Safety of early endovascular catheterization and intervention through extracranial-intracranial bypass grafts

Clinical article

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Object. The goal of this study was to demonstrate feasibility and evaluate technical aspects of early endovascular access through extracranial-intracranial (EC-IC) bypass grafts.

Methods. Patients undergoing endovascular interventions through the graft in the acute postoperative period following EC-IC bypass are presented. Results, complications, and technical nuances are reviewed.

Results. Fourteen endovascular procedures were performed in 5 patients after EC-IC bypass for ruptured aneurysms in 4 patients and posterior circulation ischemia in 1 patient. In 2 patients, a saphenous vein graft (SVG) was used to bypass the common carotid artery (CCA) to the middle cerebral artery (MCA). One patient underwent a superficial temporal artery (STA)–MCA bypass, and in 2 other patients the STA stump was connected to the intracranial circulation via an interposition SVG. The interval from surgery to endovascular intervention spanned 2–18 days; the indication was intracranial vasospasm in all patients. One case involved angioplasty of the proximal anastomosis on postoperative Day 14. All other interventions entailed proximal access through the bypass conduit for intraarterial infusion of vasodilators. Significant vasospasm of the STA itself was encountered in 2 patients during endovascular manipulation, and it was treated with intraarterial nitroglycerin. There were no cases of anastomotic disruption.

Conclusions. Endovascular catheterization and intervention involving a recent EC-IC bypass is feasible. The main limitation in this series was catheter-induced vasospasm involving the STA. A vein graft may be the more appropriate option in patients with subarachnoid hemorrhage who may require subsequent endovascular intervention for vasospasm. (DOI: 10.3171/2011.8.JNS11747)

Key Words • aneurysm • endovascular catheterization • extracranial-intracranial bypass • vasospasm • vascular disorders

Abbreviations used in this paper: CCA = common carotid artery; EC-IC = extracranial-intracranial; ECA = external carotid artery; ICA = internal carotid artery; MCA = middle cerebral artery; OA = occipital artery; PCA = posterior cerebral artery; PICA = posterior inferior cerebellar artery; RA = radial artery; SAH = subarachnoid hemorrhage; STA = superficial temporal artery; SVG = saphenous vein graft; VA = vertebral artery.
bypass. The study was approved by our institutional review board. Medical records were reviewed for collection of demographic and clinical data, including operative/procedural details, immediate outcome, hospital course, and outpatient follow-up. Radiological imaging studies and results were also reviewed.

Results

Five patients were identified, as summarized in Table 1. Four had undergone EC-IC bypass for treatment of acutely ruptured aneurysms, and 1 for medically refractory posterior circulation ischemia. In 2 patients, a long SVG was used to bypass the CCA to the MCA. One patient underwent a direct STA-MCA bypass. In 2 additional patients, the STA stump was connected to the intracranial circulation via a short interposition SVG (1 of these cases has been previously included in a published technical report of STA trunk bypass1). All patients suffered symptomatic vasospasm in the postoperative period, and in aggregate, underwent 14 endovascular procedures through the recently performed graft for treatment. The interval from surgery to endovascular intervention spanned 2–18 days, and entailed proximal access through the bypass conduit for intraarterial infusion of vasodilators in all cases, in addition to a single instance of angioplasty of a proximal anastomosis on postoperative Day 14. Angioplasty of the intracranial vasculature was not indicated, and thus endovascular microguidewire or catheter access through the distal anastomosis was not performed.

Technical complications included significant vasospasm of the STA graft itself, which was encountered in 2 of 3 patients during endovascular manipulation; both were treated with intraarterial nitroglycerin. There were no cases of anastomotic disruption. In the case of direct STA-MCA bypass, thrombus in an M3 branch distal to the bypass was seen following infusion of verapamil through a microcatheter positioned in the STA on postoperative Day 17. This was treated with integrilin. The patient subsequently developed multiple peripheral thromboses and a pulmonary embolism, and tested positive for heparin-induced thrombocytopenia.

Illustrative Cases

Case 1

This 37-year-old man was admitted as a Hunt and Hess Grade IV, with a modified Fisher Grade 4 SAH. Catheter angiography demonstrated a left-sided fusiform aneurysm involving the M1 (Fig. 1A and B). A frontotemporal craniotomy was performed for trapping and construction of a left CCA-MCA bypass with an interposition SVG (Fig. 1C). On postoperative Day 8, the patient became increasingly lethargic and improved only partially with hypertensive therapy. Angiography confirmed diffuse intracranial vasospasm (Fig. 1D). To treat the vasospasm optimally, endovascular intervention was pursued. After systemic heparinization, a 6 Fr guide catheter was placed in the left CCA, and the SVG was catheterized with a 2.8 Fr microcatheter tracked over a 0.014-in microguidewire. Verapamil (10 mg) was infused into the left MCA territories via the graft, with good angiographic response (Fig. 1E). The patient was subsequently discharged to an inpatient rehabilitation facility; at 1-year follow-up he had returned to work as an engineer, with a modified Rankin Scale score of 1.

Case 3

This 38-year-old woman presented with rapidly declining mental status and hemiplegia due to a large right-sided temporal parenchymal hematoma and associated SAH. An MCA bifurcation aneurysm was identified by

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Indication for Op</th>
<th>Procedure</th>
<th>Endovascular Intervention</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>37, M</td>
<td>SAH, M, aneurysm</td>
<td>proximal occl/trapping, CCA–MCA SVG bypass</td>
<td>1 8 2.8 Fr microcatheter w/in SVG</td>
</tr>
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<td>2</td>
<td>57, F</td>
<td>SAH, SP stent/coil for unruptured ICA aneurysm</td>
<td>trapping, CCA–MCA SVG bypass</td>
<td>5 2, 3, 6, 8, 11 2.8 Fr microcatheter &amp;/or 5 Fr diagnostic catheter w/in SVG</td>
</tr>
<tr>
<td>3</td>
<td>38, F</td>
<td>SAH, MCA bifurcation aneurysm</td>
<td>clipping w/ MCA branch sacrifice, STA–MCA bypass</td>
<td>2 5, 17 2.8 Fr microcatheter w/in STA</td>
</tr>
<tr>
<td>4</td>
<td>54, F</td>
<td>SAH, PCoA aneurysm</td>
<td>trapping, STA–MCA SVG bypass</td>
<td>4 3, 5, 8, 14 2.8 Fr microcatheter w/in STA</td>
</tr>
<tr>
<td>5</td>
<td>46, M</td>
<td>crescent ischemic stroke</td>
<td>STA-PCA SVG bypass</td>
<td>3 14, 18 angioplasty of STA–SVG anastomosis</td>
</tr>
</tbody>
</table>

* occl = occlusion; PCoA = posterior communicating artery; POD = postoperative day; SP = status post.
Endovascular catheterization of bypass

CT angiography (Fig. 2A), and an emergency craniotomy was performed for clot evacuation and aneurysm occlusion. The complexity of the lesion required sacrifice of the MCA frontal division, and thus an STA-MCA bypass was performed to the frontal M3 branch (Fig. 2B). The patient regained significant function of her left side and was extubated 24 hours later. On postoperative Day 5, she developed speech apraxia, which did not respond to hypertensive therapy. She underwent angiography, which revealed spasm of the right MCA proximal to the bifurcation. This was treated by intraarterial infusion via the ICA, with good results. Twelve days later her symptoms recurred and again persisted despite hypertensive therapy. Angiography demonstrated vasospasm involving the distal right MCA territories, with involvement of the bypassed region (Fig. 2C). Under systemic heparinization, a 6 Fr guide catheter was positioned in the right CCA, and 20 mg of verapamil was infused via a 2.8 Fr microcatheter positioned in the proximal aspect of the donor STA. After infusion, thrombus was visualized in the M3 segment distal to the bypass (Fig. 2D). Integrilin was administered intravenously, resulting in disruption and distal migration of the clot (Fig. 2E). The patient responded well clinically. Subsequently, she developed multiple peripheral thromboses and a pulmonary embolism, and tested positive for heparin-induced antiplatelet antibody. She underwent anticoagulation and was ultimately discharged home in good neurological condition. Six months later she maintains a modified Rankin Scale score of 1.

Case 5

This 46-year-old man presented with a 1-week history of dysarthria, diplopia, and progressive lethargy. A CT scan of the brain showed a pontine ischemic infarct. Catheter angiography demonstrated occlusion of the dominant right VA distal to the PICA, as well as diffuse disease of the left VA resulting in functional occlusion. He was deemed a candidate for surgical revascularization and underwent a left temporal craniotomy for construction of a left STA-PCA bypass in which an interposition SVG was used. Postoperative angiography revealed a patent graft (Fig. 3A). On postoperative Day 13 he developed new ischemic strokes in the left MCA and in both PCA territories. Catheter angiography revealed severe spasm on the surgical side, in the supraclinoidal ICA and MCA. Extracranially, there appeared to be narrowing of the proximal anastomosis between the STA stump and the interposition SVG. This did not appear
to be flow limiting, and thus only angioplasty of the left ICA and MCA was performed. Repeat angiography on postoperative Day 14 showed progressive narrowing of the STA-SVG anastomosis. Under systemic heparinization, a 6 Fr guide catheter was placed in the left CCA and the proximal portion of the STA was catheterized with a 2.8 Fr microcatheter. Nitroglycerin (300 μg) was infused to the surgical anastomosis, with nominal improvement. Further clinical decline warranted surgical exploration, but no external compression was found. Thus, intraoperative endovascular catheterization for angioplasty of the STA-SVG anastomosis was performed by placing a 6 Fr guide catheter in the left ECA and using a 4 × 15–mm compliant balloon (Fig. 3C). This resulted in distal flow cessation secondary to vasospasm of the STA at the anastomosis and proximally (Fig. 3D). Four days later, on Day 18, STA resulted in considerable reversal of the spasm over the next 45 minutes (Fig. 3D). Four days later, on Day 18, mild distal STA spasm was still present, but responded to nitroglycerin infusion. The patient remained stable for the next 4 weeks without new ischemic events, but ultimately died due to pneumonia and consequent sepsis.

Discussion

Endovascular intervention performed through a recently created EC-IC bypass is not well described in the literature. Potential concerns inherent in such an endeavor include disruption of the anastomosis, the use of intraprocedural anticoagulation therapy, or graft flow compromise due to catheter-induced vasospasm or dissection. Sekhar et al. reported 2 cases in which angioplasty was performed on an RA interposition graft for vasospasm within the graft itself. One of the interventions resulted in graft rupture, with poor outcome. The timing of the intervention in relation to the bypass and the technical details, however, were not described. Natarajan et al. recently presented a case in which multiple serial endovascular interventions were performed in a patient after an EC-IC bypass for moyamoya disease. An interposition RA graft had been used to connect the OA to the MCA. Recurrent and persistent vasospasm of the OA and RA was identified on the 1st, 2nd, 3rd, and 6th postoperative days, requiring repeated infusions of calcium channel blockers on all 4 occasions and angioplasty on the last 3. A semi-compliant balloon was used, and although an intimal flap was created after angioplasty on postoperative Day 2, the patient evidently recovered without clinical morbidity.

These 2 reports demonstrate some of the concerns associated with access through a cerebral bypass graft. The vasospasm seen in both cases was related to the use of the RA as a bypass conduit, but exacerbation by catheter manipulation was a probable factor, at least in the second report. Our experience similarly suggests a high rate of mechanically induced spasm associated with the catheterization of arterial conduits, namely the ECA branches, and specifically the STA itself when used as the donor vessel. Although catheter-induced vasospasm is typically thought to be transient in nature, the consequent cerebral ischemia may be even less well tolerated when coupled with SAH-induced intracranial vasospasm.

A review of our cases has led to the formulation of various technical recommendations that may limit vasospasm during endovascular access through a recently constructed EC-IC bypass graft. In our experience, resolution of catheter-related vasospasm is typically achieved by withdrawal of the catheter and administration of nitroglycerin. However, the response to treatment is not immediate, with a resultant risk of cerebral ischemia. Although not used in this series, the efficacy of administering nitroglycerin to treat extracranial vasospasm prophylactically has been mentioned in the literature, and seems appropriate here. This may be done by adding 1 mg of the agent to the guide catheter flush for continuous infusion throughout the case, or by applying 7.5–15 mg of topical nitroglycerin beforehand. Systemic hypotension or intracranial hypertension does not appear to be a significant issue, but continuous monitoring of the blood pressure and oxygen saturation is recommended.

Fig. 2. Case 3. A: Axial CT angiogram demonstrating parenchymal hemorrhage within the temporal lobe (arrow) and an MCA bifurcation aneurysm (arrowhead), with the M, branch arising from the aneurysm rather than the bifurcation. B: Postoperative angiography study, with lateral view of the ECA injection showing the patent STA graft; the anastomosis is indicated by the arrow. C: Angiography study visualizing vasospasm within the bypassed territory. D: Study identifying thromboembolus within the MCA branch after infusion of intraarterial verapamil (arrow). E: Study showing that infusion of integrilin resulted in disruption and distal migration of the thrombus (arrow).
pressure is recommended. Mechanical irritation can also be minimized in cases of intraarterial drug infusion, by positioning the larger guide catheter proximally in the distal CCA, allowing for access through the STA with only a microcatheter.

It is noteworthy that the SVG portions of our bypass conduits were not affected by vasospasm, and this was probably related to the paucity of smooth muscle in the tunica media of venous relative to arterial grafts. With reduced concern for catheter-induced vasospasm in CCA-MCA long SVG bypasses, the endovascular procedure can be simplified by eliminating a proximal guide catheter for microcatheter insertion, and alternatively using the 5 Fr diagnostic catheter directly for graft access and infusion. This simplification potentially reduces the risk associated with intervention. In this series, selective catheterization of the intracranial anastomosis and distal vessels, as would be used for intracranial angioplasty, was not performed. The efficacy of angioplasty for SAH-induced vasospasm has been well demonstrated in the neurosurgical literature, and offers the benefit of durable results compared with the transient benefit offered by vasodilators and the subsequent need for repeated interventions. Although we favor intracranial angioplasty for vasospasm in proximal vessels, the cases in this series primarily involved spasm of more distal and smaller-caliber vessels, which were thought to be less amenable to a balloon strategy. If such access were needed, how-
ever, the use of an SVG would be more likely to facilitate direct access to the distal anastomosis and intracranial vasculature by allowing for more distal placement of a larger guide catheter. Although vein grafts are generally believed to have inferior longevity compared with primary STA grafts, the long-term patency rate is nonetheless acceptable.\(^9\) For these reasons, in appropriate cases in which there is a high risk of subsequent intracranial vasospasm, use of a long SVG and avoidance of the STA or RA as donors may be the more suitable option.

Another concern in early postsurgical endovascular intervention is the intraprocedural use of intravenous heparin. Although systemic heparinization is not mandatory during intraarterial infusion, multiple factors must be considered. The intraarterial infusion of vasodilators to treat vasospasm must be performed slowly to avoid hypotension and consequent exacerbation of global cerebral ischemia. This can result in prolonged periods in which a catheter remains static within or proximal to the graft conduit, increasing the risk of associated thromboembolic events,\(^13,\)\(^16\) and thus supporting the use anticoagulation. Furthermore, the metabolic disarray consequent to intracranial SAH is associated with a hypercoagulable state\(^2\) and favors procedural anticoagulation. In our series, heparinization administered in accordance with a weight-based algorithm did not result in intracranial hemorrhagic complications, and we believe that intraprocedural heparinization generally offers a better risk profile than the potential morbidity associated with an embolic event or the more powerful antiaggregants required to treat it.\(^14\) The only thromboembolic complication encountered in this series occurred in a patient subsequently discovered to have heparin-induced thrombocytopenia, a condition known to be associated with thrombotic complications.

Mechanical disruption of the bypass was not seen in this small series. Only 1 procedure involved angioplasty, and the remainder entailed positioning of the catheter in proximity to or beyond the proximal anastomosis. Although advances in technology have resulted in the availability of multiple relatively atraumatic endovascular commercial products, vessel dissection or rupture is a possibility and must be kept in mind, as exemplified by the previous case reports referenced above.\(^13,\)\(^20\) Our preference in treating vasospasm is to use a compliant balloon capable of vessel expansion at much lower atmospheric pressures. The visualization of expansion is used to limit inflation, as opposed to the predetermined pressure or volume of injection suggested by the manufacturer. We believe that this reduces the risk of vessel rupture even when the balloon is not sized correctly.

**Conclusions**

The case series presented here demonstrates some of the potential pitfalls associated with early endovascular access through a cerebral bypass graft in the perioperative period. Although the procedure is not without risk, we believe that the associated morbidity may be reduced by systemic anticoagulation, the prophylactic use of anti-spasmocic agents, and by minimizing mechanical irritation. The use of a long SVG for EC-IC bypass may be a more suitable option in cases of ruptured aneurysm at high risk for intracranial vasospasm, in which subsequent treatment through the graft is likely to be needed. Distal anastomotic access and intracranial entry through the bypass was not required in our series, and therefore the safety of direct intracranial endovascular interventions in the early postoperative setting has yet to be determined.

**Disclosure**

Dr. Aletich has received a research grant from Micrus Endovascular Corp.; Drs. Alaraj and Aletich are both consultants for Cordis and ev3 Neurovascular.

Author contributions to the study and manuscript preparation include the following. Conception and design: all authors. Acquisition of data: Qahwash, Alaraj. Analysis and interpretation of data: all authors. Drafting the article: Amin-Hanjani, Alaraj. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Amin-Hanjani.

**References**

Endovascular catheterization of bypass


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