The Y-shaped double-barrel bypass in the treatment of large and giant anterior communicating artery aneurysms

Technical note

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Large and giant anterior communicating artery (ACoA) aneurysms usually show partial thrombosis and incorporate both the A1 and A2 segments and crucial perforating vessels. Therefore, direct clip placement or endovascular strategies often fail, leaving cerebral bypass surgery as a relevant therapeutic option. The authors present 3 cases in which a giant or large ACoA aneurysm was successfully occluded using a new technique that applies a double-barrel radial artery bypass. A radial artery graft is modified into a Y-shaped double-barrel conduit. After both pterional and parasagittal craniotomies are carried out, the graft is tunneled between both sites and anastomosed in an end-to-side fashion proximally to either a superficial temporal artery (STA) or M2 branch and distally to bilateral A3 branches. Aneurysm occlusion is then conducted through the pterional or parasagittal craniotomy. In one case, a 42-year-old patient in whom an endovascular approach had failed, the authors performed an STA-A3-A3 bypass and proximal aneurysm occlusion. In two others, a 49-year-old man in whom coiling had failed and a 56-year-old man in whom a giant ACoA aneurysm was partially thrombosed, the authors performed an M2-A3-A3 double-barrel bypass followed by either proximal or distal aneurysm occlusion. Complete aneurysm occlusion with excellent bypass perfusion was documented in the first two cases. In the third case, the authors observed good bypass perfusion with persistent antegrade aneurysm filling, and thus endovascular coil embolization was added to completely occlude the aneurysm.

The Y-shaped double-barrel bypass using a radial artery graft allows for safe and effective occlusion of large and giant ACoA aneurysms that cannot be treated by direct clip application.

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KEY WORDS • anterior communicating artery aneurysm • vascular disorders • surgical revascularization • double-barrel bypass • giant intracranial aneurysm

Abbreviations used in this paper: ACoA = anterior communicating artery; EC = extracranial; IC = intracranial; ICA = internal carotid artery; ICG = indocyanine green; MCA = middle cerebral artery; mRS = modified Rankin Scale; STA = superficial temporal artery.

Surgical Technique

Combined Craniotomy and Radial Artery Graft Dissection

The patient is placed in the supine position with the head rotated to the left side by 60°. The arm from which...
the radial artery graft is harvested is positioned so that access is possible without additional maneuvers. Using a right frontolateral approach with a modified skin incision extended beyond the midline, two craniotomies are conducted: the first in the pterional location for access to the ACoA aneurysm and, if an IC-IC bypass is performed, the MCA. The second craniotomy is paramedian to the sagittal sinus, with bur holes anterior and posterior to the coronal suture for bilateral access to the A2 and A3 segments. At this site the dura is opened on one side and reflected over the midline. The interhemispheric fissure is visualized and opened using blunt resection. Both the A2 and A3 segments are visualized bilaterally along the corpus callosum. Next, a 25-cm segment of the radial artery is carefully dissected, removed, and subjected to hydrostatic distension to treat vasospasm.

**Proximal Anastomosis**

Two minutes prior to and during all bypass anastomoses the inspirational oxygen fraction is raised to 100% for brain protection. Also, transcranial motor evoked potentials are monitored continuously.

If the STA is chosen as host vessel, as in Case 1, the right frontal skin incision is used to subcutaneously dissect the dominant branch of the STA. The proximal end of the radial artery graft is then tunneled subcutaneously between the STA and the parasagittal craniotomy. The anastomosis between the STA branch and the radial artery graft is carried out in end-to-side fashion using a continuous 9-0 monofilament nylon suture.

If the proximal bypass anastomosis is located at an M2 branch, as in Cases 2 and 3, the dura is opened at the pterional site and reflected toward the cranial base. The Sylvian fissure is visualized and opened using blunt resection. Both the A2 and A3 segments are visualized bilaterally along the corpus callosum. Next, a 25-cm segment of the radial artery is carefully dissected, removed, and subjected to hydrostatic distension to treat vasospasm.

**Illustrative Cases**

**Case 1**

**History and Examination.** This 42-year-old man was diagnosed with a giant ACoA aneurysm after suffering a generalized epileptic seizure (Fig. 3A). The aneurysm did not rupture, and the patient recovered fully. Initial attempts at endovascular therapy in another hospital had failed due to aneurysm size and poor aneurysm accessibility. The patient was referred to our institution. Angiography showed that the giant ACoA aneurysm was filled by the right A1 segment, while the left A1 was hypoplastic (Fig. 3B). Both A2 segments originated directly from the ACoA aneurysm and were normally perfused.

**Operation.** Since the angiogram showed a right frontal STA branch of large caliber, we conducted an EC-IC bypass for revascularization of both A3 segments using an STA-A2-A1 Y-shaped double-barrel graft. Because the ACoA aneurysm was exclusively filled by the right A1, we decided on proximal clip occlusion of the right A1 (Fig. 3C). To establish the bypass, the radial artery graft was converted distally into a Y-shaped double barrel and bilaterally anastomosed to two A2 segments. Next, a right frontal skin incision was conducted and followed by careful dissection of the frontal branch of the STA. The proximal end of the bypass was tunneled subcutaneously and anastomosed to the frontal STA branch in end-to-end fashion. Intraoperative ICG-videoangiography and Doppler flowmetry showed sufficient bypass patency. The frontal skin incision was now extended caudally to conduct a pterional craniotomy through which the giant ACoA aneurysm was proximally occluded by placing a clip on the dominant right A1. Before skin closure, bypass patency was reconfirmed by ICG-videoangiography.

**Postoperative Course.** Both postoperative and 1-year
follow-up angiography revealed excellent bypass perfusion and complete aneurysm occlusion (Fig. 3D and E). The patient displayed mild concentration deficits during the 1st week after surgery from which he recovered completely. Six months after surgery, he was able to resume his regular work; his status was an mRS score of 1.

Case 2

**History and Examination.** This 49-year-old man presented to the emergency department with headache and nausea. Initial CT scanning and angiography revealed a subarachnoid hemorrhage from a large ACoA aneurysm (Fig. 4A). The patient was admitted to the intensive care unit, and endovascular coil embolization was chosen as the primary therapy. During this intervention, 15 Guglielmi detachable coils were deployed. Postinterventional angiography demonstrated complete occlusion of the aneurysm and normally perfused A2 segments (Fig. 4B). One year later follow-up angiography showed significant reperfusion at the aneurysm base (Fig. 4C).

**Operation.** In this situation of failed coil embolization in a large ACoA aneurysm, we opted for revascularization of both A3 segments in combination with proximal aneurysm occlusion. Since the STA branches were not large enough to match the diameter of the radial artery graft, the M2 segment was chosen as host vessel for an M2-A3-A3 Y-shaped double-barrel bypass (Fig. 4D). The procedure was performed as described in Case 1. Because the aneurysm was exclusively filled by the left A1 (the right A1 was hypoplastic), placement of a permanent clip on the left A1 was sufficient to proximally occlude the aneurysm.

**Postoperative Course.** Postoperative and 1-year follow-up angiography revealed excellent perfusion of the bypass and complete occlusion of the ACoA aneurysm (Fig. 4E). The patient recovered without neurological deficit and his status was an mRS score of 1.

Case 3

**History and Examination.** This 65-year-old man presented to our clinic with progressive bilateral visual loss. Cranial MRI showed a giant ACoA aneurysm that was partially thrombosed. Angiography demonstrated that there was a dominant left-side A1 segment filling the aneurysm (Fig. 5A). Both A2 segments were normally perfused.

**Operation.** Due to the extent of the thrombus within the aneurysm, direct clipping and endovascular strategies were ruled out as primary therapies. As in Case 2, we could not find an STA branch large enough to guarantee sufficient filling of the radial artery graft. Both A3 segments were chosen for revascularization, which involved an M2-A3-A3 double-barrel bypass, as described in Case 1. Due to the incorporation of the left A1 segment into the aneurysm, proximal occlusion was ruled out. We...
The Y-shaped double-barrel bypass

therefore went for distal occlusion of both \( A_2 \) segments through the parasagittal craniotomy (Fig. 5B).

**Postoperative Course.** Postoperative angiography showed that the bypass was completely perfused (Fig. 5C). However, we noted unchanged perfusion of the aneurysm through the left \( A_1 \) and even antegrade filling of the left \( A_2 \) segment in spite of its clip occlusion, potentially caused by clip slippage or an accessory vessel (Fig. 5D). Therefore, in a second step, the remaining aneurysm lumen was successfully proximally occluded by endovascular coil embolization of the left distal \( A_1 \) segment (Fig. 5E). Both distal \( A_2 \) segments were now exclusively filled by the bypass. The patient displayed a high-grade hemiparesis of the left leg and a low-grade hemiparesis of the left arm after surgery. Magnetic resonance imaging showed no marked ischemia. The arm paresis resolved completely within 3 months, as did the proximal paresis in the leg. Despite minor paresis of foot extension and flexion, the patient is able to walk without assistance and his status is an mRS score of 3.

**Discussion**

We report on the double-barrel bypass for revascularization of the distal anterior cerebral artery segments in the treatment of large and giant ACoA aneurysms. Although this bypass strategy has been described in theory previously,\(^1\) we are the first to present specific cases. Large and giant intracranial aneurysms are usually fusiform and partially thrombosed or even calcified and are therefore not directly comparable to their smaller and less complex counterparts.\(^1\) Conventional therapies often fail to produce satisfactory outcomes. Coil embolization usually results in reperfusion or further growth of the aneurysm.\(^2\) Most recent advances in endovascular stent techniques, such as flow-diversion stents, have yielded mixed results regarding morbidity and mortality.\(^2\),\(^1\) Direct clipping of large and giant aneurysms is often viewed to be the optimal treatment with the best outcomes, yet it can only be applied in about 30%-50% of cases.\(^9\),\(^1\) To facilitate direct clip placement, hypothermic circulatory arrest is often used, which in itself is associated with substantial surgical morbidity.\(^1\) Therefore, in the majority of cases proximal occlusion of the vessel carrying the giant aneurysm is the most promising strategy, yet it often requires a feasible distal revascularization strategy.

Intracranial bypass surgery has become an indispensable tool to maintain blood flow distal to large and giant aneurysms. Depending on the location and lumen size of the vessels carrying the aneurysm, different bypass grafts can be used. More distal aneurysms, for example, \( P_2 \) or \( M_1 \), are often bypassed by an STA-MCA direct graft, while more proximal aneurysms (for example, ICA, \( A_1 \), and ACoA) usually require a higher blood flow rate, which can be supplied by grafts of the radial artery (intermediate flow) or the saphenous vein (high flow).\(^4\),\(^1\),\(^1\)

Determining the appropriate bypass strategy is often complicated because giant aneurysms can harbor more than one efferent vessel requiring revascularization.
This is especially true in cases of giant ACoA aneurysms. As in our 3 cases, these lesions usually integrate both A1 and A2 segments in a fusiform fashion. Also, the vascular area harbors numerous important hypothalamic and chiasmal perforating arteries as well as the origin of the recurrent artery of Heubner, which perfuses the anterior parts of the internal capsule. Apart from aneurysm occlusion, the main goal of treatment therefore has to be the preservation of these important vessels, as well as the revascularization of both A2 segments.

An A2-A2 or A3-A3 side-to-side bypass with partial ACoA aneurysm clipping has been suggested as a feasible strategy. However, this technique can only be applied if at least one A2 orifice is left open and normally perfused. Such persistent antegrade flow through the A2 in the context of a large or giant fusiform ACoA aneurysm means that the aneurysm remains partially perfused, which leaves an increased risk of rupture. Furthermore, A2-A2 and A3-A3 bypasses require simultaneous bilateral temporary A2 or A3 clipping. This bears an increased risk of cerebral hypoxia. Finally, the procedural risk of a side-to-side anastomosis, a procedure that is technically more challenging to carry out than an end-to-side anastomosis, should not be ignored: intraprocedural bypass failure (for example, thrombosis or vessel rupture) will most likely lead to bilateral anterior infarctions.

An option that reduces some of the aforementioned risks is a radial artery graft to one A2 branch combined with an A2-A2 or A3-A3 bypass. In this case, bilateral proximal or distal ACoA aneurysm occlusion is possible, thereby reducing the risk of future rupture. However, the disadvantages of the side-to-side A2-A2 or A3-A3 bypass remain.

Sekhar et al. have therefore suggested a modification of the latter approach by using a Y-shaped double-barrel radial bypass graft connected to both A2 segments in the end-to-side technique. As we show in the present report, this technique has relevant advantages.

First, it allows for proximal anastomosis to different host vessels and therefore offers a chance to modify the treatment strategy according to each individual case. In our case series, both the STA (for EC-IC bypass) and the M2 (for IC-IC bypass) proved to be reliable host vessels. In Case 1 a well-perfused temporal STA branch was present and allowed for a less complicated EC-IC bypass. In Case 2 and 3 no strong STA branches could be identified. In this situation, the double-barrel graft was proximally connected to an M2 segment and used as an IC-IC bypass.

Another advantage of the double-barrel bypass is that it can be combined with complete proximal or distal ACoA aneurysm occlusion so that important perforating vessels (for example, recurrent artery of Heubner and hypophyseal perforators) can still be perfused in either an antegrade or a retrograde fashion. This “non-trapping” strategy was applied in all of our 3 cases with good results in Cases 1 and 2, in which only the dominant A1 segment was clipped, leading to complete thrombosis of the aneurysm. However, in Case 3 one could argue that...
by only distally occluding the aneurysm at the A2 segments the unimpeded persistent inflow into the aneurysm through the dominant left A1 was to be expected. Yet the double-barrel bypass then served as a protection during the coiling of the left distal A1 segment, which resulted in complete aneurysm occlusion.

One can therefore say that the double-barrel bypass can also be viewed as an additive therapy when, as in Case 2, initial coiling fails to permanently occlude the aneurysm and clipping can only be carried out safely under bypass protection. Likewise, this bypass helps when surgical strategies fail, as in Case 3, in which the distal clip occlusion of the aneurysm proved to be insufficient. In such a situation additional and more aggressive endovascular therapy can be conducted in a second step still under bypass protection.

We therefore support the view that the Y-shaped double-barrel bypass that uses a radial artery graft should be viewed as a valid option in the treatment of large and giant ACoA aneurysms.

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