Clinical Science

A tailored approach to operative repair of extracranial carotid aneurysms based on anatomic types and kinks

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KEYWORDS:
Carotid artery aneurysm; Surgery; Internal carotid artery kinking

Abstract

BACKGROUND: To present outcomes following an operative approach of extracranial carotid artery aneurysm (ECAAs) based on anatomic types and associated kinks.

METHODS: This study represents retrospective analysis of anatomic type based approach to operative repair of 84 patients with ECAA from 1994 to 2011, 28 (33.3%) with associated kinking. Patients were followed for neurological ischemic events, hematoma, cranial nerve injury, myocardial infarction, neurological, and overall mortality. The results are presented as early, within 30 days after the surgery, and long term during the follow-up.

RESULTS: In the early postoperative period, there were no strokes or mortalities, cranial nerve injury rate was 2.4% while 1 patient had myocardial infarction (1.2%). During the follow-up, 4 patients (4.8%) had stroke, out of which 2 patients died (2.3%), while overall mortality was 4.6%. The average 5-year survival rate was 96 ± 3%.

CONCLUSION: Excellent outcomes can be obtained with surgical repair of ECAA, which should be tailored to the anatomic types and presence of kinks.

Extracranial carotid artery aneurysm (ECAA) is a rare disease triggered by atherosclerosis, trauma, fibromuscular dysplasia, or related to previous carotid surgery (post-endarterectomy aneurysms). Since a high risk of rupture and embolization has been described in patients with ECAA, surgical treatment is the preferable treatment option. Isolated extracranial internal carotid artery (EICA) aneurysms are uncommon entity as well, estimated at .1% to 2% of the total carotid surgery procedures. The exact incidence is not entirely known but it is expected to be about .8% to 1% of all arterial aneurysms and about 4% of all peripheral arterial aneurysms. EICA could also be initiated by atherosclerosis, dysplasia, infection, trauma, or iatrogenic cause.

The exact incidence of associated kinking and extracranial carotid aneurysms is not known. After reviewing the
literature, only a few case reports have been published on this subject.\textsuperscript{8–11} The aim of this study was to present our experience in carotid aneurysm surgical treatment with special emphasis on isolated internal carotid artery (ICA) aneurysms with associated kinking.

\section*{Patients and Methods}

\subsection*{Study design}

This study represents retrospective review of prospectively collected data in 2 major vascular surgery university clinics. Ethical Committee of both institutions approved this study. The study included 84 patients who were surgically treated for ECAA’s from January 1994 to July 2011, and 28 patients (33.3\%) had ICA aneurysm with associated kinking.

Out of this number, 23 patients from our 2 centers were also included in our previous article reporting on surgical outcome of ECAA repair from 3 university centers.\textsuperscript{12}

All patients were initially diagnosed using Doppler ultrasonography when aneurysmal disease of carotid arteries was discovered, followed by selective angiography in 33 patients (39.3\%), and multidetector computed tomography angiography (MDCT) in 51 patients (60.7\%) for detailed evaluation.

According to our institution experience, kinking was considered significant if peak systolic velocity was $>180$ cm/sec. In all patients with ICA kinking, selective or MDCT angiography confirmed its significance. Observed angle at the site of the kinking was between $30^\circ$ and $60^\circ$ with a large number of patients with observed angle $<30^\circ$.

Attending neurologist examined all patients to evaluate actual neurological status, whereas brain computed tomography was performed in all symptomatic patients. After all these neurological examinations, surgical treatment was indicated.

\subsection*{Surgical techniques and intraoperative management}

Surgical treatment was performed under either general endotracheal anesthesia or in regional anesthesia if severe obstructive pulmonary disease or cardiac comorbidity was present. Carotid arteries and aneurysm exposure were followed by systemic heparinization and clamping. For intraoperative cerebral perfusion assessment, we used cerebral oximetry that indicated a need for intraluminal shunt placement.

Carefully balanced anesthetics influenced appropriate cerebral protection during clamping time. Several surgical techniques were performed depending on the characteristics of the intraoperative findings. We have used anatomical classification proposed by Attigah et al\textsuperscript{13} but modified in some parts because of kink presence. The first type (Type I) included aneurysm resection, shortening of the artery (in case of associated kinking), and end-to-end anastomosis (Fig. 1). This type refers to the first part of Attigah’s Type I that include end-to-end anastomosis.\textsuperscript{13}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig1}
\caption{ICA aneurysm and kinking – surgical technique Type I: (A) before the surgery and (B) after aneurysm resection and end-to-end anastomosis. CCA = common carotid artery; ECA = external carotid artery; ICA = internal carotid artery; STA = superior thyroid artery; T-T = termino-terminal anastomosis.}
\end{figure}
If ICA aneurysm with associated kinking was located proximally, just at the first kink level, we have done a simple ellipsoid transection of the artery at the bifurcation level followed by prolonged ICA incision on the medial wall in the length of the kinking and standard ICA reimplantation (Type II, Fig. 2). Before placing the final sutures complete exclusion of the aneurysm was done by shortening of the excess of the artery (Fig. 2). This type is our modification which was not previously described by Attigah et al.\textsuperscript{13} since no kinks were verified in their series.

Figure 2  ICA aneurysm and kinking – surgical technique Type II: (A) ICA transection from carotid bifurcation followed by prolonged incision on medial wall; (B) ICA suturing; and (C) the end of the anastomosis with previous complete aneurysm exclusion. CCA = common carotid artery; ECA = external carotid artery; ICA = internal carotid artery; STA = superior thyroid artery.

Figure 3  ICA and CCA aneurysm – surgical technique Type III: (A) before the surgery and (B) after aneurysm resection and Dacron graft insertion. CCA = common carotid artery; DTG = Dacron tubular graft; ECA = external carotid artery; ICA = internal carotid artery; STA = superior thyroid artery; T-T = termino-terminal anastomosis.
If large aneurysm of the common carotid artery (CCA), aneurysm affecting both, CCA and ICA or significant atherosclerotic lesions were verified during the surgery, Dacron tubular graft was inserted between CCA and ICA (Type III, Fig. 3). This type refers to Attigah’s Type IV.13 Type IV included Dacron tubular graft insertion between the distal ICA and ICA origin from carotid bifurcation (Fig. 4). This type refers to Attigah’s second part of Type I that include Dacron graft insertion.13

**Statistical analysis and follow-up**

Patients were followed for significant postoperative events (eg, transient ischemic attack [TIA], stroke, hematoma, cranial nerve injury, myocardial infarction, neurological, and overall mortality) after 1 month, 6 months, after 1 year, and annually afterwards. Results are presented as early, within 30 days after surgery, and long term during the follow-up.

Numeric variables, consistent with the normal schedule, were described by arithmetic mean and standard deviation. Numeric variables without a normal distribution were described by median and interquartile range. Categorical variables were presented as frequency and percentage, according to modalities of appropriate categories. The minimum accepted level of significance of the first-order

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>$n = 84$ patients (%)</th>
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<tbody>
<tr>
<td><strong>Sex</strong></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>60 (71.4%)</td>
</tr>
<tr>
<td>Female</td>
<td>24 (28.6%)</td>
</tr>
<tr>
<td><strong>Age (years ± SD)</strong></td>
<td>65.01 ± 7.53</td>
</tr>
<tr>
<td><strong>Arterial hypertension</strong></td>
<td>76 (90.5%)</td>
</tr>
<tr>
<td><strong>Hyperlipidemia</strong></td>
<td>48 (57.1%)</td>
</tr>
<tr>
<td><strong>Smoking history</strong></td>
<td>46 (54.8%)</td>
</tr>
<tr>
<td><strong>Diabetes</strong></td>
<td>9 (10.7%)</td>
</tr>
<tr>
<td><strong>Heredity</strong></td>
<td>20 (23.8%)</td>
</tr>
<tr>
<td><strong>Brain CT positive for ischemia</strong></td>
<td>22 (26.2%)</td>
</tr>
<tr>
<td><strong>Previous MI</strong></td>
<td>12 (14.3%)</td>
</tr>
<tr>
<td><strong>Previous CABG</strong></td>
<td>3 (3.6%)</td>
</tr>
<tr>
<td><strong>Previous PCI</strong></td>
<td>3 (3.6%)</td>
</tr>
<tr>
<td><strong>Previous TIA</strong></td>
<td>10 (11.9%)</td>
</tr>
<tr>
<td><strong>Previous stroke</strong></td>
<td>19 (22.6%)</td>
</tr>
<tr>
<td><strong>Amaurosis fugax</strong></td>
<td>3 (3.6%)</td>
</tr>
<tr>
<td><strong>Global cerebral ischemia</strong></td>
<td>36 (42.9%)</td>
</tr>
<tr>
<td><strong>Coronary artery disease</strong></td>
<td>35 (41.7%)</td>
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</tbody>
</table>

CABG = coronary artery bypass grafting; CT = computed tomography; MI = myocardial infarction; PCI = percutaneous coronary intervention; SD = standard deviation; TIA = transient ischemic event.
error was .05. Data were statistically analyzed by the statistical package SPSS Version 15 (SPSS Inc, Chicago, IL).

Results

Patients’ characteristics

Out of 84 patients, 60 were men (71.4%) and 24 women (28.6%), with mean age 65.01 ± 7.53 years (Table 1). Overall patients’ demographic characteristics are shown in Table 1.

Isolated aneurysm of CCA was noted in 22 patients (26.2%), EICA aneurysm was registered in 54 patients (64.3%), while 4 patients (4.8%) had aneurysm that involved both CCA and ICA.

In 28 patients (33.3%), ICA aneurysm was associated with kinking. Among these patients, 15 (17.9%) had contralateral ICA kinking. Aneurysm characteristics and classification are shown in Table 2.

None of the aneurysms were the result of previous trauma or carotid infection (wound swab analysis were sterile in all cases). One patient had inflammatory aneurysm, but the wound swab was sterile as well. This patient was treated by wide spectrum antibiotics during and after the surgery and 1 week following discharge. Likewise, in 1 patient pathohystological specimen showed cystic medial degeneration in the arterial wall.

Four patients had associated intracranial aneurysm (4.8%), 2 in anterior cerebral artery, and 1 in middle cerebral artery basin. These aneurysms were asymptomatic and small, grade 0 according to Hant et al.[14,15] and all 3 are localized on the opposite side of carotid aneurysm localization. The consulting neurosurgeon recommended proceeding with surgery.

Fourteen patients (16.7%) had associated infrarenal aorta aneurysm, 8 were treated either surgically or by endovascular aortic aneurysm repair 1 month after carotid aneurysm resection. None of the patients had associated thoracic aorta or popliteal artery aneurysm, while 1 patient had associated left anterior descending coronary artery aneurysm.

Only 16 patients were asymptomatic (19.04%), 36 patients (42.9%) had global cerebral ischemia symptoms (vertigo, dizziness, etc.), 10 patients (11.9%) had previous TIA, 19 patients (22.6%) had stroke, and 3 patients (3.6%) had amaurosis fugax.

Twenty-two patients (26.2%) had brain computed tomography positive for ischemia before surgery. Nearly one third of the patients had discomfort because of local compression of the aneurysm.

In patients with ICA kinking, average aneurysm diameter was larger than in patients without kinking (24.5 vs 20 mm; \( P = .038 \)), while average overall aneurysm diameter was 22.6 ± 7.4 mm (range, 12 to 40 mm). Patients without kinking more frequently suffered from diabetes (16.07% vs 0%; \( P = .021 \)) and had a higher rate of stroke (30.4% vs 7.1%; \( P = .013 \)) and myocardial infarction (19.6% vs 3.6%; \( P = .042 \)).

Operative results

Surgical treatment was performed under general endotracheal anesthesia in 64 patients (76.2%) and in regional anesthesia in 20 patents (23.8%) (Table 3). Average clamping time was 13.93 ± 8.31 min (11.5 min in patients with kinking vs 14 min without kinking; \( P = .028 \)). The characteristics of surgical reconstruction are shown in Table 3. During the clamping time, cerebral function was monitored by cerebral oximetry that indicated intraluminal shunt use in 2 patients (2.4%) – in 1 patient because of low brain saturation with oxygen caused by contralateral ICA occlusion and poor retrograde flow in other. Shunt was placed through Dacron graft in the first case and through native arteries in the second and taken out just before final sutures were placed.

In 43 patients (51.2%), we were able to preserve external carotid artery. As for grafts used in revascularization, in all patients Dacron graft of 6 mm was used which on the basis of our experience showed to be a very good solution for extracranial arterial revascularization.

In patients with Type I and Type II, arterial wall was of good quality and direct anastomosis was performed safely. In all 4 surgical reconstruction types, hypoglossal nerve localization did not complicate surgical procedure.

Early results

Follow-up ranged from 1 to 12 years with median follow-up of 5.01 ± 3.33 years. In the first 30 postoperative
days, there were no TIA’s, strokes, or deaths. One patient (1.2%) had myocardial infarction followed by urgent percutaneous coronary artery intervention. Two patients (2.4%) were reoperated for surgical site hematoma, while 2.4% of the patients had transitory recurrent laryngeal nerve injury successfully treated by corticosteroids. Postoperative Doppler ultrasonography showed regular findings in all cases with preserved blood flow, no residual kinks, technical failure, or stenosis.

Long-term results

In the long-term results, 4 patients (4.8%) had stroke out of which 2 patients (2.3%) died. Overall observed mortality was 4.6%. During the follow-up, Doppler ultrasonography showed nonsignificant restenosis (<50%) in 5 patients (5.9%) and significant restenosis (>50%) in 4 patients (4.8%) requiring additional percutaneous angioplasty. Because of extensive lesions in all patients requiring angioplasty, carotid stent was placed with cerebral protection devices used during the procedure. In 2 patients (2.3%), asymptomatic carotid occlusion was verified.

In 1 patient, carotid occlusion was verified 23 months after the surgery and after 45 months in other. Residual or newly created kinks were not verified. The average 5-year survival rate was 96 ± 3%.

Comments

ECAAs are rare entities with a total share in overall carotid surgery from .2% to 5%.1–5,16–22 As ECAA, isolated EICA aneurysms are extremely rare entities with reported incidence around .8% to 1% of all arterial aneurysms.6,23

On the other hand, the exact incidence of kinks and coils is unknown since many patients are asymptomatic. Some studies report that ICA kinking affected 16% of studied subjects,24–27 nearly 4 times more often seen in women.24

Only a few case reports have been published describing the relationship between ICA kinking and aneurysmal growth.8–11 In these reports, mutual kinking and ICA aneurysmal formation were evaluated, but still the focus was on surgical technique. In 2 of these cases the authors performed aneurysmal resection and end-to-end anastomosis,8,9 while in 1 patient repair using autologous vein graft was done.11

In this study, kinking presence significantly influenced surgical approach and techniques used for ECAA treatment. For this reason, we used modified classification proposed by Attigah et al.13 The presence of kinking greatly facilitated Type I surgical reconstruction in our study, given the sufficient material for end-to-end anastomosis. This type refers to the first part of Attigah’s Type I that include end-to-end anastomosis.13

Type II in this study is the surgical reconstruction introduced by our surgeons that was not previously described by Attigah et al,13 namely, aneurysm presence just at the first kink level enabled us to use excess of the artery for direct anastomosis to ICA bifurcation following exclusion of the aneurysm.

Type III in our study (Dacron graft insertion between CCA and ICA) refers to Attigah’s Type IV, while our Type IV (Dacron graft insertion between distal ICA and ICA origin from bifurcation) refers to Attigah’s Type I that include graft insertion.13 In addition to Attigah’s classification of ECAA surgical approach,13 our modification could be useful as well especially in the case of associated kinks.

Another interesting point regarding our results is small percent of shunt use with excellent outcomes. Our institute is high-volume center for eversion carotid endarterectomy28–32 with more than 800 surgeries per year and 10,000 procedures done for the last 20 years.32 Both our surgeons, senior and young, have comprehensive training in eversion carotid endarterectomy resulting in short clamping time (11.9 ± 3.2 min).32 This fact made shunting practically unnecessary that is very rarely used in recent years (.5% of all patients) with excellent neurological and overall outcome (neurological morbidity 1.1% and overall morbidity 3.9%; neurological mortality .52% and overall mortality 1.32%).32 Extensive experience of our surgeons in carotid surgery is reflected in the good results of ECAA surgical treatment in this study with short clamping time (13.93 ± 8.31 min) and rare shunt use. In patients with aneurysm and kinking, clamping time was significantly shorter compared to patients without kinking (11.5 vs

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**Table 3** Types of surgical procedures

<table>
<thead>
<tr>
<th>Types</th>
<th>Patients (%)</th>
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<tbody>
<tr>
<td>Type I: ICA resection and end-to-end anastomosis</td>
<td>29 pts (34.5%)</td>
</tr>
<tr>
<td>Type II: resection, shortening, and ICA reimplantation</td>
<td>46 pts (54.8%)</td>
</tr>
<tr>
<td>Type III: Dacron tubular graft insertion (CCA–ICA)</td>
<td>9 pts (10.7%)</td>
</tr>
<tr>
<td>Type IV: Dacron tubular graft insertion (ICA origin to distal ICA)</td>
<td>41 pts (48.8%)</td>
</tr>
<tr>
<td>Associated ICA bifurcation endarterectomy</td>
<td>5 pts (4.8%)</td>
</tr>
<tr>
<td>Endotracheal anesthesia</td>
<td>25 (29.8%)</td>
</tr>
<tr>
<td>Regional anesthesia</td>
<td>64 (76.2%)</td>
</tr>
<tr>
<td>Associated ICA bifurcation endarterectomy</td>
<td>20 (23.8%)</td>
</tr>
</tbody>
</table>

CCA = common carotid artery; ICA = internal carotid artery.
14 min; \( P = .028 \)); thanks to facilitated anastomosis creation because of elongation of the arteries and sufficient quantity of the arterial wall.

One more issue to discuss is frequent Dacron graft usage compared to vein grafts. We choose to use Dacron graft more often since reconstruction is faster and clamping time is shorter. Likewise, we have great experience in graft utilization in carotid surgery\(^1,3\) with excellent outcome and almost complete absence of infection. On the other hand, in most of the patients great saphenous vein was not of acceptable quality described by ultrasound.

As for the diagnosis, it might seem that large number of patients in our study had conventional angiography done for the final aneurysm evaluation (conventional 33 patients [39.3%]; MDCT 51 pts [60.7%]), but this is because of the fact that our study analyzed patients who were operated from January 1994 to July 2011 and MDCT has been only recently introduced at our institutions in 2005 and 2006 that is nowadays routinely used.

An interesting finding in our study is that patients with ICA kinking had aneurysms of a greater diameter compared to patients without kinking probably because of a weakened arterial wall contributing to aneurysm enlargement, especially when high prevalence of hypertension (96.4%) is taken into account. This fact did not aggravate surgical procedure since clamping time was significantly shorter in patients with ICA aneurysm and kinking than without kinking.

In addition to good results of surgical treatment of ECCA,\(^21\) results of ECCA endovascular treatment have been also recently published with favorable outcome.\(^3,34\) Li et al\(^13\) published systematic review of 113 studies involving 224 patients endovascularly treated for ECCA. Procedure success was 92.8% with postoperative endoleak reported in 8.1% of the patients and stent-graft patency of 93.2% during the follow-up.

When these results\(^33\) are compared with the results of this study, early stroke rate was higher in patients treated endovascularly (1.8% vs 0%) as well as inhospital mortality (4.1% vs 0%). Although considered, exclusion by covered stent was not an option for our patient’s treatment because of the close relationship of the aneurysm and kinking in some patients and high risk of embolization in others.

Groot de et al suggest a hybrid approach for simultaneous carotid aneurysm and ICA kinking that consists of surgical shortening of the proximal ICA to reduce the kinking followed by stent placement with favorable outcome.\(^34\) Still, this report consisted of small number of patients with short-term results waiting for larger series and longer follow-up to establish the safety of these interventions.\(^34\)

For the safe and reliable extracranial carotid aneurysm treatment, good surgical technique is required with complete aneurysm exposure to provide enhanced anatomical reconstruction, especially in the presence of pathological elongations seen in our report. Whether the kinking of the ICA is a cause or just associated with aneurysm is yet to be determined, but the prevalence of this entity is on the rise in our series and we believe that special attention should be addressed to this phenomenon. Patients with ICA aneurysm and kinking required specific surgical approach and various surgical techniques that resulted in favorable outcome.

**Conclusions**

Extracranial carotid aneurysms are relatively uncommon and frequently associated with kinks. Excellent outcomes can be obtained with surgical repair, which should be tailored to the anatomic types and presence of kinks.

**References**
