

Emergent Stenting of Extracranial Internal Carotid Artery Occlusion in Acute Stroke Has a High Revascularization Rate

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Background and Purpose—Acute ischemic stroke attributable to extracranial internal carotid artery (ICA) occlusion is frequently associated with severe disability or death. In selected cases, revascularization with carotid artery stenting has been reported, but the safety, recanalization rate, and clinical outcomes in consecutive case series are not known.

Methods—We retrospectively reviewed all of the cases of ICA occlusions that underwent cerebral angiography with the intent to revascularize over a 38-month period. Two groups were identified: (1) patients who presented with an acute clinical presentation within 6 hours of symptom onset (n=15); and (2) patients who presented subacutely with neurologic fluctuations because of the ICA occlusion (n=10).

Results—Twenty-five patients with a mean age of 62 ± 11 years and median National Institutes of Health Stroke Scale (NIHSS) of 14 were identified. Twenty-three of the 25 patients (92%) were successfully revascularized with carotid artery stenting. Patients in group 1 were younger and more likely to have a tandem occlusion and higher baseline NIHSS when compared with group 2. Patients in group 2 were more likely to show early clinical improvement defined as a reduction of their NIHSS by ≥ 4 points and a modified Rankin Score of ≤ 2 at 30-day follow-up. Two clinically insignificant adverse events were noted: 1 asymptomatic hemorrhage and 1 nonflow-limiting dissection.

Conclusions—Endovascular treatment of acute ICA occlusion appears to have a high-recanalization rate and be relatively safe in our cohort of patients with acute ICA occlusion. Future prospective studies are necessary to determine which patients are most likely to benefit from this form of therapy. (*Stroke*. 2005;36:2426-2430.)

Key Words: angioplasty ■ endovascular therapy ■ stents ■ carotid arteries

Management of stroke attributable to acute internal carotid artery (ICA) occlusion continues to represent a challenge because it may result in significant disability in 40% and death in 20% of cases.¹ Carotid occlusion with hemodynamic impairment portends a particularly worse prognosis being associated with early clinical deterioration and late stroke recurrence risk.^{2,3} In this group of patients, early restoration of flow in the occluded ICA may improve the symptoms of acute stroke, prevent worsening, and reduce long-term stroke recurrence risk. Some authors have reported successful revascularization of patients with acute stroke symptoms secondary to ICA occlusion in isolated case reports.⁴⁻⁷ These patients were selected for aggressive therapy because of clinical fluctuations or deterioration from presumed hemodynamic instability and improved neurologically with revascularization. The technical success rates and complication rates of carotid artery stenting (CAS) for this condition in a larger consecutive case series are not known.

We report our experience on patients treated with CAS for symptomatic ICA occlusion.

Methods

This retrospective analysis was conducted with Institutional Review Board approval. All of the patients with acute carotid occlusion who underwent angiography with the intent to revascularize from January 2002 to March 2005 were identified retrospectively at the University of Pittsburgh Medical Center Stroke Institute. Clinical and radiographic data were reviewed through medical charts and electronic records of these 25 patients that met inclusion criteria. Clinical data included the following: demographic information, time to treatment, medications used during endovascular treatment, National Institutes of Health Stroke Scale (NIHSS) and modified Rankin Scale (mRS) at >1-month follow-up. Computed tomography (CT) scans before angiography were reviewed, and the Alberta Stroke Programme Early CT Scores were tabulated as described previously by 1 of the authors (K.U.) blinded to clinical outcome data.⁸ Angiograms were reviewed for the location of occlusion, collateral patterns, presence or absence of intracranial thrombus, and sizes of the stent used.

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Referral to angiography occurred at the request of the treating stroke neurologist as part of routine clinical care. Patients were considered for endovascular revascularization in the following 2 instances. For group 1, it was presumed to be because of middle cerebral artery (MCA) occlusion with onset of symptoms <6 hours. The diagnosis of ICA occlusion was made at the time of diagnostic angiography (15 patients). For group 2, patients were considered for subacute presentation with clinical fluctuations (an increase in the NIHSS of ≥ 4 points) and an ICA occlusion documented by magnetic resonance (MR) angiography or CT angiography along with a perfusion mismatch on MR or CT >50% (10 patients). The first group of patients underwent stenting of the carotid artery primarily to access the distal intracranial embolus in the acute setting. The subacute group did not have evidence of an intracranial occlusion on noninvasive studies and was felt to be at imminent risk of progression of ischemia unless flow restoration was achieved in the target vessel.

A transfemoral approach was used to perform the diagnostic angiogram using a standard 5F catheter. Digital subtraction angiography of the ipsilateral and contralateral common carotid arteries and of the vertebral artery was performed to demonstrate the ipsilateral ICA and MCA, as well as to assess potential collateral routes. Tandem occlusions were confirmed before crossing the proximal ICA occlusion by examining the cross-fill patterns through the anterior communicating artery and posterior circulation. Complete occlusion was considered when no antegrade flow was present in the ipsilateral extracranial and intracranial ICA despite delayed filming.

After complete occlusion was demonstrated, a steerable guide wire was gently negotiated from the ipsilateral common carotid artery through the occlusion into the distal cervical ICA. Attempts were made to cross the lesion with a 0.014-inch or 0.018-inch microwire in most cases. However, in some cases this was not possible; thus, a 0.035-inch or 0.038-inch wire with different degrees of stiffness was used to cross the lesion. At this point, the patients were given intravenous heparin before crossing the occlusion. In the 8 patients who received intravenous tissue plasminogen activator (tPA), a 2000-U bolus of heparin was administered. The other 17 patients were given an initial bolus of 5000 U of heparin with adjustments made to achieve an activated clotting time >250. A microcatheter or diagnostic catheter was then advanced over the wire into the distal cervical ICA. Repeat angiography of the ICA distal to the occlusion was performed to assess for thrombus/occlusion in the intracranial circulation (tandem occlusion).

Through the catheter, an exchange length wire was placed in the high-cervical and petrous segment of the ICA. Deployment of a self-expanding Wallstent (Boston Scientific) in 23 patients or Accu-link (Guidant Corp.) in 2 patients (patients 14 and 15) of different sizes, depending on the presumed parent size, was performed over the wire. The stent was deployed with the proximal end in the distal common carotid artery and the distal end in the proximal ICA. In 3 patients, deployment of an additional stent was necessary because of residual occlusive thrombus distal to the first stent. Poststenting angioplasty was performed in all of the cases. Embolic protection devices were not used except for the 2 most recent patients (patient 14 and 15) for several reasons: (1) the majority of cases were performed on an emergent basis with the aim of revascularizing the target vessel in the shortest possible time because of concerns of ongoing cerebral ischemia; (2) traversing the occlusion required wires that are more steerable than the currently used filter wires; and (3) the presence of a proximal occlusion precluded us from visualizing the segment where the filter should be deployed. Once the lesion was traversed with a wire, microcatheter runs helped us document the length of the occlusion and assess for the presence of intraluminal thrombus. This is not possible when using the embolic protection device because usage of the filter wire precludes microcatheter injections. Immediately after stent placement, all of the patients were given an oral load of clopidogrel (300 mg) and aspirin (325 mg) and were maintained on clopidogrel (75 mg/day) and aspirin (325 mg/day). Clopidogrel therapy was discontinued after 30 days, and patients were maintained on aspirin indefinitely. In addition, strict blood pressure parameters were adhered to by

maintaining a systolic blood pressure <140 mm Hg after revascularization because of concerns of hyperperfusion to the ipsilateral hemisphere. All of the patients underwent a CT scan of the head within 24 hours after CAS to look for hemorrhage. All of the surviving patients underwent a carotid duplex ultrasound or MR angiography 24 to 48 hours after procedure to assess patency of the stent.

Results

The mean age of our cohort was 62 ± 11 years (range 39 to 82 years) with a median NIHSS of 14 (range 1 to 24) and median Alberta Stroke Programme Early CT Scores of 8 (range 6 to 10) at the time of angiography. Eight patients had received intravenous tPA before angiography, and 11 patients had a tandem intracranial occlusion. Twenty-three of 25 patients (92%) underwent successful crossing of the carotid occlusion and subsequent CAS. Among the 23 revascularized patients, 10 (43%; 3 of 15 [20%] were from group 1 and 7 of 8 [88%] from group 2) exhibited an improvement in their NIHSS by >4 points at 24-hour follow-up. Of these 10 patients, 9 (90%) had patent intracranial vessels after intervention. Patient 19 had a distal M2 occlusion that was not recanalized and had early clinical improvement. The mean time to angiography for group 1 was 5 ± 0.9 hours (range 3.5 to 6 hours) and for group 2, 30 ± 35 hours (range 7 to 120 hours). Attempts in 2 patients were unsuccessful; 1 patient was 5 days from stroke onset. He underwent a successful endarterectomy and showed early neurological improvement after recanalization. The second patient was maintained on vasopressor therapy and showed clinical stabilization. A favorable 30-day outcome of a mRS ≤ 2 was noted in 5 of 15 patients (33%) in group 1 and 7 of 8 patients (88%) in group 2. Four of the 5 patients with favorable outcomes in group 1 had an absence of a tandem occlusion, and the fifth patient was revascularized successfully with intra-arterial thrombolysis.

The absence of an intracranial tandem occlusion was predictive of a favorable outcome at 30-day follow-up. Of the 12 patients lacking a tandem occlusion, 11 (92%) had a mRS ≤ 2 in compared with 2 of 11 patients (18%) with a tandem occlusion ($P < 0.001$). In 11 patients with a tandem occlusion, intraarterial tPA was attempted in 8, balloon angioplasty in 2, and no intervention in 1 patient. Partial or complete recanalization occurred in 6 of these 10 patients (60%), including patient 8 who had a favorable outcome at 30-day follow-up. No patient with tandem occlusion who did not recanalize had a favorable outcome.

Table 1 summarizes the clinical and radiographic differences between the acute and subacute stroke groups. Group 1 was younger, more likely to have a tandem occlusion, and had a higher baseline NIHSS, whereas group 2 was significantly more likely to show rapid improvement and better outcomes at follow-up. Table 2 summarizes individual outcomes based on the presence of tandem occlusion and baseline NIHSS.

There were 3 in-hospital deaths: one patient (patient 10) died of large anterior cerebral artery and MCA distribution ischemic stroke with malignant cerebral edema; a second patient (patient 14) had a complete left MCA territory infarct because of a persistent left M1 MCA occlusion, and the family requested withdrawal of care; and a third (patient 16)

TABLE 1. Comparison of 2 Groups With Regard to Baseline Clinical and Radiographic Characteristics

Variable	Group 1 (Acute Stroke; n=15)	Group 2 (Subacute Stroke; n=8)*	P Value
Age, y±SD	59±11	65±11	0.15†
NIHSS, mean±SD	16±5	12±5	0.04†
ASPECT, mean±SD	8±1	8±1	0.85†
Tandem occlusion, no. (%)	10 (67%)	1 (13%)	0.02‡
NIHSS improved ≥4 points 24 hours after stent, no. (%)	3 (20%)	7 (88%)	0.01‡
mRS≤2 at 30-day follow-up, no. (%)	6 (40%)	7 (88%)	0.05‡

ASPECT indicates Alberta Stroke Programme Early CT Score.

*2 patients excluded because the lesion could not be crossed; †Student *t* test; ‡Fisher exact test.

showed a neurological improvement after the procedure, but died secondary to pneumonia and sepsis 21 days after the procedure. Adverse events occurring in patients undergoing revascularization included 1 asymptomatic hemorrhage in the basal ganglia and 1 asymptomatic, nonflow-limiting carotid dissection distal to the stent.

Discussion

The main finding of this report is that endovascular revascularization of occluded ICA in the setting of acute or subacute ischemic stroke carries a high-revascularization rate and is safe in selected patients. The lack of a control or alternative treatment group does not allow us to assess whether this approach is clinically beneficial but does provide pilot data for subsequent study.

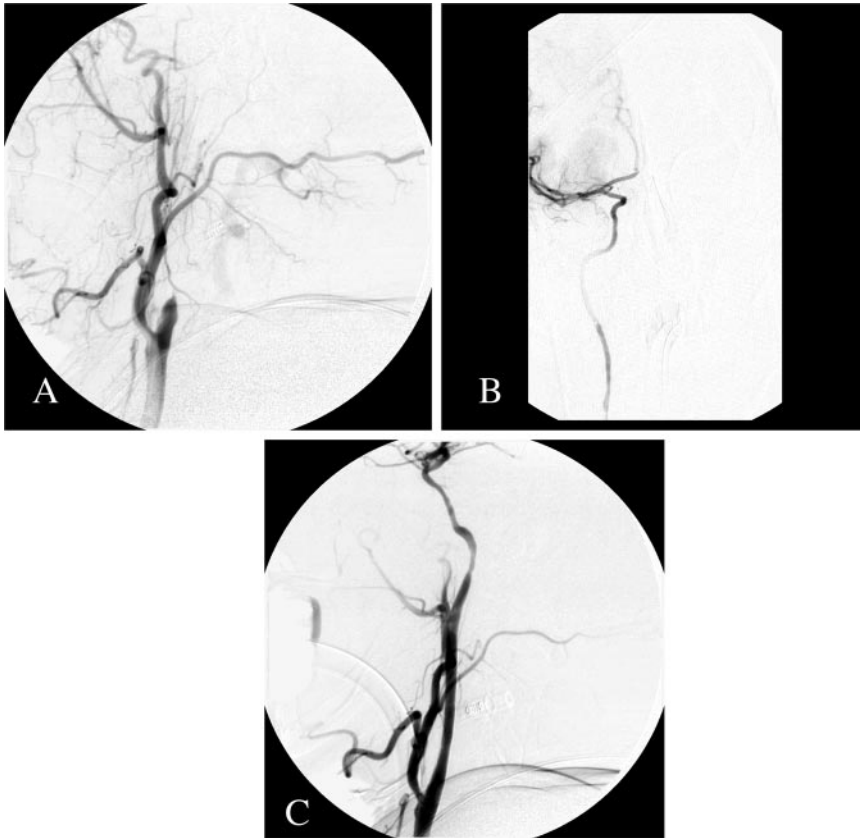
We found that patients without a tandem occlusion were more likely to show rapid neurologic improvement within the first 24 hours after CAS and a mRS ≤2 at follow-up. We considered this approach in patients who present in the time window for acute stroke (ie, group 1), as well as the subacute group of patients thought to have hemodynamic impairment distal to the occlusion (ie, group 2). For patients presenting within the time frame for intravenous tPA treatment, this approach was considered in conjunction with intravenous tPA because tPA alone has a low probability of recanalizing ICA occlusions and tandem occlusions.^{9,10} The lack of serious complications encountered in the 8 patients who received systemic tPA and acute ICA stenting indicates that this procedure may be performed safely.

Ideal candidates for endovascular ICA revascularization in the setting of acute stroke because of ICA occlusion would be

TABLE 2. Individual Outcomes of Patients Based on Tandem Occlusion and Baseline NIHSS

Patient	Successful Stenting	Proximal Intracranial Artery Patency	NIHSS Before Angiography	Discharge Status	>30-day mRS
1	Yes	No	18	Inpatient rehabilitation	4
2	Yes	No	14	Inpatient rehabilitation	4
3	Yes	Yes	7	Inpatient rehabilitation	1
4	Yes	Yes	13	Inpatient rehabilitation	2
5	Yes	No	21	Inpatient rehabilitation	4
6	Yes	Yes	17	Home	1
7	Yes	Yes	10	Inpatient rehabilitation	1
8	Yes	No	11	Inpatient rehabilitation	0
9	Yes	No	15	Inpatient rehabilitation	4
10	Yes	No	24	Death at day 11 because of poor neurology condition	6
11	Yes	Yes	20	Home	0
12	Yes	No	18	Died (withdrawal of care)	6
13	Yes	No	18	Inpatient rehabilitation	4
14	Yes	No	23	Died (withdrawal of care)	6
15	Yes	No	12	Inpatient rehabilitation	3
16	Yes	Yes	16	Death at day 21 because of sepsis	6
17	Yes	Yes	8	Home	0
18	Yes	Yes	1	Home with minimal aphasia	0
19	Yes	No	11	Inpatient rehabilitation	2
20	Yes	Yes	15	Inpatient rehabilitation	2
21	Yes	Yes	15	Inpatient rehabilitation	1
22	Yes	Yes	12	Inpatient rehabilitation	1
23	Yes	Yes	13	Inpatient rehabilitation	2
24	No	Yes	14	Inpatient rehabilitation	3
25	No	Yes	10	Inpatient rehabilitation	4

*Patients 1 through 15 were in group 1 (acute stroke), whereas patients 16 through 25 comprised group 2 (subacute stroke).



Patient 23 presented with left hemiparesis and right gaze preference 12 hours from stroke onset. A, A diagnostic angiogram confirmed the presence of a right carotid occlusion at the bifurcation. The occlusion was crossed with a 0.014-inch microwire, and a B, microcatheter injection confirms patency of the intracranial circulation. C, Poststenting and angioplasty reveals a normal caliber right carotid and patent intracranial circulation.

patients with a small area of tissue irreversibly compromised (core) and a large area of tissue that is viable but threatened to undergo infarction. We selected the subacute group (group 2) of patients clinically based on fluctuating clinical course despite pharmacologically induced elevations of blood pressure and evidence of large perfusion deficits on CT or MR imaging (Figure). Modern neuroimaging techniques (CT/CT perfusion, MRI diffusion/perfusion, xenon-CT) allow determination of these parameters with reasonable accuracy within time frames relevant for treatment.^{11–13} Restoration of flow into the ischemic area would aim to reverse the ischemic process by stopping the expansion of the ischemic core into the penumbra. Because the size of the ischemic core is known to correlate with clinical outcome,¹³ this approach would maximize the chance of a favorable outcome. This hypothesis is supported by the rapid clinical improvement in 88% of patients in group 2.

Our cases reveal the complexity of the stroke mechanisms with ICA occlusion. Whereas some patients have tandem occlusion with associated intracranial thrombus, in others, the clinical symptoms appear to be caused only by a focal thrombus at the site of carotid occlusion. Both groups had similar clinical presentations.

In contrast to the surgical approach, the endovascular approach affords the opportunity to define the length of the occluded ICA. We found that all of the patients had short-segment occlusions, none of which extended to the petrous segment. Additionally, endovascular therapy allows treatment of the occluded intracranial segment in patients with tandem occlusions. In our series, 11 patients had demonstra-

ble occlusion of large intracranial arteries. We believe that proximal revascularization, preferably before intracranial thrombolysis, confers several advantages, which offset the theoretical concern of additional time required for placement of the proximal ICA stent.

Better Access to the Intracranial Lesion

Restoration of flow in the ICA allows better visualization of intracranial vascular structures. Navigation through an occluded proximal ICA and its angioplasty has been reported previously as an adjunct to intracranial intervention.^{5,14}

Increasing the Chance of Recanalizing the Occluded Intracranial Artery

Proximal flow restoration through enhanced collateral supply with resultant improvement in distal hemodynamics may result in higher distal recanalization rates. Jovin et al¹⁵ reported that MCA recanalization rates are positively correlated with ipsilateral regional hemispheric cerebral blood flow values before thrombolysis, suggesting that baseline (pretreatment) hemispheric flow is a factor affecting vessel recanalization.

Reduction of Long-Term Risk of Ischemic Events

Proximal revascularization at the time of the acute intervention would reduce the long-term risk of additional ischemic events. Symptomatic ICA occlusion carries a significant risk of subsequent stroke of 16% at 2 years, with the highest risk group of patients being those with hemodynamic failure.² Intervention on the occluded ICA acutely before the artery is

thrombosed along its entire course would reduce the long-term risk of stroke.

There were no serious procedure-related complications. In 1 patient, an asymptomatic intracerebral hemorrhage was observed on MRI. This would be in the category of hemorrhagic transformation type 1 in the classification used in the European Cooperative Acute Stroke Study trial analysis.¹⁶ This patient's (patient 10) intracranial ICA terminus thrombus could not be recanalized. Thus, the patient had a massive stroke and herniation because of cerebral edema. We did not see any hyperperfusion-related complications after carotid revascularization in this case series. Blood pressure was aggressively treated in these patients after ICA recanalization by maintaining a target systolic blood pressure <140 mm Hg. In carotid stenting series for stenotic disease, hyperperfusion was relatively rare, occurring in 5% to 7% of carotid stenting cases.^{17,18} It is possible that the limited number of patients presented herein precluded the detection of such a complication.

The 2 patients who we were unable to revascularize were outside of the 6-hour time window. It is possible that these 2 patients had a more chronic occlusion that was symptomatic, and, thus, it was difficult to pass a guide wire across the lesion.

Our study has limitations largely derived from its retrospective nature. In addition, an inherent selection bias of patients taken for revascularization is present in our cohort. Lastly, the distal protection device was used in only 2 patients. There is the theoretical concern that thrombus may be dislodged distally when crossing the occlusion in the extracranial ICA. All of the patients had a CT angiogram or MR angiogram before revascularization, and, thus, intracranial tandem occlusions were noted before the procedure. The 1 patient who deteriorated (patient 10) had an ICA terminus occlusion that could not be recanalized thereby leading to a massive infarct with cerebral edema. Our experience with this small number of patients shows that in a select group of patients with an ICA occlusion, CAS may be performed with a reasonable margin of safety.

The endovascular interventional approach is becoming a part of the stroke therapy armamentarium for intracranial occlusion. It may also now be considered in select patients with acute ICA occlusion and deteriorating neurological symptoms. Our case series suggest that stenting/angioplasty for acute ICA occlusion appears to be feasible, safe, and may be associated with early neurological improvement. These encouraging preliminary results await confirmation from prospective, randomized studies.

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