



Surgical Results of Carotid Endarterectomy for Twisted Carotid Bifurcation

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■ **BACKGROUND:** The internal carotid artery is normally positioned posterolateral to the external carotid artery at the carotid bifurcation. An anatomic variation with the internal carotid artery positioned medial to the external carotid artery, the so-called twisted carotid bifurcation (TCB), is sometimes encountered in patients undergoing carotid endarterectomy (CEA). Little is known about the TCB or the implications for CEA.

■ **OBJECTIVE:** The present study investigated the demographics and surgical results of our patients with TCB who underwent CEA, and demonstrates the surgery in a video clip.

■ **METHODS:** Eleven of our series of 73 consecutive CEA patients (15.1%) had a TCB (TCB group). The basic surgical method was the same for both the TCB and non-TCB groups.

■ **RESULTS:** The patient demographics were almost identical between the 2 groups. No significant difference was observed in the degree of stenosis, the duration of operation, or the surgery-related complications between the 2 groups. However, 9 of 11 cases were right-sided in the TCB group; the only significant difference between the groups.

■ **CONCLUSIONS:** CEA for TCB can be safely performed by extension of the normal procedure, but with more meticulous preoperative assessment and gentle maneuvers. The reason for the right-side dominance is still unknown. Further investigation is needed of this anatomic entity.

INTRODUCTION

Carotid endarterectomy (CEA) is a recommended surgical treatment option for selected patients with internal carotid artery (ICA) stenosis in both the U.S. and Japanese guidelines. The normal ICA is positioned posterolateral to the external carotid artery (ECA) at the carotid bifurcation in the neck. However, anatomic variations such as the ICA positioned medial to the ECA, the so-called twisted carotid bifurcation (TCB),^{1,2} are sometimes encountered in patients undergoing CEA. CEA for carotid stenosis in a patient with TCB will be complicated by the location of the ICA behind the ECA. Although TCB as an anatomic variation has been known, not much literature has discussed the implications for CEA in a patient with TCB. The present study investigated the clinical characteristics and surgical results in our patients with TCB who underwent CEA and demonstrates the surgical procedure in a video clip.

METHODS

Patients and Methods

A total of 73 consecutive CEAs were performed from August 2011 to March 2018. Conventional angiography or 3-dimensional computed tomographic angiography was performed for diagnosis of the ICA stenosis. The surgical indication was considered as >70% stenosis for asymptomatic and >50% stenosis for symptomatic patients. TCB was defined in this study as the center of the ICA located medial to the center of the ECA in the preoperative anteroposterior angiographic view. We divided the patients into the TCB and non-TCB groups and compared the clinical characteristics and surgical results. The protocol of this study had been approved by the local ethics committee, and the patient in the video had provided signed informed consent.

Key words

- Anatomy
- Carotid stenosis
- Revascularization stroke
- Surgical procedure
- Surgical result

Abbreviations and Acronyms

- CEA:** Carotid endarterectomy
EBSLN: External branch of the superior laryngeal nerve
ECA: External carotid artery
ICA: Internal carotid artery
TCB: Twisted carotid bifurcation

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Surgery

A unified procedure was used for the CEA in each group. The surgery is briefly described as follows. Under general anesthesia, the neck of the patient was adequately extended, and the head was rotated approximately 30° to the contralateral side of the lesion for wide exposure. A transverse skin incision was selected for cosmetic reasons. Isolation of the common carotid artery, ECA, ICA, and the superior thyroid artery followed by plaque removal and repair of the arteriotomy were all performed under the surgical microscope. An intraluminal shunt was inserted in all patients and no patch graft was used. In the patients with TCB, the common carotid artery and ECA were first isolated, then the ICA was identified behind the ECA. The ECA was medialized and the ICA was gently dissected and dragged out laterally with the carotid sheath; then the carotid bifurcation was temporarily mobilized to the normal anatomic position (**Video 1**). Repair of the arteriotomy was achieved with interlocking sutures using 6-0 Prolene (Ethicon, Cincinnati, Ohio, USA). After declamping the arteries, improvement of the blood flow was confirmed by indocyanine green videoangiography. The essence of the surgery is demonstrated in the video clip with narration. Pre- and postoperative images of a representative case are shown in **Figure 1**.

Statistical Analysis

Data are expressed as mean \pm standard deviation or median (25th percentile–75th percentile) for continuous data and categorical data are tabulated as frequencies and proportions. Between-group comparison used the 2-sample t-test or the Wilcoxon rank-sum test for continuous variables and the χ^2 test for categorical data. All statistical tests were 2-sided and significance level was set at 0.05. Data analysis were performed using SAS V.9.4 (SAS Institute, Cary, North Carolina, USA).

RESULTS

TCB was found in 11 of the 73 patients (15.1%). We found no significant differences in the patient characteristics, but the side of the lesion showed obvious right-sided dominance in 9 of the 11 patients (81.8%) ($P = 0.019$) (**Table 1**). No significant difference was found in the surgical results, such as the duration of the

operation, symptomatic and/or asymptomatic infarctions, hyperperfusion syndrome, and peripheral cerebral nerve paresis.

DISCUSSION

No definite terminology or anatomic definition has been established for the so-called TCB.² TCB has also been described as side-by-side carotid artery³ dorsal/dorsomedial origin of the ICA,⁴ lateral ECA,⁵ lateral position of the ECA,⁶⁻⁹ and complete transposition of the carotid bifurcation.¹⁰ The earliest description of this phenomenon was given by Hyrtl in 1841 (as described by Handa et al.⁷), but otherwise only sporadic reports are available such as case series studies,^{1,2,6} cadaveric studies,^{11,12} angiographical study,¹³ and case reports.^{5,7,9} The case series studies

including ours were all series of patients undergoing CEA, and the TCB was found in 5.3%–15.1%. This 3-fold difference might be caused by the various anatomic definitions used in each study. Because the definition of TCB has not been unified, the working definitions are based on the angiographical, ultrasound, or intraoperative findings. The angle of rotation of the bifurcation necessary to introduce the term ‘twisted’ might be different in each study. We almost followed the definition of Katano and Yamada² as we described earlier, which seemed to be the most objective method to evaluate the degree of the ‘twist.’

CEA can be performed either with the TCB corrected to the normal anatomic position or in the original location. The TCB was not corrected in 1 in a series of 7 cases,² and in 4 in another series of 7 cases.¹ The superior thyroid artery and other vessels crossing the ECA branches had to be relocated. The superior thyroid artery, and the lingual and facial arteries, if necessary, could be sacrificed without problems or sequela.¹⁰ In our series, we corrected the position of the TCB in all cases without problems. Correction of the position of the TCB will require much more manipulation toward the ICA than normal for the dissection. Carotid dissection is the most vulnerable stage for the generation of microemboli that cause postoperative ischemic lesions and are detected by transcranial Doppler echosonography.¹⁴⁻¹⁶ The key points for safe surgery are gentle maneuvering and using small hooks to pull the carotid sheath underneath the ICA located



Video available at
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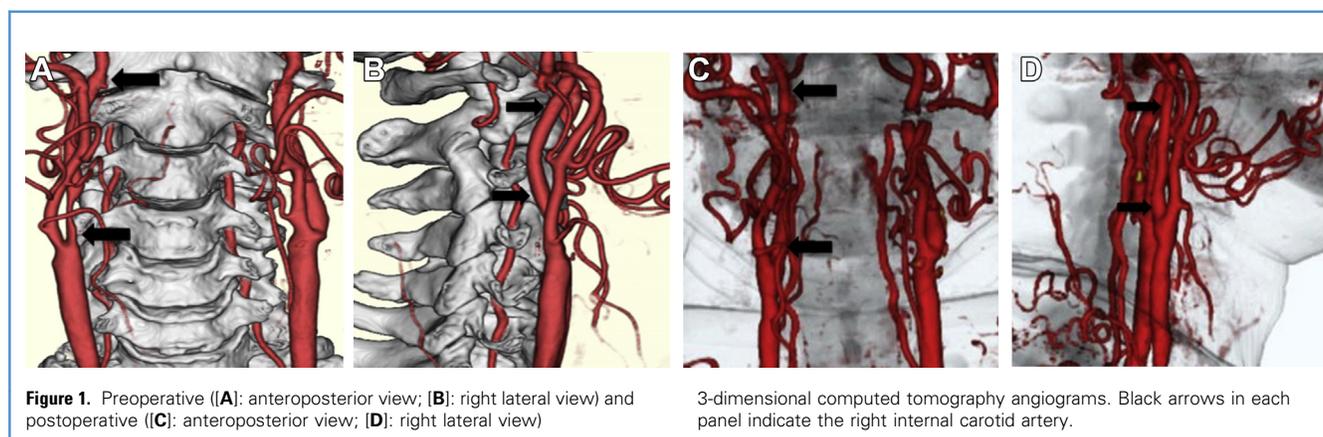


Figure 1. Preoperative ([A]: anteroposterior view; [B]: right lateral view) and postoperative ([C]: anteroposterior view; [D]: right lateral view)

3-dimensional computed tomography angiograms. Black arrows in each panel indicate the right internal carotid artery.

Table 1. Patient Characteristics

	TCB (n = 11)	Non-TCB (n = 62)	P Value
Male sex, n (%)	9 (81.82)	56 (90.32)	0.5976
Age, years	68.8 ± 2.0	70.7 ± 0.8	0.6979
Right side, n (%)	9 (81.82)	27 (43.55)	0.0193
Stenosis (%)	80 (70–90)	80 (70–90)	0.839
Symptomatic, n (%)	8 (72.73)	32 (51.61)	0.3248
Postoperative DWI positive, n (%)	2 (18.18)	8 (13.33)	0.6478
Hyperperfusion syndrome, n (%)	1 (9.09)	2 (3.23)	0.3919
Postoperative symptomatic stroke, n (%)	1 (9.09)	0 (0)	0.1507
Hoarseness, n (%)	1 (9.09)	2 (3.23)	0.3919
Peripheral facial palsy, n (%)	1 (9.09)	3 (4.84)	0.4875
Duration of operation (min)	285.5 ± 44.4	282.5 ± 39.3	0.8241

DWI, diffusion-weighted image; TCB, twisted carotid bifurcation.

behind the ECA. The small hooks attached to a rubber band can help to pull the carotid sheath gently and continuously and may reduce direct contact with the ICA. Radical turning of the neck makes it easier to correct the position of the ICA.³ At the same time, however, the overlying sternocleidomastoid muscle may lead to a wrong orientation. The external branch of the superior laryngeal nerve (EBSLN) is sometimes damaged during the surgery.¹⁰ The EBSLN runs close to the superior thyroid artery and could be injured during isolation of the superior thyroid artery. Injury to the EBSLN is likely to clinically manifest as vocal cord dysfunction such as hoarseness or breathy voice. As the EBSLN is difficult to identify in the surgical field, careful and gentle maneuvers are crucial. Taking into consideration all these factors, correction of the TCB has both advantages and disadvantages, and vice versa. Each patient has a different angle of twist, a different ECA branching pattern, or a different plaque morphology. To choose 1 way or the other should be decided for each case. A well-planned operative strategy with meticulous

preoperative studies would contribute to a good operative outcome.

All reported cases show right-sided dominance of this phenomenon. More than 80% of cases were found in the right side in the 3 case series mentioned earlier as well as in our series. Two major hypotheses have been proposed to date, the ‘congenital’ hypothesis and the ‘acquired’ or ‘arteriosclerosis’ hypothesis. However, no convincing scientific evidence has been obtained for either hypothesis, and no consensus has been established. In the future, we need more findings in patients with various backgrounds, a wider range of age, and a larger series to investigate the etiology of this phenomenon.

CONCLUSIONS

TCB is not an uncommon variation of the carotid bifurcation, occurring in 5%–15% of candidates for CEA. CEA for TCB can be safely performed by extension of the normal procedure but with more meticulous preoperative assessment and gentle maneuvers.

REFERENCES

- Kamide T, Nomura M, Tamase A, et al. Simple classification of carotid bifurcation: is it possible to predict twisted carotid artery during carotid endarterectomy? *Acta Neurochir (Wien)*. 2016;158:2393-2397.
- Katano H, Yamada K. Carotid endarterectomy for stenoses of twisted carotid bifurcations. *World Neurosurg*. 2010;73:147-154.
- Loftus CM. Carotid endarterectomy. principles and technique. In: *Side-by-Side*. 2nd ed., Chapter 3. New York, NY: Informa Healthcare; 2006:158-159.
- Sitzer M, Puac D, Buehler A, et al. Internal carotid artery angle of origin: a novel risk factor for early carotid atherosclerosis. *Stroke*. 2003;34:950-955.
- Bailey M, Scott D, Tunstall R, Gough M. Lateral external carotid artery: implications for the vascular surgeon. *EJVES Extra*. 2007;14:22-24.
- Ito M, Niiya Y, Kojima M, et al. Lateral position of the external carotid artery: a rare variation to be recognized during carotid endarterectomy. *Acta Neurochir Suppl*. 2016;123:115-122.
- Handa J, Matsuda M, Handa H. Lateral position of the external carotid artery. Report of a case. *Radiology*. 1972;102:361-362.
- Teal JS, Rumbaugh CL, Bergeron RT, Segall HD. Lateral position of the external carotid artery: a rare anomaly? *Radiology*. 1973;108:77-81.
- Ueda S, Kohyama Y, Takase K. Peripheral hypoglossal nerve palsy caused by lateral position of the external carotid artery and an abnormally high position of bifurcation of the external and internal carotid arteries—a case report. *Stroke*. 1984;15:736-739.
- Marcucci G, Accrocca F, Gabrielli R, et al. Complete transposition of carotid bifurcation: can it be an additional risk factor of injury to the cranial nerves during carotid endarterectomy? *Interact Cardiovasc Thorac Surg*. 2011;13:471-474.
- Ozgun Z, Govsa F, Ozgun T. Anatomic evaluation of the carotid artery bifurcation in cadavers: implications for open and endovascular therapy. *Surg Radiol Anat*. 2008;30:475-480.
- Lucev N, Bobinac D, Maric I, Drescic I. Variations of the great arteries in the carotid triangle. *Otolaryngol Head Neck Surg*. 2000;122:590-591.
- Trigaux J, Delchambre F, Van Beers B. Anatomical variations of the carotid bifurcation: implications

- for digital subtraction angiography and ultrasonography. *Br J Radiol.* 1990;63:181-185.
14. Aso K, Ogasawara K, Sasaki M, et al. Preoperative cerebrovascular reactivity to acetazolamide measured by brain perfusion SPECT predicts development of cerebral ischemic lesions caused by microemboli during carotid endarterectomy. *Eur J Nucl Med Mol Imaging.* 2009;36:294-301.
15. Wolf O, Heider P, Heinz M, et al. Microembolic signals detected by transcranial Doppler sonography during carotid endarterectomy and correlation with serial diffusion-weighted imaging. *Stroke.* 2004;35:e373-e375.
16. Ackerstaff RG, Moons KG, van de Vlasakker CJ, et al. Association of intraoperative transcranial doppler monitoring variables with stroke from carotid endarterectomy. *Stroke.* 2000;31:1817-1823.

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