Lateral Position of the External Carotid Artery: A Rare Variation to Be Recognized During Carotid Endarterectomy

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Abstract

Background

External carotid artery (ECA) positioned laterally to the internal carotid artery (ICA) at the level of the common carotid artery (CCA) bifurcation is occasionally encountered during carotid endarterectomy (CEA). This study aimed to determine the frequency of this phenomenon and provide technical tips for performing CEA.

Methods

The study included 199 consecutive patients (209 carotid arteries) who underwent CEA at Otaru Municipal Medical Center in 2007–2014. The position of the ECA with respect to the ICA at the CCA bifurcation was preoperatively rated as either lateral or normal, using three-dimensional computerized tomographic angiography (3-D CTA) anteroposterior projections. Postoperative diffusion-weighted images (DWIs), and postoperative 3-D CTA images were reviewed.

Results

Among the 209 carotid arteries with atherosclerosis, 11 instances (5.3 %) of lateral position of the ECA were detected in 11 patients. Ten of these arteries (91 %) were right-sided (odds ratio 11.1; 95 % confidence interval 1.38–88.9). Wider longitudinal exposure of the arteries was used during CEA, and the CCA and ECA were rotated clockwise or counter clockwise. The ICA lying behind the ECA along the surgical access route was then pulled out laterally and moved to the shallow surgical field. Cross-clamping, arteriotomy, plaque removal, and wall suturing were performed as usual. No cerebral infarcts were detected on postoperative DWIs, and 3-D CTA revealed no CCA and ICA kinking.

Conclusions

Lateral position of the ECA is not extremely rare in patients undergoing CEA for atherosclerosis and may be a congenital variation, although this is still controversial. CEA can be performed safely if the arteries from the CCA to the ICA are rotated, and the ICA is moved to the shallow surgical field under wider longitudinal exposure. Although no postoperative cerebral infarcts were detected, the risk of artery-to-artery embolism resulting from artery repositioning prior to plaque removal should be taken into consideration.

Keywords Atherosclerosis • Carotid endarterectomy • Carotid artery • External carotid artery abnormalities • Variation

Introduction

A growing number of reports describe instances of anomalous origin, course, and branching of the internal carotid artery (ICA) and the external carotid artery (ECA) of the neck. In light of the importance of the regions supplied by these arteries, the anatomical variants of the carotid arteries are of considerable interest for several medical

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specialties, including neurosurgery, plastic surgery, otorhinolaryngology, ophthalmology, odontostomatology, and vascular surgery. Failure to detect these vascular anomalies preoperatively increases the risk of peri- and postoperative complications.

Atherosclerotic disease in the carotid arteries of the neck is a major cause of ischemic cerebrovascular events. Therefore, comprehensive knowledge of the vascular anatomy is essential for successful neurosurgical and neurovascular interventions associated with carotid artery pathology, including severe atherosclerotic luminal stenosis. A number of articles and textbooks are currently available that present a detailed description of the relevant vascular anatomy for surgeons performing carotid endarterectomy (CEA) [2, 3]. In particular, knowledge of the common variations and anomalies at the bifurcation of the ICA and ECA, including lateral positioning of the ECA, is considered essential for performing CEA safely. In general, the ECA is positioned medially to the ipsilateral ICA at the level of the common carotid artery (CCA) bifurcation. However, the ECA is occasionally positioned laterally to the ipsilateral ICA. Several unbiased diagnostic cerebral angiography studies conducted in Japan and the USA reported the incidence of this inversed configuration of the ECA and ICA to be within 4.3–12.3 %, and most cases were found to be unilateral [1, 8–10]. However, no reports have focused on CEA of the ECA in the lateral position. In this paper, we retrospectively reviewed the data of the patients with atherosclerotic carotid artery luminal stenosis who underwent CEA over the course of 7 years. The incidence of lateral positioning of the ECA was investigated, and technical notes are presented on the treatment of such cases.

Methods and Materials

Study Subjects

This study included 199 consecutive patients with atherosclerotic luminal stenosis and/or ulcer formation in the cervical portion of the ICA who underwent CEA between April 2007 and February 2014 at the Otaru Municipal Medical Center. CEA via the standard anterior sternocleidomastoid (SCM) approach [4] was generally considered appropriate for patients who experienced transient ischemic attack or minor completed stroke due to ipsilateral cervical carotid artery stenosis of >50 %, calculated according to the North American Symptomatic Carotid Endarterectomy Trial method from angiography data. CEA was also indicated for asymptomatic patients with severe carotid artery stenosis (>70 %). When bilateral CEA was required, the two procedures were performed at least 6 weeks apart, and the patient was examined by an otolaryngologist to ensure that no occult cranial nerve or vocal cord dysfunction was present before the second procedure. Three-dimensional computerized tomographic angiography (3-D CTA) was performed on all patients before and after the surgery, except for cases with planned renal replacement therapy because of severe reduction in glomerular filtration rate. A total of 209 carotid arteries treated with CEA were included in this study. We performed carotid artery stenting in about ten patients during the study period.

Protocol for 3-D CTA

All 3-D CTA procedures were performed using a 64-row multislice computed tomography scanner (Aquilion™ TSX-101A; Toshiba Medical Systems, Otawara, Japan). The scanogram included the area between the levels of the aortic arch and the atlas. A total volume of 50–80 mL of iopamidol (Iopamiron 370; Bayer Healthcare, Leverkusen, Germany), a low-osmolarity iodinated contrast material, was administered intravenously using a bolus tracking method via an 18- to 20-gauge catheter positioned in the antecubital vein. A trigger value of 150 Hounsfield units was set in the ascending aorta. The scanning parameters were 120 kV, 300–400 mA, speed: 1 s/cycle, field of view diameter: 240 mm, slice thickness: 0.5 mm, and slice interval: 0.5 mm. The post-processing was conducted using a workstation (Ziostation; Ziosoft, Tokyo, Japan) by an experienced radiology technician (M.K., third author), and 3-D multi-colored images were produced. Volume rendering and maximum-intensity projection were applied as post-processing techniques to aid evaluation.

Determination of the Position of the ECA and ICA at the CCA Bifurcation by 3-D CTA

The common carotid bifurcation and the courses of the ECA and ICA in the neck were clearly discernible in the post-processed 3-D CTA images in all cases. The position of the ECA with respect to the ICA at the CCA bifurcation was rated as either lateral or normal in the anteroposterior projections, as reported previously [9]. ECAs with equivocal positions were presumed to be normal. The degree of carotid bifurcation was measured using 3-D CTA anteroposterior projections with the above-mentioned workstation (Fig. 1). For the purposes of this study, the angle of carotid bifurcation was considered positive when the ECA was positioned

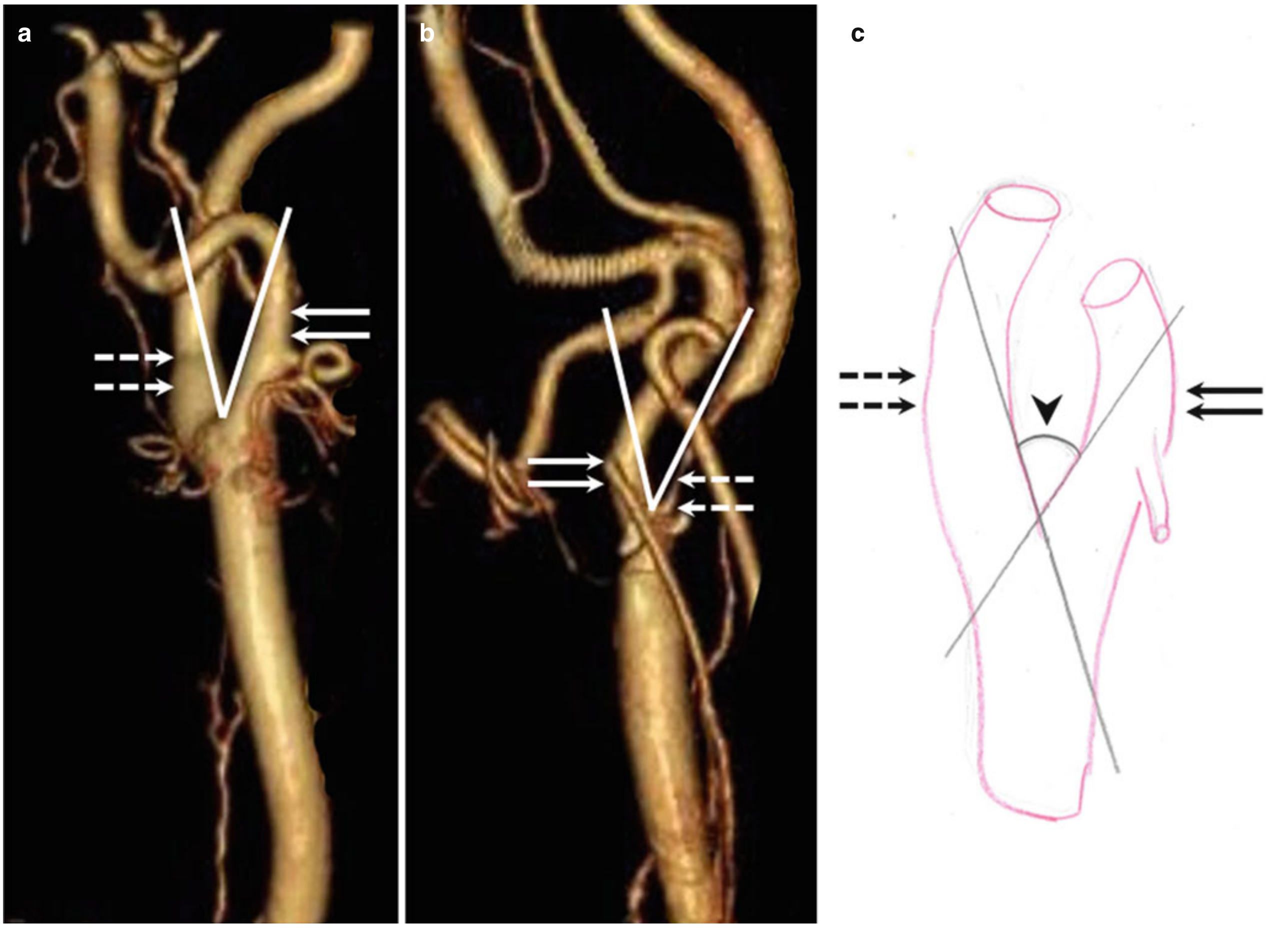

Fig. 1 Three-dimensional computerized tomographic angiography anteroposterior images of the right carotid artery in the neck. The degree of carotid bifurcation was considered positive when the external carotid artery (ECA) was positioned medially with respect to the internal carotid artery (ICA) (Panel **a**) and negative when the ECA was positioned laterally (Panel **b**). (Panel **c**) shows the carotid bifurcation angle (*arrowhead*), which was measured in this study. *Solid and dashed double arrows* indicate the ECA and the ICA arising from the common carotid artery, respectively

medially with respect to the ICA, whereas negative values corresponded to ECAs positioned laterally.

Surgical Procedure

General endotracheal anesthesia was induced after the patient was placed in the supine position. Non-invasive monitoring of the regional frontal lobe oxygenation state during the surgery was performed using near-infrared spectroscopy. Except for patients receiving dual or triple antiplatelet therapy, the dose of antiplatelet agents was not reduced preoperatively. The CCA and its bifurcation were exposed, using a standard approach reported elsewhere [7]. In brief, the head and neck were extended and rotated to the side contralateral to the surgical incision, as appropriate. A curvilinear skin incision along the anterior portion of the SCM muscle was made toward the mastoid tip. The skin and subcutaneous tissue were divided to the level of the platysma. Following sharp cutting of the platysma along the skin incision and proper retraction, the underlying connective tissue, including fat, was dissected to identify the anterior edge of the SCM muscle. The posterior margin of the parotid gland was meticulously dissected without damaging the parotid membrane, so that the anterior border of the SCM muscle was exposed as widely as the longitudinal operative window allowed. After the SCM muscle was retracted dorsally by hooks, dissection was performed in the mid-portion of the operative window until the internal jugular vein (iJV) was identified. Retracting the iJV dorsally permitted the exposure of the carotid sheath overlying the CCA, and the carotid sheath was dissected to expose the carotid artery. At this point, we gently cut the sheath lineally along the CCA toward the ECA-ICA complex. A clockwise or counterclockwise rotation of the CCA and ECA-ICA was then performed by hitching up the underlying carotid sheath. Finally, the CCA and ICA were drawn out to the shallow surgical field. The completion of this process with satisfactory hemostasis allowed proceeding with the conventional steps, including arterial clamping, arteriotomy, three-way internal shunt tube insertion, meticulous dissection of the carotid plaque, and arteriotomy closure with a running suture under an operative microscope. A routine magnetic resonance imaging scan including diffusion-weighted imaging and magnetic resonance angiography was performed as part of routine postoperative imaging immediately after the surgery or at postoperative day 1. In cases with suspected or predicted postoperative hyperperfusion syndrome [5], single-photon emission computed tomography was performed to measure the regional cerebral blood flow. The surgical procedure is schematically illustrated in Fig. 2, which also shows representative 3-D CTA images before and after the surgery in a patient with lateral position of the ECA.

Analysis of Postoperative Changes in the Degree of Carotid Bifurcation and Surgical Complications

3-D CTA was repeated in all the enrolled patients between postoperative days 1 and 3 to visualize postoperative changes in the operated carotid artery. Pre- and postoperative anteroposterior 3-D CTA images were inspected for all the 209 carotid arteries to compare the degrees of carotid bifurcation. A surgical complication was defined as postoperative death, postoperative stroke, ipsilateral carotid occlusion or carotid artery stenosis of >50 %, postoperative hyperperfusion syndrome, myocardial infarction, gastrointestinal bleeding, wound complication, or cranial nerve palsy that occurred within 1 week of the surgery.

Statistical Analysis

All continuous data were expressed as mean ± standard deviation. The 209 carotid arteries were divided into two groups (lateral or normal position of the ECA) according to preopera-

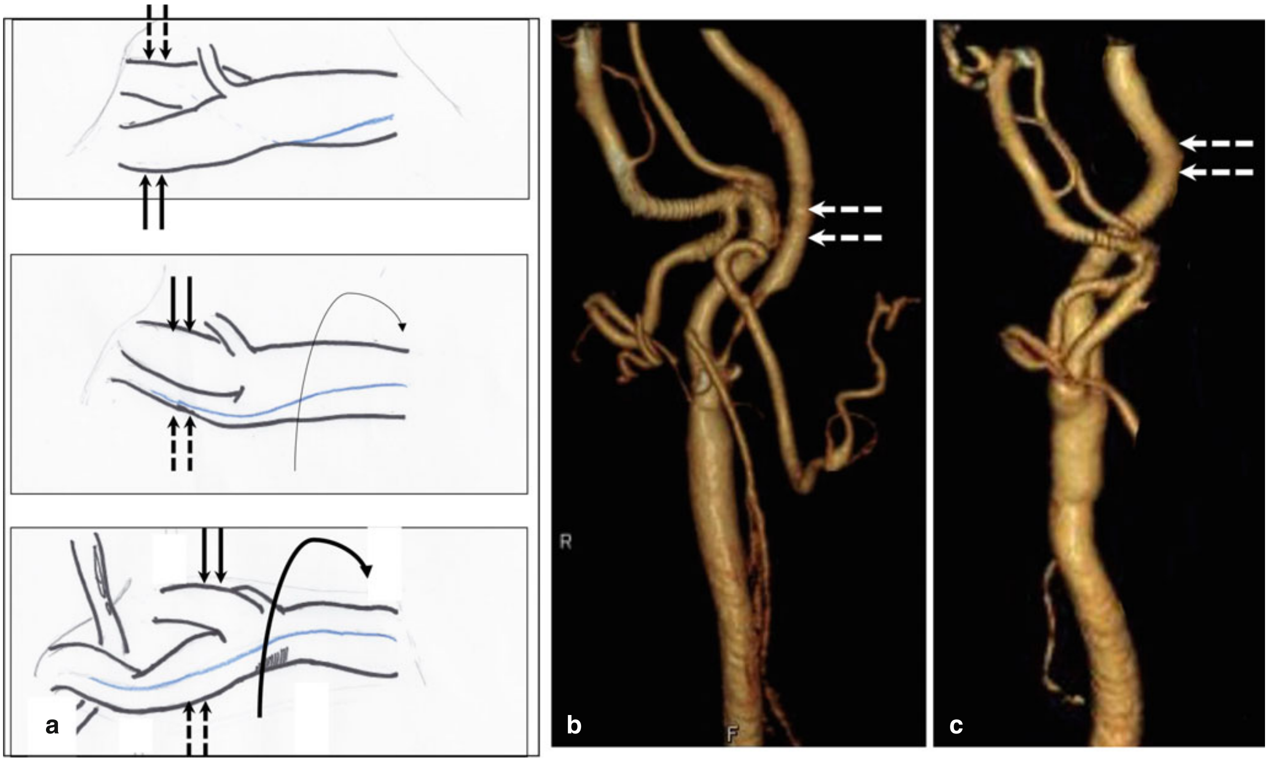

Fig. 2 A schematic illustration of the steps necessary to expose the right internal carotid artery (ICA). Initially, the ICA (*dashed double arrows*) and the proposed arteriotomy line (*blue*) lay behind the external carotid artery (ECA, *double arrows*) (Panel **a**, *top*). The right carotid artery was gently rotated clockwise along the common carotid artery (CCA) toward the ECA-ICA complex by hitching up the underlying carotid sheath (Panel **a**, *middle*). Finally, the CCA and ICA were drawn out to the shallow surgical field, and the proposed arteriotomy line on the ICA was exposed (Panel **a**, *bottom*). (Panels **b** and **c**) show representative anteroposterior three-dimensional computerized tomographic angiography images of the right carotid artery (*dashed double arrows* indicate the ICA) before and after carotid endarterectomy, respectively, in a 79-year-old man with lateral position of the ECA

tive 3-D CTA findings. Comparisons between the two groups were performed using Fisher's *t*-test and the Chi-square, or Fisher's probability test, as appropriate, for continuous and dichotomous variables, respectively. Multivariate logistic regression was used to calculate odds ratios (ORs) and 95 % confidence intervals (CIs) after controlling simultaneously for potential confounders. The continuous and dichotomous variables considered in the model were age and gender, side (right or left), and lesion characteristics (i.e., symptomatic or asymptomatic lesion; severe or moderate stenosis), respectively. The significance level was set at $P<0.05$. Statistical analyses were carried out with Excel (EXCEL-TOUKEI 2012^{R}, Social Survey Research Information Co., Ltd., Tokyo, Japan).

Results

Baseline Patient Characteristics

Of the 199 consecutive patients with atherosclerotic stenosis of the cervical portion of the ICA, 173 were men and 26 were women, with the mean age of 73.4 (range: 44–88). The baseline characteristics are summarized in Table 1. Unilateral CEA was performed in 189 patients (96 right side, 93 left side), and bilateral-staged CEA was performed in 10 patients. There were 97 patients with asymptomatic carotid stenosis.

Incidence of Lateral Position of the ECA and Characteristics Related to Atherosclerotic Carotid Stenosis

Eleven instances of lateral position of the ECA were observed in 11 patients with atherosclerotic carotid stenosis who underwent CEA over 7 years (5.3 % of the carotid arteries and 5.5 % of the patients). Clinical summaries of these patients before and after CEA are given in Table 2. We compared potential confounding factors between laterally and normally positioned ECAs (106 right and 103 left carotid arteries). As shown in Table 3, lateral positioning of the ECA was much more common for the right-side carotid artery than for the left (right, 10 of the 11 carotid arteries; left, 1 carotid artery) when compared with normal positioning of the ECA (right, 96 of the 198 carotid arteries; left, 102 carotid arteries). Thus, lateral positioning of the ECA was observed much more frequently on the right side than on the left (90.9 % and 48.5 % of laterally and normally positioned ECAs were located on the right, respectively; OR 11.1; 95 % CI 1.38–88.9; $P=0.024$); there were no patients with laterally positioned ECAs on both sides. Atherosclerosis-related factors such as age, gender, and lesion characteristics (i.e., symptomatic lesion and severe carotid stenosis) were not associated with the incidence of lateral position of the ECA.

Postoperative Changes and Surgical Complications After CEA

Preoperatively, the degree of carotid bifurcation was significantly different between the groups with lateral and normal positioning of the ECA when the position of the ECA with respect to the ICA at the CCA bifurcation was rated in the 3-D CTA anteroposterior projections ($-21\pm9.5°$ and $9.5\pm9.2°$, $P<0.001$). The postoperative angles were $-12\pm10°$ and $9.6\pm9.1°$ in these two groups, respectively. The postoperative change of the degree of bifurcation was significant in the group with lateral positioning of the ECA ($9.7\pm11°$, $P=0.02$), but not in the normal group ($0.1\pm7.0°$, $P=0.88$).Surgical results can be summarized as follows: Carotid stenosis was corrected in all the 209 treated carotid arteries. In the group with lateral positioning of the ECA,

Table 1 Baseline characteristics of the enrolled patient

		Unilateral operation		Bilateral operation
	All	Right side CEA	Left side CEA	Staged CEA
Valuable	(*n* = 199)	(*n* = 96)	(*n* = 93)	(*n* = 10)
Age, y, ± SD	73 ± 7.5	73 ± 8.1	73 ± 7.1	74 ± 5.1
Male gender, *n* (%)	173 (86.9)	86 (89.6)	79 (84.9)	8 (80.0)
Asymptomatic case, *n* (%)	97 (48.7)	46 (47.9)	47 (50.5)	4 (40.0)
Hypertension, *n* (%)	159 (79.9)	80 (83.3)	69 (74.2)	10 (100)
Dyslipidemia, *n* (%)	83 (41.7)	36 (37.5)	43 (46.2)	4 (40.0)
Diabetes mellitus, *n* (%)	59 (29.6)	26 (27.1)	30 (32.3)	3 (30.0)
Ischemic heart disease, *n* (%)	71 (35.7)	28 (29.2)	38 (40.9)	5 (50.0)
Lateral position of ECA, *n* (%)	11 (5.5)	6 (5.9)	5 (5.2)	0

CEA carotid endarterectomy, *SD* standard deviation, *ECA* external carotid artery

Table 2 Clinical data in patients with the lateral position of external carotid artery before and after carotid endarterectomy

Age, y / gender	Side	Clinical diagnosis	NASCET criteria	Degree of carotid bifurcation		Complication	
				Before CEA	After CEA	Postoperative stroke	Others
58/M	Right	Cerebral infarct	Severe	−2.4	1.3	None	None
71/F	Right	Asymptomatic CS	Moderate	−16.8	−5.3	None	None
72/M	Right	Cerebral infarct	Severe	−21.1	−13.4	None	None
73/M	Right	TIA	Moderate	−23.8	−23.6	None	None
78/M	Right	TIA	Moderate	−34.9	0	None	Periauricular numbness
79/M	Right	Cerebral infarct	Severe	−25	−13.8	None	hyperperfusion syndrome
79/M	Right	Cerebral infarct	Severe	−21.4	0	None	None
80/F	Right	Asymptomatic CS	Severe	−11.6	−14.3	None	None
74/M	Right	Asymptomatic CS	Moderate	−14.8	−11.4	None	None
77/M	Right	Asymptomatic CS	Severe	−30.81	−13.76	None	None
72/M	Left	Asymptomatic CS	Moderate	−30.67	−31.96	None	None

M male, *F* female, *CS* carotid stenosis, *TIA* transient ischemic attack, *CEA* carotid endarterectomy

Table 3 Relationship between lateral position of the external carotid artery and potential co-founders in atherosclrerotic carotid stenosis

	Lateral position of ECA		Univariate analysis	Logistic regression analysis	
	Yes	No	*P* value	*P* value	OR (95 % CI)
No. of carotid artery	11	198			
Degree of carotid bifurcation, mean ± SD	−21 ± 9.5	9.5 ± 9.2			
Age, y, mean ± SD	74 ± 6.2	73 ± 7.4	0.812	0.534	
Male gender, *n*	9	172	0.645	0.649	
Right side, *n*	10	96	0.0062	0.024	11.1 (1.38–88.9)
Symptomatic lesion, *n*	6	96	0.696	0.686	
Severe stenosis, *n*	6	141	0.308	0.270	

ECA external carotid artery, *OR* odds ratio, *CI* confidence interval, *SD* standard deviation

one patient experienced transient periauricular numbness caused by injury to the great auricular nerve, and another patient experienced transient postoperative hyperperfusion syndrome (Table 2). No permanent surgical complications, including cranial nerve palsy or postoperative stroke as well as postoperative ipsilateral carotid occlusion, were observed in the lateral position group. In the normal position group, postoperative stroke was observed in two patients, including an ipsilateral cerebral infarct and a brain stem-cerebellar infarct. An asymptomatic ipsilateral petechial thalamic hemorrhage and a myocardial infarct were observed and resolved in two other patients. Eight patients developed transient postoperative hyperperfusion syndrome in the normal group. Taken together, two permanent surgical complications (1.0 %) were observed in the normal position group. Thus, although there was no mortality in either group, the rates of permanent morbidity were 0 % and 1.0 % in the lateral and normal position groups, respectively. The overall morbidity was 6.7 % in this patient series (14 instances of transient and permanent morbidities were observed among 209 procedures).

Discussion

Lateral Position of the ECA in a Series of CEAs

Previous reports used unbiased series of angiograms taken for the purpose of diagnosis of head trauma, intracerebral or subarachnoid hemorrhage, head and neck tumors, and cerebral aneurysms in patients ranging from newborns to the elderly in their 80s, to show that the incidence of lateral position of the ECA in the Japanese population is within 4.3–4.9 % [1, 8, 10]. Thus, lateral position of the ECA is not an uncommon phenomenon, and its occurrence was assumed to result from congenital anomalies (excessive migration of the embryonic external carotid artery trunk) or atherosclerosis (elongation or tortuosity of the carotid arteries). Our 199 consecutive Japanese patients with atherosclerotic carotid stenosis who underwent CEA in a single center in the course of 7 years were mostly men (87 %) with advanced age (73 ± 7.5 years; range: 44–88), and 5.3 %

of the ECAs were positioned laterally. In agreement with the published data, the results of the multivariate logistic regression analysis indicated that laterally positioned ECAs were encountered significantly more often on the right than on the left (90.9 % and 48.5 % of the laterally and normally positioned ECAs were found on the right, respectively; OR 11.1; 95 % CI 1.38–88.9; $P = 0.024$). Based on several reasons, we believe that the etiology of lateral positioning of the ECA is heterogeneous. First, despite controlling for potential confounders, including age, gender, and factors related to carotid atherosclerosis, the predominantly right-side location of the anomaly was still observed in our atherosclerotic patients. If atherosclerosis were the main precipitating factor, we would expect this predominance to be weaker. Second, if this condition resulted purely from atherosclerosis, lateral positioning of the ECA would be observed bilaterally more frequently than in the unbiased series. Third, asymmetry of the carotid atherosclerosis may still be a result of congenital variations or anomalies even in these elderly, atherosclerotic patients, as this ECA position defect may be present and undetected until the treatment for atherosclerosis is carried out. Very recently, Selwaness et al showed that plaque incidence, severity, and composition were not equally distributed between left and right carotid arteries [6]. Based on this result, they proposed that the asymmetry of carotid atherosclerosis might be explained by geometric factors, such as bifurcation angle and configuration of the right and left carotid arteries with respect to the aortic arch. Because the left carotid artery directly connects to the aortic arch and the right carotid artery arises from the brachiocephalic artery, the authors suggested that vessel anatomy might influence the hemodynamic forces, and the left carotid artery might be exposed to higher arterial pressure. Although there is no conclusive evidence on whether lateral position of the ECA has a congenital origin or results from atherosclerosis, we tend to agree with the authors of the above report – that it may be caused by variations or anomalies associated with geometric factors. Irrespective of the origin, knowing about the incidence of this condition in patients with atherosclerosis is essential for surgeons performing CEA.

Technical Notes and Postoperative Changes

We found that the angle of carotid bifurcation was significantly changed in the group with lateral position of the ECA after the surgery (−21 ± 9.5° vs. −12 ± 10°), whereas no such change was observed in the normal position group (9.5 ± 9.2° vs. 9.6 ± 9.1°). CEA may alter the arterial wall stiffness, length, or tortuosity because arterial plaque is removed and the arterial wall is sutured. It can be anticipated that the courses of the ECA and ICA arising from the CCA may change after CEA, resulting in kinks, especially in carotid arteries with unusual anatomical configuration, including lateral position of ECA. Moreover, from the viewpoint of a surgeon performing CEA, the ICA always lies behind the ECA in patients with lateral position of the ECA; therefore, the ICA should be drawn out to the shallow surgical field by rotating the carotid arteries. The steps following this maneuver can be performed in the usual manner, as described in the Methods and Materials section (above). Kinking or occlusion after CEA has not been reported in patients with lateral position of the ECA. In agreement with this, we did not observe carotid occlusion or kinking immediately after CEA, although the position of the ECA was shifted 9.7° medially with respect to the ipsilateral ICA at the CCA bifurcation after the surgery. The incidence of surgical complications was lower in the lateral position group than in the normal position group. However, it should be noted that the number of patients with lateral position of the ECA was quite small. Since this procedure involves mobilization of the ICA, which may carry rupture of vulnerable plaque, surgeons should be aware of the potential risk of intraoperative artery-to-artery embolism. Therefore, CEA with distal protection at an earlier stage or carotid artery stenting should be considered in patients with highly anticipated plaque vulnerability and lateral position of ECA.

ConclusionsThe incidence of lateral positioning of the ECA was 5 % in our single-center, 7-year study of atherosclerotic carotid stenosis patients who underwent CEA. Although there is no conclusive evidence, based on the predominantly unilateral nature and right-side location of the laterally positioned ECAs in the atherosclerotic population, we speculate that this condition is more likely to be a result of congenital variations or anomalies rather than atherosclerosis. Wider longitudinal exposure, rotation of the carotid arteries, and drawing the ICA out to the shallow surgical field are essential for performing CEA safely in such patients. Although no kinking of the CCA and ICA occurred in the cases with laterally positioned ECA, the risk of artery-to-artery embolism resulting from artery repositioning prior to plaque removal should be kept in mind.

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Conflict of Interest The authors declare that they have no conflicts of interest.

Ethical Standards This retrospective study was approved by the Institutional Review Board at Otaru Municipal Medical Center, and informed consent was obtained from all the patients prior to their inclusion in the study.

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