Endovascular recanalization of the completely occluded internal carotid artery using a flow reversal system at the subacute to chronic stage

Clinical article

Tomoki Terada, M.D., Ph.D.,¹ Hideo Okada, M.D.,¹ Masataka Nanto, M.D.,¹ Akishintani, M.D., Ph.D.,¹ Ryo Yoshimura, M.D.,¹ Koji Kakishita, M.D., Ph.D.,¹ Osamu Masuo, M.D., Ph.D.,¹ Hiroyuki Matsumoto, M.D., Ph.D.,¹ Toru Itakura, M.D., Ph.D.,¹ Kosuke Ohshima, M.D., Ph.D.,¹ and Hiroo Yamaga, M.D.²

¹Department of Neurological Surgery, Wakayama Rosai Hospital, Wakayama; ²Department of Neurological Surgery, Wakayama Medical University, Wakayama; ³Department of Neurosurgery, Ishioka Cardiology and Neurosurgery Hospital, Ishioka, Ibaraki; and ⁴Department of Neurological Surgery, Kishiwada Tokushukai Hospital, Kishiwada, Japan

Object. The efficacy and pitfalls of endovascular recanalization were evaluated in cases of internal carotid artery (ICA) occlusion in the subacute to chronic stage.

Methods. Fourteen cases (15 lesions) of symptomatic ICA occlusion with hemodynamic compromise or recurrent symptoms were treated at the subacute to chronic stage using an endovascular technique. The Parodi embolic protection system was used during the recanalization procedure to prevent embolic stroke by reversing the flow from the distal ICA to the common carotid artery.

Results. Recanalization of the occluded ICA was possible in 14 of 15 lesions. The occlusion points were 10 cervical ICAs and 4 petrous/cavernous ICAs in successfully recanalized cases. Ischemic symptoms disappeared completely after the treatment, and new ischemic symptoms did not appear related to the treated lesion. Single photon emission computed tomography findings demonstrated the improvement of hemodynamic compromise in all cases. One case showed right middle cerebral artery branch occlusion during the procedure, but this patient’s neurological symptoms were stable due to preexisting hemiparesis. Endovascular recanalization was possible and effective in improving hemodynamic compromise. However, there are still several problems with this technique, such as hyperperfusion syndrome after recanalization, cerebral embolism during treatment, durability after treatment, and identification of the occlusion point before treatment.

Conclusions. Endovascular recanalization using an embolic protection device can be considered as an alternative treatment for symptomatic ICA occlusion with hemodynamic compromise or refractoriness to antiplatelet therapy, even in the subacute to chronic stage of the illness. (DOI: 10.3171/2009.6.JNS09125)

Key Words • carotid artery • occlusion • stenosis • endovascular therapy • percutaneous transluminal angioplasty • stenting

It is well known that occlusion of the cervical ICA with hemodynamic compromise involves a higher risk of cerebral infarction than this type of occlusion without hemodynamic compromise.¹⁰ Beneficial effects of EC-IC bypass surgery for occlusion or stenosis of the MCA or intracranial ICA were not observed in the results of a cooperative study,⁷ although efficacy in improving hemodynamic compromise by EC-IC bypass at the chronic stage was reported.¹² The recent development of endovascular therapy has enabled the recanalization of completely occluded iliac or subclavian arteries in the chronic stage.⁵,⁶,¹⁸,²⁷ We reported the first case of endovascular recanalization of the occluded cervical ICA in the chronic stage in 2005.²⁵ Fifteen cases of complete ICA occlusion were treated from 2003 to 2008 in our institute out of 850 CAS procedures. Our results, as well as the efficacy and pitfalls of this procedure, are presented in this paper.

Abbreviations used in this paper: CAS = carotid artery stenting; CBF = cerebral blood flow; CCA = common carotid artery; ECA = external carotid artery; EC-IC = extracranial-intracranial; ICA = internal carotid artery; MCA = middle cerebral artery; PTA = percutaneous transluminal angioplasty; SAH = subarachnoid hemorrhage.
Methods

Study Population

Fourteen patients (15 total lesions) with symptomatic ICA occlusion who satisfied the study inclusion criteria were treated with endovascular recanalization at some point from 2003 to 2008 (Table 1). The study inclusion criteria were: 1) symptomatic ICA occlusion; 2) opacification of the proximal part of the cavernous segment (C3) or the more proximal portion of the ICA on angiography via collateral channels; and 3) hemodynamic compromise (so-called Stage II) or recurrent clinical symptoms related to ICA occlusion refractory to medical treatment. Internal carotid artery occlusion was confirmed by selective carotid artery angiography in all cases to rule out pseudooclusion, which is difficult to differentiate from ICA occlusion using MR angiography or ultrasonography. There were 13 men and 1 woman, with a mean age of 66.2 years (range 57–77 years). All patients had a history of hypertension, 5 of 14 had a history of diabetes mellitus, and 4 of 14 had a history of hyperlipidemia.

Evaluation of Hemodynamic Compromise

For the evaluation of hemodynamic compromise, technetium-99m ethyl cysteinate dimer or technetium-99m hexamethylpropyleneamine oxime SPECT was used in cases treated at the chronic stage (> 1 month after onset). However, cases treated at the subacute stage (1 week to 1 month after onset) were not evaluated using SPECT in all cases because of the time limitation of the SPECT examination. Positive hemodynamic compromise was defined as an increase in reactivity of < 0% for acetazolamide challenge testing in the affected MCA territory and reduction of resting CBF to < 80% of the normal value. Single photon emission computed tomography was performed in 10 cases, and all cases satisfied the criteria noted above. The other 5 lesions showed recurrent ischemic symptoms despite the medical therapy. Dual antiplatelet drugs were administered for all patients in the combination of 100 mg of aspirin with 200 mg of ticlopidine, 75 mg of clopidogrel, or 200 mg of cilostazol at least 1 week before treatment.

Endovascular Method

The flow-reversal technique was used to cross the occluded lesion to prevent distal embolism in all cases. The CCA was occluded with a 9 or 10.5 Fr occlusion balloon catheter, and the proximal portion of the ECA was occluded with various types of single-lumen balloon catheters (Guardwire, Medtronic, Inc., or HyperGlide, ev3 Neurovascular). The proximal portion of the balloon catheter in the CCA was connected to the 4 Fr sheath located in the femoral vein via the filter with 100-μm pores to eliminate debris appearing during recanalization. A microcatheter (Rapid Transit II, Johnson & Johnson) and microguidewire (0.016-in Terumo Glidewire GT, Terumo, or 0.014-in Transend EX, Boston Scientific) were typically used to cross the occluded ICA. However, in a few cases, a 0.035-in guidewire was used to penetrate the occluded portion. A microcatheter entered the distal true lumen, a contrast agent was gently injected, and the occlusion was confirmed to be located inside the distal

<table>
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<th>ICA Type</th>
<th>Stroke Type</th>
<th>Endovascular Method</th>
<th>Stent Type</th>
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* All patients were Stage II (hemodynamic compromise) on SPECT, except for Cases 5, 7, and 9 in which SPECT was not performed. Abbreviations: FU = follow-up; mParodi = modified Parodi.
true lumen. After this procedure, a 300-cm exchange microguidewire (Choice PT, Boston Scientific, or Deja-vu, Johnson & Johnson) was left in the true lumen, and the microcatheter was withdrawn. A 3.0-mm PTA balloon catheter (Savvy, Johnson & Johnson, or Gateway, Boston Scientific) 20–40 mm in length was navigated over the microguidewire. Percutaneous transluminal angioplasty was then performed from the distal occluded ICA to the proximal portion.

After PTA and aspiration of the 50–60 ml of blood from the double lumen balloon catheter placed in the CCA, gentle angiography was performed using the same catheter. The occluded point was usually identified by this angiogram when demonstrating residual narrowing or dissection. A self-expanding stent (Precise, Johnson & Johnson) 8–10 mm in diameter and 40 mm in length was then deployed at the occluded portion. However, in the 5 recent cases in which the distal ICA was opacified to the level of the petrous portion, the occlusion point was usually difficult to penetrate with guidewires; therefore, the occlusion point was identified from the resistance of the guidewire.

Procedural Complications

The most common complication related to the procedure was an embolic complication of the MCA branch. This embolic complication seemed to appear during angiography just after PTA for the occluded point from the guiding balloon catheter placed in the CCA. Forceful injection of the contrast agent might cause the emboli to migrate. Fortunately, neurological symptoms were transiently aggravated but returned to the previous state after 30 days because of the development of collateral circulation from the leptomeningeal anastomosis and preexisting hemiparesis in this patient. Based on this case, we now routinely aspirate 30–60 ml of blood from the guiding balloon catheter before angiography.

The other complication was a small SAH, which was caused by perforation of the branch of the distal MCA by the microguidewire during exchange of the microcatheter into the PTA balloon catheter. Angiography was immediately performed, but no extravasation was observed. The procedure was then continued, and CT scanning demonstrated a small SAH in the right insular portion. The treatment course for the patient was uneventful, and heparin was reversed after the end of the procedure in this case.

Bradycardia and hypotension were noted in 3 of 14 lesions, but all disappeared within 24 hours. Hyperperfusion syndrome was not encountered in our patient series.

Follow-Up

Ischemic symptoms disappeared completely after treatment, and new ischemic symptoms did not appear related to the treated lesion during the follow-up period (mean 26.1 months). Single photon emission computed tomography findings demonstrated the improvement of reactivity for acetazolamide challenge testing in all cases with hemodynamic compromise before treatment. No case demonstrated restenosis > 50% in the treated site. A case of failed recanalization was free from any stroke during the follow-up period.

Illustrative Cases

Case 2

This 65-year-old man was admitted to our hospital due to a disturbance in consciousness. On admission he was alert but demonstrated eye deviation to the right and dense left hemiparesis. His hemiparesis rapidly improved to the level of 3–4/5 on the manual muscle test within an hour after admission. The diffusion-weighted MR image revealed multiple spotty high-intensity areas in the watershed zone of the right cerebral hemisphere (Fig. 1A). Magnetic resonance angiography demonstrated right ICA

Follow-Up Evaluation

A complete neurological evaluation was performed within 24 hours after the procedure. Patients were followed up at 1, 3, 6, and 12 months after the procedure. Clinical events, including any stroke or death, were documented on the medical chart. Angiographic follow-up was generally performed between 6 and 12 months after the procedure.

Results

The technical success rate of recanalization of the occluded ICA was 93.3% (14 of 15 patients). The occlusion points were 10 cervical ICAs and 4 petrous or cavernous ICAs in successfully recanalized cases. In the 1 case of failed recanalization, a microguidewire was left in the stump of the recanalized lumen to migrate by the activating clotting time was controlled to between 250 and 350 seconds by the bolus injection of heparin.

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occlusion and stenosis of the left cervical ICA. Aspirin (100 mg) and ticlopidine (200 mg) were administered after admission. Single photon emission computed tomography using technetium-99m ethyl cysteinate dimer showed a reduction of resting CBF and reactivity for acetazolamide challenge testing in the right MCA territory on the 4th day after admission (Fig. 2A and B). Cerebral angiography conducted 10 days after admission depicted right ICA occlusion and left ICA stenosis (Fig. 1B–E). Left CAS was performed to improve the collateral blood flow to the right MCA territory via the anterior communicating artery in the 3rd week. The stenosed ICA was dilated using stenting, but the patient’s left hemiparesis was aggravated due to hypotension after CAS. The patient’s blood pressure was elevated by the infusion of dopamine, but his left hemiparesis was aggravated to the level of 2/5 and fluctuated according to the changes in blood pressure. The high intensity spots on the right cerebral hemisphere increased in number as well as in area.

During the 4th week, endovascular recanalization of
the right ICA was performed. A 10.5 Fr occlusion balloon catheter for the CCA was introduced into the right CCA. A 4 Fr diagnostic catheter was also introduced into the right CCA to navigate the Hyperglide balloon catheter into the right ECA so as to occlude its proximal portion (Fig. 3A). The proximal end of the 10.5 Fr balloon catheter was connected with the 4 Fr sheath inserted into the left femoral vein via the filter to eliminate debris. A microcatheter (Transit II, Johnson & Johnson) was navigated into the distal ICA at the cavernous portion under microguidewire control (Terumo GT wire; Fig. 3B). The microguidewire appeared to enter the pseudolumen, judging from the movement of the guidewire, but it eventually accessed the distal ICA true lumen. Angiography from the microcatheter demonstrated that the microcatheter was in the distal true lumen (Fig. 3B). A guidewire was exchanged in the 300-cm–long wire (Choice PT, Boston Scientific), a microcatheter was withdrawn, and a 3.0 × 40–mm PTA balloon catheter (Savvy, Johnson & Johnson) was introduced into the cavernous ICA. Percutaneous transluminal angioplasty was then performed to the level of the cervical ICA in the entire occluded lesion. A self-expanding stent (8 × 40 mm) was deployed at the cervical ICA, and angiography was performed. Angiography demonstrated occlusion of the ICA at the entrance of the petrous portion (Fig. 3C). Internal carotid artery dissection during navigation of the microguidewire was suspected. The microguidewire was then navigated into the distal true lumen of the ICA again, and a self-expanding stent (Radius, Boston Scientific) was deployed at the portion of the ICA dissection (Fig. 3D). The occluded ICA was recanalized, and the stenotic portion was identified at the petrous-cavernous ICA. At this juncture, the occlusion point in this patient was confirmed to be an intracranial ICA and not a cervical ICA. A PTA procedure was added for the stenotic ICA using a 3.0 × 12–mm PTA balloon catheter (Gateway, Boston Scientific; Fig. 3E). The patient experienced hypotension after treatment, but neurological aggravation was not observed and his hemiparesis gradually improved after reconstruction of the right ICA. Two weeks after treatment, his hemiparesis improved to a 4/5 level, and his reactivity during acetazolamide challenge testing and his CBF both improved at rest on SPECT (Fig. 2C and D). The patient was transferred to the rehabilitation hospital and was able to walk. No restenosis was found on the follow-up angiography 6 months after PTA and stent placement (Fig. 3F).

Case 12

This 59-year-old man experienced mild left hemiparesis and was admitted to the hospital near his home. Diffusion-weighted images demonstrated small high-intensity spots in the left watershed zone. The left ICA was not demonstrated on MR angiography, and ultrasonography showed an occlusion pattern of the left cervical ICA. The patient experienced a transient ischemic attack of mild left hemiparesis a few days after the initial attack and was transferred to our hospital for further treatment. The right ICA angiogram revealed complete occlusion of the ICA at the cervical portion, and the distal ICA was opacified at the clinoid portion via the collateral
flow from the ascending pharyngeal artery (Fig. 4A and B). Hemodynamic compromise was demonstrated in the right MCA territory with a reduction in CBF and poor reactivity for the acetazolamide challenge test. Endovascular recanalization was planned after full assessment of the patient’s condition. A 9 Fr sheath was introduced into the right femoral artery, and 4 Fr sheaths were introduced into the left femoral artery and left femoral vein. The left ECA was occluded by a single-lumen balloon catheter and the left CCA was occluded by a 9 Fr double-lumen balloon catheter. The proximal portion of the 9 Fr balloon catheter was connected with the sheath in the femoral vein via the filter. Under flow-reversal conditions, a 4 Fr catheter and 0.035-in angle-type guidewire (Terumo, Japan) was introduced for the occluded ICA. The guidewire easily penetrated the occlusion point and reached the distal cavernous portion of the ICA. The 4 Fr catheter was advanced over the guidewire and introduced at the point of the clinoid segment (Fig. 4C). The guidewire was withdrawn, and 10 ml of blood was aspirated from the tip of the 4 Fr catheter to eliminate the embolus that might appear during penetration of the occluded ICA. Gentle injection of the contrast material confirmed that the catheter was located in the distal ICA true lumen.

The single-lumen balloon catheter left in the ECA was then deflated and withdrawn. It was introduced into the clinoid portion of the ICA through the 4 Fr catheter. The single-lumen balloon catheter was inflated to the size of 5 mm, and the distal ICA was occluded to prevent migration of the embolus. The balloon of the 9 Fr catheter was then deflated, and PTA was performed using the 3.0-mm PTA balloon catheter. The aspiration catheter was introduced just below the balloon of the clinoid portion and the stenosis existed at the petrous ICA (arrow). An 8 × 40–mm Precise stent was deployed to cover the stenotic portion, and a postdilatation procedure was added using a 5.0-mm PTA balloon catheter (Amiia, Johnson & Johnson). After aspiration of debris inside of the occluded ICA lumen, retrograde angiography from the aspiration catheter placed just below the single-lumen balloon catheter was performed to confirm the patency of the reconstructed ICA and remove debris (Fig. 4D). The distal balloon was then deflated. The ICA was completely recanalized without any complications (Fig. 4E). The SPECT findings demonstrated the improvement of hemodynamic compromise without hyperperfusion.

Discussion

The annual rate of ipsilateral recurrent stroke associated with cervical ICA occlusion has been reported to be between 6 and 20%, despite the best medical management.9,11,16 Cases with hemodynamic compromise (so-called Stage II) are considered a high-risk group for recurrent stroke in patients with ICA occlusion.10 Revas-
Endovascular recanalization of completely occluded ICAs

Endovascular recanalization using EC-IC bypass or endovascular repair is believed to be effective for these cases, and clinical studies to prove the efficacy of bypass surgery for these patients are ongoing. We have reported the first case of endovascular recanalization for completely occluded ICAs with recurrent symptoms associated with hemodynamic compromise at the chronic stage.

Recently, Kao et al. reported a series of endovascular recanalizations for symptomatic cervical ICA occlusion at an acceptable risk level (3.3%) with a technical success rate of 73%, although their series included mainly subacute cases and CBF was not fully evaluated. We treated 15 lesions of symptomatic ICA occlusion with supposed hemodynamic compromise on SPECT findings at the subacute to chronic stage. The essence of our technique was using a flow-reversal technique to cross the occluded lesion to prevent embolic stroke during the procedure, which was different from the method used in the study of Kao et al. After crossing the lesion, we used 2 different methods: the Parodi method and the modified Parodi method. Using the latter method means that the lesion crossing was performed under a flow-reversal condition, and after securing the distal true lumen, the distal balloon protection device was introduced into the distal true lumen and the procedure was changed into a distal protection technique from the flow-reversal technique. Our method is theoretically reasonable for use in preventing embolic complications during the procedure, compared with the method of Kao et al., which involves a risk of distal embolism during lesion crossing, although they reported no stroke related to the procedure.

The diagnosis of total occlusion was obtained by digital subtraction angiography, and patients with so-called pseudoocclusions were completely excluded from this series. Accurate diagnosis of total occlusion was sometimes difficult using MR angiography, and the opacification of the distal ICA via ECA collaterals was not accurately evaluated.

The next important point of this study was the identification of the occlusion point. It is very difficult to identify the occlusion point using only angiography after total ICA occlusion. As shown in our series, 4 cases showed...
occlusion at the cavernous to petrous ICA. We assume that ICA occlusion at the cavernous to petrous portion was included in the patient series of Kao et al., considering their lower recanalization rate of 73% compared with our rate of 93%. It is important to determine the feasibility of petrous to cavernous ICA occlusion in cases of difficult recanalization at the distal ICA.

The risk of endovascular recanalization for symptomatic cervical ICA occlusion appears relatively low based on the series of Kao et al., Thomas et al., and our own, although the total number of reported cases is only 47 and the number of chronic cases is even lower. The risk of ischemic stroke related to recanalization of a completely occluded ICA is believed to be high. However, if a protection device is used, as shown in our series as well as that of Kao et al., ischemic stroke might be prevented even in a series with complete occlusion. The other possible risk related to endovascular recanalization was hyperperfusion syndrome. Hyperperfusion syndrome usually occurs in cases with hemodynamic compromise, as observed in the series of carotid endarterectomy and CAS reported by Ogasawara and colleagues. This treatment is appropriate for cases with ICA occlusion and hemodynamic compromise. It was postulated that the progression of neurological symptoms is most likely caused by decreased perfusion and/or decreased potential for developing collateral circulation to the ischemic zones. In contrast, Henderson and colleagues and Caplan have reported that sufficient collateral circulation lowers the risk of an ischemic event in patients with severe ICA stenosis. The treated cases with symptomatic ICA occlusion were associated with hemodynamic compromise in our series. Fortunately, hyperperfusion syndrome was not observed in either our series or that of Kao and associates. However, it is possible to cause hyperperfusion syndrome in patients undergoing endovascular recanalization because they usually have severe hemodynamic compromise. The control of blood pressure will be very important to prevent hyperperfusion syndrome after endovascular recanalization.

The EC-IC bypass trial failed to show a benefit for surgical revascularization when compared with medical therapy for symptomatic ICA occlusion. However, a recent Japanese study of EC-IC bypass revealed a significant effect for preventing ischemic stroke in cases with hemodynamic compromise with ICA occlusion or MCA stenosis or occlusion. The ongoing Carotid Occlusion Surgery Study is comparing surgical revascularization with medical therapy in higher risk patients based on PET imaging criteria.

As for the long-term results, completely occluded iliac or subclavian arteries show lower restenosis rates after recanalization than does the coronary artery. The difference between the two appears to be determined by the size of the native artery. If the diameter of the native artery is > 3.0 mm, the restenosis rate is low, as observed in the iliac or subclavian artery. Therefore, the restenosis rate can be supposed to be low in the completely occluded cervical ICA, given that the patient series of Kao et al. showed a 13.6% restenosis rate and our case series showed a 0% rate.

Conclusions

Endovascular recanalization for the chronically occluded ICA is feasible with acceptable midterm follow-up results. A future prospective, randomized controlled trial will be necessary to establish the clinical efficacy and indications of this procedure.

Disclaimer

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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Address correspondence to: Tomoaki Terada, M.D., Department of Neurological Surgery, Wakayama Rosai Hospital, 93-1 Knomoto, Wakayama City, 640-8505, Japan. email: tma-terada@wakayamah.refuku.go.jp.