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Technical Notes

A technique for reconstruction of a giant extracranial internal carotid artery aneurysm: A technical note

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ABSTRACT

Background: Surgery is effective for extracranial internal carotid artery (EICA) aneurysms. However, the risk of cranial nerve injury associated with surgical repair, such as graft-assisted resection and extracranial-intracranial bypass techniques, is relatively high. Here, we report two cases of surgical treatment for EICA aneurysms and describe the surgical techniques and strategies to avoid cranial nerve injury.

Methods: Two patients presented to our facility with an increasing cervical pulsatile mass and no neurological symptoms. Angiography showed a large aneurysm in the cervical internal carotid artery. Surgical treatment was performed to prevent rupture of the aneurysm. In both patients, the aneurysm was strongly attached to the vagus nerve. The aneurysm and vagus nerve were carefully dissected using a low-power bipolar (20 Malis; 3 watts), leaving connective tissue on the vagus nerve side.

Results: The aneurysm was detached from the vagus nerve without injury. Based on intraoperative findings, one patient underwent clipping, and the other underwent aneurysmectomy and primary closure for aneurysm obliteration and angioplasty. Both patients were discharged without any cranial nerve dysfunction.

Conclusion: The selection of a strategy based on intraoperative findings and low-power bipolar cutting is important for the treatment of extracranial carotid artery aneurysms to preserve cranial nerves.

Keywords: Aneurysmectomy, Bipolar cutting, Extracranial internal carotid artery aneurysm, Reconstruction, Vagus nerve

INTRODUCTION

Extracranial internal carotid artery (EICA) aneurysms are rare, with an incidence of <1% of all arterial aneurysms[13,15] and accounting for <1% of all surgically treated extracranial carotid arteries.[13] The underlying pathology of EICA formation has been reported to be atherosclerosis (in >75% of cases), trauma, infection, and many other less common causes.[1,4,20,23] Although aneurysms may remain silent, EICAs become symptomatic more frequently than intracranial aneurysms. Cerebral ischemia (transitory ischemic attack or stroke) occurs in approximately 40% of patients, and local symptoms develop in approximately half of these patients.[13,15,19]

Conservative treatment has a high mortality rate (60–70%),[21,24] and either endovascular or surgical treatment are viable modalities, with open surgery remaining advantageous in patients with atherosclerosis.[15] Endovascular treatment is the method of choice for EICA of traumatic origin.[18]

Technical success of surgery is achieved in almost all cases; however, the risks of mortality and complications are significant.[7] Cranial nerve damage/deficit associated with surgical repair of EICA ranges between 2.2% and 44%[1,2,5,19] but has never been reported with endovascular treatment, leaving an impression of being a "surgeon-related" risk factor, and opening space for surgical technique improvement.

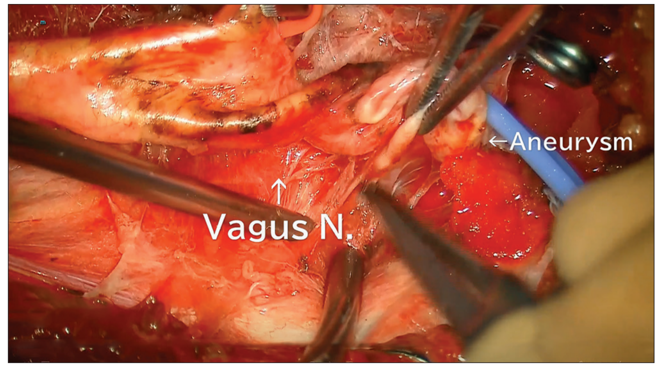
We report the two cases of patients with EICA who underwent aneurysmectomy and internal carotid artery (ICA) repair, emphasizing the technical aspects of improving safety and preserving the cranial nerves.

Written informed consent to publish this report was obtained from the patients before the submission process.

CASE DESCRIPTION

Case 1

A 76-year-old woman presented to our institution with a pulsatile mass in her left neck. She had no neurological symptoms or history of cervical trauma, infection, surgery, or cerebral ischemic events. Three-dimensional computed tomography and digital subtraction angiography revealed an aneurysm measuring 18 mm in the left ICA of the neck [Figures 1a and b]. Surgery was planned to prevent the rupture. The patient was placed in the supine position under general anesthesia, with the head rotated 45°. An incision was made in the skin along the anterior sternocleidomastoid border. Monitoring sensors were placed to measure motor and somatosensory-evoked potentials and monitor cerebral blood oxygenation. The vagus nerve was located medial to the aneurysm and strongly attached to the back of the aneurysm in the operative field [Figure 1d]. Due to the risk of aneurysm rupture during dissection of the aneurysm and vagus nerve, the superior thyroid and external, common, and internal carotid arteries were clamped, in that order, before the aneurysm was dissected from the vagus nerve. The aneurysm and vagus nerve were carefully dissected using a low-power bipolar (20 Malis; 3 watts), leaving connective tissue on the vagus nerve side [Figures 1e and f and, Video 1]. Since the aneurysm was not thrombosed and there were no atherosclerotic changes, two clips were used to block the aneurysm and perform ICA angioplasty. After the aneurysm was circumferentially detached from the surrounding tissue, two ring clips were used to clip the aneurysm and form the ICA [Figure 1g]. Micro-Doppler and intraoperative infrared video angiography using indocyanine green video angiography confirmed sufficient blood flow. Postoperative



Video 1: A surgical video of Case 1 demonstrating the dissection of the vagus nerve from the aneurysm using bipolar cautery. The video is accessible from the portal.

3D digital subtraction angiography showed that the aneurysm had disappeared [Figure 1c]. The patient was discharged home 15 days postoperatively with a modified Rankin scale (mRS) of 0 and no postoperative complications.

Case 2

A 79-year-old male sought medical attention for a growing pulsatile mass in his left neck without any symptoms or pathological findings. Contrast-enhanced computed tomography showed a dilatation of the left cervical ICA with a partial luminal thrombus. Digital subtraction angiography revealed a giant aneurysm at the carotid bifurcation [Figures 2a and b]. He had a history of surgery for an abdominal aortic aneurysm but no history of cervical trauma, infection, surgery, or cerebral ischemic events. Significant cardiac comorbidities (hypertension, atrial fibrillation, and chronic heart failure) were also observed. The surgical procedure was performed under general anesthesia in the supine position, with the head rotated 45° through a skin incision along the anterior sternocleidomastoid border. As in Case 1, monitoring sensors were installed to measure motor and somatosensory-evoked potentials and cerebral blood oxygenation. The common carotid artery (CCA) and its branches, the external carotid artery, ICA, and superior thyroid artery, are widely exposed. The ICA, vagus nerve, and jugular vein ran side by side, and an aneurysm in the ICA compressed the vagus nerve and jugular vein, causing strong adhesions. In the operative field, the vagus nerve was attached around the dome of the aneurysm [Figure 2e]. Careful dissection with a non-stick cutting bipolar set to low power (20 Malis; 3 watts) for nerve dissection, leaving connective tissue on the vagus nerve side [Figure 2f], and vascular structure dissection (25 Malis; 5 watts) allowed exposure of the entire aneurysm dome. When dissecting the nerve from the aneurysm, keeping the bipolar cutting away from the nerve toward the aneurysm wall is important because it overtakes the less vulnerable structure of the

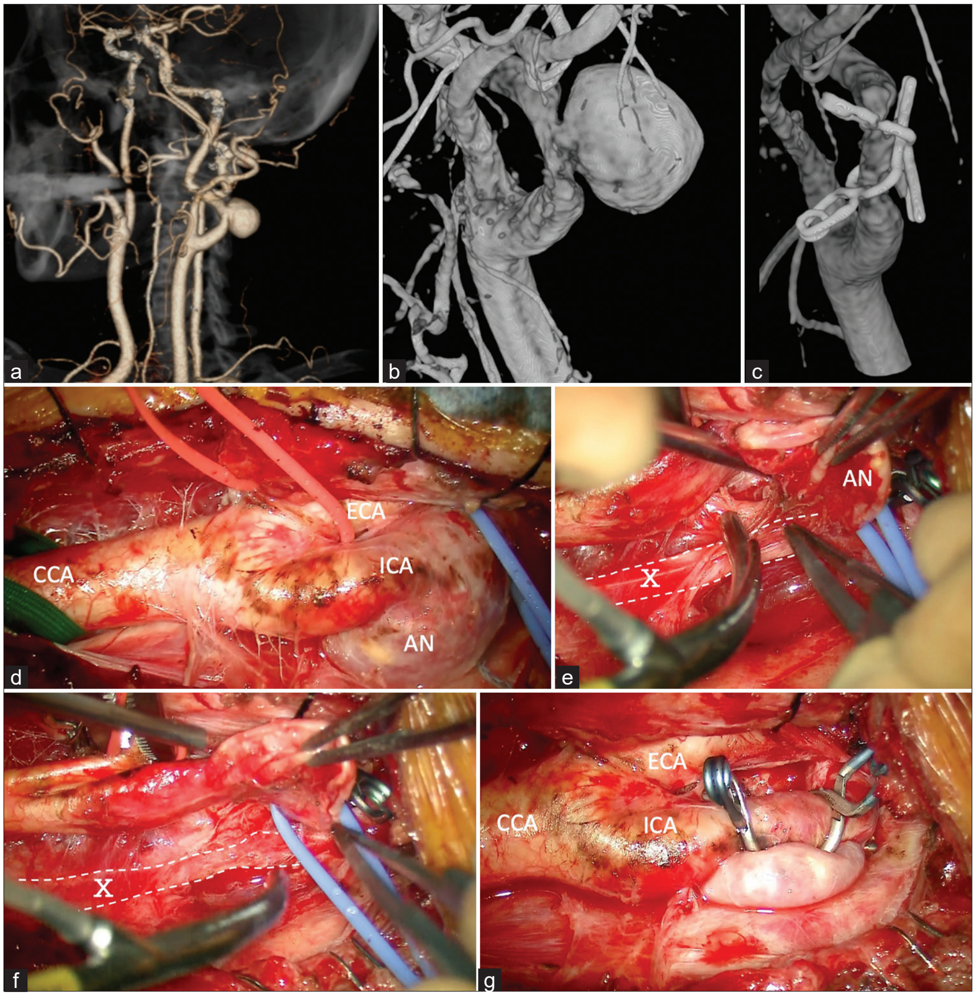


Figure 1: Case 1 (a) Three-dimensional computed tomography angiogram demonstrating a saccular aneurysm located at the left cervical ICA. (b and c) (b) Pre- and post-operative three-dimensional digital subtraction angiography showing the 18 mm aneurysm in the ICA (c) and disappearance of the aneurysm. (d-g) (d) Intraoperative photographs showing an exposed cervical ICA aneurysm, (e and f) before and after dissecting the aneurysm and vagus nerve using a cutting bipolar after clamping the CCA, ECA, ICA, and superior thyroid artery to prevent rupture of the aneurysm (g) two clips were used to clamp the aneurysm, and revascularization was performed. AN: Aneurysm, CCA: Common carotid artery, ECA: External carotid artery, ICA: Internal carotid artery, X: Vagus nerve.

two. Once the aneurysm dome was dissected and the vagal nerve was covered securely, the vessels were prepared for clamping, with special emphasis on preparing the ICA as distally as possible to avoid plaque remnants. Clamps were applied, and a shunt was placed from the CCA to the distal ICA to proceed with the resection and ICA repair. The incision was extended from the distal ICA to the carotid bifurcation over the aneurysmal neck to secure complete plaque removal (intra-aneurysmal and intra-arterial) using standard carotid endarterectomy (CEA). Subsequently, the aneurysm wall was assessed under higher magnification and cut into a healthy vessel wall for direct suture reconstruction of the ICA. Micro-Doppler and intraoperative infrared video angiography using indocyanine green video angiography confirmed sufficient blood flow. The patient recovered well after surgery without neurological deficits and remained under follow-up. He was discharged 18 days postoperatively with an mRS of 2 due to the extended bed rest associated with hospitalization. Postoperative imaging confirmed complete EICA resection and patency of the reconstructed ICA [Figures 2c and d]. Histopathology of the aneurysm wall specimen found a decrease in elastic fibers, calcifications, cholesterol clefts, hemosiderin depositions, and granulation tissue-like zones, indicating an atherosclerotic origin of the EICA [Figures 3a-d].

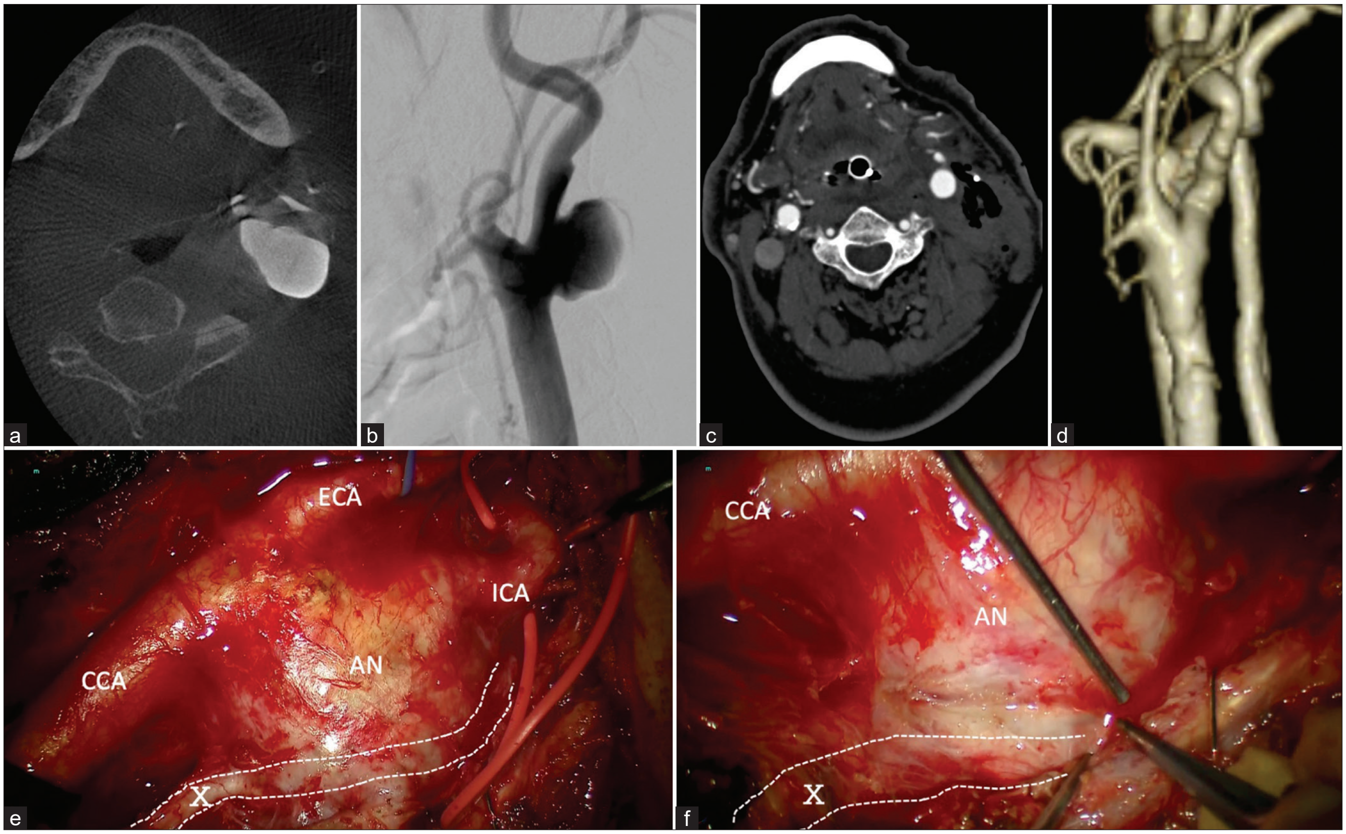


Figure 2: Case 2 (a) Cone-beam computed tomography (CT) scan of the neck showing a mass on the left side of the neck, which appeared to be a partially thrombosed aneurysm (axial view). (b) During angiography, a saccular aneurysm measuring 2.1 cm is observed near the bifurcation site of the left common carotid artery into the ICA (lateral view). (c and d) Postoperative contrast-enhanced CT scans of the neck (c) and three-dimensional computed tomography angiogram (d) show the disappearance of the aneurysm. (e and f) Intraoperative photographs.(e) The connective tissue around the aneurysm is completely exfoliated . (f)The aneurysm was strongly adherent to the vagus nerve in some areas, although it was dissected using a cutting bipolar device to expose the aneurysm . AN: Aneurysm, CCA: Common carotid artery, ECA: External carotid artery, ICA: Internal carotid artery, X: Vagus nerve

DISCUSSION

We reported two surgical cases of EICA. The aneurysm and vagus nerve sometimes adhered to each other, and a low-power bipolar cut was useful to dissect the aneurysm without causing vagus nerve damage. In addition, for better treatment, flexible strategy changes based on intraoperative findings are essential.

Reportedly, 2.2–44% of the lower cranial nerve injuries are caused by surgical repair of the EICA.[1,2,5,19] In addition to understanding the anatomy around the carotid artery to avoid damage to the lower cranial nerve,[16] safe intraoperative manipulation with a clear surgical field using a bipolar cutter with minimal bleeding is important. Vagus nerve injury can cause serious disabilities, such as dysphagia and aspiration pneumonia, and can lead to a life-threatening condition referred to as bilateral paralysis of the vocal cords.[22] We report an intraoperative technique to dissect the connective tissue between the aneurysm and the vagus nerve. The problem with tissue dissection using bipolar resection is thermal damage to the dissected tissue.[10] Thus, the key technical point for protecting the vagus nerve during surgery is to dissect it close to the aneurysm, not close to the vagus nerve, and leave a sufficient amount of connective tissue around the vagus nerve. The cause of injury to the vagus nerve is the detachment of connective tissue from the aneurysm and close to the vagus nerve for fear of rupture of the aneurysm. However, the connective tissue between the aneurysm and the vagus nerve can be sharply dissected. Dissection near the aneurysm, as in these cases, is important to protect the vagus nerve. While there are many reports on surgical methods for EICA and reasonable results have been obtained, there are no reports describing how to prevent vagal nerve damage. Therefore, we emphasize that dissection near the aneurysm with a cutting bipolar device is an important surgical technique to avoid nerve damage in any surgical procedure.

The natural history of the EICA remains to be elucidated. Ruptured aneurysms are thought to be very rare and

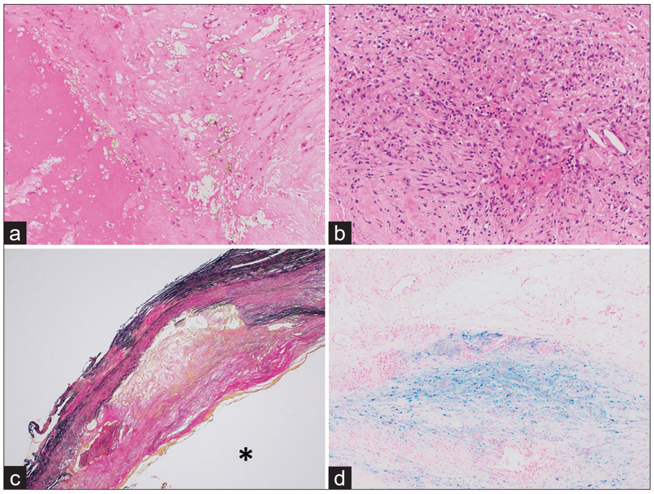


Figure 3: Histopathological findings in Case 2. Hematoxylin and eosin staining (a: ×100, b: ×200) revealed calcification, cholesterin clefts, and granulation tissue-like parts of the aneurysm wall. Elastica van Gieson staining (c: ×2) showed a decrease in aneurysm wall elastic fibers and bleeding on the vessel wall (*: Vascular lumen). Berlin Blue staining (d: ×100) showed hemosiderin deposition in the vessel wall. The etiology of the aneurysm formation was considered to be arteriosclerosis.

potentially life-threatening. EICA commonly leads to transient ischemic attacks, cerebral infarction due to inter-arterial embolism, and pulsatile masses in the neck and pharynx. As the aneurysm enlarges, symptoms due to compression of surrounding biological structures, such as dysphagia and hoarseness, may occur.[6,15] In addition, a high mortality rate has also been reported with conservative treatment.[21,24] Therefore, surgical treatment is often required in these cases. The basic strategy for the surgical treatment of EICA is aneurysm resection and revascularization of the ICA.

Several procedures for the treatment of EICA have been reported, such as direct suture of the defect after aneurysm resection, direct end-to-end anastomosis of the ICA or CCA after aneurysm resection, autologous or artificial vascular graft after aneurysm resection, or ligation of aneurysms under combined bypass.[2,8,21] Direct suturing of the defect is an option after aneurysm resection when a sufficient normal carotid artery wall remains.[21] This method has the advantage of being able to suture the residual wall after aneurysm resection without any additional antiplatelet therapy. The disadvantage of this method is the risk of vessel narrowing due to the suturing. When no normal vessel wall remains after saccular aneurysm resection, making angioplasty difficult, a patch is used to reconstruct the vascular defect. Garg *et al*.[2] reported good results using a patch to reconstruct the EICA in traumatic pseudoaneurysms. In CEA, Rerkasem and Rothwell[14] also found that the risk of cranial nerve palsy under patch use was low, and there was no significant difference between the patch use and primary closure groups. In addition, there is a report that there is no difference in infection between the patch and primary closure in CEA [14], whereas, in the case of revascularization of infected aneurysms, some authors proposed autologous conduits using the superficial femoral artery or hypogastric artery,[12] which might depend on the cause of the aneurysm. Moreover, the need for antiplatelet therapy in the perioperative period is considered a disadvantage of patch-based surgery.[11] In cases where end-to-end anastomosis is difficult due to insufficient carotid artery length, revascularization using autologous or artificial vessel grafts after aneurysm resection is used.[21] Garg *et al*.[2] reported a reconstruction using a saphenous vein rather than an artificial vascular graft. The advantage of graft-based reconstruction after aneurysm resection is that it can be performed regardless of the size of the aneurysm to be resected, even if the remaining vessel wall is small or fragile. The disadvantage of this revascularization procedure is the need for antiplatelet therapy in the perioperative period, as seen in cardiovascular surgery, such as coronary artery bypass grafting.[17] Another method involves ligation under combined bypass. The advantages of ligation of proximal and distal aneurysms with bypass are minimal dissection around the aneurysm and a low risk of lower cranial nerve injury. Yoneyama *et al*.[21] reported that reconstruction with vascular graft or bypass is performed when there is no redundancy in the residual vessel after aneurysm resection. Han *et al*.[3] reported a case of STA-MCA bypass and EICA ligation in a patient with hoarseness and dyspnea who had EICA and Moyamoya disease. However, hemodynamic changes after bypass may cause hyperperfusion.[21] In any of the techniques mentioned above, manipulation of the area around the vagus nerve is essential, especially because damage to the vagus nerve affects functional prognosis. Thus, dissecting away from the vagus nerve and around the aneurysm is extremely useful.

The most common cause of EICA is atherosclerosis, followed by arterial dissection and trauma.[15,19] Other reported causes include infections, granulomatous diseases, connective tissue disorders, iatrogenic aneurysms, and radiation therapy.[4,12,19] In atherosclerosis, the initial damage to the internal elastic lamina is accompanied by subsequent intimal proliferation. Further, angiogenesis occurs within the thickened intima, leading to intramural hemorrhage leading to aneurysmal changes.[9] In Case 2, the patient's clinical history and histopathological findings, such as granulation tissue-like parts of the aneurysm wall, support the idea that degeneration of the arterial wall due to atherosclerosis is the cause of EICA formation. However, Case 1 had no arteriosclerotic changes on intraoperative examination; therefore, it was possible to clamp the aneurysm and perform angioplasty using two clips.

CONCLUSION

We reported an intraoperative technique to protect the vagus nerve in EICA surgery by dissecting the connective tissue between the aneurysm and the vagus nerve in the vicinity of the aneurysm and leaving the connective tissue around the vagus nerve. This technique may improve functional outcomes after EICA surgery. This case is also a reminder that proper selection of the procedure for aneurysm repair and reconstruction of the ICA and the device for dissection are important for this rare cervical vascular pathology.

Ethical approval

The Institutional Review Board approval is not required.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

REFERENCES

1. El-Sabrout R, Cooley DA. Extracranial carotid artery aneurysms: Texas Heart Institute experience. J Vasc Surg 2000;31:702-12.
2. Garg K, Rockman CB, Lee V, Maldonado TS, Jacobowitz GR, Adelman MA, *et al.* Presentation and management of carotid artery aneurysms and pseudoaneurysms. J Vasc Surg 2012;55:1618-22.
3. Han Q, Zhou P, Huang Y. Surgical revascularization: Ligation of extracranial internal carotid artery and superficial temporal artery-to-middle cerebral artery bypass in patient with extracranial internal carotid aneurysm and hemorrhagic moyamoya disease. World Neurosurg 2019;126:129-33.
4. Hanada Y, Sasai H, Kamakura A, Nakamura M, Sakata Y, Miyahara H. Rupture of an internal carotid artery pseudoaneurysm after irradiation for a nasopharyngeal carcinoma--case report. Nihon Jibiinkoka Gakkai Kaiho 2013;116:606-11.
5. Hoffman ME, Squiers JJ, Hamandi M, Lanfear AT, Calligaro KD, Shutze WP. Systematic review of the influence of anatomy and aneurysm type on treatment choice and outcomes in extracranial carotid artery aneurysms. Ann Vasc Surg 2022;83:349-57.
6. Komine H, Teranishi A, Kayahara T, Take Y, Ikegami M, Kikkawa Y, *et al*. Surgical management of a thromobotic extracranial carotid artery aneurysm: A case report. No Shinkei Geka 2019;47:653-8.
7. Kraemer CJ, Zhou W. Carotid aneurysm review. Int J Angiol 2019;28:17-9.
8. Maeda T, Sakai S, Osakabe M, Okawara M, Nomura T, Yamaguchi H, *et al*. Giant saccular aneurysm of the cervical internal carotid artery treated with aneurysmectomy and side-to-end anastomosis. Surg Neurol Int 2023;14:202.
9. Nakatomi H, Segawa H, Kurata A, Shiokawa Y, Nagata K, Kamiyama H, *et al*. Clinicopathological study of intracranial fusiform and dolichoectatic aneurysms. Stroke 2000;31:896-900.
10. Ohyama S, Takahashi S, Tamai K, Hori Y, Hirakawa Y, Hoshino M, *et al*. Prevention of nerve root thermal injury caused by bipolar cauterization near the nerve roots. Spine 2019;44:E321-8.
11. Okazaki T, Kanematsu Y, Shimada K, Korai M, Satomi J, Uno M, *et al*. A single-center retrospective study with 5- and 10-year follow-up of carotid endarterectomy with patch graft. Neurol Med Chir 2019;59:231-7.
12. Pirvu A, Bouchet C, Garibotti FM, Haupert S, Sessa C. Mycotic aneurysm of the internal carotid artery. Ann Vasc Surg 2013;27:826-30.
13. Radak D, Davidović L, Vukobratov V, Ilijevski N, Kostić D, Maksimović Z, *et al*. Carotid artery aneurysms: Serbian multicentric study. Ann Vasc Surg 2007;21:23-9.
14. Rerkasem K, Rothwell PM. Patch angioplasty versus primary closure for carotid endarterectomy. Cochrane Database Syst Rev 2009;2009:CD000160.
15. Sharma RK, Asiri AM, Yamada Y, Kawase T, Kato Y. Extracranial internal carotid artery aneurysm - challenges in the management: A case report and review literature. Asian J Neurosurg 2019;14:970-4.
16. Takamizawa S, Morino M. Knowledge of anatomical relationships of the vagus nerve with internal jugular vein and common carotid artery in the neck necessary for vagus nerve stimulation VNS surgery. Jpn J Neurosurg 2015;24:705-11.
17. Valgimigli M, Bueno H, Byrne RA, Collet JP, Costa F, Jeppsson A, *et al*. 2017 ESC focused update on dual antiplatelet therapy in coronary artery disease developed in collaboration with EACTS: The Task Force for dual antiplatelet therapy in coronary artery disease of the European Society of Cardiology (ESC) and of the European Association for Cardio-Thoracic Surgery (EACTS). Eur Heart J 2018;39:213-60.
18. Vitošević F, Milošević-Medenica S. Traumatic intracranial aneurysms associated with traffic accidents and endovascular management options. Serb J Neurosurg 2022;1:27-32.
19. Welleweerd JC, den Ruijter HM, Nelissen BG, Bots ML, Kappelle LJ, Rinkel GJ, *et al*. Management of extracranial carotid artery aneurysm. Eur J Vasc Endovasc Surg 2015;50:141-7.
20. Welleweerd JC, Nelissen BG, Koole D, de Vries JP, Moll FL,

Pasterkamp G, *et al*. Histological analysis of extracranial carotid artery aneurysms. PLoS One 2015;10:e0117915.
21. Yoneyama T, Kawashima A, Sugiura M, Yamaguchi K, Itou K, Namioka A, *et al*. Technical options for the surgical management of extracranial carotid artery aneurysms. Three case reports. Neurol Med Chir 2012;52:208-12.
22. Zannetti S, Parente B, De Rango P, Giordano G, Serafini G, Rossetti M, *et al*. Role of surgical techniques and operative findings in cranial and cervical nerve injuries during carotid endarterectomy. Eur J Vasc Endovasc Surg 1998;15:528-31.
23. Zhang Q, Duan ZQ, Xin SJ, Wang XW, Dong YT. Management of extracranial carotid artery aneurysms: 17 years' experience. Eur J Vasc Endovasc Surg 1999;18:162-5.
24. Zwolak RM, Whitehouse WM Jr., Knake JE, Bernfeld BD, Zelenock GB, Cronenwett JL, *et al*. Atherosclerotic extracranial carotid artery aneurysms. J Vasc Surg 1984;1:415-22.

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