Online April 19, 2023
Journal of Neuroendovascular Therapy 2023; 17: 101–106 DOI: 10.5797/jnet.cr.2023-0003

Case Report

# Carotid Artery Stenting Using Stent-in-Stent Technique with a Closed-Cell Stent and a Dual-Layer Micromesh Stent: A Case Report

*Yoshitaka Yamaguchi,[1] Tatsuro Takada,[1] Kazuki Uchida,[2] Kei Miyata,[2] Kota Kurisu,[2] Tomohiro Okuyama,[2] Fumiki Tomeoka,[1] Minoru Ajiki,[1] Masaaki Hokari,[2] and Katsuyuki Asaoka[2]*

**Objective:** Recent studies evaluating plaque protrusion at carotid artery stenting (CAS) using optical coherence tomography showed not a few cases of plaque protrusion when using double-layer micromesh stents. We report a case of symptomatic internal carotid artery (ICA) stenosis with at-risk unstable plaques in which CAS was successfully performed using a stent-in-stent technique by the combined use of a closed-cell stent and a dual-layer micromesh stent.
**Case Presentation:** An 87-year-old Japanese man with dysarthria and right hemiparesis was diagnosed with atheromatous cerebral embolism caused by severe left ICA stenosis on MRI and DSA. MRI with T1-weighted black blood methods showed high intensities in the plaques of the left ICA, suggesting unstable plaque characteristics with intraplaque hemorrhage components. On day 20, CAS was performed. After the pre-stent dilation under proximal and distal protection, a Carotid WALLSTENT was placed to cover the stenotic lesion. Then, a CASPER Rx was placed from the proximal left ICA to the common carotid artery to cover the Carotid WALLSTENT. Although visible plaque debris was recognized in the aspirated blood, the debris became invisible after aspiration of 1300 mL. Postoperative angiography showed enough dilation of the left ICA, with no plaque protrusion or acute stent thrombosis. The patient had an uneventful postoperative course and was discharged without any neurological sequelae.
**Conclusion:** The present case suggests that the combined stent-in-stent technique using a closed-cell stent and a micromesh stent can be considered as one of the treatment strategies for preventing plaque protrusion and procedural ischemic complications in patients with high-risk carotid plaques.

**Keywords** carotid artery stenting, closed-cell stent, dual-layer micromesh stent, plaque protrusion

## Introduction

Carotid artery stenting (CAS) has been recognized as an alternative to carotid endarterectomy (CEA) for the prevention of ischemic stroke in selected patients with contraindications to CEA due to high-risk physiological or anatomical factors.[1)] Despite the development of devices for CAS, ischemic complications occasionally occur. The rate of periprocedural ischemic complications during CAS has been reported to be 2.6% to 6.0%,[2,3)] slightly higher than that of CEA.

The risk factors associated with periprocedural ischemic complications related to CAS include high age, plaque morphology, use of open-cell stents, stent thrombosis, and in-stent plaque protrusion.[4–6)] Although in-stent plaque protrusion and stent thrombosis are relatively rare, with incidences of 7.8% to 10% in patients with CAS,[7,8)] they can be associated with a high incidence of symptomatic ischemic stroke.[4,5)] Thus, the strategy to prevent in-stent plaque protrusion, including appropriate device selection, is essential for averting periprocedural ischemic complications during CAS.[4,6)]

Double-layer micromesh stents, which have recently entered clinical use, have been shown to be more useful for

[1]*Department of Cerebrovascular Medicine, Teine Keijinkai Hospital, Sapporo, Hokkaido, Japan*
[2]*Department of Neurosurgery, Teine Keijinkai Hospital, Sapporo, Hokkaido, Japan*

Received: February 2, 2023; Accepted: March 31, 2023
Corresponding author: Yoshitaka Yamaguchi. Department of Cerebrovascular Medicine, Teine Keijinkai Hospital, 12-1-40, 1-jo, Maeda, Teine-ku, Sapporo, Hokkaido 006-8555, Japan
Email: y.yamaguchi830@gmail.com

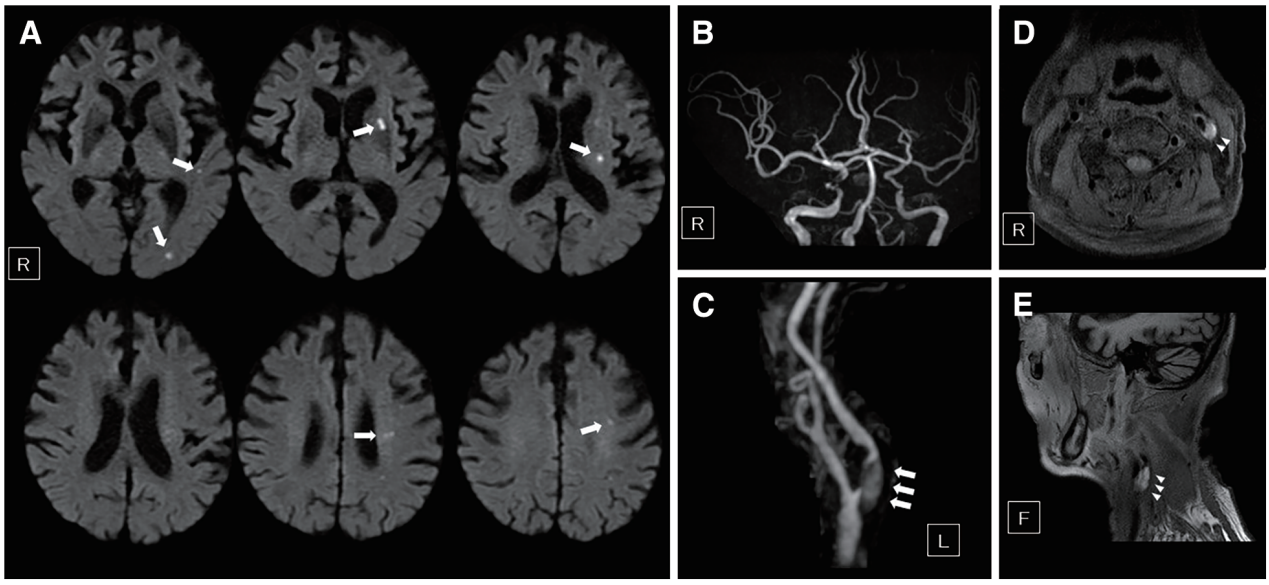


**Fig. 1** Brain MRI on admission shows hyperintense lesions on diffusion-weighted imaging in the territories of the left middle cerebral artery, including the left putamen, corona radiata, and posterior lobe (**A**, arrows). Although 3D time-of-flight MRA of his brain does not show any occluded vessel, the intensities of the left middle cerebral artery are decreased (**B**). 3D time-of-flight MRA of his neck shows severe stenosis at the origin of the left internal cerebral artery with intraplaque high intensities (**C**, arrows). MRI with T1-weighted black blood methods shows high intensities in the plaques at the left ICA suggesting the presence of intraplaque hemorrhages (**D**: axial view and **E**: longitudinal view, arrowheads). ICA: internal carotid artery

preventing periprocedural ischemic complications than conventional stents because of the smaller free cell areas.[9] However, recent studies that examined plaque protrusion with the use of double-layer micromesh stents measured by optical coherence tomography (OCT) reported the incidence of plaque protrusion in double-layer micromesh stents to range from 10.8% to 44%,[10,11] although the incidence rate and the amount of plaque protrusion were lower than with conventional stents.[10] The results suggest that we cannot necessarily prevent plaque protrusion even when using dual-layer micromesh stents. We present herein a unique case of symptomatic internal carotid artery (ICA) stenosis with at-risk soft and unstable plaques in which CAS was successfully performed using a stent-in-stent technique by the combined use of a closed-cell stent and a micromesh stent for preventing plaque protrusion and ischemic procedural complications.

## Case Presentation

An 87-year-old Japanese man was admitted to our hospital about 17 hours after the onset of dysarthria and mild right hemiparesis with a National Institutes of Health Stroke Scale score of 1. He had a history of hypertension, diabetes mellitus, dyslipidemia, chromic heart failure, and coronary heart disease treated by percutaneous coronary intervention two months prior to admission and maintenance dual antiplatelet therapy (DAPT) with prasugrel 3.75 mg and aspirin 100 mg. He had a past history of cigarette smoking (Brinkman index 300: 10 cigarettes per day × 30 years). On admission, diffusion-weighted imaging (DWI) of brain MRI showed hyperintense lesions in the left temporal lobe, occipital lobe, putamen, and corona radiata (**Fig. 1A**). Although his 3D time-of-flight MRA did not show any occluded vessel in his brain, there was severe stenosis at the origin of his left ICA with intraplaque high intensities[12] (**Fig. 1B** and **1C**). MRI with T1-weighted black blood methods showed high intensities in the plaques at the left ICA suggesting intraplaque hemorrhages components[13,14] (**Fig. 1D** and **1E**). DSA showed severe stenosis of the left ICA. The diameter of the left common carotid artery (CCA) was 5.7 mm, that of the left ICA was 4.4 mm, and that of the stenotic lesion was 0.8 mm, indicating 82% stenosis measured by the North American Symptomatic Carotid Endarterectomy Trial angiography method (**Supplementary Fig. 1**). Carotid ultrasonography showed severe stenosis, with area stenosis of 98% and peak systolic velocity of greater than 4 m/s at the origin of the left ICA (**Supplementary Fig. 2A–2C**), and the characteristics of the plaques were hypoechoic, suggesting the presence of soft plaques. Thus, he was diagnosed with atheromatous cerebral embolism due to severe stenosis of the left ICA. Moreover, the plaques in the left ICA were considered at-risk soft and unstable with intraplaque hemorrhage components.[13,14]

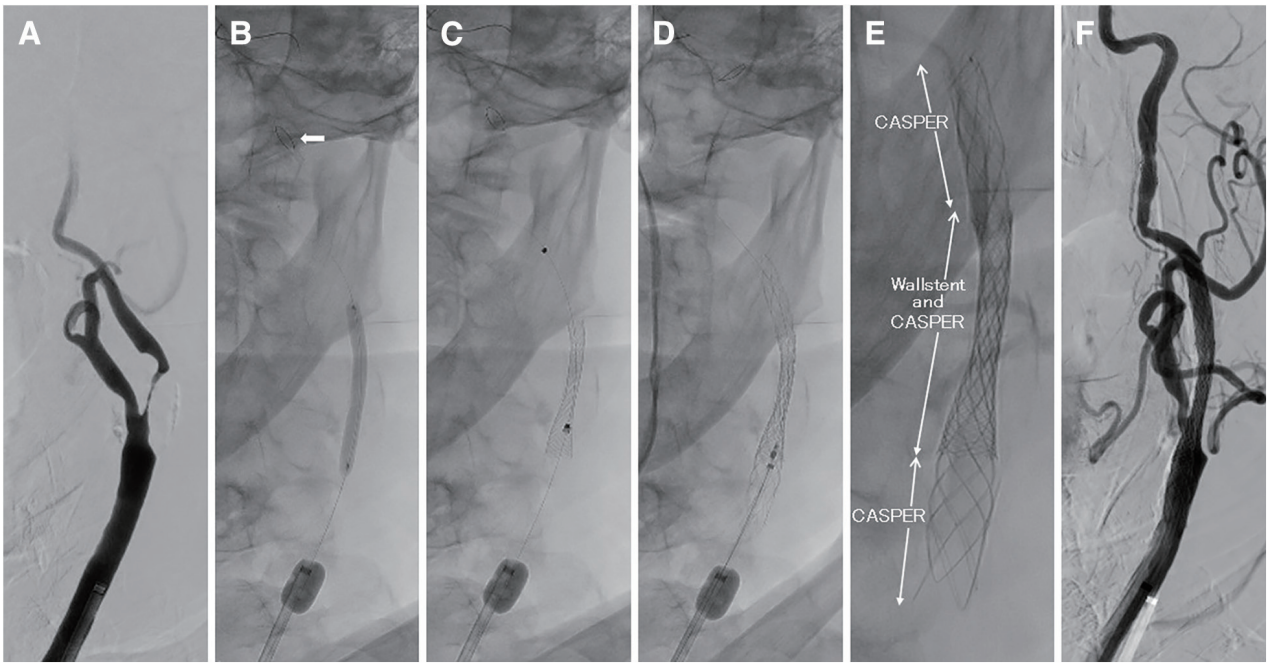


**Fig. 2** Frontal views during CAS. After the balloon of the 9-Fr Optimo balloon guiding catheter located in the distal left CCA (**A**) is inflated (**B**), a FilterWire EZ embolic protection system is advanced to the distal ICA (**B**, arrow). Pre-stent dilation is performed using a Sterling balloon dilatation catheter 4.0 mm × 40 mm (**B**). The first stent, Carotid WALLSTENT 6 mm × 22 mm, is placed to cover the stenotic lesion (**C**). The second stent, CASPER Rx 9 mm × 30 mm, is placed from the ICA to the distal CCA covering the Carotid WALLSTENT (**D**). An enlarged figure of the stents shows smaller free cell areas by overlapped stents compared with those of CASPER alone (**E**). Postoperative angiography shows enough dilation of the left ICA with no in-stent plaque protrusion or acute stent thrombosis (**F**). CAS: carotid artery stenting; CCA: common carotid artery; ICA: internal carotid artery

After antithrombotic therapy with DAPT (prasugrel 3.75 mg and aspirin 200 mg) and intravenous argatroban was started, his symptoms improved gradually. On day 8, he developed transient deterioration of his right hemiparesis, although no additional acute infarction was seen on brain MRI. He was maintained on triple antithrombotic therapy with prasugrel, aspirin, and additional cilostazol 100 mg, with no further ischemic attacks. Although the plaque appeared soft and unstable, it was considered that CAS was better than CEA because of the risk factors for CEA, including his high age and the recent coronary heart disease. However, because more than a few incidences of plaque protrusion has been reported during the use of dual-layer micromesh stents,[10,11] there was concern that plaque protrusion might occur due to the fragility of the plaque even when using a micromesh stent. As a strategy for preventing plaque protrusion and plaque-related embolism, CAS using a stent-in-stent technique with a closed-cell stent and a micromesh stent was planned.

On day 20, he underwent CAS under local anesthesia. A 9-Fr Optimo balloon guiding catheter (Tokai Medical Products, Aichi, Japan) was placed in the left CCA via a left femoral artery approach (**Fig. 2A**). Intravenous heparin was administered to maintain an activated clotting time >300 s. When the balloon was inflated as proximal protection, reversed flow status, confirmed by carotid pulse Doppler ultrasonography, was established from the left ICA to the right femoral vein through the guiding catheter. Then, a FilterWire EZ embolic protection system (Boston Scientific, Natick, MA, USA) was carefully navigated to the distal ICA through the stenotic lesion using road-mapping guidance (**Fig. 2B**). Pre-stent dilation of the stenotic lesion was performed with a Sterling balloon dilatation catheter, 4.0 mm × 40 mm (Boston Scientific) (**Fig. 2B**). First, a Carotid WALLSTENT 6 mm × 22 mm (Boston Scientific) was placed to cover the stenotic lesion (**Fig. 2C**). Second, a double-layer micromesh stent CASPER Rx 9 mm × 30 mm (Terumo, Tokyo, Japan) was deployed from the ICA to the CCA covering the Carotid WALLSTENT from the proximal ICA to the distal CCA (**Fig. 2D** and **2E**). Post-stent dilatation was not performed because of concern about plaque protrusion. An aspiration catheter 7-Fr Thrombuster PRO SL (Kaneka-medics, Osaka, Japan) was placed to the stent, and forced aspiration of the blood from the aspiration catheter was performed using 20-mL VacLok syringes (Merit Medical, Tokyo, Japan), and the blood was returned from the right femoral vein via a blood filter Optimo chamber (Tokai Medical Products). The presence of plaque debris was checked at every 100 mL of aspirate

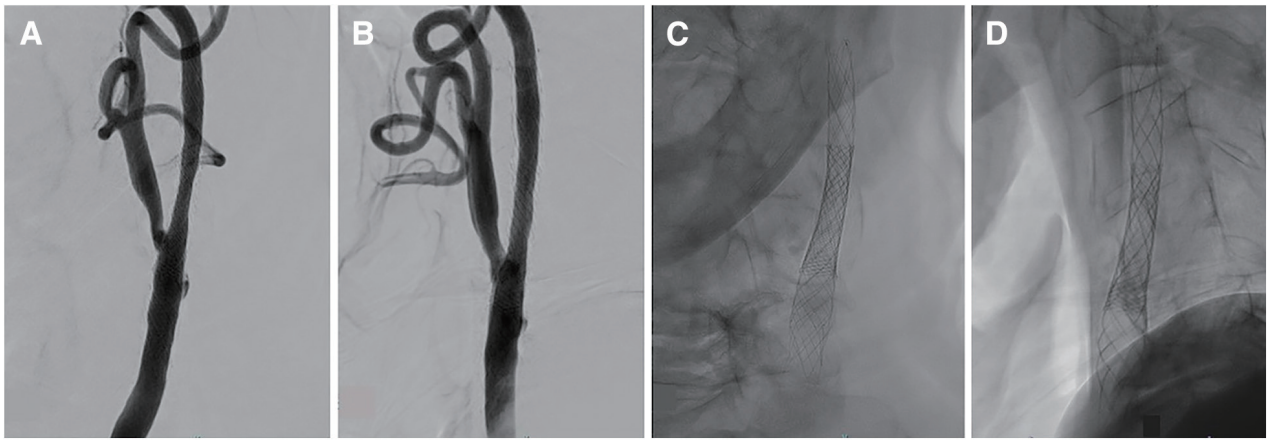


**Fig. 3** DSA 6 months after the operation shows no in-stent restenosis (**A**: frontal view and **B**: lateral view). There is no dislocation between the two stents or migration of the stents (**C**: frontal view and **D**: lateral view).

by filtering 20 mL of aspirated blood through a cell strainer. Although visible plaque debris was recognized in the aspirated blood, the debris became invisible after aspiration of 1300 mL. Postoperative angiography showed enough dilation of the left ICA with no in-stent plaque protrusion or acute stent thrombosis (**Fig. 2F**). Postoperative intracranial angiography showed no embolism. MRI on postoperative day 1 showed no additional cerebral embolic lesion (**Supplementary Fig. 3**). Carotid ultrasonography on postoperative day 1 showed no plaque protrusion and no acute stent thrombosis (**Supplementary Fig. 4A–4C**). The patient's postoperative course was uneventful, and he was discharged without any neurological sequelae on postoperative day 14 on maintenance DAPT with prasugrel 3.75 mg and aspirin 100 mg, and he did not develop any further ischemic events or in-stent restenosis on DSA 6 months after the operation (**Fig. 3A**–**3D**).

## Discussion

To the best of our knowledge, this is the first case report of CAS by a stent-in-stent technique using a closed-cell stent and a micromesh stent. Although preoperative evaluations suggested soft and unstable plaque with intraplaque hemorrhage components, CAS was successfully performed with no plaque-related embolism, plaque protrusion, or acute stent thrombosis.

The stent-in-stent technique was initially used for highly-calcified lesions and later for rescue stenting for plaque protrusion in CAS.[15] Recently, Myouchin et al. investigated the utility of CAS using the stent-in-stent technique with conventional overlapped closed-cell stents (Carotid WALLSTENTs) in 35 patients having carotid artery stenosis with unstable plaques.[16] This study was done before micromesh stents were available for clinical use in Japan. They performed CAS for 35 patients with unstable plaque by stent-in-stent technique using conventional overlapped closed-cell stents. The technical success rate was 100%, and no plaque protrusion or periprocedural ischemic events were observed in the study.[16] During the follow-up period (mean 11.6 months), no ipsilateral stroke occurred. Asymptomatic restenosis and asymptomatic occlusion occurred in only one patient (2.9%) each. The results supported the feasibility and efficacy of the stent-in-stent technique for prevention of ischemic complications associated with CAS, and the benefit of the stent-in-stent technique is considered due to the smaller free cell areas by overlapped stents.[16] They reported that the free cell areas by overlapped closed stents (WALLSTENTs) were theoretically equivalent to or better than those of micromesh stents.

Recently, double-layer micromesh stents have been in clinical use for the treatment of patients with carotid artery stenosis. A meta-analysis of four clinical studies involving CAS patients using double-layer micromesh stents reported that the incidence of periprocedural stroke was 1.08% (6 of 556 patients), lower than with conventional stents.[9] Similar results were reported in a multicenter, prospective study in Japan, in which the major adverse event rate following use of the CASPER stent was low (1.4%).[17] The reason for the lower procedural adverse event rate of the double-layer micromesh stents is mainly considered to be due to the smaller free cell areas compared with those of conventional stents. However, a recent study evaluating plaque protrusion using OCT reported that plaque protrusion was found in 44% patients with the use of CASPER stents,[10] although the rate was lower than with conventional stents.[10] In addition, the rate of plaque protrusion with other micromesh stents assessed by OCT was 10.8% for CGuard (Inspire MD,

Tel Aviv, Israel) and 20.7% for RoadSaver (same product as CASPER; Terumo).[11] Because we cannot necessarily prevent plaque protrusion whatever the stents we use, we should carefully pay attention to the occurrence of plaque protrusion during CAS even with micromesh stents, especially in patients with high-risk carotid plaques. Interestingly, the rate of plaque protrusion was significantly lower for CGuard than RoadSaver ($p = 0.05$). Because the pore sizes of the stents for CGuard are smaller than for RoadSaver (150–180 μm vs 375 μm), the result may suggest that the use of stents with smaller free cell areas reduces the incidence of plaque protrusion even with micromesh stents. Thus, the combined use of a close-cell stent and a micromesh stent in the present case was likely to have produced more complete coverage of the plaque by reducing the free cell areas than with a single micromesh stent and might have prevented plaque protrusion, acute thrombosis, and procedural ischemic complications.

Because the presence of plaque protrusion was not examined using intravascular ultrasound (IVUS) imaging after the first stenting with a Carotid WALLSTENT, whether the combined use with a micromesh stent was needed for preventing plaque protrusion or procedural ischemic complications in the present case should be considered. Moreover, examination of the presence of plaque protrusion using IVUS imaging should also be performed after the second stenting. After the deployment of the two stents in the present case, aspiration of 1300 mL of blood was needed for the debris in the aspirated blood to disappear. If a single stent had been used in the present case, more plaque debris would have been produced through the larger free cell areas. The risk of flow impairment, the so called stop-flow or slow-flow, might have been increased. Aspiration of more blood might have been needed for the disappearance of debris in the aspirated blood, and the time to reperfusion by deflating the balloon catheter might have been extended. Thus, we consider that the risk of procedural ischemic complications would have been increased if a single stent had been used in the present case.

When performing CAS by the stent-in-stent technique for prevention of plaque protrusion, a dual-layer micromesh stent should be combined with a closed-cell stent, rather than an open-cell stent, because of the smaller free cell areas. In the combination of two stents, a closed-cell stent should be an outer stent because a closed-cell stent has a risk of malapposition[15] between the two stents if used as an inner stent. In addition, a closed-cell stent should be placed at stenotic lesion with a short length in a matched-vessel diameter, because a long closed-cell stent, especially when there is mismatch between CCA and ICA diameters, has a risk of shortening of the stent and can result in slipping of the two stents from the intended position.[15] Moreover, because overlapped stenting has been reported to be an important factor associated with intraoperative or postoperative hypotension among CAS patients,[18] blood pressure should be carefully controlled when performing the stent-in-stent technique, especially for patients with heart diseases. From the perspectives of medical economics, it may not be appropriate to treat all unstable plaques using the stent-in-stent technique that combines the use of a closed-cell stent and a dual layer micromesh stent, because most cases with unstable plaques might be treated successfully by a single dual-layer micromesh stent or a single closed-cell stent. Thus, the indication of the combined stent-in-stent technique should be limited to plaques with a particularly high risk, such as those with abundant intraplaque hemorrhagic components.[19]

Whether there is an increased risk of in-stent restenosis at CAS by the stent-in-stent technique with a closed-cell stent and a micromesh stent compared with CAS using a single micromesh stent remains unclear. Although the precise pathology of in-stent restenosis after CAS has not been fully clarified, the major cause of in-stent restenosis after CAS is believed to be neointimal hyperplasia induced by vessel injury from chronic mechanical stress of the stents.[20] In the present case, because the closed-cell stent was used only for covering the stenotic portion at the ICA for a short length, the straightening effect, a characteristic of closed-cell stents, may almost be ignored. Thus, the mechanical stress from the closed-cell stent to the vessel wall might be limited. Evaluation of more cases and further research are needed to clarify the risk of in-stent restenosis after CAS by the stent-in-stent technique using a closed-cell stent and a micromesh stent.

## Conclusion

A case of symptomatic ICA stenosis with unstable plaques successfully treated by CAS using the stent-in-stent technique with a closed-cell stent and a micromesh stent is described. The present case suggests that the combined stent-in-stent technique using a closed-cell stent and a micromesh stent can be considered as one of the treatment strategies for preventing plaque protrusion and procedural ischemic complications in CAS patients with high-risk carotid plaques.

## Disclosure Statement

The authors declare that they have no conflicts of interest.

## Supplementary Information

Supplementary files are available online.

### Supplementary Fig. 1

DSA shows 82% stenosis of the left ICA measured using the North American Symptomatic Carotid Endarterectomy Trial angiography method (arrows) (**A**: frontal view and **B**: lateral view). ICA: internal carotid artery

### Supplementary Fig. 2

Carotid ultrasonography shows severe stenosis with hypoechoic carotid plaques in the origin of the left ICA (**A**: longitudinal view and **B**: axial view). The rate of area stenosis is 98% (**B**), and peak systolic velocity is greater than 4 m/s (**C**). CCA: common carotid artery; ICA: internal carotid artery

### Supplementary Fig. 3

MRI on postoperative day 1.

### Supplementary Fig. 4

Carotid ultrasonography on postoperative day 1 shows no plaque protrusion and no acute stent thrombosis (**A**: B-mode, and **B** and **C**: color Doppler).

## References


1) Massop D, Dave R, Metzger C, et al. Stenting and angioplasty with protection in patients at high-risk for endarterectomy: SAPPHIRE worldwide registry first 2,001 patients. *Catheter Cardiovasc Interv* 2009; 73: 129–136.
2) Brott TG, Hobson RW II, Howard G, et al. Stenting versus endarterectomy for treatment of carotid-artery stenosis. *N Engl J Med* 2010; 363: 11–23.
3) Rosenfield K, Matsumura JS, Chaturvedi S, et al. Randomized trial of stent versus surgery for asymptomatic carotid stenosis. *N Engl J Med* 2016; 374: 1011–1020.
4) Kotsugi M, Takayama K, Myouchin K, et al. Carotid artery stenting: investigation of plaque protrusion incidence and prognosis. *JACC Cardiovasc Interv* 2017; 10: 824–831.
5) Beppu M, Mineharu Y, Imamura H, et al. Postoperative in-stent protrusion is an important predictor of perioperative ischemic complications after carotid artery stenting. *J Neuroradiol* 2018; 45: 357–361.
6) Funatsu N, Enomoto Y, Egashira Y, et al. Tissue protrusion with attenuation is associated with ischemic brain lesions after carotid artery stenting. *Stroke* 2020; 51: 327–330.
7) Chiocchi M, Morosetti D, Chiaravalloti A, et al. Intravascular ultrasound assisted carotid artery stenting: randomized controlled trial. Preliminary results on 60 patients. *J Cardiovasc Med (Hagerstown)* 2019; 20: 248–252.
8) Shinozaki N, Ogata N, Ikari Y. Plaque protrusion detected by intravascular ultrasound during carotid artery stenting. *J Stroke Cerebrovasc Dis* 2014; 23: 2622–2625.
9) Stabile E, de Donato G, Musialek P, et al. Use of dual-layered stents in endovascular treatment of extracranial stenosis of the internal carotid artery: results of a patient-based meta-analysis of 4 clinical studies. *JACC Cardiovasc Interv* 2018; 11: 2405–2411.
10) Yamada K, Yoshimura S, Miura M, et al. Potential of new-generation double-layer micromesh stent for carotid artery stenting in patients with unstable plaque: a preliminary result using OFDI analysis. *World Neurosurg* 2017; 105: 321–326.
11) Umemoto T, de Donato G, Pacchioni A, et al. Optical coherence tomography assessment of new generation mesh-covered stents after carotid stenting. *EuroIntervention* 2017; 13: 1347–1354.
12) Yoshimura S, Yamada K, Kawasaki M, et al. High-intensity signal on time-of-flight magnetic resonance angiography indicates carotid plaques at high risk for cerebral embolism during stenting. *Stroke* 2011; 42: 3132–3137.
13) Moody AR, Murphy RE, Morgan PS, et al. Characterization of complicated carotid plaque with magnetic resonance direct thrombus imaging in patients with cerebral ischemia. *Circulation* 2003; 107: 3047–3052.
14) Brinjikji W, Lehman VT, Huston J 3rd, et al. The association between carotid intraplaque hemorrhage and outcomes of carotid stenting: a systematic review and meta-analysis. *J Neurointerv Surg* 2017; 9: 837–842.
15) Musiałek P, Roubin GS. Commentary: Double-layer carotid stents: from the clinical need, through a stent-in-stent strategy, to effective plaque isolation... the journey toward safe carotid revascularization using the endovascular route. *J Endovasc Ther* 2019; 26: 572–577.
16) Myouchin K, Takayama K, Wada T, et al. Carotid artery stenting using a closed-cell stent-in-stent technique for unstable plaque. *J Endovasc Ther* 2019; 26: 565–571.
17) Imamura H, Sakai N, Matsumoto Y, et al. Clinical trial of carotid artery stenting using dual-layer CASPER stent for carotid endarterectomy in patients at high and normal risk in the Japanese population. *J Neurointerv Surg* 2021; 13: 524–529.
18) Ishii D, Sakamoto S, Okazaki T, et al. Overlapped stenting is associated with postoperative hypotension after carotid artery stenting. *J Stroke Cerebrovasc Dis* 2018; 27: 653–659.
19) Zhao G, Tang I, Tang H, et al. Predictors of ipsilateral new ischemic lesions on diffusion-weighted imaging after carotid artery stenting in asymptomatic patients: a retrospective observational study with conventional multicontrast MRI. *Ann Vasc Surg* 2021; 74: 95–104.
20) Clark DJ, Lessio S, O'Donoghue M, et al. Mechanisms and predictors of carotid artery stent restenosis: a serial intravascular ultrasound study. *J Am Coll Cardiol* 2006; 47: 2390–2396.