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## ACUTE M2 BIFURCATION STENTING FOR CEREBRAL INFARCTION: LESSONS LEARNED FROM THE HEART: TECHNICAL CASE REPORT

**OBJECTIVE AND IMPORTANCE:** Acute ischemic stroke is the third leading cause of death in the United States. For patients with NIHSS scores >10 and evaluated within 6 hours, intra-arterial thrombolysis is the treatment of choice. The Merci retriever (Concentric Medical Inc., Mountain View, CA) and IV TPA are currently the only FDA-approved treatments for acute ischemic stroke. For patients who do not meet the criteria for TPA administration and/or in whom the Merci device fails, options are limited. Intracranial stenting for acute ischemic stroke after failed thrombolysis is now possible because of improved delivery systems and appropriately sized stents.

**CLINICAL PRESENTATION:** A 26-year-old woman presented with an NIHSS score of 11 (right-sided hemiparesis and mixed aphasia) 4 hours from the time of symptom onset. CT perfusion demonstrated increased time to peak in the entire left hemisphere; conventional angiography demonstrated a left M1 occlusion.

**INTERVENTION:** After crossing the occlusion with a microcatheter, reteplase (2 units) was administered into the clot. Mechanical thrombolysis was then attempted, without restoration of flow. Two 3 × 12-mm coronary stents were placed from the M1 into the superior and inferior divisions, respectively, with complete restoration of flow (TIMI 3). Within 72 hours, the patient had an NIHSS score of 1, with a small infarction in the external capsule.

**CONCLUSION:** Novel stroke interventions need to be developed for patients with acute ischemic stroke in whom traditional interventions fail. We present (to our knowledge) the first case of successful revascularization of an acute M1 occlusion accomplished with placement of two coronary stents.

**KEY WORDS:** Acute stroke, Intracranial stenting, Ischemic stroke

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Treatment for acute MI has undergone a remarkable and steady intellectual progression over the last 15 years. Patients with acute MI were initially treated with IV streptokinase and TPA. Although thrombolytic therapy was attempted, many patients did not benefit. Direct intra-arterial (IA) intervention with angioplasty and subsequently with stent-assisted angioplasty in conjunction with thrombolytic and antiplatelet therapy is now standard of care for patients with acute MI. Stenting has reduced restenosis rates and provided a framework to maintain patency in arteries recanalized with angioplasty alone.

IA stroke intervention is still in its infancy. The first device for IA intervention in stroke,

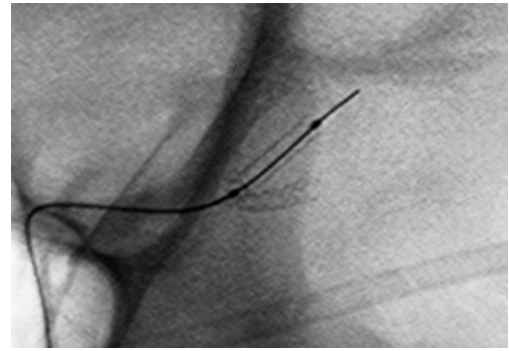
the Merci retriever, was approved by the FDA in 2004 (5). Each year, 700,000 patients have a cerebral infarction, and less than 2% receive IV or IA therapy. For patients with NIHSS scores >10 who are not treated with IV therapy, the relative odds of a functional recovery is lowered by 75% (1). IA stroke intervention results in successful, sustained recanalization of the thrombosed artery in only 50% of patients; repeated occlusion occurs in 17% of vessels initially opened with mechanical clot disruption and/or thrombolytic agents (12). Nevertheless, results of the Prolyse in Acute Cerebral Thromboembolism studies (4, 6) suggest that IA therapy is of benefit in patients with high NIHSS scores. Stenting of intracranial

vessels after failed thrombolytic therapy provides an intriguing alternative and might parallel the cardiac experience, although ischemic stroke tends to result from emboli, whereas coronary vessel occlusions most often result from underlying stenoses. Although stents designed for intracranial use may not have enough radial outward force to open and support an intracranial vessel, balloon-mounted cardiac stents are available that can be appropriately sized and navigated for this purpose. In this report, we describe what is, to our knowledge, the first successful deployment of two balloon-mounted cardiac stents in the left M2 branches at a bifurcation in a kissing configuration, which led to vessel recanalization after failed thrombolytic therapy.

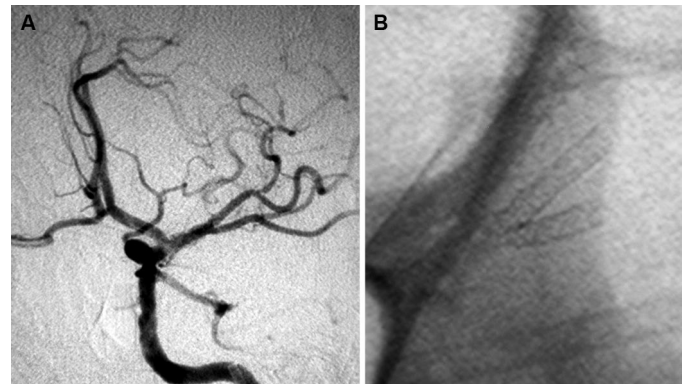
## CASE PRESENTATION

A 26-year-old woman was transferred to our institution with a four-hour history of right-sided hemiplegia and fluctuating aphasia. The patient was a smoker in previously good health and was not taking oral contraceptives. Neurological examination confirmed the right-sided hemiplegia and a mixed aphasia (NIHSS 11). A noncontrast head CT scan demonstrated only a subtle linear hypodensity in the region of the lateral insular cortex. CT perfusion imaging revealed an increased time to peak (delayed or reduced flow) in the entire left hemisphere.

Cerebral angiography revealed a proximal left MCA occlusion. A 6-F guide catheter was inserted into the distal left internal carotid artery. A Prowler Plus microcatheter (Cordis, Miami Lakes, FL) coaxially loaded over a 0.14-inch PVS exchange-length microwire was used to cross the lesion and was directed into the inferior M2 division. The catheter was progressively pulled back into the M1 while 2 units of reteplase was injected. Mechanical clot perturbation with the wire and the catheter was also performed. Control imaging confirmed persistent occlusion. The catheter was then exchanged for a 3 × 12-mm Vision balloon-mounted stent (Guidant, Indianapolis, IN) that was deployed slowly in the inferior division at subnominal pressure (1 atm/30 s to 4.5 atm), with complete recanalization of the division. An IV bolus of eptifibatidate was given (because the patient was not yet therapeutic on clopidogrel and required potent antiplatelet medication to maintain patency of the newly deployed stent) and the occluded superior M2 division was crossed with a 0.014-inch PVS microwire (Boston Scientific, Natick, MA). Mechanical thrombolysis with a Maveric 3 × 9-mm balloon (Medtronic AVE, Santa Rosa, CA) was performed from the M2 to the M1. Transient recanalization occurred, with subsequent reocclusion after several minutes. A second Vision 3 × 12-mm balloon-mounted stent was positioned in the superior M2 (Fig. 1). Slow, subnominal inflation (1 atm/30 s to 4.5 atm) resulted in complete recanalization of the M2 division (TIMI 3 flow) (Fig. 2, A and B). The postprocedure head CT scan demonstrated contrast material in the previously noted region of hypodensity in the lateral insular cortex. This region corresponded to the patient's only residual stroke burden. The patient was discharged home on hospital Day 4 with a subtle expressive aphasia and complete motor recovery.



**FIGURE 1.** Unsubtracted anteroposterior image with the first balloon-expandable stent deployed in the inferior division of the M2 and the second balloon-expandable stent deployed in the superior division with the balloon and microwire still in place.



**FIGURE 2.** A, angiogram after deployment of stents in the M2 divisions of the MCA with both M2 divisions filling without delay or evidence of thrombus; B, anteroposterior unsubtracted angiogram with stents deployed in a kissing configuration in the M2 divisions.

She was reevaluated in our office 1 week later and did not demonstrate any neurological deficits (NIHSS = 0).

## DISCUSSION

Endovascular treatment of acute stroke is a novel field, still in its infancy stage of development. IA thrombolytic therapy for acute stroke, although not FDA approved, has been shown to be efficacious in several trials (4, 6, 9, 11). For occlusions that remain recalcitrant to pharmacologic thrombolysis, IA mechanical thrombolysis may be initiated. Currently, the Merci retriever is the only approved device for recanalization of IA occlusions during acute stroke treatment (8).

At our institution, patients who present more than three hours after the onset of stroke symptoms or have NIHSS scores  $\geq 10$  receive angiograms and are treated with IA therapy (if the CT scan and perfusion studies document no evidence of frank or developing infarction over regions  $>3$  cm). In the case presented, the vessels remained occluded, despite administration of reteplase directly into the occlusion and mechanical clot perturbation. For this reason, we elected to

attempt mechanical thrombolysis using stent-assisted angioplasty (the Merci retriever was unavailable at the time of treatment). The rationale for using the stent was that occlusive clot, which becomes morselized by the angioplasty balloon, is then held in place against the vessel wall by the stent struts (10). By using extremely slow inflation techniques at a rate of 1 atm per 30 seconds, the vessel is able to accommodate slight dilatation, which may be caused by the stent pressing thrombus against the intima and decrease the likelihood of rupture. Additionally, the stents are deployed at pressures well below nominal pressure (4.5 atm, as opposed to 8 or 10 atm), resulting in deployment of the stent at two-thirds of the intended diameter (deployment is estimated to be 2.5–2.8 mm, rather than 3 mm). This, in turn, leads to a reduction in the relative porosity of the stent, making it less likely for thrombus to extrude back through the stent and cause acute reocclusion. When performing angioplasty alone, we have frequently found that thrombus recurs and occludes the vessel minutes after angioplasty. This may be caused by local platelet activation from existing thrombus and by intimal damage from the angioplasty balloon. In the case presented here, intimal injury may have occurred during attempts to recanalize the superior division after initial stenting of the inferior division of the MCA, thus necessitating stenting of the superior division.

Stenting of bifurcation lesions has been described for coronary atherosclerotic disease but not for intracranial pathological conditions. Stenting of coronary lesions at or near bifurcations for the treatment of atherosclerotic disease remains challenging (3). Suggestions have been given for T, Y, reverse-Y, and numerous other stent-configuration techniques (3). Even dedicated bifurcation stents have been developed and studied (14). A study was performed to compare two specific techniques: simultaneous deployment of bifurcation (or kissing) stents and provisional stenting of the side branch following stenting of the main vessel (13). Simultaneous deployment of stents at a bifurcation, as described in the coronary literature, requires that the diameter of the vessel proximal to the bifurcation be greater than two-thirds the aggregate diameter of the two stents (13). The stents should be sized to the diameter of the branch vessels. The more conventional technique for stenting of coronary bifurcation lesions involves placing a wire in each of the branch vessels, deploying the first stent in the main branch, and then advancing the second stent over the wire, through the first stent, into the other branch should revascularization of the second branch be required (13). The incidence of in-hospital and 30-day major adverse cardiac events, the need for target lesion revascularization, and procedure time were reduced using the simultaneous deployment technique. Others have found significantly higher rates of permanent or transient side-branch compromise with sequential balloon angioplasty than with the simultaneous angioplasty technique (33% versus 0%, respectively;  $P = 0.003$ ) (2).

For intracranial occlusions or stenoses, clinicians are limited by the lack of stents sized appropriately to accommodate MCAs. For deployment in the MCA, a stent must be suffi-

ciently pliable and navigable to traverse the carotid siphon and the turn into the M1 portion of the MCA. The Vision stent is one of the most navigable coronary stents currently available, but it is not appropriately sized for 2-mm vessels. The smallest available Vision stent is 3 mm in diameter; therefore, we could not perform a simultaneous deployment strategy, as the two stents together would be oversized for the M1 portion. Additionally, because the stent would have to be deployed at a subnominal diameter (thus reducing stent porosity), the navigation of a second stent through the pores of the first stent would be extremely challenging.

In our case, deployment of the first stent predominantly in the M2, with minimal overhang into the M1, allowed enough room for the second stent to be placed into the superior division without compromising or compressing the first stent. Before placing a second stent in the superior division, multiple attempts were made at angioplasty, but vessel reocclusion occurred within a few minutes. This necessitated the placement of the second stent, and permanent patency was achieved.

The realization that a second stent would likely be needed, in addition to the possibility of thrombus migration into the superior division as a result of "snowplowing" from the first stent, should have prompted the use of a second wire placed in the superior division before deployment of the first stent (7). This would have enabled continued access to the superior division even if the first stent was suboptimally deployed and obstructed the ostia of the superior division. Although stenosis or occlusion at or near coronary bifurcations accounts for 15 to 18% of all percutaneous coronary interventions, this occurrence is relatively rare in the intracranial circulation (7). We can apply the technique from coronary experience but are likely dealing with a different entity. In the intracranial circulation, most ischemic strokes result from embolic disease; whereas in the coronary circulation, occlusions tend to result from plaque rupture of underlying stenoses. For future cases, provisional stenting of the second division would be performed after microwire access to both divisions had been confirmed and successful stent-assisted recanalization of the first division had been determined.

## CONCLUSION

Acute stroke intervention is an exciting and dynamic field. There are many lessons to be learned from the vast cardiology and peripheral vasculature literature. We describe a novel procedure of stent-assisted recanalization of the MCA bifurcation during an acute stroke that is based on modifications of previously described techniques in the coronary literature. Stent positioning in the MCA bifurcation during deployment of the initial stent is critical for allowing passage of the second stent. Although not described in this report, the use of two microwires, each placed in one of the M2 branches before placement of the first stent, ensures continued access of both vessels throughout the procedure. The use of stent-assisted revascularization for acute stroke remains controversial. More



experience with these techniques is needed to gain further insight into the safety, durability, and appropriate indications for this technique.

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## COMMENTS

Levy et al. describe their experience in treating a 26-year-old woman who presented with a left middle cerebral artery occlusion. Four hours from the time of onset, computed tomographic perfusion was performed to increase transit time of the entire left hemisphere, and conventional angiography demonstrated a left M1 occlusion. Despite mechanical and pharmacological thrombolysis using Reteplase, restoration of flow could not be achieved. In paralleling experiences from the cardiac literature, two 3 x 12 mm coronary stents were placed in the M1 segment into the superior and inferior divisions and were only inflated with nominal inflation pressure to 4.5 atmospheres. Remarkably, flow was established and maintained. As the authors report, without stent assistance, this procedure often results in re-occlusion in an acute fashion.

There is absolutely no question that novel concepts and applications to the cerebral circulation of lessons learned from the cardiac literature are directly applicable. As experience increases and our tools improve, these procedures will become commonplace and will be able to be achieved with less risk. The potential population, as the authors allude, is enormous, and we face the challenge in neurosurgery of training individuals to be able to deal with this overwhelming problem when this becomes the standard of care. The authors are to be congratulated, once again, in providing us with new concepts to treat these very devastating disorders.

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This case report documents the successful use of superior and inferior division middle cerebral artery stents for the acute revascularization of occlusion refractory to low dose intra-arterial tissue plasminogen activator and mechanical clot disruption attempts. This technique has been described in the interventional cardiology literature, and the authors decided to use the two-stent procedure after thrombolysis and angioplasty failed. An excellent result was obtained with only a small infarction in what was likely to be a devastating event in a young woman.

Given limited Food and Drug Administration-approved endovascular options for acute stroke, such innovative approaches are performed with varying degrees of success and complication rates. Technological advancements such as the cobalt chromium stent and lower-profile, smaller delivery systems will allow endovascular surgeons to perform more distal stenting procedures. The long-term effect of stents in such small intracranial vessels is unknown. What role will drug delivering stents play in the brain? What anti-platelet drugs will be necessary, and for what length of time? Should mechanical clot retrieval devices or primary stent angioplasty be front-line attempts for acute vascular occlusion? Reports such as these raise more questions than they answer, but the successful treatment of this patient will advance the field by inspiring investigation of these questions.

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