REVIEW

Dacron Patch Infection Following Carotid Endarterectomy: A Systematic Review of the Literature

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Endarterectomy; Carotid; Polyethylene Terephthalates; Infection; Complication; Post-operative; Stroke; Carotid Stenosis

Abstract
Our report encompasses two cases of Dacron patch infection following carotid endarterectomy and a systematic review of the literature. Particular attention is placed on the incidence, aetiology, investigation, presentation and management dilemmas of this rare complication of carotid surgery. We present all known cases of synthetic patch infection following carotid endarterectomy over the last 12 years. 14 publications have been identified totalling 77 cases of graft infection. Approximately 0.25 – 0.5% of all Dacron patches appear to get infected. Infection may present early or late and appears to have a bi-modal distribution depending on the presence of low- or high-grade infection. Post-operative complications especially wound haematoma is associated with the later development of infection. Most patients present with pseudoaneurysm formation, neck swelling or a draining local sinus and are infected with either Staphylococcus epidermidis or Staphylococcus aureus. Duplex ultrasound is the investigation of choice and complete excision of all infected material and arterial reconstruction with a vein patch or graft is recommended.

Dacron patch infection is a rare but recognised complication of carotid surgery and knowledge of this condition is vital for vascular surgeons and other speciality surgeons to whom cases may present.

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Introduction

Stroke is the third most common cause of death in the UK. 80% of strokes are ischaemic and 80% of those are confined to the carotid artery territory.1 James Ramsey Hunt2 first described the syndrome of stroke secondary to carotid
artery disease in 1914 with the first successful carotid endarterectomy performed by DeBakey in 1953 (although not published). Data from the European Carotid Surgery Trial (ECST) and the North American Symptomatic Carotid Endarterectomy Trial (NASCET) show that carotid endarterectomy (CEA) reduces the long-term risk of stroke for severe symptomatic carotid artery stenosis and is superior to medical therapy in preventing ipsilateral stroke, this is of course also true for asymptomatic patients with high-grade stenotic lesions.

Arterial endarterectomy and reconstruction can be performed by employing a wide range of techniques including standard endarterectomy and primary closure, eversion endarterectomy and re-implantation of the internal carotid artery and endarterectomy with patch angioplasty. There are several commonly employed techniques used to repair the carotid artery following endarterectomy. These include interposition vein graft, vein patch, (with either the long saphenous vein, facial vein or internal jugular vein) and synthetic patch with either woven polyester (Dacron), Polytetrafluoroethylene (PTFE) or bovine pericardium. Most surgeons now routinely use patch angioplasty of the carotid artery as it results in lower rates of long-term re-stenosis and post-operative stroke. Synthetic grafts are essentially equal to vein grafts in terms of recurrent re-stenosis and peri-operative stroke rate. They are attractive as they are readily available, avoid any additional wounds, preserve the saphenous vein for later use in peripheral vascular and coronary surgery and have a lower graft rupture rate than vein patches. A disadvantage is that they may well be susceptible to suture hole haemorrhage, pseudoaneurysm formation and higher infection rates.

Synthetic patch infection is a rare but recognised complication of carotid endarterectomy. We have performed a systematic review of all reported cases of synthetic patch infection following carotid endarterectomy from 1996 to present day and included 3 episodes of patch infection in 2 patients of our own. Knowledge of this condition is essential for vascular surgeons and other specialist surgeons to whom cases may present.

Case 1 is a 75-year-old woman who underwent a right carotid endarterectomy followed by a left carotid endarterectomy 13 months later for high-grade stenosis. Both carotid arteries were reconstructed with a Dacron patch. There were no intra-operative or post-operative complications. She re-presented to our service 49 months after her initial surgery with a right sided mass in the anterior triangle of the neck (Fig. 1). Histology confirmed the presence of fibrous tissue with foamy macrophages and foci of multinucleated giant cells in keeping with a ruptured cyst or abscess cavity. Microbiology cultures of the mass were negative after 5 days of incubation. A repeat procedure on the right side (performed by a vascular consultant) yielded a 3 cm encapsulated mass related to the suture line of the Dacron graft (Fig. 2). The patch and suture line were left undisturbed. Histological and microbiological analysis was the same for the previous operation.

Case 2 is an 85-year-old diabetic gentleman who presented to the outpatient clinic 14 months after a bilateral carotid endarterectomy and reconstruction with a Dacron patch for symptomatic high-grade stenosis. There were no reported peri-operative or post-operative complications.

He presented with a gradually enlarging mass along the line of the right carotid endarterectomy scar. Carotid duplex ultrasound showed no evidence of re-stenosis, patch corrugation or pseudoaneurysm formation. Surgical exploration was undertaken and a 2 cm mass of inflammatory tissue was excised anterior to the Dacron patch. The carotid artery and patch were left undisturbed. Histology revealed inflammatory fibrous tissue with numerous polymorphs and focal necrosis. Microbiology cultures were positive for Staphylococcus epidermidis.
The presentation, management and outcome of both cases have been summarised in Table 1.

Materials and Methods

A Medline search from 1996 to 2007 was conducted and all reported cases of synthetic patch infection after carotid endarterectomy were sort. Only cases reported in humans and printed in the English language were included. Keyword search was performed using thesaurus mapping. Search Booleans were exploded and major descriptors included. The literature search was conducted using "carotid", "infection", "endarterectomy", "complications post-operative", "Dacron" (Polyethylene terephthalates) as the keyword descriptors.

Results

14 published case series of infection following Dacron patch carotid endarterectomy have been identified. Some of the case series reported were not specifically designed to identify synthetic patch infection which has inevitably resulted in some partial data loss. All reported cases over the last 12 years are summarised in Table 2. The incidence, aetiology, presentation, investigations, infective pathogens, complications and management of carotid patch infection will now be discussed.

Incidence

The incidence of prosthetic patch infection following carotid endarterectomy appears to be quite low with relatively few case series reported in the literature. A systematic Medline review from 1996 to present day revealed a total of 77 cases of patch infection reported in 14 case series (not including the 3 infected at risk arteries in this series). Litwinski et al. reported two further cases of pseudoaneurysm formation after carotid endarterectomy. However, in one case a synthetic patch had not been used during the primary procedure and in the second case no convincing evidence of infection was identified. For this reason these cases have not been included.

The incidence of patch infection cannot be calculated for all of the available series, however, the six largest series reports an overall incidence of 0.25–0.5% of all carotid endarterectomies performed. The incidence of prosthetic patch infection was slightly higher, varying from 0.37 to 1.76%. The three infected grafts reported here compare favourably. We report 3 infected grafts following 480 patch endarterectomies performed by a single consultant surgeon (0.63%).

Aetiology

Currently no single identifiable aetiological agent for patch infection exists. There are however associations between post-operative wound haematoma and early graft infection. Wound haematoma has been reported postoperatively in up to 50% of all infected synthetic grafts. In the case series reported by Naylor et al. 80% of patients who presented with graft infection within 9 weeks of surgery, had documented wound complications in the post-operative period.

Any underlying pre-morbid conditions or illnesses will predispose to graft infection as with anywhere else in the body. Poor general and dental hygiene, long-term oral steroids or immunosuppressants, tobacco smoking and diabetes have been reported in up to 50% of infected carotid grafts. The reduction of infection rates depends on excellent glycaemic control in the peri-operative period and eradication of infective foci prior to surgery.

Presentation

The presentation of patch infection is often insidious. In our case series, both patients re-presented with a gradually enlarging neck mass. There were no signs of local or systemic infection at presentation and pain did not seem to be a predominating feature. Understandably, the presentation may raise suspicion of an underlying oropharyngeal malignancy and opinions were sought (case 1) initially from Ear, Nose and Throat (ENT) and oral-maxillo-facial surgeons which unfortunately lead to inappropriate investigations, unnecessary procedures and ultimately a delay in diagnosis.

Tables 3 and 4 summarise the presenting symptoms and management strategies from the data series in the literature. Unfortunately Chiesa et al. have not recorded any

<table>
<thead>
<tr>
<th>Case no.</th>
<th>Initial Procedure</th>
<th>Post-operative problems</th>
<th>Presentation</th>
<th>Time to re-presentation</th>
<th>Culture</th>
<th>Management</th>
<th>Outcome a</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Left CEA</td>
<td>Nil</td>
<td>Painless mass</td>
<td>36 months</td>
<td>Nil</td>
<td>Bilateral excision of infected phlegmon.</td>
<td>A, NR</td>
</tr>
<tr>
<td></td>
<td>Right CEA</td>
<td>Nil</td>
<td>Painless mass</td>
<td>49 months</td>
<td>Nil</td>
<td>Patch left in situ.</td>
<td>A, NR @ 8 months</td>
</tr>
<tr>
<td>2</td>
<td>Right CEA</td>
<td>Nil</td>
<td>Painless mass followed by discharging sinus</td>
<td>14 months</td>
<td>S. aureus and mixed skin organisms</td>
<td>Excision of infected phlegmon. Patch left in situ.</td>
<td>A, discharging sinus @ 6.5 years</td>
</tr>
</tbody>
</table>

N/a, not applicable.

a A, NR (alive with no recurrence).
presenting symptoms. Rockman et al.\textsuperscript{23} and El Sabrout et al.\textsuperscript{28} have also not documented the presence of neck swelling.

Neck swelling, pseudoaneurysm and local sinus formation appear to be the most common presenting symptoms. In total, 25 (33\%) cases presented with a pseudoaneurysm (PA). Local draining sinus was present in 23 (30\%) cases. Neck swelling was present in 18 cases (24\%). Although, in the series by El Sabrout et al.\textsuperscript{28} and Rockman et al.,\textsuperscript{23} the presence of neck swelling was not documented, and given

Table 3  Presentation of 77 carotid patch infections

<table>
<thead>
<tr>
<th></th>
<th>Neck swelling</th>
<th>Pain Local infection</th>
<th>Draining sinus</th>
<th>Stroke</th>
<th>Haemorrhage</th>
<th>PA</th>
<th>Systemic sepsis</th>
<th>Bacteriology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chaudhuri et al.\textsuperscript{17} (n = 1)</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Asciutto et al.\textsuperscript{20} (n = 6)</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>SA x25E x1Sterile x3</td>
</tr>
<tr>
<td>Krishnan et al.\textsuperscript{21} (n = 1)</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>SE x1</td>
</tr>
<tr>
<td>Lewis et al.\textsuperscript{19} (n = 1)</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>Sterile</td>
</tr>
<tr>
<td>Borazjani et al.\textsuperscript{22} (n = 3)</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>SE x2Culture —ve despite purulence x1 SA x25E x3BF x2SE x4BA x1</td>
</tr>
<tr>
<td>Rockman et al.\textsuperscript{23} (n = 10)*</td>
<td>NR</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Grego et al.\textsuperscript{24} (n = 1)</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Chiesa et al.\textsuperscript{18} (n = 21)</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Naylor et al.\textsuperscript{25} (n = 8)</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>MRSA x3β St x1Ps x1SA x15E x2</td>
</tr>
<tr>
<td>Rizzo et al.\textsuperscript{26} (n = 8)</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>SE x2SA x2St M x2St Mit x1No growth x1</td>
</tr>
<tr>
<td>Byer et al.\textsuperscript{27} (n = 1)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>MRSA x1</td>
</tr>
<tr>
<td>El Sabrout et al.\textsuperscript{29} (n = 13)</td>
<td>NR</td>
<td>0</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>Dougherty et al.\textsuperscript{29} (n = 1)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>SE x1</td>
</tr>
<tr>
<td>Zacharoulis et al.\textsuperscript{30} (n = 2)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

NR, not recorded; SA, Staphylococcus aureus; StV, Streptococcus viridans; SE, Staphylococcus epidermidis; BF, Bacteroides fragilis; BA, Bacteroides acnes; MRSA, methicillin resistant Staphylococcus aureus; β St, beta haemolytic Streptococcus; Ps, Pseudomonas; StM, Streptococcus milleri; St Mit, Streptococcus mitis.

* One patient cultured positive for Streptococcus viridans and Staphylococcus epidermidis, one patient cultured positive for Streptococcus viridans and Bacteroides fragilis.
Table 4  Management strategies of 77 carotid patch infections over the last 12 years

<table>
<thead>
<tr>
<th>Study</th>
<th>Vein patch</th>
<th>Vein graft</th>
<th>Aspiration of pus and antibiotics</th>
<th>Excision of infected material and antibiotic irrigation</th>
<th>Primary repair</th>
<th>Synthetic patch</th>
<th>Excision of infected material and artery ligation</th>
<th>Operative outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chaudhuri et al.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>Transient III nerve palsy</td>
</tr>
<tr>
<td>Asciutto et al.</td>
<td>1</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>NC x4 Re-infection x2 Stroke x1 (after re-infection)</td>
</tr>
<tr>
<td>Krishnan et al.</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>NC x1</td>
</tr>
<tr>
<td>Lewis et al.</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>NC</td>
</tr>
<tr>
<td>Borazjani et al.</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Death x1 NC x2</td>
</tr>
<tr>
<td>Rockman et al.</td>
<td>8</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Transient hoarseness x1 Sterile pseudoaneurysm x1 (required interposition graft) NC x1</td>
</tr>
<tr>
<td>Grego et al.</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Peri-operative death x1 IX injury and stroke x1 XII injury x1 Vocal cord paralysis x1 (normal at 2 years) MI x1 Stroke and XII nerve injury x1 (normal at 4 months) NC x5</td>
</tr>
<tr>
<td>Chiesa et al.</td>
<td>21</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>NC x1</td>
</tr>
<tr>
<td>Naylor et al.</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>Vocal cord paralysis x1 (normal at 2 years) MI x1 Stroke and XII nerve injury x1 (normal at 4 months) NC x5</td>
</tr>
<tr>
<td>Rizzo et al.</td>
<td>5</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>N/a Pt treated with Antibiotics and serial scans</td>
</tr>
<tr>
<td>Byer et al.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Re-infection of Dacron patch x3 Death x1 (due to haemorrhage from Dacron patch)</td>
</tr>
<tr>
<td>ElSabrout et al.</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>1</td>
<td>Re-stenosis requiring vein patch x1</td>
</tr>
<tr>
<td>Dougherty et al.</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>NC x2</td>
</tr>
<tr>
<td>Zacharoulis et al.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2 (plus sternomastoid rotational flap)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>NC x2</td>
</tr>
</tbody>
</table>

NC, no complications; N/a, not applicable.
that there were 16 PAs in these series, I suspect this figure to be higher. Pain was only a predominately feature in 4 (5%) cases. Signs of local infection were documented in 12 (16%) cases with systemic sepsis present in only 6 (8%) cases. Only 3 (4%) patients presented with a stroke and all of these had infected pseudoaneurysms. These presenting symptoms are in keeping with the 3 patch infections in our case series.

By reviewing four larger series, Krishnan and Clowes,21 noted an apparent bi-modal distribution of time to presentation. Approximately 50% of patients presented before 3 months and 50% presented after 3 months. Early graft infections may be a result of post-operative wound infections or the presence of more virulent organisms.21 In the series published by Naylor et al.,25 50% of patients had wound infections postoperatively and all of these patients presented within 9 weeks.

In the same series, mean time to representation for those grafts infected with coagulase negative staphylococci was 156 weeks compared to 16.8 weeks for those infected with other organisms (mixture of Staphylococcus aureus, methicillin resistant Staphylococcus aureus and Streptococci sp.). Late presentations (after 6 months) may well be a result of less virulent skin commensals e.g. S. epidermidis, which have gradually colonised via local penetration into the underlying tissue or haematogenous spread from a distant focus. Rockman et al.23 presented 10 cases of patch infection. Four cases presented later than 6 months and these were all infected with S. epidermidis.

As with any implanted foreign tissue, the synthetic patch acts a focus for infection. Interestingly in the absence of a synthetic patch it has also been postulated that the non-absorbable suture line can also suffice as a nidus for infection as cases have been reported in vein patch endarterectomy.16

Investigations

Imaging modalities for the assessment of infected carotid grafts includes plain ultrasonography, duplex ultrasonography, plain angiography, magnetic resonance angiography (MRA), cross sectional magnetic resonance imaging (MRI) and computerised tomography (CT).32,33 Duplex ultrasonography is the modality of choice as it is non-invasive, cost effective and readily available. It allows excellent visualisation of internal carotid artery and assessment of its patency. It can also be used to visualise the surrounding soft tissues and identify fluid collections and is highly sensitive for detecting pseudoaneurysm formation.34 It may also be used to detect early signs of graft infection. Although not seen in any of our cases, Lazari et al.35 reported 4 cases of Dacron patch infection and noted that patch corrugation on duplex ultrasound preceded clinical infection. In one case, patch corrugation was noted 11 months prior to clinical patch infection (see Fig. 3).

Although plain angiography has been regarded as the gold standard in detecting pseudoaneurysms,26 it is often not indicated (especially in suspected patch infections). Carotid artery angiography carries a risk of seeding distal emboli resulting in a transient ischaemic attack or permanent neurological deficit.26,37,38 It is also associated with wound complications and can convey high false negative rates. In the study performed by Rizzo et al.,26 three patients underwent carotid angiography and it failed to identify the only two pseudoaneurysms. Also, one patient suffered a stroke secondary to their pre-operative angiogram.

Infective pathogens

Graft colonisation appears to be due to a wide number of infective pathogens. Table 3 summarises the variety of pathogens cultured from the 14 case series. Infective pathogens include alpha haemolytic Streptococcus sp., Group A beta haemolytic Streptococcus sp., Bacteroides sp., Pseudomonas sp., and methicillin resistant S. aureus sp. By far the most common infective pathogens appear to be S. aureus and S. epidermidis. This comes as no surprise as they are the commonest skin commensal.39 Reviewing all the case series, there are 39 recorded microbiology cultures. 23 (59%) of these were positive for either S. aureus or epidermidis. One of our cases cultured positive for S. aureus. However, case 1 failed to grow any infective pathogens from either graft, as did five other cases reported in the literature despite there being obvious infective material during re-exploration. It is possible that the liberal use of pre-operative antibiotics leads to a sterile antibiotic or that the patients own immune system may suppress a less virulent pathogen leading to a sterile phlegmon.

Figure 3  Duplex ultrasound of a normal Dacron patch (left picture). Corrugation of the Dacron patch. (right). Images courtesy of Krishnan et al.
containing macrophages and inflammatory cells (as with our cases). Surgery has also been deferred until microbiology cultures were available.\textsuperscript{25} If employing this strategy, one must keep an open mind that you may never achieve positive cultures and must not tirelessly chase after them.

**Complications**

Complications of carotid patch infection may arise as a natural progression of the disease or as a consequence of surgical intervention. Presumably, if patch infection is allowed to take its natural course, it would begin with local sepsis and/or systemic sepsis, pseudoaneurysm formation and culminate in patch rupture. Varying degrees of stroke may well be expected with death as the inevitable outcome.

Surgical intervention is perceived to be fraught with complications most notably cranial nerve injury, peri-operative stroke, post-operative bleeding, recurrent infection and death. A total of 66 surgical procedures was carried out for infection in the six largest series.\textsuperscript{18,20,23,25,26,28} There were 5 (8%) re-infections, 5 (8%) cranial nerve injuries, 4 (6%) strokes and 3 (5%) peri-operative deaths. One stroke was a consequence of pre-operative angiography.\textsuperscript{26} Neither strokes nor cranial nerve injuries left any long lasting disability. There was one pseudoaneurysm formation following a vein patch, which necessitated an interposition vein graft (Rockman et al.\textsuperscript{23}).

Byer et al.\textsuperscript{27} reported 1 case which developed a re-stenosis 16 months after an interposition vein graft necessitating a vein patch. Of the 3 infected cases reported by Borazjani,\textsuperscript{22} no patient suffered cranial nerve injury. 1 patient suffered a stroke and died as a result of it. Regarding the four cases published by Krishnan,\textsuperscript{21} Grego,\textsuperscript{24} Byer\textsuperscript{27} and Zacharoulis et al.,\textsuperscript{30} there was no reported peri-operative morbidity or mortality.

**Management**

The management of infection following carotid patch endarterectomy is the same as for anywhere else in the body, which is primarily to remove all infected material and to minimise peri-operative morbidity and mortality. Most authors advocate wide excision of all infected material including the patch with vascular reconstruction to maintain distal perfusion. However, no consensus exists over the arterial reconstruction methods. Certainly in the six largest series, wide excision of the infected patch and reconstruction with either a vein patch or vein graft was the most popular option.\textsuperscript{18,20,23,25,26,28} In total, 44/76 (58\%) infected synthetic patches were repaired with a vein patch and is the recommended operation. There were however two deaths in this group. 15 (20\%) patients’ carotid arteries were reconstructed using an interposition vein graft. There was one reported re-stenosis in this group demanding a vein patch. 6 infected Dacron patches were replaced with further Dacron patches after thorough excision of all apparently infected material (El Sabrout et al.\textsuperscript{28}). Unfortunately 50\% of these developed further infection and is therefore not recommended.

Ligation of the carotid artery remains controversial. It has previously been condemned, as it is associated with a very high stroke rate (50\%) and mortality.\textsuperscript{16,28,40} Over the last 12 years, carotid artery ligation has been reported in 5 cases, 3 of which performed by Naylor et al.\textsuperscript{25} All of these cases had a positive outcome with no infective recurrences or associated peri-operative morbidity. This was likely due to the judicious use of pre-operative duplex ultrasonography and intra-operative transcranial Doppler (TCD) to monitor cerebral perfusion. Preoperatively, two patients had proven occlusion of the internal carotid artery allowing safe ligation of the common carotid artery once the external carotid artery was shown not to contribute to collateral circulation. The remaining patient had their common carotid artery ligated after adequate collateral circulation from the opposite carotid artery had been proven with TCD (middle cerebral artery velocity $>20\text{ cm/s}$).

The balloon occlusion test (BOT) of the internal carotid artery also allows assessment of the collateral circulation from the contra-lateral hemisphere prior to ligation of the internal carotid artery. It involves the deployment of a catheter into the carotid artery and inflation of the balloon to occlude antegrade flow of the internal carotid artery and any retrograde flow back down the external carotid artery. This technique was employed by Chaudhuri et al.\textsuperscript{17} with a Hyper foam\textsuperscript{34} balloon occluding the internal carotid artery for 20 min. The patient developed no neurological symptoms and subsequently had his internal carotid artery ligated after excision of all infected material with no permanent neurological sequele. The use of single photon emission computerised tomography (SPECT) has also been used to predict which patients are at high risk of developing post-operative neurological deficits although it is rarely used in modern clinical practice.\textsuperscript{41}

Removal of a patch and reconstruction of the extra cranial cerebral circulation carries its own unique set of complications. A small number of studies and the cases highlighted here shows that this is not the only management strategy available. Both cases in our series were treated relatively conservatively with complete excision of macroscopically infected material, thorough antiseptic washout and prescription of tailored long-term antibiotics. In each case the grafts were left undisturbed. These decisions were made on an entirely individual basis. Each patient developed low-grade infections in their grafts and had presented insidiously with no evidence of fulminant systemic infection. Intra-operatively a well-circumscribed phlegmon was found which was excised as a whole leaving a pristine graft and underlying tissue. Both patients were elderly with significant co-morbidities including ischaemic heart disease, diabetes, cerebro-vascular disease and chronic obstructive airways disease. Thus, in our cases it was difficult to justify excision of a functioning graft and encounter the associated morbidity and mortality in high risk patients and this is why we adopted our management strategy. Interestingly four other patients underwent a combination of excision of infected material and antibiotic wash out.\textsuperscript{25,28,30} Sternomastoid rotational muscle flaps were used in two cases (Zacharoulis et al.\textsuperscript{30}). All of these patients did extremely well with no peri-operative complications and were all infection free at the termination of data collection.
Conclusion

We have found carotid patch infection to be a rare but recognised complication of carotid surgery. It is of unknown aetiology and affects approximately 1% of all synthetic patch endarterectomies. Patients may present with a variety of symptoms including local sepsis, pain, haemorrhage or neurological deficit. However neck swelling and sinus formation appear to be the commonest symptoms. Signs of systemic infection are rare. Delays in diagnosis may be caused by the lack of symptomatology and in our case non-urgent referrals to non-vascular specialties. Patients presenting with a neck swelling who have a history of CEA, must have an urgent vascular opinion.

Duplex ultrasound is the investigation of choice. It is readily available, allows visualisation of the carotid arteries and assessment of patch corrugation. From our experience and review of the literature, surgical exploration and drainage of infection should be regarded as mandatory. Replacement of a synthetic patch with a second synthetic patch carries a high re-infection rate and is not recommended. Antibiotics are essential and should be tailored to Staphylococcus sp. or Streptococcus sp. as these are the most likely pathogens.

Excision of all infected material including the Dacron patch and arterial reconstruction with a vein graft or patch is the recommended procedure for these patients. However, along with others, we have demonstrated that successful outcomes can be achieved by excision of the infected tissue and leaving the graft intact if deemed reasonable at the time of exploration. This option is particularly favourable in the elderly population and those with significant co-morbidities and low-grade infection. The fact that these methods have been successful highlights the importance of an individually tailored decision making process.

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None.

References

24 Grego F, Antonello M, Lepidi S, Bonvini S, Deriu G. Prospective, randomised study of external jugular vein patch versus polytetrafluoroethylene patch during carotid endarterectomy;


