneurysm. The anatomy and aneurysm features of the particular patient should guide this method. Few difficult intracranial aneurysms treated with bypass surgery have been documented in the literature, and only a small number of cases have specifically addressed the effect of FD stenting on the indication for bypass surgery in unruptured anterior circulation aneurysms. In order to analyze the specific indications, various treatment modalities, technical nuances, complication rate, and long-term follow-up of our case series of consecutive patients with complex intracranial aneurysms in the anterior circulation who underwent bypass at our institution in the period 2015-2022, well after the introduction of FD.

Discussion

In order to preserve distal flow before treating the aneurysm, a bypass procedure was crucial to the treatment approach for a group of patients with complex anterior circulation aneurysms that were deemed unsuitable for direct surgical or endovascular methods. In our demonstrations of various bypass procedures, high rates of both short- and long-term bypass patency as well as low rates of pre and postoperative problems was shown. Depending on the location and participation of perforators, anterior circulation aneurysms could be treated using either surgical or endovascular methods thanks to the use of bypass to maintain distal outflow.

An aneurysm that is bigger than 25 mm in diameter, fusiform or serpentine in shape, has intraluminal thrombosis or wall calcification and has a significant branch or perforating artery emerging from the aneurysm sac are all considered complicated aneurysms. The aneurysms in our sample had a mean maximum diameter of 12.16 mm, and the majority of cases (78.2%) had significant branches or perforators that emerged from the aneurysm sac. The difficulty of aneurysms was further compounded by the failure of prior endovascular attempts in four cases. Despite the fact that there is no consensus in the literature about the definition of aneurysm complexity, the traits identified in our series made these instances particularly difficult for direct microsurgical or endovascular treatment.

By causing vessel wall remodeling and aneurysm occlusion, Flow Diverters (FD) were shown to be a safe and effective treatment for complex intracranial aneurysms located from the petrous to hypophyseal segments of the ICA. As a result, their use quickly spread to other locations and, in some cases, acute settings. However, the complexity of aneurysm issues have not been entirely alleviated by its use. In particular, it has been demonstrated that one of the most significant indicators of aneurysm persistence following treatment with FD is the existence of a big branch vessel emerging from the aneurysm sac or a fusiform shape, as in the majority of our instances with complicated aneurysms. Additionally, although the management of aneurysms distal to ICA, such as those on ACA or MCA, has been documented with varying degrees of success and complications, these indications are still regarded as off-label in the USA, and more research must be published before any firm conclusions can be made regarding the safety and efficacy of FD in these locations.

The use of various types of cerebral revascularization to retain distal flow along with parent artery blockage to give a permanent cure for the aneurysm sac represents an alternate method of treating these difficult lesions. In addition, when a sacrifice of one significant artery branch is required to totally exclude the aneurysm from brain circulation, distal flow preservation by bypass procedures could potentially be used as a component of the treatment plan.

With patients presenting with complicated cerebral aneurysms in the anterior circulation, our retrospective study sought to assess the justifications for and outcomes of the application of various revascularization procedures. Our series includes complicated aneurysms of MCA or ACA in the most majority (69.6%), where FD still has certain inherent drawbacks that prevent its adoption in all situations. Our neurovascular team also believed that in the case of complex ICA aneurysms, a direct surgical or endovascular approach, including FD, was not ideal for completely excluding the aneurysm from brain circulation, particularly in cases where an endovascular approach was deemed inappropriate due to stage IV renal insufficiency (patient no. 4). A flow-diverting method may be used to cure the aneurysm, but in one case (patient number 6), the aneurysm was so big and calcified that it constricted the M1 segment of the MCA, resulting in symptomatic left

hemisphere hypoperfusion. Before our endovascular colleagues could effectively treat the aneurysm with an FD, this required to be addressed with a STA-MCA bypass. The idea of treating an aneurysm more specifically is crucial, especially in cases where the aneurysm has not ruptured and when the treatment's impact must be weighed against the disease's natural course.

By learning the three types of vascular micro anastomosis, it is feasible to postulate many innovative revascularization techniques, such as EC-IC or IC-IC bypasses, that might be fitted to the unique anatomy of the patient and the specific requirements for flow revascularization. Interposition grafts have potential drawbacks related to a lower patency rate with a higher risk of failure, the need for multiple micro anastomosis, and the difficulties of additional procedures for graft harvesting and potential donor sites. When possible, we preferred to avoid using these grafts. Instead, we preferred a more straightforward strategy using double-barrel or single-barrel STA-MCA bypasses, which, despite being typically thought of as low-flow bypasses, have the ability to offer higher flow, depending on brain demand. Although it is thought to be more difficult because of the depth and narrowness of the interhemispheric approach, we prefer in situ microanastomosis for flow preservation in the distal ACA territory because it has a higher patency rate than using an arterial or venous graft because these bypasses are more resistant to external force, being protected from neck torsion, injury, and occlusion with external compression.

In reality, only two of the cases-patients no. 4 and patient no.16—included a high-flow EC-IC bypass with an interpositional radial artery graft; all of the other revascularizations involved either the less complex STA-MCA or in situ IC-IC bypasses. According to ICG, fluorescein videoangiography, and CeUS, this approach was linked with a high percentage of intraoperative bypass patency (95.6%), and this was maintained in the majority of cases at long-term radiological follow-up (95.4%).

The various revascularization techniques were necessary as a prerequisite for treating the aneurysms later on in the most effective manners. Complete surgical trapping should be chosen whenever possible, especially for complicated MCA or ICA aneurysms because it can be done using the same surgical technique. After revascularization, we were able to completely capture seven difficult MCA aneurysms and one ICA aneurysm. When cortical branches or perforators grow from the aneurysmal sac, partial trapping proximal inflow or distal outflow occlusion to limit aneurysm flow and trigger intraaneurysmal thrombosis can be thought of as a viable alternative. In these situations, partial distal occlusion is preferred in order to promote progressive aneurysmal thrombosis and anterograde flow in the branches close to the aneurysm. The difficulty in predicting the extent and rate of aneurysmal thrombosis, as well as the requirement for a continuous supply of good blood flow to the perforators of the branches that must remain patent, constitute two significant limitations of this strategy. ICG-VA and FLOW 800 software are frequently used to evaluate blood flow in arteries and brain parenchyma intraoperatively, but this can only provide information about the area exposed during the surgical approach and cannot serve as a substitute for a standardized assessment of preoperative and postoperative blood flow in the areas vascularized by the bypass. In two complicated MCA cases where the aneurysm was buried in eloquent tissue, prohibiting a safe exposure of its proximal end (patient no. 2), or where perforators were present in the aneurysm sac, we performed partial distal trapping (patient no. 3). In the initial instance, we were able to immediately achieve intraoperative thrombosis of the aneurysm sac, which was shown using intraoperative CeUS with Doppler and then verified by postoperative DSA and MRI. In the second case, 24 hours after surgery, during the developing thrombotic alterations inside the fusiform aneurysm sac, a capsular stroke caused by the obstruction of one lenticulostriate artery originating from the aneurysm sac occurred. Additionally, a partial trapping procedure was carried out on a massive ICA aneurysm by clipping the main inflow (ICA) and the two main outflows while leaving a patent posterior communicating artery to maintain flow in the anterior choroidal artery, both of which originated from the aneurysm sac. In this case, the aneurysm shrank gradually while the posterior communicating and anterior choroidal arteries remained patent at longterm F-U. On the other hand, following the revascularization treatments, the majority of the difficult ICA aneurysms and all of the ACA aneurysms were completely occluded by endovascular methods. For ICA aneurysms, where proximal exposure was thought to be more challenging to achieve with a direct surgical approach, this method was chosen. Additionally, the anterior communicating arteries or anterior cerebral arteries were the preferred option. Although it is technically conceivable to do both the bypass and the surgical trapping in a single session, this would necessitate either a significant bifrontal exposure or two separate craniotomies for more proximal aneurysms. Therefore, we believed that in these situations a combined surgical and endovascular technique could be regarded safer in order to avoid excessive vessel manipulation in a single session. During complex vascular cases that call for multimodal management, in our experience, the combination of multiple intraoperative visualization tools is crucial. In particular, each tool can offer specialized information that is complementary to the others in order to better understand flow dynamics and vessel anatomy while undergoing surgery. We discovered that CEUS made it possible to examine aneurysm characteristics, its calcification, and the vascular anatomy even at remote locations that the surgical approach would not have directly exposed. In addition, intraoperative evaluation of bypass patency and the absence of parenchymal hypoperfusion was possible thanks to ICG videoangiography with FLOW 800 analysis and SF videoangiography. They might be carried out in concert since SF-VA provides a considerably higher definition of small perforators and tiny cortical vessels while Zeiss' FLOW 800 software has the uniqueness of providing semi quantitative flow measurement. On a sizable cohort of patients, our team demonstrated the potential combination of both tracers without any negative medication effects. There are a few restrictions on this study. First of all, it is a retrospective case series with an inherent selection bias because we only considered difficult aneurysms that could not be treated with a straightforward microsurgical or endovascular technique, including the use of FD. As a result, no control group using various treatments for aneurysms with similar characteristics could be utilized as a comparison. Furthermore, we were unable to conduct a subgroup analysis to look at potential predictors of poor outcome, such as hemodynamics and bypass geometry, due to the relatively small number of cases and the heterogeneity of the series, as well as the fact that the majority of patients had good outcomes at the time of their last follow-up. In the end, patients were followed up for only a little time period, and no conclusive data regarding very long-term bypass patency could be collected.

Future modelling of complex intracranial aneurysm hemodynamics and predictions of the impact of various bypass strategies on aneurysm occlusion and ischemic complications could both be assisted by computational fluid dynamics, which has recently been used to more precisely predict the risk of rupture of UIAs.

Conclusion

Both neurosurgeons and neuroradiologists still struggle with treating difficult anterior circulation aneurysms. In certain circumstances where a more straightforward direct method, like the use of FD, is not practical, the employment of revascularization strategies remains a viable option. Our series demonstrated that the best short- and long-term outcomes for this challenging disease require a patient-specific tailored approach, based on the unique anatomy and neurophysiology of each individual, including multimodality treatment and a strict collaboration between all the parts of a tertiary referral hospital with an expert neurovascular team.

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