Proximal Common Carotid Artery Lesions: Endovascular and Open Repair

K. Linni*, M. Aspalter, A. Ugurluoglu, T. Hölzenbein

Department of Vascular and Endovascular Surgery, PMU Salzburg, Salzburg, Austria

Submitted 7 November 2010; accepted 21 February 2011
Available online 21 March 2011

Abstract
Objectives: Management of proximal common carotid artery (pCCA) lesions is infrequently reported. We described open and endovascular treatment with regard to the neurological outcome and patency in patients suffering from atherosclerotic pCCA lesions.

Methods: Data were collected prospectively and analysed in a retrospective manner.

Results: From November 1991 to January 2010, 52 procedures, 24 surgical (11 bypasses, 12 transpositions and retrograde endarterectomy) and 28 endovascular (13 open transcervical and 15 transfemoral stent implantations) were performed (40.4% female, mean age 62.3 years, 65.4% left-sided). A total of 25 lesions (48.1%) were symptomatic (13 stenoses and 12 occlusions); 27 (51.9%) lesions were asymptomatic (22 stenoses and five occlusions). Two bypasses occluded within 30 days. Two early ipsilateral strokes were observed (3.8%). There was one perioperative death due to myocardial infarction after transcervical stent (1.9%). Mean follow-up was 61 months. In one transposition and two stent implantations, late redo interventions were performed. Fourteen of 48 patients died during follow-up.

Conclusion: pCCA repair for atherosclerotic lesions is associated with a substantial perioperative risk (combined stroke/death rate: 5.7%). Endovascular intervention is the preferred invasive treatment option in patients suffering from stenotic pCCA lesions. In cases of pCCA occlusion, open surgery is a valid alternative. Late survival in patients suffering from pCCA lesions is poor.

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The proximal common carotid artery (pCCA) is the second most common site for stenosis in the extracranial carotid arteries and causes 1–2% of all cerebral ischaemic events. Yet, reports on the treatment of pCCA lesions are rare. Shimizu and Sano were the first to report operative repair of two common carotid artery (CCA) lesions in 1951. Initially, supraaortic trunk (SAT) lesions were treated via a transthoracic approach. Due to high mortality rates,
extrathoracic procedures avoiding thoracotomy became popular in the 1960s. In the 1980s, percutaneous transluminal angioplasty (PTA) was first described. In the 1990s, stent-supported PTA (sPTA) extended the therapeutic armamentarium and improved the long-term patency of endovascularly treated SAT lesions. The aim of this retrospective study was to compare safety and efficacy of the surgical and endovascular treatment of pCCA lesions with regard to neurological outcome and patency.

Patients and Methods

Patients were recruited at a university-based tertiary care centre. Patient data were entered prospectively in a dedicated data base and analysed in a retrospective manner. Data were prepared according to the suggested Reporting Standards by the European Society for Vascular Surgery (EVS). There are currently no guidelines available from ESVS or Society for Vascular Surgery (SVS) regarding the management of pCCA lesions.

Indication for pCCA revascularisation

Revascularisation of symptomatic pCCA lesions was performed for CCA occlusion or stenosis of >70%. Asymptomatic pCCA lesions were treated in case of CCA stenosis >80% lumen reduction. Asymptomatic occlusions were treated if the ipsilateral internal carotid artery (ICA) had a high-grade (>80%) stenosis or if the contralateral ICA was occluded. This was in accordance with previous publications. There are currently no guidelines available from ESVS or Society for Vascular Surgery (SVS) regarding the management of pCCA lesions.

Preoperative examination

The preoperative evaluation was performed by vascular surgeons and an independent neurologist. Prior to surgery, the medical history was evaluated and a physical examination was performed. Imaging before surgery or endovascular treatment included colour-coded duplex sonography (DS), magnetic resonance angiography (MRA), computed tomography angiography (CTA) and/or digital subtraction angiography (DSA) of the aortic arch vessels. Most patients received at least two different imaging studies. Preoperative brain imaging was routinely performed using either CT or magnetic resonance imaging (MRI).

Technique of open pCCA revascularisation

Subclavian artery (SA)-to-carotid bypasses and CCA-to-SA transpositions were carried out under general anaesthesia. We used the lateral supraclavicular approach for bypasses and the medial approach in between the bellies of the sternocleidomastoid muscle for transpositions. In patients with high-grade ipsilateral ICA stenosis, a bypass was the preferred technique. After standard endarterectomy of the ICA, the SA-to-carotid bypass was anastomosed to the endarterectomised segment. Completion angiography was done routinely.

Retrograde ring-stripper endarterectomy of the pCCA was performed via standard exposure of the CCA. After clamping of the distal CCA proximal to the carotid bifurcation, a longitudinal incision of the CCA was performed. After transection of the intima of the CCA, the ring-stripper was introduced into the subintimal cleavage plane. When the ring-stripper reached the aortic arch, the endarterectomised core was removed via the arteriotomy. Completion angiography was performed via a pigtail catheter positioned in the aortic arch.

Technique of hybrid endovascular procedures

Open retrograde stenting of the pCCA was performed in an angiography-compatible operating room. After cutdown to the CCA under local anaesthesia, the artery was clamped and punctured proximal to the carotid bifurcation. The position of the clamp allowed blood flow between the external carotid artery (ECA) and the ICA, and prevented embolisation into the brain during angioplasty. After traversing the stenosis with a standard 0.035-inch guide wire, the lesion was predilated and stented by balloon- or self-expandable stents. Balloon-expandable stents were used for ostial stenoses. Self-expandable stents were used in the proximal body of the CCA. The size of the stents was chosen according to the diameter of the CCA beyond the stenosis. A <30% residual stenosis was judged as a successful intervention. After removing the sheath and the arterial clamp, the CCA was flushed extensively. In cases with concomitant ICA stenosis, a standard carotid endarterectomy (CEA) was performed prior to the pCCA repair. As the CCA lesion was treated by endovascular means, these cases were defined as endovascular.

Technique of percutaneous procedures

sPTA procedures were performed in the angio suite under local anaesthesia with femoral approach in all cases. Indication for and size of self-expandable and balloon-expandable stents were the same as for hybrid procedures. A <30% residual stenosis with completion angiography was judged as a successful intervention. Embolic protection devices were used at the discretion of the vascular surgeon.

The technical details of CCA revascularisation were described previously. The type of intervention was at the discretion of the vascular surgeon.

Postoperative examination

All patients underwent post-procedural examination by an independent neurologist. In surgical cases, laryngoscopy was routinely performed for detection of recurrent laryngeal nerve injuries. Fluoroscopy was undertaken in all surgical cases to rule out phrenic nerve palsies.

Long-term follow-up

After discharge, patients were routinely evaluated in the outpatient department and tracked with phone calls, if they missed a scheduled appointment for more than 6 months. They were seen every 3 months during the first...
year and annually thereafter. Colour-coded DS was carried out at every postoperative visit. High-grade pCCA stenosis was suspected if the peak systolic velocity exceeded 300 cm s\(^{-1}\), or if the end-diastolic velocity was >100 cm s\(^{-1}\). MRA, CTA and/or DSA of the aortic arch vessels were performed only if there was suspicion of a significant recurrent stenosis of the pCCA reconstruction or the need for repair of another supraaortic artery.

### Statistical analysis

Data were prepared as suggested by the guidelines.\(^{14}\) Statistical analysis was performed calculating each intervention individually. Data are presented as percentage and means with ranges. Survival rates and patency estimations were obtained using the Kaplan–Meier analysis (SPSS, Chicago, IL, USA). A value of \( p < 0.05 \) (log rank test) was considered significant.

### Results

#### Patient demographics and risk factors (Table 1)

From November 1991 until January 2010, 52 pCCA interventions (endovascular group \( n = 28 \), surgical group \( n = 24 \)) in 48 patients (40.4% female, mean age 62.3 years, range, 40.9–81.4 years) were carried out. During the same time period, more than 3400 CEAs have been performed in our department. pCCA lesions were left in 65.4% of cases. All lesions were atherosclerotic. Patient characteristics and risk factors were equally distributed between the surgical and endovascular groups.

#### Preoperative neurological symptoms (Table 2)

In 51.9% (27/52) of cases, pCCA lesions were asymptomatic (21/28 endovascular, 6/24 surgical; \( p = 0.007 \)).

Nearly half (48.1%, 25/52) of cases had ipsilateral central neurological symptoms preoperatively. In the surgical group, 75% (18/24) and in the endovascular group, 25% (7/28) were symptomatic, respectively. The most common preoperative neurological symptoms were transient ischaemic attacks (TIAs, 17/52, 32.7%), followed by amaurosis fugax (7/52, 13.5%) and minor stroke (1/52, 1.9%), respectively.

### Preoperative antiaggregation

All patients were treated without cessation of anti-thrombotic therapy; 80.8% (42/52) of cases were under acetylsalicylic acid (ASA) (100 mg day\(^{-1}\), 13.5% (7/52) of patients were treated with ASA (100 mg day\(^{-1}\)) and clopidogrel (75 mg day\(^{-1}\)) mainly because of previous coronary stenting and 5.8% (3/52) of patients received clopidogrel (75 mg day\(^{-1}\)) only because of ASA intolerance. No patient received anticoagulation.

### Anatomy of the supraaortic vessels in 52 pCCA cases

Two-thirds (67.3%, 35/52) of patients revealed a high-grade (>80%) pCCA stenosis (left-sided \( n = 22 \), asymptomatic \( n = 22 \), symptomatic \( n = 13 \)); an equal percentage (24/35, 69%) stenoses were in the proximal body of the CCA. Nearly one-third (11/35, 31%) stenoses were ostial; 32.7% (17/52) of patients revealed CCA occlusion (left-sided \( n = 12 \), symptomatic \( n = 12 \), asymptomatic \( n = 5 \)); 71.1% (37/52) of patients revealed an additional SAT lesion; 17.3% (9/52) of patients revealed a concomitant ipsilateral significant ICA stenosis (left-sided \( n = 6 \), asymptomatic \( n = 6 \), symptomatic \( n = 3 \)). One patient with asymptomatic pCCA occlusion also had an asymptomatic contralateral ICA occlusion.

### Surgical and endovascular procedures (Table 3)

There were 52 interventions (49 for primary unilateral pCCA lesions, three for recurrent unilateral lesions) in 48 patients. Twenty-eight procedures (53.8%) were endovascular and 24 f (46.2%) were surgical, respectively.

The most commonly performed procedure was sPTA (28.8%, 15/52).

Twelve primary and three recurrent pCCA lesions were treated by sPTA. Recurrent pCCA stenoses occurred 5, 12 and 19 months after primary intervention (one after transposition for CCA occlusion, two after sPTA for CCA stenosis each), respectively. In 60% (9/15) of sPTA procedures, four self-expandable Astron stents (Biotronik GmbH, Berlin, Germany), three self-expandable Sinus stents (Optimed,
Table 2 Preoperative central neurological symptoms in 52 pCCA cases (Reporting Standards for Cerebrovascular Disease published by ESVS14).

<table>
<thead>
<tr>
<th>Neurological symptoms</th>
<th>Endovascular group (n = 28)</th>
<th>Surgical group (n = 24)</th>
<th>Both groups (n = 52)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIA</td>
<td>2 (7.1)</td>
<td>15 (62.5)</td>
<td>17 (32.7)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Amaurosis fugax</td>
<td>4 (14.3)</td>
<td>3 (12.5)</td>
<td>7 (13.5)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Minor stroke</td>
<td>1 (3.6)</td>
<td>0 (0.0)</td>
<td>1 (1.9)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Asymptomatic</td>
<td>21 (75.0)</td>
<td>6 (25.0)</td>
<td>27 (51.9)</td>
<td>0.007</td>
</tr>
</tbody>
</table>

pCCA: proximal common carotid artery, TIA: transient ischaemic attack, n.s.: not significant.

Ettlingen, Germany) and two self-expandable Absolute stents (Guidant, USA) were implanted, respectively. In 40% (6/15) of sPTA procedures, three balloon-expandable Palmaz stents (Johnson and Johnson Interventional Systems, Warren, NJ, USA) and three balloon-expandable Palmaz Genesis stents (Cordis, Miami, FL, USA) were inserted. The mean stent length was 4 cm (range, 2.5–5 cm) and the mean stent diameter was 8 mm (range, 8–10 mm). In 40% (6/15) of sPTA procedures, a distal embolic protection device (Angio-Gard, Cordis, Miami, FL, USA) was used (all for primary pCCA stenoses).

In 25% (13/52) of patients, open retrograde stent implantation was carried out. All procedures were done for primary stenoses (symptomatic n = 7, concomitant CEA n = 3). In 61.5% (8/13) of open retrograde stenting, three self-expandable Sinus stents, three self-expandable Absolute stents and two self-expandable Astron stents were used, respectively. In 38.5% (5/13) of open retrograde stenting, three balloon-expandable Palmaz stents and two balloon-expandable Palmaz Genesis stents were used. The mean stent length and stent diameter were equal to sPTA procedures.

In 23% (12/52) of cases, CCA-to-SA transposition was carried out. All transpositions were done for symptomatic pCCA lesions (stenoses n = 6, occlusions n = 6).

In 21.1% (11/52) of cases, SA-to-carotid bypass was carried out (symptomatic n = 6, asymptomatic n = 5, occlusions n = 10, stenosis n = 1, concomitant CEA n = 6). Bypass graft material was polytetrafluoroethylene (PTFE, n = 6) or Dacron® (Hemashield; Meadox Medicals, Inc, Warren, NJ, USA) (n = 4). Reversed greater saphenous vein was used in one case. The mean diameter of synthetic grafts was 7 mm (range, 6–8 mm).

One patient (1.9%, 1/52) with asymptomatic occlusion of the left CCA and contralateral occlusion of the ICA was treated by retrograde ring-stripper endarterectomy.

Postoperative antiaggregation

A little more than half (59.6%, 31/52) of patients received ASA (100 mg day\(^{-1}\)) as single therapy; 34.6% (18/52) of patients received dual antiaggregation with ASA (100 mg day\(^{-1}\)) and clopidogrel (75 mg day\(^{-1}\)). In these cases, clopidogrel was given either for 3 months postoperatively (n = 11) or for a longer time period (i.e., due to coronary stenting, n = 7). In 5.8% (3/52) of cases, the postoperative antiaggregation was by clopidogrel (75 mg day\(^{-1}\)) only.

Perioperative complications and outcome

There was no statistically significant difference between both treatment groups concerning overall perioperative complication rates (p = 0.0514).

For the entire patient cohort, the combined perioperative death/stroke rate and overall perioperative complication rate was 5.7% (3/52) and 13.5% (7/52), respectively.

In the surgical group, the perioperative death and stroke rates were 0% and 4.2% (1/24); the overall perioperative complication rate was 20.8% (5/24).

In the endovascular group, the perioperative death and stroke rates were 3.6% (1/28) each; the overall perioperative complication rate was 7.1% (2/28).

Ninety-six percent of symptomatic patients (24/25) were neurologically asymptomatic at discharge. One patient (4%) died due to myocardial infarction 5 days after open retrograde stent implantation for symptomatic CCA stenosis. In two primarily asymptomatic stenoses (7.4%), we observed an early ipsilateral non-fatal ischaemic stroke within 30 days of intervention: one patient during left-sided primary sPTA (without protection device) and one patient due to bypass occlusion 2 days after a right-sided Dacron® bypass.

Table 3 Endovascular and surgical procedures in 52 pCCA cases.

<table>
<thead>
<tr>
<th>Procedures</th>
<th>Endovascular group (n = 28)</th>
<th>Surgical group (n = 24)</th>
</tr>
</thead>
<tbody>
<tr>
<td>sPTA</td>
<td>15 (53.6)</td>
<td></td>
</tr>
<tr>
<td>Open retrograde stenting without CEA</td>
<td>10 (35.7)</td>
<td></td>
</tr>
<tr>
<td>Open retrograde stenting with CEA</td>
<td>3 (10.7)</td>
<td></td>
</tr>
<tr>
<td>CCA-to-SA transposition</td>
<td>12 (50.0)</td>
<td></td>
</tr>
<tr>
<td>SA-to-Carotid bypass with CEA</td>
<td>6 (25.0)</td>
<td></td>
</tr>
<tr>
<td>SA-to-Carotid bypass without CEA</td>
<td>5 (20.8)</td>
<td></td>
</tr>
<tr>
<td>Retrograde ring-stripper endarterectomy</td>
<td>1 (4.2)</td>
<td></td>
</tr>
</tbody>
</table>

grafting with concomitant CEA. In 8.2% (2/24) of cases, postoperative cranial nerve injuries (CNIs) were diagnosed in the surgical group: one recurrent laryngeal nerve injury after bypass grafting and one hypoglossal nerve injury after bypass grafting. In addition, one Horner’s syndrome after transposition was observed. All CNIs were transient and resolved 4 weeks to 5 months postoperatively. In 4.2% (1/24) of the surgical group, a lymphatic leak was observed. This case could be handled conservatively with cessation of the lymphatic secretion 18 days postoperatively.

**Technical success, patency, neurologic outcome and survival**

Primary technical success rate was 100%. No patient was lost to follow-up.

Mean follow-up time was 61 months (range, 0.9–218 months) for both groups, 50.5 months (range, 0.9–101 months) for the endovascular group and 72.9 months (range, 1–218 months) for the surgical group, respectively.

**Patency**

Two bypasses occluded within 30 days after operation. There were no late bypass occlusions. In three cases (5.8%), we performed late redo sPTA because of high-grade (>80%) asymptomatic recurrent stenosis. In one patient, right-sided high-grade stenosis of the pCCA was detected by DS and CTA 19 months after transposition for symptomatic occlusion. In two patients, right-sided >80% stenosis of the pCCA was detected 5 and 12 months after sPTA. The patency probabilities were 89.3% (confidence interval (CI): 5.8%) for endovascular surgery and 91.7% (CI: 6.5%) for open treatment at 5 years with no statistical significance between both groups (log rank: \( p = 0.741 \)).

**Late neurologic outcome**

One primarily symptomatic patient (1.9%) suffered a late non-fatal ipsilateral ischaemic stroke during left-sided CEA 16 months after ipsilateral transposition for pCCA stenosis.

**Patient survival**

There was one perioperative death due to myocardial infarction (open retrograde sPTA). Fourteen of 48 patients (29.2%, endovascular group \( n = 8 \), surgical group \( n = 6 \)) died during follow-up. The most common cause of death was ischaemic cardiac disease (57.1%). Five-year survival was 79.6% after endovascular surgery and 70.7% after open intervention. There was no statistically significant difference between both groups (Log rank: \( p = 0.335 \)).

**Discussion**

Our study described the neurological and overall outcome of patients with pCCA pathology undergoing either endovascular or open surgical intervention. There has been no report so far dedicated exclusively to this entity. All reports on pCCA pathology are within larger series including repair of all SAT lesions.

At the beginning of the study period, all our patients underwent open surgery. Yet, it has become common practice in our department to offer primary endovascular procedures in patients suffering from pCCA lesions to reduce complications, such as CNI and lymphatic damage, and to shorten hospital stay. The only indication to refrain from endovascular management was the presence of CCA occlusion.

Takach et al. in 2005 reported on 391 consecutive patients, who were treated from 1996 to 2004 for a single-vessel brachiocephalic disease. Only a small part of this large series were CCA lesions (\( n = 17, 4.3\% \)). Takach et al. did not make a subgroup analysis of the CCA group and failed to describe the surgical and endovascular results within that group. Furthermore, it is difficult to draw any conclusion from a study, which comprises for a large part SA lesions because these are more benign in natural history and treatment compared with CCA lesions.

Our study shows that perioperative stroke and death rates were not significantly different between both treatment groups. In the endovascular group, one patient died due to myocardial infarction 5 days after open retrograde stenting for symptomatic pCCA stenosis. This patient presented with known ischaemic heart disease, and this was not believed to be a contraindication for the carotid procedure. One patient suffered a major ipsilateral stroke during sPTA without a protection device, which were then not available. Previous publications reported similar mortality rates for open \( 15,20,21 \) and endovascular \( 22 \) treatment. Use of embolic protection devices is not reported in literature on a routine basis. Although these devices have been available in recent years, their use in pCCA lesions is controversial, mainly due to the fact that ostial lesions may not be suitable to be traversed with these devices. A major advantage of endovascular procedures compared with surgical treatment of CCA lesions is the remote access of the intervention resulting in decreased neck complication rates, such as CNI damage or lymphatic leak. In our open surgical group, 12.5% (3/24) suffered from CNI and 4.2% (1/24) from damage of the thoracic duct. Although all complications could be handled conservatively, they cause significant discomfort to the patient.

According to the literature, open retrograde stenting has the potential advantage of embolic protection during the intervention reducing major peri-procedural neurological events. Sullivan et al. concluded that difficult CEA and synchronous retrograde stenting in patients suffering from tandem lesions should be treated with caution because of poor outcome following combined treatment of ICA and CCA lesions. In our study group, endovascularly treated tandem lesions (3/28, 10.7%) were without complications and patent at a mean follow-up time of 53 months.

The most commonly cited argument to prefer extrathoracic surgery over endovascular treatment is the excellent long-term patency of bypasses and transpositions. Takach et al. reported a significantly better midterm freedom from graft failure in the bypass group (92.7%) compared with the sPTA group (83.9%, \( p = 0.03 \)) 5 years after the procedure. Berguer et al. reported on a 16-year experience with 182 extrathoracic brachiocephalic reconstructions with
cumulative primary patency rates of 91% and 82% at 5 and 10 years, respectively.\textsuperscript{15} Such long-time results in a large study population have not been reported for endovascular therapy. Yet, midterm results of endovascular treatment may concur with surgical outcomes. Paukovits et al. reported on 153 pCCA lesions treated by sPTA ($n = 108$) or PTA ($n = 45$). Cumulative primary patency rates were 97.9% at 1 year and 82% at 4 years, respectively, without statistically significant difference between sPTA and PTA.\textsuperscript{21} In our study, patency probabilities were identical between open surgery and endovascular therapy (log rank: $p = 0.741$).

Survival rates are poor in patients suffering from SAT lesions, mainly because of ischaemic cardiac disease. Berguer et al. reported survival rates of 72% and 41% at 5 and 10 years, respectively.\textsuperscript{15} Archie reported survival rates of 64% and 28% at 5 and 10 years, respectively, in patients undergoing extrathoracic bypass grafting for symptomatic severe CCA occlusive disease.\textsuperscript{25} In our study, survival probability was poor even though cardiac disease was only present in one-third of the patients at the time of intervention. During follow-up, most of the patients died due to cardiac disease. We assume, in accordance with literature that, in patients suffering from SAT lesions, the atherosclerotic process seems more aggressive and leads to earlier mortality compared with other groups of vascular disease.

In the light of poor long-term survival of patients with SAT lesions and the unknown natural history, it is a constant debate how to treat asymptomatic CCA lesions. In 1999 Cull et al. reported on asymptomatic patients with CCA occlusion and patent ICA, which were treated conservatively.\textsuperscript{26} The authors concluded that their patients usually remained asymptomatic with a long-term patency of the ICA up to 8 years. There are no guidelines concerning this issue. It has been our practice to treat CCA lesions in the same manner as ICA lesions.

Our study has several drawbacks. One is the difficulty of therapy selection in this patient group, as both management options were not available over the entire study period. Endovascular therapy has become the preferred option during the second half of the study period, mainly for stenotic lesions. Our study is retrospective, leading to a significant difference of preoperatively asymptomatic patients between the endovascular and surgical group (75% vs. 25%). This should be overcome by prospective studies in the future.

**Conclusion**

pCCA repair for atherosclerotic lesions can be achieved with a combined perioperative death/stroke rate of 5.7%. The endovascular approach should be the invasive treatment of choice in these patients with stenotic lesions, irrespective of the preoperative neurologic status. If an endovascular repair is impossible because of anatomical or technical reasons, an operative extrathoracic repair seems a valid alternative. In patients suffering from pCCA lesions, the neurological outcome and the patency probability for endovascular and surgical procedures are equal but the late survival is poor. Because pCCA lesions are rare and much less frequently reported compared with ICA lesions, larger multicentre trials would be necessary to answer questions concerning the best treatment modality for asymptomatic patients.

**Conflict of Interest/Funding**

None of the authors has any conflict of interest or funding.

**References**


