

Surgical Revascularization of Symptomatic Kinking of the Internal Carotid Artery

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Ji-heng Hao, MD^{1,2}, Li-yong Zhang, MD², Kai Lin, MD²,
Wei-dong Liu, MD², Shi-gang Zhang, MD², Ji-yue Wang, MD²,
Gang Li, MD¹, and Le-Xin Wang, MD, PhD, FRACGP³

Abstract

Objective: To evaluate the safety and outcomes of surgical revascularization for patients with symptomatic kinking of the internal carotid artery (ICA). **Methods:** Twenty-five consecutive patients presented with symptomatic kinking of the ICA and a history of transient ischemic attack (TIA) or stroke were prospectively enrolled in this study. All patients were treated with ICA transection and end-to-side reimplantation at the level of the carotid bulb. Patients were followed up for a median of 32 months. **Results:** There were no deaths or strokes within the 30 days of the treatment. No postprocedural thrombosis or narrowing of the ipsilateral ICA was observed. One (4%) patient had temporary recurrent nerve palsy, which was completely recovered at 4-week follow-up. One (4%) patient had a myocardial ischemic event. At the end of the 32-month follow-up, 1 (4%) patient developed ipsilateral minor stroke. No recurrent stenosis was detected by Doppler ultrasound. **Conclusion:** Surgical treatment for isolated, symptomatic kinking of the ICA and a history of TIA or stroke is safe, and the outcomes are acceptable.

Keywords

revascularization, internal carotid artery, kinking, stroke, surgery

Introduction

Kinking of the internal carotid artery (ICA) is defined as an angulation of the cervical segments of the carotid artery due to elongation, which may cause disturbances in the blood flow to the brain.¹ Kinking is detected in approximately 5% of cervical artery images obtained for the evaluation of cerebrovascular symptoms in patients with suspected ICA stenosis.² Unlike tortuosity, kinking often causes neurologic symptoms, such as paresthesia or weakness in the arms or speech disturbances, in 4% to 20% of patients, even without any associated atherosclerotic plaque of the carotid bifurcation.^{3,4} Although some studies have shown that surgical correction of ICA kinking can relieve symptoms and prevent stroke in symptomatic patients, the ideal surgical approaches to the ICA kinking are still controversial.¹⁻³ Some investigators recommended resection with end-to-end reanastomosis of the ICA, whereas others applied shortening and reimplantation of the ICA end-to-side or bypass grafting.¹⁻³ Furthermore, the perioperative outcomes of surgical interventions remain unclear, and long-term follow-up results are lacking.¹⁻³

In this study, we performed surgical revascularization in 25 patients with symptomatic kinking of the ICA and summarized the long-term outcomes following the procedures.

Patients and Methods

Patients

The study was approved by the local ethics committee, and informed consents were obtained from all patients. From April 13, 2009, to July 26, 2013, 41 consecutive patients with symptomatic kinking of the ICA were screened and 25 were enrolled in this study at the Neurovascular Department of Liaocheng People's Hospital. The exclusion of the 16 patients was due to the inability to give a written consent ($n = 3$) or failed to meet

¹Department of Neurosurgery, Qilu Hospital of Shandong University, Jinan, Shandong, People's Republic of China

²Department of Neurosurgery, Liaocheng People's Hospital and Liaocheng Clinical School of Taishan Medical University, Liaocheng, Shandong, People's Republic of China

³School of Biomedical Sciences, Charles Sturt University, Wagga Wagga, New South Wales, Australia

Corresponding Authors:

Gang Li, Department of Neurosurgery, Qilu Hospital of Shandong University, 44 Wenhua Xi Road, Jinan 250012, Shandong, People's Republic of China.

Email: doctorligang@126.com

Le-Xin Wang, School of Biomedical Sciences, Charles Sturt University, Wagga Wagga, NSW 2678, Australia.

Email: lwang@csu.edu.au

the inclusion criteria ($n = 13$), as listed in the next section. Nonhemispheric symptoms (dizziness, blurred vision, lateral homonymous hemianopsia, or sudden onset of weakness in one side of the body or drop attack) were defined after ruling out any possible labyrinthine disorders, orthostatic hypotension, and even cervical spondylosis.

All patients were treated with aspirin and atorvastatin for 3 months before being considered for operative revascularization. Only patients with recurrent transient ischemic attack (TIA) or stroke were considered for operative correction. Preoperatively, all patients had a duplex ultrasonography of the carotid arteries, a magnetic resonance imaging scan of the brain, and a computer tomography angiography (CTA). A 12-lead electrocardiography (ECG) and a transthoracic echocardiography were also performed to exclude cardiac source of the TIA.

Duplex ultrasonography was performed using the standard technique with location of the site of kinking, measurement of flow velocity, and estimation of the degree of stenosis. Patients were initially examined in a neutral position. Head and neck postures identified by the patients as the origin of their symptoms were also reproduced, where duplex ultrasound was also performed to measure the kinking and flow velocity. Transcranial Doppler was performed in all patients to confirm that emboli were arising from the extracranial vessels.

Inclusive and Exclusive Criteria

In this study, kinking of the ICA was defined as an excess length of the ICA, causing an angulation of 60° or more, and a hemodynamically significant stenosis of the artery on duplex ultrasound and CTA.⁴ On duplex ultrasound, kinking caused stenosis of more than 70%, with a peak systolic velocity of more than 230 cm/s, end-diastolic velocity greater than 100 cm/s, and ICA/common carotid artery (CCA) velocity ratio greater than 2.⁴

Patients were all interviewed and evaluated by 2 experienced neurologists to confirm that there was a potential relationship between their symptoms and kinking, ruling out labyrinthine disorders, orthostatic hypotension, and even cervical spondylosis. Patients with luminal thrombus, proximal or distal atherosclerotic lesion, or irregularity were excluded. Patients were also excluded if they had previously undergone ICA surgery or endovascular treatment.

Surgical Approach

All the operations were performed under general anesthesia with endotracheal intubation and continuous intraoperative transcranial Doppler monitoring. The shunting criteria consisted of middle cerebral artery velocity <30 cm/s. No case required an intravascular shunt. Systemic heparin (0.5 mg/kg) was provided before clamping the CCA, ICA, and external carotid artery (ECA), and the initial heparin dose was not reversed at the end of the operation.

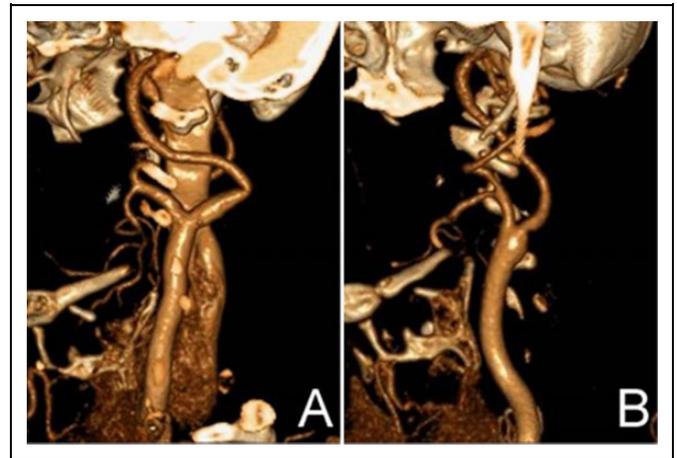


Figure 1. Computer tomography angiography (CTA) of the left carotid artery revealed kinking of the left internal carotid artery before operation, the angulation was greater than 60° (A, preoperative CTA), and the kinking disappeared after revascularization (B, postoperative CTA).

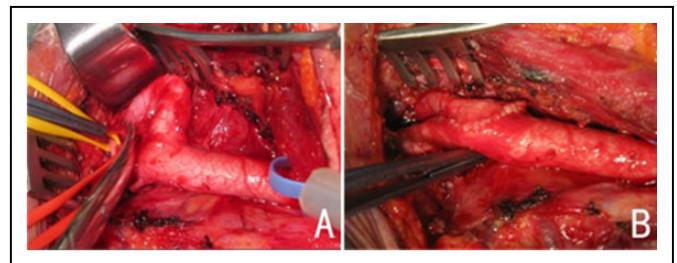


Figure 2. Pictures of the carotid artery revealed kinking of the internal carotid artery before revascularization, the angulation was greater than 60° (A, before revascularization), and the kinking disappeared after revascularization (B, after revascularization).

The aim of the surgery was to straighten the kinking of affected ICA and to remove the atherosclerotic plaque when it was necessary. Eversion endarterectomy approach was used. The revascularization of redundant ICA included the following steps: (1) transection of the ICA at the bulb, with an incision almost longitudinal to the CCA; (2) straightening of the kinking after gently releasing all the adhesions; (3) removal of the atherosclerotic plaque when present; (4) oblique transection at the base of the ICA; (5) proximal prolongation of the arteriotomy on the CCA; (6) prolongation of the arteriotomy distally on the ICA; and (7) reimplantation of the ICA end-to-side more proximally on the CCA (Figures 1 and 2).

In 21 (84%) cases, the standard correction of redundant ICA was performed and 4 patients had an eversion carotid endarterectomy before the correction of ICA. The mean time of carotid occlusion was 28.7 minutes (range: 20-42 minutes).

Postoperative Follow-Up

On awakening, the neurologic status of the patients was assessed; thereafter, they were monitored for 24 hours in the

neurosurgical intensive care unit and finally returned to the ward. The activated coagulation time was monitored, and heparin sodium was administered by intermittent subcutaneous injection for 3 days. Intravenous administration of nitroglycerin was performed in patients with hypertension as necessary to control the blood pressure. Antiplatelet was not discontinued perioperatively, and atorvastatin was prescribed for all the patients.

Before being discharged from the hospital, patients had an assessment of the revascularization by CTA (18 patients [72%]) and/or duplex ultrasound scanning (12 patients [48%]). During follow-up, the clinical status of the patients and patency of arterial reconstruction were assessed at 4 weeks, 6 months after the operation, and at 12-month intervals, thereafter by clinical examination and duplex ultrasound scanning. Restenosis was defined as the occurrence of hemodynamically significant stenosis (>50%) demonstrated by duplex ultrasound.

Results

General Data

There were 12 men and 13 women, with a mean age of 61.5 years (range: 44-78 years). Six (24%) patients had diabetes mellitus, 5 (20%) were smokers, 12 (48%) were receiving medical treatment for hypertension, and 13 (52%) had hyperlipidemia. Twenty-one (84%) patients had hemispheric symptoms, consisting TIAs in 18 (86%) and stroke in 3 (14%). Four (16%) patients were initially seen with nonhemispheric TIAs. Of the 25 patients, 11 (44.0%) experienced nonhemispheric symptoms such as dizziness, blurred vision, or drop attack. Five (23.8%) patients had position-dependent carotid artery kinking before the operation. None of the patients had an aneurysmal or a dilated ICA. In all patients, resection of ICA was required, and surgical success was achieved in all cases.

Short-Term Outcome

There was no perioperative stroke or death. Median length of stay in hospital until discharge was 7.8 days (range: 5-15 days). No symptomatic or asymptomatic thrombosis of the ipsilateral ICA was noted. No hyperperfusion syndrome was observed in any patient. One (4%) patient had temporary recurrent nerve palsy, which was transient and had completely recovered at 4-week follow-up. Two cases showed signs of wound infection, which was alleviated after oral antibiotics. Other perioperative complication included 1 (4%) angina chest pain, which was successfully managed with medical treatment.

Long-Term Outcome

Long-term follow-up was available for all the 25 patients. Median follow-up was 32 months (range: 15-66 months). No patient developed new TIA; 1 (4%) patient had a minor ipsilateral

neurological event during follow-up, 14 months after revascularization, but no restenosis was detected. Echocardiogram and ECG showed no cardiac abnormalities, and the patient was compliant with antiplatelet therapy. The overall rate of freedom from neurologic symptoms was 96%. The 11 patients who had preoperative nonhemispheric symptoms such as dizziness or blurred vision remained symptom-free during follow-up. No stenosis of the anastomotic stoma was observed, but 2 cases of ICA atherosclerotic plaque were detected by Duplex ultrasound scanning in the ICA residual. Subsequent studies did not demonstrate progression of these atherosclerotic plaques in the 2 patients.

Discussion

Terms such as kinking or coiling have been proposed to describe the nonstraightened course of the ICA due to elongation. Based on angiographic findings, kinking is defined as an angulation of 1 or more segments of the ICA, being associated with a functional stenosis in the affected segment.⁵ Although there are numerous studies in the literature on carotid elongation with coiling or kinking, many doubts remain as to its etiology, clinical role, and best management.^{2,3,6,7}

It was postulated that the etiology of carotid kinking seems to be related to a congenital basis, which may become exaggerated with aging of the artery and degeneration of the organ.⁸⁻¹⁰ In the present study, kinking was observed to be more prevalent in elderly patients, and these data are consistent with several previous reports.^{5,6,10,11} The degenerative process includes the decreased height of intervertebral disks, the greater elongation of the muscular layer of ICA compared with the adventitia, which determines the bending of the artery.^{12,13} Chronic arterial hypertension, causing a progressive moving upward of the aortic arch, may favor the process of kinking.^{4,12}

The ICA anomalies have been reported to occur more commonly in females.¹³ However, in our study, there was no statistically significant difference between genders (12 males and 13 females). This is likely explained by the limited number of the patients enrolled.

Kinking can induce neurological symptoms in 2 general ways. First, a thromboembolic mechanism, due to local flow alterations at the site of arterial bending; second, a hemodynamic mechanism that seems to play an important part in both neutral and dynamic conditions.⁶ An experimental study demonstrated that blood flow may be reduced by >40% with an ICA angle of 60° and by >60% with an angle of 30°,¹ that is, the smaller the angle the greater the blood flow reduction. In the present study, of all the patients, the ICA angulations were 60° or less. At duplex ultrasound, a peak systolic velocity of more than 230 cm/s and end-diastolic velocity greater than 100 cm/s were detected, and ICA/CCA velocity ratio was greater than 2, which correlates with a greater than 70% stenosis.

The reduction in blood flow within the kinked ICA may be exacerbated or even completely blocked with neck extension, bending, or turning of the head, and patients may present with strokes, hemispheric TIAs, or amaurosis fugax.^{9,14} The isolated

kinked ICA can be clinically significant and cause cerebral infarction, even in the absence of atherosclerosis.^{1,5} Our 25 patients all had symptoms of cerebrovascular insufficiency, whereas no ICA stenosis at the carotid bifurcation was detected before surgery. These findings are consistent with several previous reports including a series of patients presenting with isolated kinking without stenosis of the bifurcation.^{5,12,15} Studies report excellent results through anatomic reconstruction with low morbidity and mortality rates. In a prospective, randomized clinical study, Ballotta et al¹ reported the outcomes of a group of 182 patients with isolated symptomatic ICA kinking, 92 of whom were assigned to surgery and 90 to medical therapies with antiplatelet drugs alone. In the surgical group, there were no perioperative strokes or deaths.¹ The incidence of late hemispheric and retinal TIAs in the surgical group was significantly lower than in the medical group.¹ In our study, we did not observe any perioperative stroke or mortality, and after a follow-up of more than 30 months, 1 (4%) patient was found to have an ipsilateral neurological event.

Different techniques have been reported for the treatment of kinking of the ICA, essentially including resection with end-to-end reanastomosis of the ICA, shortening and reimplantation of the ICA end-to-side on the CCA, resection and anastomosis with shortening of the CCA, and bypass grafting.^{1,6,15} Resection and shortening of the CCA was indicated when both ICA and ECA were kinked, which was never encountered in this study. When the kinking is complex, not allowing shortening by reimplantation, transposition on the ECA or bypass grafting is an alternative option.⁶

Dividing the ICA at its origin and shortening by proximal reimplantation on the CCA was the standard technique used in most of the patients in our series. If kinking of the ICA is complex, which may be anticipated at preoperative CTA, either transposition or bypass is the possible alternative.

The treatment of ICA kinking usually requires more extensive dissection. The ICA must be dissected free from the perivascular surrounding tissues to obtain adequate mobilization of the entire affected artery. This extensive surgical dissection might increase the rate of peripheral neurological impairment and wound swelling.^{4,5,15} In this study, 1 (4%) patient had temporary recurrent nerve palsy, which was transient and had completely recovered at 4-week follow-up. And 2 cases showed signs of wound swelling, which was resolved after intravenous antibiotic treatments.

No carotid restenosis was detected during the follow-up period. This may be related to the reimplantation technique of the ICA onto the CCA and prolongation of the arteriotomy on ICA and CCA, which simplifies the arteriotomy closure and prevents potential restenoses. Our results are consistent with the reports on eversion carotid endarterectomies performed in patients with severe carotid stenosis.¹⁶ One (4%) patient developed ipsilateral minor stroke without signs of restenosis. The preoperative and postoperative cardiac work-up did not show any cardiac abnormalities, and the patient was compliant with antiplatelet therapy. Therefore, the cause of the minor stroke in this patient is unclear.

It is worth noting that endovascular stent placement has become a major therapeutic option for symptomatic carotid stenosis due to atherosclerosis. Although the role of carotid stenting in the management of severe vessel elongation and kinking is unclear, it may be feasible in selected cases where surgical endarterectomy is not favorable because of the distal location of the stenosis.¹⁷ Advances in stent technology with flexible materials are likely to make stenting a more attractive option in patients with symptomatic carotid kinking.

A main limitation of the study is that this is a case series report that is associated with all the inherent shortcomings of case reports. Although 96% of the patients remained symptom-free during the follow-up, this may be attributable to other factors, such as medication therapy or nonpharmacological measures. A randomized controlled trial would provide further evidence on the effectiveness of this surgical intervention for carotid artery kinking.

Conclusion

From this small series of patients, we found that surgery for isolated, symptomatic kinking of the ICA and a history of stroke or TIA is safe, and the outcomes are acceptable. Surgical correction may be considered for patients with symptomatic carotid kinking.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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References

1. Ballotta E, Thiene G, Baracchini C, et al. Surgical vs medical treatment for isolated internal carotid artery elongation with coiling or kinking in symptomatic patients: a prospective randomized clinical study. *J Vasc Surg*. 2005;42(5):838-846.
2. Poorthuis MH, Brand EC, Toorop RJ, Moll FL, de Borst GJ. Posterior transverse plication of the internal carotid artery to correct for kinking. *J Vasc Surg*. 2014;59(4):968-977.
3. Tetik O, Yurekli I, Yilik L, Akhan G, Gurbuz A. Surgical treatment of symptomatic coiling or kinking internal carotid artery. *Vascular*. 2010;18(5):294-296.
4. Illuminati G, Ricco JB, Calio FG, D'Urso A, Ceccanei G, Vietri F. Results in a consecutive series of 83 surgical corrections of symptomatic stenotic kinking of the internal carotid artery. *Surgery*. 2008;143(1):134-139.
5. Illuminati G, Calio FG, Papaspyropoulos V, Montesano G, D'Urso A. Revascularization of the internal carotid artery for isolated, stenotic, and symptomatic kinking. *Arch Surg*. 2003; 138(2):192-197.
6. Saba L, Mallarini G. Correlation between kinking and coiling of the carotid arteries as assessed using MDCTA with symptoms and degree of stenosis. *Clin Radiol*. 2010;65(9):729-734.

7. Ascher E, Hingorani A, Gunduz Y, Mazzariol F, Yorkovich W, Salles-Cunha S. Posterior transverse plication technique for treatment of redundant internal carotid artery during endarterectomy. *Cardiovasc Surg*. 2001;9(1):16-19.
8. Beigelman R, Izaguirre AM, Robles M, Grana DR, Ambrosio G, Milei J. Are kinking and coiling of carotid artery congenital or acquired? *Angiology*. 2010;61(1):107-112.
9. Togay-Isikay C, Kim J, Betterman K, et al. Carotid artery tortuosity, kinking and coiling: stroke risk factor, marker or curiosity? *Acta Neurol Belg*. 2005;105(2):68-72.
10. Le Bret E, Pineau E, Folliguet T, et al. Congenital kinking of the internal carotid artery in twin brothers. *Circulation*. 2000;102(22):E173-E174.
11. Benes V, Mohapl M. Alternative surgery for the kinked internal carotid artery. *Acta Neurochir (Wien)*. 2001;143(12):1267-1271.
12. Pancera P, Ribul M, Presciuttini B, Lechi A. Prevalence of carotid artery kinking in 590 consecutive subjects evaluated by Echocolor Doppler. Is there a correlation with arterial hypertension? *J Intern Med*. 2000;248(1):7-12.
13. La Barbera G, La Marca G, Martino A, et al. Kinking, coiling, and tortuosity of extracranial internal carotid artery: is it the effect of a metaplasia? *Surg Radiol Anat*. 2006;28(6):573-580.
14. Milic DJ, Jovanovic MM, Zivic SS, Jankovic RJ. Coiling of the left common carotid artery as a cause of transient ischemic attacks. *J Vasc Surg*. 2007;45(2):411-413.
15. Aleksic M, Schütz G, Gerth S, Mulch J. Surgical approach to kinking and coiling of the internal carotid artery. *J Cardiovasc Surg (Torino)*. 2004;45(1):43-48.
16. Ballotta E, Da Giau G, Piccoli A, Baracchini C. Durability of carotid endarterectomy for treatment of symptomatic and asymptomatic stenoses. *J Vasc Surg*. 2004;40(2):270-278.
17. Ahmadi RA, Schillinger M, Haumer M, Willfort A, Minar E. Carotid stenting in a case of combined kinking and stenosis. *Cardiovasc Intervent Radiol*. 2001;24(3):197-199.