Carotid Artery Stenting to Internal Carotid Artery Stenosis at the Distal Cervical Portion near the Carotid Canal: A Report of Six Cases

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Objective: Six cases in which carotid artery stenting (CAS) was performed using a distal embolic protection device (EPD) for distal internal carotid artery (ICA) stenosis near the carotid canal are reported.

Case Presentations: Of the 504 consecutive cases of ICA stenosis endovascularly treated at our hospital between April 1, 2008 and December 31, 2016, six cases with lesions in the distal portion of the cervical ICA near the carotid canal underwent CAS using Carotid Guardwire PS. The six patients were all males aged 68–80 years (median: 78.5 years), and three patients were symptomatic. The mean percent stenosis was 91% (80%–96%) preoperatively and 10.3% (0%–27%) postoperatively. In five patients, gross debris was detected in the blood aspirated during the procedure. In the patient with 27% residual stenosis, calcified plaque was confirmed at the entry of the carotid canal on postoperative CTA. No stroke, myocardial infarction, or death was noted within 30 days after the perioperative period, but a new ischemic lesion was detected in one patient on diffusion-weighted MRI. The mean follow-up period in the six patients was 28 months (7–66 months), and ipsilateral stroke or restenosis was not observed.

Conclusion: CAS using EPD is considered an effective option for the treatment of distal ICA stenosis near the carotid canal.

Keywords ▶ internal carotid artery stenosis, distal cervical portion, carotid artery stenting

Introduction

Carotid artery stenting (CAS) using an embolic protection device (EPD) is performed for cervical internal carotid artery (ICA) stenosis, and percutaneous transluminal angioplasty (PTA) not using EPD or stent is performed primarily for intracranial arterial stenosis.

However, for distal ICA stenosis near the carotid canal, which of CAS and PTA not using a stent is a more appropriate treatment is unknown. In this report, six patients with stenosis of the distal cervical portion of the ICA treated at our facility by CAS using EPD are presented with clinical and imaging findings.

Case Presentations

Patient background

We encountered six patients with distal cervical ICA stenosis between April 1, 2008 and December 31, 2016. They were all males, aged 68–80 years (median: 78.5 years), and three were symptomatic (Table 1). While arterial dissection is frequently observed at this site, the six patients had no clear history of trauma, sudden headache, or neck pain, and no findings suggestive of Marfan syndrome were noted. Also, as they all had some factors that promote atherosclerosis such as hypertension, diabetes, dyslipidemia, chronic renal dysfunction, and smoking, and as five of the six patients showed generalized arteriosclerotic changes with three having coronary artery disease (CAD) and two...
having peripheral artery disease (PAD) (Table 2), we judged that the stenotic lesions in the six patients were likely to be caused by atherosclerosis. Concerning the smoking history, the patients were divided into those who smoked at or within 1 year before CAS (current smokers) and those who stopped smoking 1 year or longer before CAS (ex-smokers).

The indications for treatment were symptomatic ≥50% or asymptomatic ≥80% ICA stenosis according to the criteria of the Stenting and Angioplasty with Protection in Patients at High Risk for Endarterectomy (SAPPHIRE) trial.1)

CAS procedure
Since the vascular diameter at the site of EPD placement was <3.5 mm in all six patients on preoperative angiography, Carotid Guardwire PS (CGW; Medtronic, Santa Rosa, CA, USA) was used as EPD.

The patients were orally administered aspirin at 100 mg and clopidogrel at 75 mg at least for 4 days prior to CAS.

Heparin was administered intravenously (100 IU/kg), additional heparin was administered when necessary to maintain the activated clotting time (ACT) at ≥300, and the lesion was approached via the femoral artery. An 8 Fr. Brite tip (Cordis Endovascular systems, Miami Lakes, FL, USA) was guided to the common carotid artery, the CGW was placed at a site beyond the posterior loop, inflated to 4.0 mm to interrupt the blood flow, and predilatation, stent placement, and postdilatation were carried out. The open-cell type Precise (Cordis, J&J, Fremont, CA, USA) was selected as the stent in consideration of the apposition to the wall of the tortuous proximal petrous segment to the distal cervical portion of the ICA. Stents with a total length of 30 mm or ≤20 mm were used. Predilatation was performed using a balloon 3.0 mm in diameter in all patients, and postdilatation was performed using a balloon 3.5–4.5 mm in diameter. Dilatation was performed at the nominal pressure specified for each balloon in all patients. After postdilatation, an export aspiration catheter (Medtronic, Minneapolis, MN, USA) was placed on the proximal side of the CGW balloon, and at least 100 mL of blood was aspirated until gross debris disappeared using a 25 mL syringe. If gross debris was noted, two additional blood aspirations were performed after the disappearance of debris. The aspirated blood was filtered through two layers of gauze, and the presence or absence of debris on the gauze was examined. After the disappearance of gross debris, the CGW was deflated and retrieved.

Table 1 Summary of the six patients in CAS

<table>
<thead>
<tr>
<th>Case no.</th>
<th>Sex/Age</th>
<th>Side</th>
<th>Symptoms</th>
<th>Degree of stenosis (%)</th>
<th>Pre-CAS/Post-CAS</th>
<th>Lesion length (mm)</th>
<th>Vessel diameter of CGW placement (mm)</th>
<th>Precise stent (mm)</th>
<th>Used pre-balloon (mm)</th>
<th>Used post-balloon (mm)</th>
<th>Volume of aspirated blood (mL)</th>
<th>Gross debris on gauze</th>
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<tr>
<td>1</td>
<td>Man/79</td>
<td>L</td>
<td>No</td>
<td>94/12</td>
<td>94/23</td>
<td>38.7</td>
<td>3.0</td>
<td>Sterling ES</td>
<td>3.0–40</td>
<td>3.0–40</td>
<td>150</td>
<td>Yes</td>
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<td>2</td>
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<td>R</td>
<td>No</td>
<td>90/23</td>
<td>90/23</td>
<td>10.0</td>
<td>3.3</td>
<td>Submarine</td>
<td>3.0–20</td>
<td>3.0–20</td>
<td>100</td>
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<tr>
<td>3</td>
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<td>R</td>
<td>Yes</td>
<td>90/23</td>
<td>90/23</td>
<td>9.6</td>
<td>3.4</td>
<td>Submarine</td>
<td>3.0–20</td>
<td>3.0–20</td>
<td>150</td>
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</tr>
<tr>
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<td>Yes</td>
<td>96/27</td>
<td>96/27</td>
<td>33.7</td>
<td>2.8</td>
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<td>80/0</td>
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<td>2.5</td>
<td>Aviator Plus</td>
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<td>100</td>
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<td>96/0</td>
<td>96/0</td>
<td>31.4</td>
<td>2.1</td>
<td>Bandicoot</td>
<td>3.0–40</td>
<td>3.0–40</td>
<td>150</td>
<td>Yes</td>
</tr>
</tbody>
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Clinical and imaging findings after CAS
All strokes, myocardial infarctions, and deaths that occurred within 30 days after CAS were regarded as major adverse events (MAEs). Neurologic symptoms were evaluated by classifying them into transient ischemic attack (TIA) and ischemic stroke.

MRI (3T, Intra; Philips Medical Systems, Best, Netherlands) was performed 2 days before and 2 days after CAS, and the presence or absence and number of new ischemic lesions were evaluated by diffusion-weighted imaging (DWI), which was performed by SE-EPI (repetition time [TR]/echo time [TE] = 3545/70 msec, slice thickness = 5 mm, spacing = 1.2 mm, B value=1000 sec/mm², field of view [FOV] = 240 m).

Case 1 (patient 3)
A 68-year-old male developed TIA with left upper extremity paralysis as the primary symptom. As MRA suggested right ICA stenosis to be responsible for TIA, the patient was referred to our hospital. Since angiography performed 14 days after the onset of TIA revealed 90% stenosis in the distal cervical segment of the right ICA, CAS was carried out 28 days after the onset (Fig. 1A–1F).

The administration of clopidogrel at 75 mg was initiated immediately after the onset of TIA, and aspirin at 100 mg was added 4 days before CAS.

An 8 Fr. Brite tip (90 cm) was guided to the right common carotid artery via the right femoral artery, and CGW was placed beyond the posterior loop and inflated to 4.0 mm. After 20-second predilatation using Bandicoot 3.0–4.0 mm (Kaneka, Osaka, Japan), Precise 6.0–30 mm was placed. Following 20-second postdilatation using Aviator Plus 4.5–30 mm (Cordis, J&J, Bridgewater, NJ, USA), an export aspiration catheter was placed proximally to the CGW, and blood was aspirated. Gross debris was observed on the 1st–4th blood aspiration, but as no gross debris was noted on the subsequent two consecutive blood aspirations, the CGW was deflated. The duration of interruption of blood flow using the CGW was 14 min and 45 sec. No acute ischemic lesion of the brain was noted on postoperative MRI. The preoperative end-diastolic blood flow velocity at the origin of the right cervical ICA measured by carotid artery ultrasonography (Toshiba Aplio500, Tochigi, Japan) was low at 5.2 cm/s, and the pulsatility index (PI) was high at 4.1, showing an external carotid artery-like blood flow waveform, but the preoperative values were improved to 19.3 cm/s and 1.1, respectively (Fig. 1G and 1H). No neurologic symptoms were observed intra- or postoperatively, and the patient was discharged on the 5th postoperative day, being capable of unassisted ambulation.

Case 2 (patient 4)
An 80-year-old male was admitted to our hospital due to repeated episodes of TIA with right hemiplegia as the primary symptom. Since angiography revealed 96% stenosis of the distal cervical portion of the left ICA, CAS was performed about 50 days after the onset of TIA (Fig. 2A–2F).

He had been administered aspirin at 100 mg and clopidogrel at 75 mg from before the onset of TIA. Under local anesthesia, an 8F. Brite tip (80 cm) was guided to the left common carotid artery via the right femoral artery, and the CGW was placed beyond the posterior loop and inflated to 4.0 mm. After 20-second predilatation using Coyote ES 3.0–40 mm (Boston Scientific Corp, Marlborough, MA, USA), Precise 6.0–30 mm was placed. However, as it could not cover the entire lesion, Precise 7.0–30 mm was placed proximally by overlapping about 5 mm of it with the first stent. Postdilatation was performed over 20 sec using Bandicoot 4.0–20 mm (Kaneka), but dilatation was insufficient in the distal part (Fig. 2). Since calcification was suspected as a cause, dilatation at an increased pressure in the carotid canal was judged to be dangerous, and dilatation at a supranominal pressure was avoided. Next, an Export aspiration catheter was placed on the proximal side of the CGW. Since gross debris was observed on the 4th–6th blood aspirations but not on the following two
Fig. 1 Angiogram of patient 3 (A–F). Angiograms of right common carotid artery anteroposterior view (A); lateral view (D) show severe stenosis (arrow) at the distal cervical, petrous junction of right ICA before CAS. Fluoroscopic images anteroposterior view (B); lateral view (E) show a placed stent (white arrow head) and the inflated balloon of Cartid Guardwire (dotted white arrow). Angiograms of right common carotid artery anteroposterior view (C); lateral view (F) show dilatation of a stenotic lesion (arrow) after CAS. Ultrasonic waveforms of the right ICA in cervical bifurcation pre-CAS (G) and post-CAS (H). Ultrasonic waveforms show the improvement of blood flow velocity, especially end-diastolic blood flow velocity after CAS. CAS: carotid artery stenting; ICA: internal carotid artery.
Fig. 2  Angiogram of patient 4 (A–F). Angiograms of left common carotid artery anteroposterior view (A); lateral view (D) show severe stenosis (arrow) at the distal cervical, petrous junction of ICA before CAS. Fluoroscopic images anteroposterior view (B); lateral view (E) show a placed stent (white arrow head) in (B) and residual stenosis (dotted arrow) in (E). Angiograms of left common carotid artery anteroposterior view (C); lateral view (F) show dilatation of stenotic lesion (arrow) in (C) and residual stenosis (dotted arrow) in (F) after CAS. Ultrasonic waveforms of the left ICA in cervical bifurcation pre-CAS (G) and post-CAS (H). Ultrasonic waveforms show the improvement of blood flow velocity, especially end-diastolic blood flow velocity after CAS. CAS: carotid artery stenting; ICA: internal carotid artery
consecutive aspirations, the CGW was deflated. The duration of interruption of blood flow by the CGW was 15 min and 25 sec. CTA 3 days after CAS showed calcified plaques at the entry of the carotid canal and in the distal cervical portion (Fig. 3A and 3B). Postoperative MRI showed no acute cerebral ischemia. Also, the end-diastolic blood flow velocity at the origin of the left cervical ICA measured by carotid artery ultrasonography was low at 6.8 cm/s before the procedure, but improved to 12.5 cm/s after the procedure (Fig. 2G and 2H). No neurologic symptom was noted intra- or postoperatively, and the patient was discharged on the 6th postoperative day, being capable of unassisted ambulation.

**Summary of cases**

The success rate of CAS for distal ICA stenosis near the carotid canal was 100%. The mean percent stenosis was 91% (80–96%) preoperatively, but it improved to 10.3% (0–27%) after treatment (Table 1). No neurologic symptoms due to interruption of blood flow by the CGW were noted. Table 1 shows the stent and balloon used for the procedure and data including the amount of aspirated blood. After Case 4, examination for calcified plaque in the carotid canal was performed before CTA.

Since it was difficult to guide a 40-mm long stent to a point near the posterior loop in the first case, we decided to use a short stent 20 mm or 30 mm long regardless of the lesion length. If the stent could not cover the entire lesion, two stents were placed by partially overlapping them as in Cases 1, 4, and 6 (Table 1). In addition, as the passability of the postdilatation balloon is considered to be related to the degree of curvature, it was considered necessary to select an appropriate balloon length.

After postdilatation, when we placed an Export aspiration catheter on the proximal side of the CGW and aspirated blood, gross debris was noted in the aspirated blood in five of the six cases, and additional blood aspirations were performed in patients who showed large amounts of debris (Table 1). The CGW was placed in the ICA with a mean diameter of 2.9 (2.1–3.4) mm and inflated to 4.0 mm in all patients for interruption of blood flow, but angiography after its deflation showed no vascular injury or dilatation at the site of its placement.

No MAEs including TIA, ischemic stroke, myocardial infarction, and death were observed within 30 days after CAS. A total of three new DWI lesions, that is, two in the ipsilateral frontal cortex and one in the occipital cortex, were noted in one of the six patients (Case 5 in Table 1). The mean follow-up period of the six patients was 28 (7–66) months. No ipsilateral stroke or restenosis was noted during the follow-up period, but unexplained death occurred in one patient (33 months after CAS).

**Discussion**

Of the 504 consecutive cases of endovascular treatment performed at our hospital for ICA stenosis between April 1, 2008 and December 31, 2016, 464 (92.1%) had cervical ICA stenosis, and 40 (7.9%) had intracranial ICA stenosis (intradural in 7 and extradural in 33). Of these patients, stenosis was located in the distal cervical portion near the carotid canal in 6 (1.2%).
For cervical ICA stenosis at the bifurcation into the external and internal carotid arteries, CAS using EPD\textsuperscript{1–3} is a standard treatment. While the results of stent-assisted PTA for intracranial ICA stenosis were poor in the Symptomatic Atherosclerotic Lesions in the Vertebral or Intracranial Arteries (SSYLVIA) trial,\textsuperscript{7} Wingspan Humanitarian Use Device (HDE) trial,\textsuperscript{8} and SAMPRIS,\textsuperscript{9} Marks et al. performed PTA in 36 and 120 patients,\textsuperscript{4,5} and Dumont et al.\textsuperscript{6} performed PTA in 24 patients, for intracranial arterial stenosis with balloon assist alone, and reported relatively favorable results with incidences of MAEs within 30 days of 0%–5.8%, suggesting the preferability of PTA not using a stent. However, appropriate treatments for distal cervical ICA stenosis are unknown.

At our facility, we performed CAS using the CGW in the first patient, giving priority to avoid the risk of intraoperative embolic events. Since gross debris was observed in the blood aspirated after postdilatation, we judged it appropriate to perform CAS by a similar procedure for ICA stenosis at this site. In fact, we noted gross debris in five of the six patients in the blood aspirated after postdilatation, indicating that the risk of intraoperative embolic events is high without the use of EPD. Hayashi et al.\textsuperscript{10} reported that plaque is related to stenosis near the petrous portion of the ICA. Ito et al.\textsuperscript{11} performed angioplasty of the coronary artery using a balloon-expandable stent without the EPD in 31 patients with stenosis of this site and reported embolic complications in 4 (12.9%). Therefore, the use of a protection device is considered recommendable for angioplasty at this site.

Favorable results of CAS with proximal embolic protection for stenosis at the bifurcation of the cervical ICA, with the incidence of MAEs being 3.2–3.8% and DWI-positive rate being 14.3–45.2%, have been reported,\textsuperscript{12,13} but CAS with proximal protection is also an effective option of stent-assisted angioplasty for distal cervical ICA stenosis as reported by Imai et al.\textsuperscript{14} In addition to the prevention of intraoperative embolic complications, the procedure is considered to have important procedural advantages such as the unecessity of navigation of the aspiration catheter after stent placement, which leads to high safety also in dissecting lesions, and augmentation of backup in stent navigation by inflation of the coaxial balloon of the balloon guiding catheter. However, as five of our six patients had type III aortic arch, and the remaining one had bovine arch (Case 2, left ICA stenosis), the lesions may have been poorly approachable. One technically difficult process in CAS is the placement of the guiding catheter, and as the balloon guiding catheter is inferior in operability and trackability compared with conventional guiding catheters, we used usual guiding catheters by placing priority to the operability. In addition, as we previously reported,\textsuperscript{15} there was no marked difference in the results between CAS with distal protection at our institution and CAS with proximal protection in the literature. We, therefore, selected CAS with distal protection for our patients.

At this site, dissecting lesions are observed, although infrequently, and Ohta et al.\textsuperscript{16} performed angioplasty using the CGW or FilterWire EZ (FWEZ; Boston Scientific) in part of the 13 patients with ICA dissection extending to both intracranial and extracranial portions. Azumi et al.\textsuperscript{17} also reported three patients in whom CAS using the CGW was useful for the treatment of distal cervical ICA dissection. In both reports, proximal protection was used in part of the patients. We used the CGW because the vascular diameter at the site of EPD placement was <3.5 mm, but the CGW is considered to have more advantages than filter-type EPDs including FWEZ and Spider FX (Medtronic). First, the CGW is more reliable for the prevention of intraoperative embolism. Next, it is considered to have more procedural advantages since the tip profile is 3.2 F in FWEZ and Spider FX but 2.8F in the CGW, and the thinness of the device leads to its better passability. Also, if the struts of Precise stent are erected, its retrieval with a retrieval sheath may become difficult. On the other hand, according to the literature, about 10% of the patients are intolerant to interruption of blood flow with a balloon type EPD,\textsuperscript{18,19} and there is a risk of the occurrence of ischemic neurologic symptoms at some frequency, necessitating the consideration of sedation or general anesthesia in patients with low ischemic tolerance.

Moreover, the percent stenosis after stent-assisted PTA at this site has been reported to be high at 12.9–23.5%,\textsuperscript{11,20} but no restenosis was observed in the six cases reported here during a mean follow-up period of 28 (7–66) months. While Ito et al.\textsuperscript{11} reported that the mean residual percent stenosis was 20% (10–40%) in four patients who developed restenosis after 6–14 months, it was 10% (0–27%) in our six patients, which is considered to partly explain the absence of restenosis.

Although the procedure of CAS for distal cervical ICA stenosis near the carotid canal was similar to that of CAS for stenosis at the bifurcation of the cervical ICA, there were characteristic findings to be noted concerning the following two aspects.
**Stent navigation**

Since the stent is placed in the tortuous part of the ICA from the proximal petrous segment to the distal cervical segment, stent navigation and placement were expected to pose problems. As, in the first case, a stent 40 mm long was difficult to navigate to a point near the posterior loop, using short stents ≤30 mm long for smooth navigation of the stent and overlapping stents for coverage of the entire lesion as in Cases 1, 4, and 6 depending on the lesion length were considered appropriate. While the Precise stent could be guided in all our patients, the use of the Wingspan stent (Stryker Neurovascular, Kalamazoo, Michigan, USA), which has a shiner shaft and is less rigid than Precise, is considered to be an option when stent navigation is extremely difficult.

**Calcification**

If calcified plaque is present in the ICA running in the carotid canal, there is a possibility that inflation of the balloon causes damages to the vascular wall surrounded by the carotid canal and calcified plaque. Therefore, it is considered important to check the presence or absence of calcified plaque in the carotid artery in the carotid canal by preoperative CTA. If calcified plaque is detected by CTA, it is considered safe to avoid applying excessive dilatation pressure by slowly inflating a balloon with a diameter smaller than the estimated normal vascular diameter.

### Conclusion

Six patients who underwent CAS using the EPD for distal ICA stenosis near the carotid canal were presented. CAS using EPD is considered an effective treatment option for ICA stenosis at this site.

### Disclosure Statement

Neither the first author nor any of the coauthors have any conflicts of interest.

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