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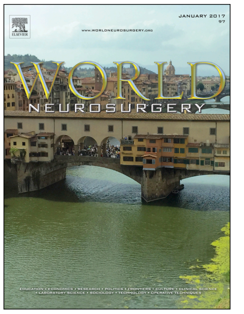

High-Cervical Carotid Endarterectomy - Outcome Analysis

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High-Cervical Carotid Endarterectomy - Outcome Analysis

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Keywords:

CEA, High-cervical-lesion, post-operative stroke

Abbreviations:

CEA; carotid endarterectomy, mRS; modified Rankin Scale SCM; sternocleidomastoid muscle, OA; occipital artery, DWI; diffusion weighted image, TRCI; technique related cerebral infrction, PRCI; perioperative related infarction, CN; cranial nerve, CAS; carotid artery stenting, ICH; intracranial hemorrhage, MRI; magnetic resonance imaging, ACT; activated whole blood clotting time, SPECT; single photon emission computed tomography, ASL; arterial spin labeling

ABSTRACT:

OBJECTIVE)

Carotid endarterectomy (CEA) for high cervical internal carotid artery stenosis is considered to be technically demanding because of the difficulty to dissect the distal end. We report the surgical technique and outcome analysis of CEA for high-cervical lesion.

METHODS)

We retrospectively analyzed the records of 98 patients treated by CEA from December 2013 to June 2018. The plaque positions rostral to the C2 vertebral level was defined as the high-cervical lesions (n = 34).

SURGICAL TECHNIQUE:

Successful expose the distal end included following elements:

1 Extending the skin incision

2 Exposure of Great auricular nerve maximally

3 Dissection between the SCM and Parotid gland fascia

4 Resection of internal deep cervical lymph nodes

5 Retraction of digastric muscle, hypoglossal nerve, and occipital artery

RESULTS)

There were 8 cases (High-cervical group: 4 cases, Non-high-cervical group: 4 cases) of postoperative DWI high signal and 6 cases (3 cases, 3 cases) of symptomatic ischemic lesion. 4 cases belonged to the technique related cerebral infarction (TRCI) group and 4 cases to the perioperative related cerebral infarction (PRCI) group. High-cervical lesion is not considered to be a risk factor for either PRCI (P = 0.610) or TRCI (P = 0.610). The difference of the diastolic blood pressure between the preoperative period and the 2nd postoperative day showed a risk factor of PRCI (P = 0.033).

CONCLUSION)

The surgical outcomes for High-cervical lesions are equivalent to that of Non-high-cervical lesions. Excessive blood pressure management from the early postoperative days will be a risk of PRCI.

Introduction:

Several trials have shown carotid endarterectomy (CEA) to be superior to medical management for the prevention of stroke in patients with symptomatic or asymptomatic carotid artery stenosis.[1-3] Surgical results of CEA have been demonstrated to be equivalent or superior to carotid artery stenting (CAS) with numerous large-scale clinical trials being conducted.[4, 5] However, with the progress of neuroendovascular treatment in recent years[6] and the fact that CEA takes time to master the surgical techniques, the number of CEA procures performed is considerably lower than CAS at present. In particular, CEA for High-cervical internal carotid artery stenosis is considered to be especially technically demanding due to the difficulty of dissecting the distal end. To deal with this, various surgical procedures have been reported in the literature.[7-9] However, it has been reported that complications such as occlusion occurred in about 10% of cases when using a filter device in intravascular therapy, and when dealing with unstable plaques, there are cases where CEA is desirable even for High-cervical lesions.[10]

The aim of this study is to describe the surgical technique of high-cervical CEA and to analyse outcome related risk factors.

Objective & Method:

This study was approved by institutional review board and approved waiver for the requirement of patients consent. 112 patients were treated by CEA from December 2013 to June 2018 in Sapporo Teishinkai Hospital. This includes emergency CEA cases which were operated on within 24 hours after stroke. Surgical cases of internal carotid artery occlusion by cardiogenic embolization (N=14) were excluded because it is difficult to evaluate the distal end of stenosis before and during surgery. Finally, we examined patient background, anatomical features, surgical results and postoperative complications in 98 patients (Table 1).

A plaque position rostral to the C2 vertebral level was defined as a High-cervical lesions (N=34). [11]

According to Japanese stroke guideline 2015, for symptomatic lesions, those with a stenosis rate of ≧50% (NASCET) were indicated for treatment. For asymptomatic lesions on the other hand, treatment was indicated for those with ≧60% stenosis or when unstable plaque was suspected.

Prior to surgery, coronary artery assessment was performed and preceded by percutaneous coronary intervention if necessary.

During the perioperative period, single antiplatelet agent was continued, and when an anticoagulant was used, heparin substitution was performed.

Postoperative blood pressure control is performed to prevent re-bleeding. If hyperperfusion state is suspected based on clinical and imaging results (Ex: 99mTc-HMPAO, 123 I-IMP, MRI), strict blood pressure control is performed to prevent cerebral hemorrhage. Hyperperfusion state is defined by unilateral headache, face & eye pain, seizure and focal symptoms related to cerebral edema or ICH.[12]

We evaluate the following 5 articles for surgical outcome:

1) Stroke.

We check the diffusion high signal on postoperative MRI imaging, and reviewed whether the lesion is symptomatic or not.

Risk factors were studied by dividing the postoperative DWI high cases into 2 groups: a technique related cerebral infarction (TRCI) group that became positive by MRI immediately after surgery and a perioperative related cerebral infarction (PRCI) group that became positive after the day of surgery.

2) Hyperperfusion rate.

After the operation, if the patient demonstrates symptoms of hyperperfusion state, we check the SPECT or MRI (ASL: Arterial Spin Labeling, T2 weighted image). We confirmed whether hyperperfusion findings or intracerebral hemorrhage were present.

3) Hypoglossal nerve palsy.

We confirmed whether hypoglossal nerve palsy is transient or permanent.

4) Deterioration of mRS.

Preoperative, discharge, and 6 months after discharge mRS were compared to assess deterioration, and a decrease of one or greater was considered to be mRS deterioration.

5) Mortality.

Surgical technique (Fig. 1-3):

We perform the CEA under general anesthesia with oral intubation. The entire CEA is performed under a microscope, from skin-to-skin. We use a bipolar cutting technique to detach tissues. In the field of operation, mobilization of soft tissues and muscles is carried out while maintaining appropriate tension by using skin hooks with rubber bands, which are very useful for dissecting tissue smoothly and achieving hemostasis.

In all cases, indwelling double-balloon shunt system[13] was used. Before placing the double-balloon shunt system, we intravenously injected 3,000 IU of heparin and controlled the ACT (activated whole blood clotting time) to around the target of about 2 times the previous value.

When we have to dissect the distal end of a High-cervical lesion, we develop the surgical field while paying attention to the following 5 points.

1) Extending the skin incision.

In Non-high-cervical cases, skin incision was planned along the skin folds, and extended toward the posterior border of mastoid process. When we have to approach for a High-cervical lesion, we extend the distal edge of the skin incision just behind the posterior border of mastoid process with a slight curve.

2) Exposure of Great auricular nerve maximally.

After dissecting the platysma muscle, great auricular nerve can be confirmed cranially from the upper edge of the platysma muscle. Great auricular nerve is sufficiently retracted from parotid gland fascia and sternocleidomastoid muscle (SCM) so that the skin can be widely opened. We preserved the nerve as much as possible. Finally, we can expose the surface of SCM very widely.

3) Dissection between the SCM and Parotid gland fascia.

The upper end of SCM is sufficiently dissected from parotid gland fascia to increase the spread of SCM toward the dorsal side and parotid gland toward the cranial side. It is important that we don’t have to injure the parotid gland. If the parotid gland is damaged, postoperative salivary leaks may appear and may require long-term conservative treatment or re-operation.

4) Resection of internal deep cervical lymph nodes.

Internal deep cervical lymph nodes are around the internal jugular vein. In particular, by resecting the superior internal deep cervical lymph node existing on the internal jugular vein, it becomes possible to pull the cranial side of the internal jugular vein toward the dorsal side. Furthermore, by sacrificing the common facial vein in addition to the removal of the lymph node, the internal jugular vein can be further pulled to the dorsal side with the SCM. This can contribute to securing a wide range of surgical fields.

5) Retraction of digastric muscle, hypoglossal nerve, and occipital artery (OA).

We can detect the digastric muscle easily after the resection of the superior deep cervical lymph node. In order to lift up the hypoglossal nerve, ansa cervicalis can be cut at its origin. The hypoglossal nerve should be pulled up gently with vascular tape. If the OA disturbs the traction of the hypoglossal nerve, it can be cut.

Results:

[Clinical characteristics and patient background]

The degree of stenosis and plaque length in the High-cervical group tends to be narrower and longer than in the Non-high-cervical group (Table 1). However, there are no remarkable differences regarding the risk factors (Hypertension, Diabetes mellitus, Dyslipidemia, Smoking, Cardiovascular disease, and previous Stroke) between the High-cervical group and Non-high-cervical groups.

[Outcome]

For postoperative DWI high signal and symptomatic ischemic lesion, both groups had 4% and 3% respectively (Table 2). Observed symptoms included numbness, weakness, and cognitive dysfunction. Among the 8 cases showing postoperative DWI positive, 4 cases belonged to the TRCI group and 4 cases to the PRCI group. In addition, 2 High-cervical lesions and 2 Non-high-cervical lesions were each included in both groups (Table 3-4). Although univariate analysis was used to examine the risk factors for TRCI, no significant difference was found in any of the variables, and the High-cervical group did not become a risk factor. The PRCI group was analyzed as well, and the High-cervical group showed no significant difference. Furthermore, when perioperative blood pressure was analyzed, the mean blood pressure from immediately after the operation through to the third postoperative day showed no significant difference. However, when the difference between the preoperative diastolic blood pressure and the postoperative diastolic blood pressure was examined, the same value on the second postoperative day showed a significant difference (P = 0.033). Although there was no significant difference on the 1st and 3rd postoperative days, they did tend to be risk factors (P = 0.159, 0.059).

As for hyperperfusion state, it seemed to be somewhat higher in the Non-high-cervical group, but no patients exhibited intracranial hemorrhage.

Regarding hypoglossal nerve palsy, transient palsies were found in 4% and 2% of the High-cervical lesion group and Non-high-cervical group, respectively, but no persistent palsy was observed.

Those showing one or more mRS deterioration at discharge were 7% and 6%, respectively. That of 6 months after discharge were 3% and 1%, respectively.

Mortality rate was 1% in Non-high-cervical group, which was death due to ischemic colitis associated with postoperative hyperperfusion.

There was no statistically significant difference between the two groups, for any of these metrics.

Risk factors were examined with respect to the appearance of mRS deterioration, postoperative DWI high, and ischemic complications (acute renal failure, ischemic colitis, acute myocardial ischemia) after CEA surgery (Table 5-7, respectively) .

Risk factors were compared between the deterioration and non-deterioration groups of postoperative mRS. The only variable showing a statistically significant difference was the appearance of postoperative cranial nerve symptoms ($p = 0.003$). Postoperative DWI positive ($p = 0.070$), postoperative cerebral infarction ($p = 0.439$), hyperperfusion syndrome ($p = 0.618$), and postoperative acute renal failure / ischemic colitis ($p = 0.249$ / 0.249) did not demonstrate a statistically significant difference.

Risk factors for cases with postoperative renal failure / ischemic colitis were evaluated. Emergency surgical cases showed a statistically significant difference ($p = 0.007$). Although it was not statistically significant, history of postoperative blood pressure and diabetes tended to show a marked difference, compared to other factors.

Discussion:

[Surgical outcome of High-cervical lesion]

There are some reports about the risk of CEA for the High-risk patients[14]. Rao et al reported that high-risk physiology or anatomy was associated with higher rates of 30-day stroke/death compared with normal-risk patients[15]. But the surgical outcomes for High-cervical lesions in our institute are equivalent to that of Non-high-cervical lesions . High cervical lesions were not a statistically significant risk factor for either postoperative DWI high factor or postoperative deterioration of mRS. In order to perform the CEA for a High-cervical lesion safely, it is important to be conscious of the various tissue layers from the first moment of skin incision. Katsuno et al said that they can get a wide operation field by wide range dissection of shallow anatomical structures without special techniques[16]. Sufficiently retracting the layers at each of the previously mentioned stages greatly contributes to securing a deep operative field. Also, in order to safely perform this step-wise retraction of tissue, the accurate identification of structures and safe mobilization and exposure of tissues are indispensable techniques fundamentally based on comprehensive anatomical knowledge.

When retracting and exposing tissue, it is critical to proceed under complete hemostasis and while using a microscope for visualization. If bleeding occurs during detachment, blood infiltrates the soft tissue and can make it difficult to identify the normal detachment border. In that case, it is possible to improve border distinction to a certain extent by repeated irrigation with saline.

In addition, bipolar cutting is a technique capable of retraction under hemostasis, and allows for the surgery to proceed both rapidly and safely. In particular, it is a very useful technique in CEA because the antiplatelet agent continues over the perioperative period. Despite its usefulness, it does require a certain degree of training, and therefore it is considered important to observe the skills of proficient surgeons and receive guidance when learning the technique.

The height of the carotid artery bifurcation in Japanese people is from the center to the lower border of the third cervical vertebral body, which is 1 vertebral body higher than that of Westerners.[17] Because of this, the distal edge of stenosis in Japanese patients tends to be higher. In verification of self-test cases, the length of stenosis of High-cervical lesions tends to be longer than that of Non-high-cervical lesions, and a procedure to secure beyond C2 for CEA in Japanese patients is an essential technique.

The surgical outcome of CEA for High-cervical lesions at our institution was comparable to that of Non-high-cervical lesions. Postoperative stroke occurred in 3% of High-cervical lesion cases and in 3% of Non-high-cervical cases. Among those, 2% and 1% were found to have deterioration of mRS, respectively. However, for all cases showing this reduction, mRS at the time of discharge was 1.

[Risk factor for postoperative DWI lesions and mRS deterioration]

CEA cannot be performed without securing the distal end of the plaque. In CEA for high-cervical lesions, it tends to be difficult to secure the plaque's distal end. We examined the results of the postoperative cerebral infarction group, which was subdivided into technique (TRCI) and perioperative related cerebral infarction (PRCI) groups; High-cervical lesion is not considered to be a risk factor for either PRCI or TRCI. Therefore, it can be said that the surgical procedure for High-cervical lesions at our hospital can secure the distal end of the plaque safely.

In some studies, systolic blood pressure is reported to be associated with perioperative stroke [18]. In our study, with regard to PRCI, it was the difference between preoperative diastolic blood pressure and postoperative diastolic blood pressure on the second postoperative day that was determined to be statistically significant. On the 1st and 3rd postoperative days, although there was no statistically significant difference, diastolic blood pressure difference did tend to be a risk factor. As perioperative management, the use of excessive antihypertensive therapy in postoperative bleeding prevention and hyperperfusion preventive management may both be risk factors for PRCI. In this study, it is considered plausible that there was no significant difference seen between the 1st and 3rd postoperative days due to the small number of treatment cases, and so it is necessary to further increase the number of cases for consideration.

With regards to hyperperfusion syndrome, by performing strict blood pressure management in our hospital, no cases demonstrating permanent neurologic symptoms due to hyperperfusion were observed. As an index of blood pressure, we manage the lowest value as a target, at which time a urine volume of 1.0 ml / kg is secured with reference to mean pressure. Fortunately, in patients with hyperperfusion at our hospital, no cases showed postoperative DWI high. There are reports which state that shunting during the CEA perioperative period reduces the risk of hyperperfusion after surgery

[19]. In our hospital, we used a double-balloon shunt in all cases, which seems to reduce the risk of hyperperfusion by shortening the intraoperative ischemic time as much as possible. However, it can be said that it is safer to refrain from performing strict blood pressure management for cases suspected of asymptomatic hyperperfusion by SPECT or MRI in order to avoid the risk of cerebral infarction.

[Risk factor of postoperative systemic ischemic complications (renal failure, ischemic colitis, acute myocardial infarction)]

Risk factors related to postoperative systemic ischemic complications were examined, but only emergent surgical case was a risk factor with significant difference. During emergency surgery, it appears that there is a high possibility of systemic complications due to insufficient systemic examination before surgery, as well as strong stress to the body as a whole within the acute phase of cerebral infarction. Blood pressure difference between pre- and postoperative measurements tended to be a risk factor. This may be related to the acute phase blood pressure management on the 1^{st}–2^{nd} postoperative days described above, which becomes a risk factor of postoperative DWI high. However, unlike postoperative DWI high factors, there was a tendency that the blood pressure difference on the 3rd day, more so than the 1st and 2nd postoperative day, became a risk factor. In systemic arteriosclerosis cases, it is considered to be a cause of reduced renal blood flow / intestinal blood flow due to excessive blood pressure control. Therefore, it is considered that continuing the strict blood pressure management even after 3 days postoperatively is likely to increase postoperative organ ischemic complications. As a matter of course, we believe that it is important to conduct systemic arteriosclerosis examinations as much as possible, even during emergency surgery.

Also, although diabetes tended to be a risk factor for postoperative ischemic complications, there was no significant difference. It has been reported that diabetes is a risk of cardiovascular disease[20], and is a common mechanism that causes arteriosclerosis and is considered to be a risk factor for postoperative ischemic complications. Our hospital sets strict blood glucose control as one of its surgical standards. Due to strict blood glucose control, it seems that diabetes did not lead to a significant difference as a risk factor. In the future, it is possible that strict preoperative blood glucose control becomes important part of perioperative risk management.

In addition, no cases of acute myocardial infarction occurred after CEA surgery at our hospital. Out of 83 patients, with emergency CEA cases excepted, 6 patients (7.2%) had a new PCI in preoperative cardiac function screening. In our hospital, preoperative coronary artery examination is performed in high-risk cases. If treatment for coronary arteries is required, a preceding PCI is considered to be a major factor in suppressing the onset of postoperative myocardial infarction.

Limitation:

There are several limitations to this study. First, the total number of treatment cases is small. As for risk factors for postoperative cerebral infarction, the difference between postoperative blood pressure and preoperative blood pressure tended to show a marked difference compared with other factors, but it was not a statistically significant difference. By increasing the number of cases and re-examining, it seems that there may be a statistically significant difference. Second, there were inconsistencies in post-operative blood pressure control methods. Because of the nature of being a retrospective study, the blood pressure management values varied, and the blood pressure control method and medication used were not identical across cases. Third, the measurement time and the number of measurements of post-operative blood pressure were not constant. The blood pressure in this study is examined by the measured mean blood pressure value. However, in cases where there are no problems or complications in the postoperative course, the number of measurements is small, and in cases showing hyperperfusion syndrome and cases with poor general condition, the number of measurements was increased because due to requiring close blood pressure management after surgery. It is necessary to consider forward looking research in the future in light of these limitations.

Conclusion:

It can be said that CEA for High-cervical lesions can be safely performed using our surgical method. In the approach to CEA for High-cervical lesions, it is important to extend the skin incision, to understand the membrane structures of the neck, and to make sharp dissections of each layer based on accurate anatomy.

The management of excessive blood pressure from the early postoperative days is a risk of PRCI and ischemic complications, so caution is necessary.

Reference:

[1] A. Halliday, A. Mansfield, J. Marro, C. Peto, R. Peto, J. Potter, D. Thomas, M.R.C.A.C.S.T.C. Group, Prevention of disabling and fatal strokes by successful carotid endarterectomy in patients without recent neurological symptoms: randomised controlled trial, Lancet, 363 (2004) 1491-1502.

[2] C. North American Symptomatic Carotid Endarterectomy Trial, H.J.M. Barnett, D.W. Taylor, R.B. Haynes, D.L. Sackett, S.J. Peerless, G.G. Ferguson, A.J. Fox, R.N. Rankin, V.C. Hachinski, D.O. Wiebers, M. Eliasziw, Beneficial effect of carotid endarterectomy in symptomatic patients with high-grade carotid stenosis, N Engl J Med, 325 (1991) 445-453.

[3] H.J. Barnett, D.W. Taylor, M. Eliasziw, A.J. Fox, G.G. Ferguson, R.B. Haynes, R.N. Rankin, G.P. Clagett, V.C. Hachinski, D.L. Sackett, K.E. Thorpe, H.E. Meldrum, J.D. Spence, Benefit of carotid endarterectomy in patients with symptomatic moderate or severe stenosis. North American Symptomatic Carotid Endarterectomy Trial Collaborators, N Engl J Med, 339 (1998) 1415-1425.

[4] J.L. Mas, G. Chatellier, B. Beyssen, A. Branchereau, T. Moulin, J.P. Becquemin, V. Larrue, M. Lievre, D. Leys, J.F. Bonneville, J. Watelet, J.P. Pruvo, J.F. Albucher, A. Viguier, P. Piquet, P. Garnier, F. Viader, E. Touze, M. Giroud, H. Hosseini, J.C. Pillet, P. Favrole, J.P. Neau, X. Ducrocq, E.-S. Investigators, Endarterectomy versus stenting in patients with symptomatic severe carotid stenosis, N Engl J Med, 355 (2006) 1660-1671.

[5] S.C. Group, P.A. Ringleb, J. Allenberg, H. Bruckmann, H.H. Eckstein, G. Fraedrich, M. Hartmann, M. Hennerici, O. Jansen, G. Klein, A. Kunze, P. Marx, K. Niederkorn, W. Schmiedt, L. Solymosi, R. Stingele, H. Zeumer, W. Hacke, 30 day results from the SPACE trial of stent-protected angioplasty versus carotid endarterectomy in symptomatic patients: a randomised non-inferiority trial, Lancet, 368 (2006) 1239-1247.

[6] J.S. Yadav, M.H. Wholey, R.E. Kuntz, P. Fayad, B.T. Katzen, G.J. Mishkel, T.K. Bajwa, P. Whitlow, N.E. Strickman, M.R. Jaff, J.J. Popma, D.B. Snead, D.E. Cutlip, B.G. Firth, K. Ouriel, Stenting, I. Angioplasty with Protection in Patients at High Risk for Endarterectomy, Protected carotid-artery stenting versus endarterectomy in high-risk patients, N Engl J Med, 351 (2004) 1493-1501.

[7] U. Batzdorf, F.K. Gregorius, Surgical exposure of the high cervical carotid artery: experimental study and review, Neurosurgery, 13 (1983) 657-661.

[8] W.J. Dichtel, R.H. Miller, D.V. Feliciano, G.E. Woodson, J. Hurt, Lateral mandibulotomy: a technique of exposure for penetrating injuries of the internal carotid artery at the base of the skull, Laryngoscope, 94 (1984) 1140-1144.

[9] I. Yamamoto, A. Ikeda, M. Shimoda, S. Oda, Y. Miyazaki, K. Ito, S. Shinozuka, O. Sato, Surgical treatment of extracranial distal internal carotid artery dissecting aneurysm--case report, Neurol Med Chir (Tokyo), 32 (1992) 21-27.

[10] I.P. Casserly, A. Abou-Chebl, R.B. Fathi, D.S. Lee, J. Saw, J.E. Exaire, S.R. Kapadia, C.T. Bajzer, J.S. Yadav, Slow-flow phenomenon during carotid artery intervention with embolic protection devices: predictors and clinical outcome, J Am Coll Cardiol, 46 (2005) 1466-1472.

[11] D.M. Frim, B. Padwa, D. Buckley, R.M. Crowell, C.S. Ogilvy, Mandibular subluxation

as an adjunct to exposure of the distal internal carotid artery in endarterectomy surgery. Technical note, J Neurosurg, 83 (1995) 926-928.

[12] K. Ogasawara, H. Yukawa, M. Kobayashi, C. Mikami, H. Konno, K. Terasaki, T. Inoue, A. Ogawa, Prediction and monitoring of cerebral hyperperfusion after carotid endarterectomy by using single-photon emission computerized tomography scanning, J Neurosurg, 99 (2003) 504-510.

[13] T. Furui, M. Hasuo, Indwelling double-balloon shunt for carotid endarterectomy. Technical note, J Neurosurg, 60 (1984) 861-863.

[14] S. Vang, S.S. Hans, Carotid endarterectomy in patients with high plaque, Surgery, 166 (2019) 601-606.

[15] V. Rao, P. Liang, N. Swerdlow, C. Li, Y. Solomon, M. Wyers, M. Schermerhorn, Contemporary outcomes after carotid endarterectomy in high-risk anatomic and physiologic patients, J Vasc Surg, DOI 10.1016/j.jvs.2019.05.041(2019).

[16] M. Katsuno, R. Tanikawa, T. Miyazaki, G. Uemori, K. Kawasaki, N. Izumi, M. Hashimoto, [Carotid endarterectomy for high cervical internal carotid artery stenosis: study of 22 consecutive patients], No Shinkei Geka, 41 (2013) 977-985.

[17] N. Hayashi, E. Hori, Y. Ohtani, O. Ohtani, N. Kuwayama, S. Endo, Surgical anatomy of the cervical carotid artery for carotid endarterectomy, Neurol Med Chir (Tokyo), 45 (2005) 25-29; discussion 30.

[18] D.D. de Waard, G.J. de Borst, R. Bulbulia, A. Huibers, A. Halliday, G. Asymptomatic Carotid Surgery Trial-1 Collaborative, Diastolic Blood Pressure is a Risk Factor for Peri-procedural Stroke Following Carotid Endarterectomy in Asymptomatic Patients, Eur J Vasc Endovasc Surg, 53 (2017) 626-631.

[19] T. Kawamata, Y. Okada, A. Kawashima, T. Yoneyama, K. Yamaguchi, Y. Ono, T. Hori, Postcarotid endarterectomy cerebral hyperperfusion can be prevented by minimizing intraoperative cerebral ischemia and strict postoperative blood pressure control under continuous sedation, Neurosurgery, 64 (2009) 447-453; discussion 453-444.

[20] A. Poudel, J.Y. Zhou, D. Story, L. Li, Diabetes and Associated Cardiovascular Complications in American Indians/Alaskan Natives: A Review of Risks and Prevention Strategies, J Diabetes Res, 2018 (2018) 2742565.

Figure Legends:

Figure 1. Design of skin incision for High-cervical lesion

Figure 2. Retraction of digastric muscle, hypoglossal nerve and occipital artery.

2-A) Before the dissection.

2-B) After the dissection.

Fig. 3: A Case of High-cervical lesion.

This is a 78-year-old man with symptomatic cervical IC stenosis. The lesion was 84%(NASCET) stenosis and High cervical lesion.

A: Preoperative 3D-CTA image with cervical spine. The distal end of lesion reaches the height of C2 vertebral body.

B: Post-operative 3D-CTA showed the improvement of IC stenosis.

C: Post-operative DWI showed an asymptomatic ischemic lesion.

AC: ansa cervicalis, DM: digastric muscle, ECA: external cerebral artery, HN: hypoglossal nerve, ICA: internal cerebral artery, MA: mandibular angle, MP: mastoid processs, OA: occipital artery, SCM: sternocleidomastoid muscle, SI: skin incision, Table. 1) Clinical characteristics and back ground of patient

	All (N=98)	High-cervical group (N=34)	Non-high-cervical group (N=64)
Mean age (yr)	71.9	73.1	71.2
Symptomatic lesion	55	20	35
Degree of stenosis (NASCET %)	73.9	77.7	72.8
Plaque length (mm)	25.1	27.8	23.5
Risk factor			
Hypertension	74	35	39
Diabetes mellitus	29	12	17
Dyslipidemia	45	20	25
Smoking	81	41	40
Cardiovascular disease	37	20	17
Previous stroke	30	16	14

Table. 2) Surgical outcome

	All (N=98)	High-cervical group (N=34)	Non-high-cervical group (N=64)
Postoperative DWI High (%)	8 (8.2)	4 (4.1)	4 (4.1)
Symptomaric ischemic lesion (%)	6 (6.1)	3 (3.1)	3 (3.1)
Hyperperfusion (%)	10 (10.2)	3 (3.1)	7 (7.1)
Intracranial hemorrhage due to Hyperperfusion	0	0	0
Transient CN.Ⅻ palsy (%)	6 (6.1)	4 (4.1)	2 (2.0)
Permanent CN.Ⅻ palsy	0	0	0
Deterioration of the mRS at discharge (%)	13 (13.3)	7 (7.1)	6 (6.1)
Deterioration of the mRS at 6 months after discharge (%)	4 (4.1)	3 (3.1)	1 (1.0)
Mortality (%)	1 (1.0)	0	1 (1.0)

Table. 3) Factors related to technique related cerebral infarction (TRCI): Univariate analysis

Variables	No, n=98	DWI positive		P value
		No, n=94(95.9%)	Yes, n=4(4.1%)	
Age		72.1(±6.1)	67.0(±5.4)	0.151
Sex	F15, M83	F:15, M:79	F:0, M:4	1.000
Symptomatic	55	52 (55.3)	3 (75.3)	0.629
Emergency	13	12(12.8)	1(25.0)	0.439
Past history				
HTN	77	74(78.7)	3(75.0)	1.000
DM	30	29(30.9)	1(25.0)	1.000
DL	45	43(45.7)	2(50.0)	1.000
AMI or AP	37	36(38.3)	1(25.0)	1.000
CI	30	29(30.9)	1(25.0)	1.000
Smoking	84	80(85.1)	4(100)	1.000
Radiologic findings				
High-cervical lesion	34	32(34.4)	2(50.0)	0.610
NASCET				0.749
Lenghth of lesion		24.8(± 7.1)	32.7 (±9.1)	0.268
Outcome				
Hyperperfusion	10	10(10.6)	0	1.000
Cranial nerve palsy	6	6(6.4)	0	1.000
Deterioration of the mRS	13	12(12.8)	1 (25.0)	0.439
Blood pressure (BP)				
BP pre Op.				0.775

Table. 4) Factors related to perioperative related cerebral infarction (PRCI): Univariate analysis

Variables	No, n=98	DWI positive		P value
		No, n=94	Yes, n=4	
Age		71.7(±6.2)	75.5(±4.7)	0.204
Sex	F:15, M:83	F:15, M:79	F:0, M:4	1.000
Symptomatic	55	54(57.4)	1(25.0)	0.316
Emergency	13	13(13.8)	0	1.000
Past history				
HTN	77	75(79.8)	2(50.0)	0.200
DM	30	28(29.8)	2(50.0)	0.584
DL	45	44(46.8)	1(25.0)	0.622
AMI or AP	37	35(37.2)	2(50.0)	0.631
CI	30	30(31.9)	0	0.309
Smoking	84	81(86.2)	3(75.0)	0.466
Radiologic findings				
High-cervical lesion	34	32(34.4)	2(50.0)	0.610
NASCET				0.138
Length of lesion				0.396
Outcome				
Hyperperfusion	10	10(10.6)	0	1.000
Cranial nerve palsy	6	4(4.3)	2(50.0)	0.018
Deterioration of the mRS	13	11(11.7)	2 (50.0)	0.084
Postop. renal failure	2	2(2.1)	0	1.000
Postop. Ileus	2	2(2.1)	0	1.000
Mean BP				
BP pre Op.				0.398
BP IAOP				0.429
BP POD 1				0.243
BP POD 2				0.398

BP POD 3				0.621
s-BP pre OP.				0.634
d-BP pre OP.				0.332
s-BP IAOP				0.815
d-BP IAOP				0.273
s-BP POD 1				0.527
d-BP POD 1				0.176
s-BP POD 2				0.276
d-BP POD 2				0.643
s-BP POD 3				0.393
d-BP POD 3				0.923
Difference of d-BP				
Pre OP. - IAOP.				0.315
Pre OP. - POD1				0.159
Pre OP. - POD2				0.033
Pre OP. - POD3				0.059

Table. 5) Factors related to mRS deterioration: Univariate analysis

Variables	All (N=98)	mRS deteriorateon		P value
		No, N=85(86.7%)	Yes, N=13(13.3%)	
Age				0.101
Sex				1.000
Symptomatic	55	47(55.3)	8(61.5)	0.770
Emergency	13	10(11.8)	3(23.1)	0.372
Past history				
HTN	77	68(80.0)	9(69.2)	0.467
DM	30	24(28.2)	6(46.2)	0.209
DL	45	40(47.1)	5(38.5)	0.766
AMI or AP	37	35(41.2)	2(15.4)	0.122
CI	30	25(29.4)	5(38.5)	0.529
Smoking	84	72(84.7)	12(92.3)	0.685
Radiologic findings				
High-cervical lesion				0.210
Outcome				
Postoperative DWI high	8	5(5.9)	3(23.1)	0.070
Symptomatic ischemic lesion	4	3(3.5)	1(7.7)	0.439
Hyperperfusion	10	8(9.4)	2(15.4)	0.618
Cranial nerve palsy	6	2(2.4)	4(30.8)	0.003
Postoperative acute renal failure	2	1(1.2)	1(7.7)	0.249
Postoperative ischemic colitis	2	1(1.2)	1(7.7)	0.249
Blood pressure (BP)				
BP pre Op.				0.185
BP immediately after Op. (IAOP)				0.245
BP POD 1				0.797
BP POD 2				0.333
BP POD 3				0.734

Table. 6) Factors related to postoperative DWI high: Univariate analysis

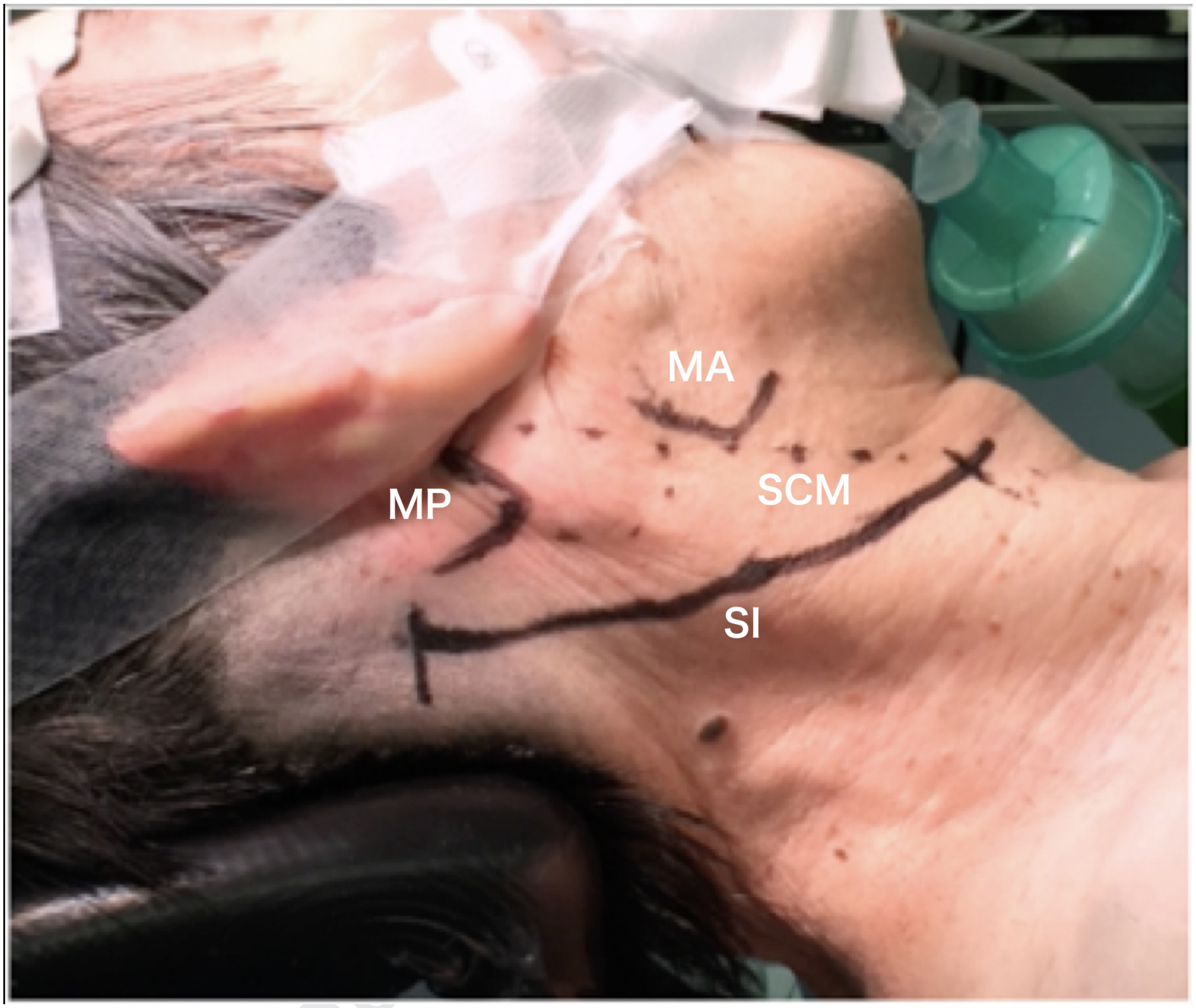
Variables	All (N=98)	DWI positive		P value
		No, N=90(91.8%)	Yes, N=8(8.2%)	
Age				0.762
Sex	F15, M83	75(83.3)	8(100)	0.352
Symptomatic	55	51(56.7)	4(50.0)	0.727
Emergency	13	12(13.3)	1(12.5)	1.000
Past history				
HTN	77	72(80.0)	5(62.5)	0.363
DM	30	27(30.0)	3(37.5)	0.697
DL	45	42(46.7)	3(37.5)	0.723
AMI or AP	37	34(37.8)	3(37.5)	1.000
CI	30	29(32.2)	1(12.5)	0.429
Smoking	84	77(85.6)	7(87.5)	1.000
Radiologic findings				
High-cervical lesion	34	30(33.7)	4(50.0)	0.445
Outcome				
Hyperperfusion	10	10(11.1)	0	1.000
Cranial nerve palsy	6	4(4.4)	2(25.0)	0.074
Postoperative acute renal failure	2	2(2.2)	0	1.000
Postoperative ischemic colitis	2	2(2.2)	0	1.000
Blood pressure (BP)				
BP pre Op.				0.775
BP immediately after Op. (IAOP)				0.004
BP POD 1				0.003
BP POD 2				0.018
BP POD 3				0.092
s-BP pre OP.				0.716
d-BP pre OP.				0.599
s-BP IAOP				0.040
d-BP IAOP				0.003

s-BP POD 1				0.009
d-BP POD 1				0.002
s-BP POD 2				0.022
d-BP POD 2				0.029
s-BP POD 3				0.085
d-BP POD 3				0.130

Table. 7) Factors related to Postoperative Renal failure or ischemic colitis: Univariate analysis

Variables	All (N=98)	No 94	Yes 4	P value
Age				0.624
Sex				0.491
Symptomatic				0.629
Emergency		1(1.2)	3(23.1)	0.007
Past history				
HTN				0.575
DM				0.084
DL				1.000
AMI or AP				0.631
CI				1.000
Smoking				0.466
Radiologic findings				
High-cervical lesion				0.610
Outcome				
Postoperative DWI high				1.000
Symptomatic ischemic lesion				1.000
Hyperperfusion				0.354
Blood pressure (BP)				
BP before Op.				0.106
BP immediately after Op. (IAOP)				0.387
BP POD 1				0.221
BP POD 2				0.148
BP POD 3				0.102
BP Pre OP.- IAOP.				0.214
BP Pre OP.- POD1				0.056
BP Pre OP.- POD2				0.059
BP Pre OP.- POD3				0.038

BP=Blood Pressure, d-BP=Diastolic Blood Pressure, s-BP=Systolic Blood Pressure, IAOP=Immediately After Operation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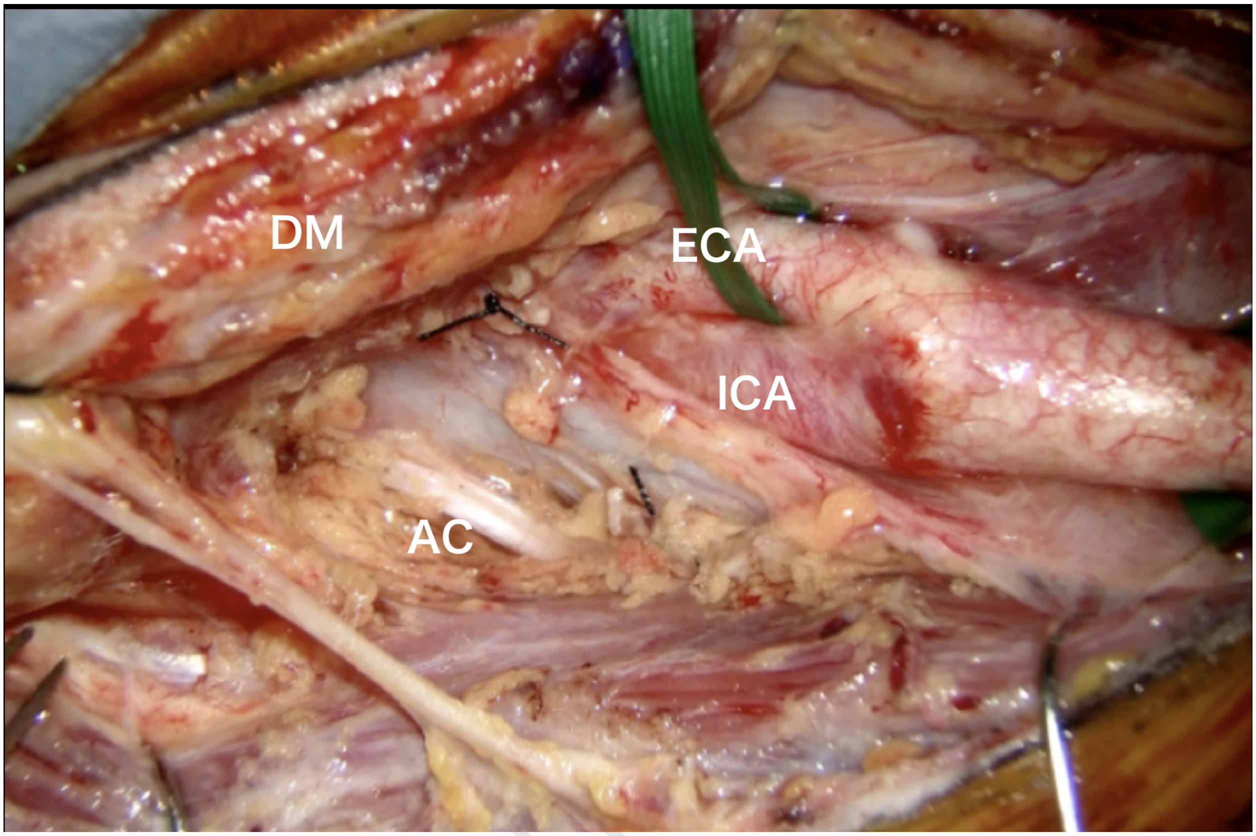
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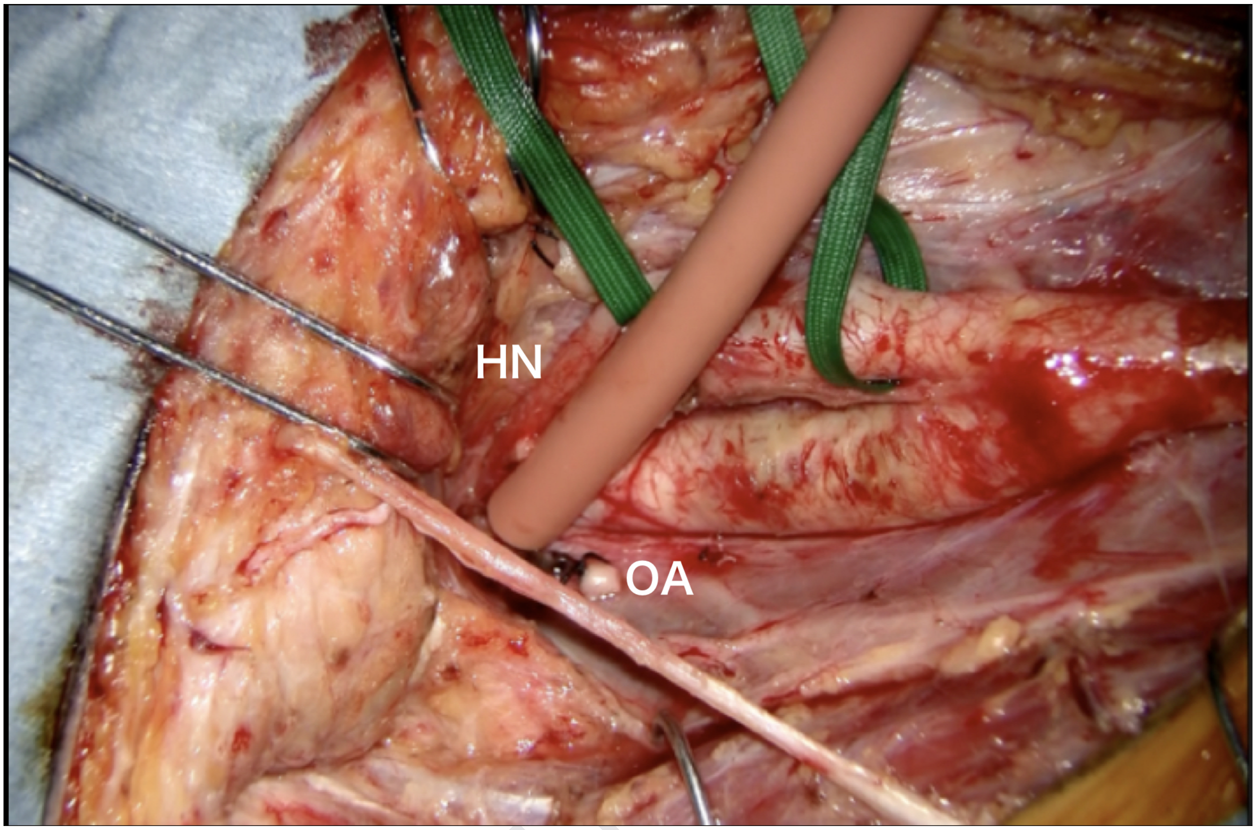
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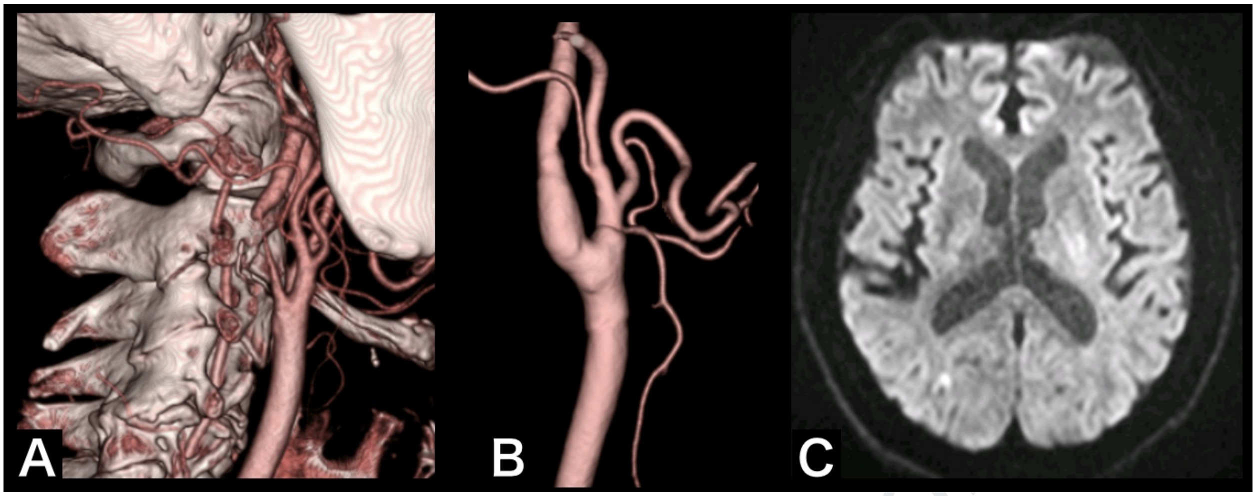
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Abbreviations:

CEA; carotid endarterectomy, mRS; modified Rankin Scale SCM; sternocleidomastoid muscle, OA; occipital artery, DWI; diffusion weighted image, TRCI; technique related cerebral infrction, PRCI; perioperative related infarction, CN; cranial nerve, CAS; carotid artery stenting, ICH; intracranial hemorrhage, MRI; magnetic resonance imaging, ACT; activated whole blood clotting time, SPECT; single photon emission computed tomography, ASL; arterial spin labeling

Disclosure

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.