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Invasive treatment for extracranial carotid artery aneurysm: a single-center case series and literature review

Xinyi Gao^{1†}, Julong Guo^{1†}, Zhu Tong¹, Xixiang Gao¹, Lianrui Guo^{1†} and Yongquan Gu^{1*†}

Abstract

Background Extracranial carotid artery aneurysm (ECAA) is a rare peripheral arterial disease. The main treatment strategies include conservative treatment, open surgery, endovascular treatment, and hybrid techniques, and there is no expert consensus or guidelines, with only a few case reports.

Method This article reviewed 10 cases diagnosed with "extracranial carotid artery aneurysm" and received invasive treatment from January 2013 to July 2023 in our medical center.

Results There were 10 patients with ECAA admitted to our center, including seven cases of true aneurysms, two cases of pseudoaneurysms, and one case of dissecting aneurysm. There were 3 females and 7 males aged between 24–61 years. Based on the characteristics of ECAA, we designed the individualized procedure including open surgery, endovascular treatment, and hybrid treatment. Procedures were technically successful for all patients, and none of them had any adverse events during the follow-up period except for one patient who developed cerebral hemorrhage on the third postoperative day and recovered after cerebral puncture and drainage.

Conclusion The current invasive treatments for ECAA mainly include open surgery, endovascular treatment, and hybrid treatment, and they all appear to be safe and effective.

Keywords Extracranial carotid artery aneurysm, Carotid pseudoaneurysm, Carotid dissecting aneurysm, Aneurysm

Introduction

Extracranial carotid artery aneurysm (ECAA) is an ultra-rare form of the peripheral aneurysm, with only 1,000 cases reported in the world literature so far [1]. Depending on the morphology, aneurysms can be classified as

true aneurysms, pseudoaneurysms, and dissecting aneurysms; true aneurysms are most often caused by atherosclerosis, trauma is often the cause of pseudoaneurysms and dissecting aneurysms often occur at the site of the most pronounced changes in blood pressure. Attigah et al. classified carotid aneurysms into 5 types based on anatomical location. Type I: isolated and short aneurysms of the internal carotid artery (ICA) above the carotid bulb. Type II: long aneurysms of the ICA ranging from the carotid bulb to Blaisdell's line. Type III: aneurysms of the proximal part of the ICA and the carotid bifurcation. Type IV: aneurysms involving the common carotid artery (CCA) and the ICA as with the Type III, extending distally and proximally. type V: isolated aneurysm of the CCA [2].

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Treatment of ECAA includes open surgery, endovascular treatment, hybrid operation, and conservative treatment with antiplatelet and anticoagulant agents, however, there are no treatment guidelines or expert consensus to date. This article summarised the case characteristics, anatomical features, and treatment measures of 10 cases of ECAA that have undergone surgical treatment in our center over the past 10 years.

Method

In this article, we reviewed 10 cases diagnosed of "extracranial carotid artery aneurysm" and treated with invasive therapy from January 2013 to July 2023 in our center. The data were obtained from electronic medical records. It was diagnosed in all patients by digital subtraction angiogram (DSA), computed tomography angiography (CTA) or duplex scan. ECAA was defined as expansion of vessel diameter to 1.5 times the expected vessel diameter. The aneurysm was identified as a true aneurysm, pseudoaneurysm, and dissecting aneurysm based on preoperative CTA or intraoperative DSA characteristics. Like other sites of aneurysms, true aneurysms could be seen with aneurysmal dilatation of the arterial wall, pseudoaneurysms could be seen with contrast leakage of the vascular wall on angiography, and dissecting aneurysms could be seen an added pseudovascular lumen formed by the arterial media. Patients without any accompanying manifestations of aneurysm (e.g., pulsatile mass, peripheral organ or tissue compression) and associated neurologic symptoms were considered asymptomatic [3]. We conducted invasive treatments for both symptomatic and asymptomatic patients. The follow-up was conducted through outpatient follow-up record review and telephone inquiries.

Result

Over the past 10 years, ten patients with ECAA were treated at our center including seven cases of true aneurysms, two cases of pseudoaneurysms and one case of dissecting aneurysm. The characteristics of the cases are shown in Table 1, consisting of three females and seven males, in the age range of 24–61 years old. The right carotid artery was involved in 4 cases and the left carotid artery in 6 cases. Regarding the initial symptoms, there were three cases of pulsatile mass in the neck, three cases of dizziness, two of which were accompanied by headache, two cases of numbness and weakness of the contralateral limbs, and one case of numbness of the left eyelid probably due to compression of the external carotid artery by the mass. Four of them had previous cerebral infarction, four suffered from hypertension, three from peripheral arterial disease, and one from coronary heart disease. Two patients had a smoking

history. According to the classification of Attigah et al., eight cases were type I, remaining two were type II and type IV respectively. The preoperative CTA or DSA, and intraoperative DSA of the cases were shown in Figs. 1 and 2. Among the patients with type I, two patients with pseudoaneurysms, one patient with true aneurysm and one patient with dissecting aneurysm underwent endovascular treatment; three patients with true aneurysm underwent open surgery, with end-to-end anastomosis; and one patient underwent individualized hybrid procedures (Fig. 1). The type II patient underwent hybrid procedure and the type V patient underwent endovascular treatment. Surgical procedures were successful in all patients (Fig. 2). Open surgery and hybrid surgery patients received preoperative mono-antiplatelet therapy medication, while endovascular therapy patients received preoperative dual antiplatelet therapy, for at least 3 days.











The patients were followed up for 7–72 months. It was recommended that patients be followed up by ultrasound at 3 months, 6 months, 12 months postoperatively and every following year, with CTA when ultrasound results indicated a stenosis >50% or when relevant symptoms were developed. All patients without lost follow-up received dual antiplatelet therapy for at least 3 months postoperatively and long-term mono-antiplatelet therapy thereafter. The first case occurred right frontal lobe cerebral hemorrhage on the third postoperative day, which was recovered after cerebral puncture and drainage. The nine remaining patients did not have any adverse events during the perioperative period, and had no new ipsilateral cerebral infarct during the follow-up period, with patency of blood flow through the treated blood vessels.

Discussion

ECAA is rarely observed, accounting for less than 1% of all aneurysms, and has been published mostly as a case report [4]. Most of the ECAA is mostly located at the carotid bifurcation or distal to the ICA, and its aetiology includes atherosclerosis, infection, fibromuscular dysplasia, connective tissue disease, trauma, previous surgery, radiation, or spontaneous entrapment [5, 6]. Initial symptom was most often reported as cerebral thromboembolism and partial compression, while rupture of the ECAA was suspected to be underreported [7, 8]. The anatomical location and characterization of the ECAA in our study cohort followed the same trend.

ECAA has typically been diagnosed by clinical symptoms and imaging examinations. A pulsatile neck mass could be found in up to 93% of patients, and neurologic symptoms were reported in about 50% of patients in previous studies [2, 9, 10]. And with the frequent use of imaging devices, asymptomatic ECAAs were increasingly being diagnosed. Grant T et al. reported that 49%

Table 1 Characteristics of the patients

Case	Sex	Age	Initial symptom	Antecedent	Smoking history	Date of operation	Type	Features of ECAA	Intervention	Follow-up
1	F	60	Pulsatile mass	—	No	11/26/2012	 Right	Distance from the beginning of ICA to the breach = 2.5 cm Diameter = 4 cm Compressed ICA	Endovascular surgery	Cerebral hemorrhage in the perioperative period Lost to follow-up
2	M	24	Dizziness	—	No	4/1/2015	 Left	Proximal with membranous stenosis	Endovascular surgery	1 year, no symptoms, stent patency
3	M	53	Numbness and weakness of the right limb	CI hypertension CAD	Yes	6/21/2017	 Left	Distally located at the level of the superior border of C2 Intracavitary thrombus; Tortuous ICA	Hybrid techniques	6 years, no symptoms, stent patency
4	M	55	Headache and dizziness	CI hypertension	No	11/24/2018	 Left	Dissecting aneurysm	Endovascular surgery	4 years 7 months, no symptoms, stent patency
5	F	61	Asymptomatic	CI	No	11/13/2019	 Left	Tortuous ICA	Open surgery	3 years 8 months, no symptoms, targeted arteries patency
6	M	30	Pulsatile mass	—	No	12/2/2020	 Right	Distally located at the level of C1 measuring approximately 4.1x3.3x3.0cm appendage thrombosis	Open surgery	2 years 6 months, no symptoms, targeted arteries patency
7	M	50	Numbness of the left eyelid	—	No	3/22/2021	 Left	Difficult exposure; Compressed ECA	Hybrid techniques	2 years 4 months, no symptoms, stent patency
8	M	54	Numbness and weakness of the left limb	hypertension PAD	Yes	8/2/2022	 Right	Spontaneous pseudoaneurysm	Endovascular surgery	11 months, no symptoms, stent patency
9	F	71	Asymptomatic	PAD	No	9/27/2022	 Right	Tortuous ICA	Open surgery	10 months, no symptoms, targeted arteries patency
10	M	60	Headache and dizziness	CI hypertension PAD	No	6/15/2023	 Left	—	Endovascular surgery	7 months, no symptoms, stent patency

F Female, M Male, CI Cerebral infarction, CAD Coronary artery disease, PAD Peripheral artery disease, ICA Internal carotid artery, ECA External carotid artery

of ECAAs in their case series were found incidentally [6]. Ultrasound is a convenient and reliable tool for the distinction of a mass as a solid tumor or a vascular disease, while CTA could be used to inform the surgical procedure [11]. In our center, the diagnosis was based on the symptoms of the patient and the ultrasound results, combined with the CTA results to provide additional information for procedures, and the follow-up was mainly based on the ultrasound results.

Invasive treatment has been advocated for any ECAA, whether symptomatic or asymptomatic, due to the high mortality rate of non-invasive cases [12]. In 1808, Cooper documented the first successful ECAA procedure, the proximal ligation; although the method was reported to have a high stroke rate of 25% and a high mortality rate of 20%, it was used until the early 1950s [13]. Resection of the aneurysm with target artery reconstruction was first successfully performed in 1956, and open repair reduced postoperative mortality and stroke rates, making carotid artery reconstruction the gold standard treatment [14, 15]. In 2009 Attigah et al. typed ECAA based on the anatomical location of the aneurysm and its position to the

cranial base, and revascularization options were generalized based on the typing, primarily including aneurysmoplasty, patch angioplasty, and Vein or Dacron-graft interposition [2]. Despite the success of open surgery, intraoperative protection of cranial nerves from injury has become a stronger concern; moreover, aneurysms near the cranial base have become a new challenge because of the difficulty in exposing the operative field.

The advent of endovascular treatment has solved the issue of high aneurysms due to the difficulty of exposing the operative field for open repair, while protecting the cranial nerves as much as possible, allowing it to proceed under regional anesthesia, reducing the surgical invasiveness, which in turn shortens the length of hospitalization [16, 17]. A recent systematic review included 959 cases of ECAAs, of which, 750 were treated with open surgery (perioperative complication rates: cranial nerve injury 9%, stroke 4%, and death 2%), while 85 were treated with endovascular therapy without perioperative complications despite one case of restenosis [18]. Cornwall et al. reviewed 18 cases of endovascular therapy for ECAA with a mean follow-up of 338 days; all operations

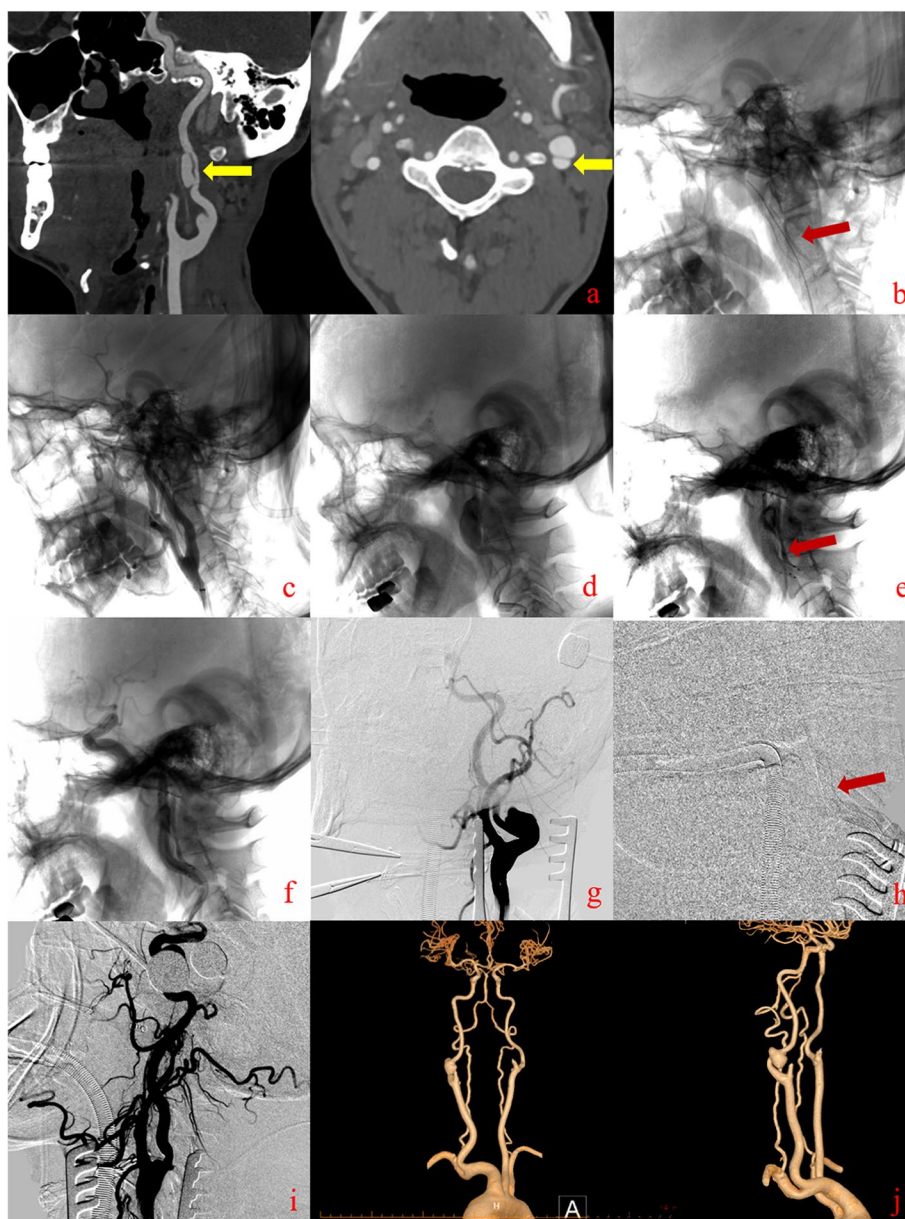


Fig. 1 The preoperative image assessment and intraoperative digital subtraction angiogram (DAS) of type I cases. Image (a), (b), and (c) show the preoperative assessment and intraoperative DAS of case 4; (d), (e), and (f) show case 10; (g), (h), and (i) show case 3; (j) shows case 9. The CTA (a), DSA (d), (g), and (j) show the type I dissecting aneurysm and type I aneurysms preoperatively; DSA (b), (c), (e), and (f) show the ECAA treated with endovascular treatment has disappeared and target artery patency without endoleak. DSA (h) and (i) show the ECAA treated with hybrid procedure. The yellow arrows point out the dissecting aneurysms. Red arrows point out stents

were technically successful, postprocedural surveillance imaging confirmed the elimination of ECAA, and all stents were maintained patent on follow-up imaging [19]. A systematic review involving 224 patients receiving endovascular therapy suggest that stenting for ECAA is technically feasible, with a high procedural success rate (92.8%), a relatively low complication rate (postprocedural endoleak, 8.1%; stroke, 1.8%; cranial nerve injury,

0.5%), a mean follow-up time of 15.4 ± 15.3 months, and an covered stent patency rate of 93.2% [13].

The principal objective in the management of ECAA is to prevent permanent neurologic impairment due to thromboembolism and thrombosis, as well as to exclude the risk of rupture. The management of ECAA has advanced with the development of surgical techniques. Complete removing of the aneurysm

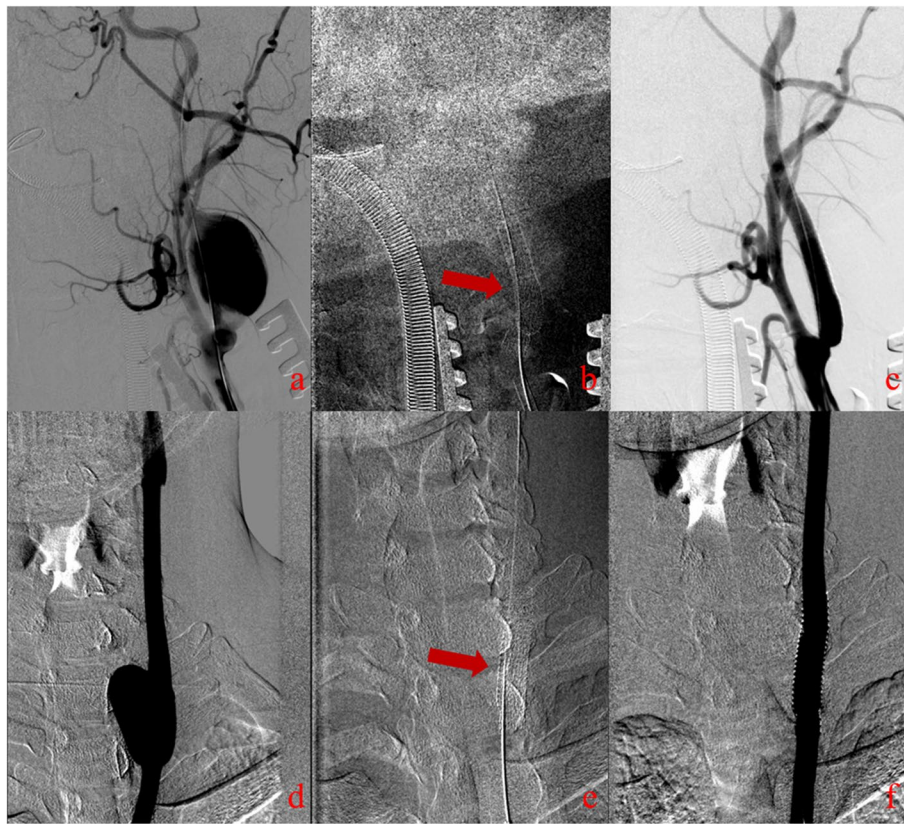


Fig. 2 The preoperative image assessment and intraoperative digital subtraction angiogram (DAS) of type II and V cases. Image (a), (b), and (c) show the preoperative assessment and intraoperative DAS of case 7; (d), (e), and (f) show case 2. The DSA (a) and (d) show the type II and V aneurysms preoperatively; DSA (b) and (c) show the ECAA treated with hybrid procedure. DSA (e) and (f) show the ECAA treated with endovascular treatment has disappeared and target artery patency without endoleak. Red arrows point out stents

and reconstruction of blood flow to the target arteries has been pursued as the ideal procedure. However, there are currently no treatment guidelines or expert consensus for the treatment of ECAA. Based on the characteristics of ECAA, we designed the individualized procedure. For ECAA, we prioritized endovascular treatment, as shown in cases 1, 2, 4, 8, and 10 (Figs. 1a-f and 2d-f). For the type V patient with membranous stenosis, we placed a covered stent. For both dissecting aneurysm and pseudoaneurysms, stenting was performed with the dissection and at the rupture site, respectively, and case 1 with pseudoaneurysm combined with a coil embolization. Covered stents and stent-assisted embolization were the predominant endovascular treatments used in our center, and there is evidence suggesting that treatment with flow-directed braided stents and overlapping bare-metal stents are also safe and effective [19]. For patients with the difficulty of endovascular approach and high embolization risk but without difficulty in lesion exposure, we performed open surgeries, such as case 5, 6 and 9 with end-to-end anastomosis (Fig. 1j). For patients with difficult

lesion exposure and anatomical risk factors hindering the safe deployment and placement of stents (such as target artery tortuosity and thrombus in the aneurysm lumen), individualized hybrid procedures were devised, for instance, cases 3 and 7 (Figs. 1g-i and 2a-c). In case 3, we punctured the ICA retrogradely and antegradely under direct vision to establish the extravascular access, and then placed a covered stent into the appropriate position to completely isolate the aneurysm. In case 7, a covered stent was placed by direct puncture of the ipsilateral CCA, and the graft was sutured to the entire arterial wall outside the proximal neck of the aneurysm in order to prevent endoleak.

Except for case 1 of cerebral hemorrhage during the perioperative period, none of the patients experienced adverse events during the follow-up period. Cerebral hemorrhage was possibly linked to severe compression of the ICA in patients with ECAA, potentially associated with postoperative hyperperfusion syndrome [20]. Patients with severe carotid artery stenosis and compromised collateral circulation might benefit from staged

angioplasty to mitigate the risk of hyperperfusion syndrome [21].

Conservative treatment of ECAs has very rarely been reported. Welleweerd et al. proposed medication following the medical treatment guidelines for the most likely underlying disease, such as according to generalized atherosclerosis [12]. Patients were recommended to receive dual antiplatelet therapy for at least 3 months postoperatively in our center, and thereafter the medication regimen was adjusted according to other comorbidities.

There is scant data on natural follow-up. McCollum et al. have suggested that asymptomatic ECAA can have a conservative treatment through antiplatelet therapy or anticoagulation [22]. However, as surgical techniques have improved over the past 20 years and interventional devices have been updated, treatment options for asymptomatic ECAA may change. In our cohort, both asymptomatic patients underwent open surgery and were followed up for 3 years and 8 months and 10 months respectively without any new symptoms. Therefore, it is crucial to obtain data on the natural progression of ECAA. A prospective international registry study called the Carotid Aneurysm Registry Study (CAR) is currently conducting, and we look forward to data on the natural history, intervention outcomes, and follow-up of participants with ECAA [23].

ECAA is rare and only 10 cases have been treated in our center in the last 10 years. Although this study has limitations due to the small number of cases and retrospective nature, we have shared valuable experience and successful cases in developing personalized treatment strategies, thereby providing clinicians with insights, particularly in the current absence of standardized treatment guidelines. We anticipate larger-scale clinical studies and the establishment of ECAA guidelines.

Conclusion

Based on the characteristics of the aneurysm and target arteries, individualized invasive treatments for ECAA primarily include open surgery, endovascular treatment, and hybrid treatment, and they all appear to be safe and effective.

Abbreviations

ECAA	Extracranial carotid artery aneurysm
ICA	Internal carotid artery
CCA	Common carotid artery
DSA	Digital subtraction angiogram
CTA	Computed tomography angiography
CAR	Carotid Aneurysm Registry Study

Acknowledgements

Not applicable.

Authors' contributions

Conception and design: XY.G. and JL.G.; Provision of study materials or patients: Z.T. and XX. G.; Data interpretation: LR.G. and YQ.G.; Manuscript writing: All authors. All authors have read and agreed to the published version of the manuscript.

Funding

National Key Research and Development Program of China [2021YFC2500500].

Availability of data and materials

The datasets supporting the conclusions of this article are included within the article.

Declarations

Ethics approval and consent to participate

All procedures performed involving human participants were in accordance with the ethical standards of the institution and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by The Ethics Committee of Xuan Wu Hospital of the Capital Medical University. Informed consent was obtained from all participants included in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Received: 29 December 2023 Accepted: 29 July 2024

Published online: 05 August 2024

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