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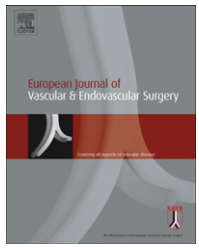

Prospective Randomized Study of Carotid Endarterectomy with Fluoropassiv™ Thin Wall Carotid Patch versus Venous Patch

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Abstract *Introduction:* The practice of carotid endarterectomy (CEA) with patch angioplasty is more effective compared to primary closure. However, the type of patch material remains a controversy. The Fluoropassiv™ thin wall carotid patch is a polyester patch with an interpenetrating, nanometer-scale, solvent-applied surface modification, based on a biocompatible fluoropolymer. The present pilot study is the first clinical trial evaluating results of CEA with Fluoropassiv™ versus venous patch.
Materials/Methods: Eighty-seven patients were randomized to 42 Fluoropassiv™ patching and 45 venous patching. Patients were observed by a vascular surgeon and a neurologist and scanned using duplex ultrasound with a follow-up of 2 years. No patients were lost to follow-up. Restenosis was defined as a Peak Systolic Velocity ratio >2.6, lumen reduction >50%.
Results: Perioperative stroke rate was 2.4% in the Fluoropassiv™ group and 8.9% in the venous group ($p = 0.02$; 1 regressive, 4 non-regressive strokes). Multivariate analysis showed that bilateral carotid stenosis and stroke as indication for CEA were related to perioperative stroke. There was no link between perioperative stroke and patch type after correction for these factors. Patch type had no influence on operation time, clamp time, cranial nerve damage, hypertension, hematoma, infections, time to discharge, or early thromboembolic events. There were no significant differences between the Fluoropassiv™ and the venous group for cumulative mortality (respectively 4.4 vs 4.8%), patch occlusion (4.8 vs 2.2%), or stroke rate during 2 year follow-up (2.2 vs 2.4%).
Conclusion: This first clinical study with the Fluoropassiv™ thin wall carotid patch showed no enhanced thrombogenicity compared to a venous patch. The Fluoropassiv™ patch is not related to a higher rate of postoperative bleeding events either.
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Introduction

The effectiveness of carotid endarterectomy (CEA) in symptomatic and asymptomatic patients for the prevention of cerebral infarction has been clearly demonstrated.[1–4] The practice of CEA with patch angioplasty has been shown to be more effective compared to primary closure.[5] Patching decreases the rate of perioperative and postoperative stroke and late recurrent stenosis. However, the type of patch material remains a controversy.[6] Patch angioplasty may be performed with autologous vein or synthetic material. Several studies have shown comparable perioperative and long-term results with vein and polytetrafluoroethylene (PTFE; Gore-Tex; WL Gore and Associates, Flagstaff, AZ, USA) patching.[7,8] The advantages of synthetic patches over vein patches are decreased incidence of aneurysmal dilatation and patch rupture, patch harvesting complications, and availability.[9,10] PTFE patching does have the disadvantage of prolonged hemostatic time.[11] Knitted polyester patches (Boston Scientific Corp, Natick, MA, USA) have been advocated to avoid this, but are related to higher rates of perioperative strokes and late recurrent stenosis.[12]

The Fluoropassiv™ thin wall carotid patch (Vascutek, a Terumo Company, Scotland, UK) is a polyester patch with an interpenetrating nanometer-scale, solvent-applied surface modification, based on a biocompatible fluoropolymer and combining biocompatibility with reduced hemostatic time. In vitro and animal studies confirm that Fluoropassiv™ exhibits reduced thrombogenicity and suture hole bleeding compared to other synthetic materials.[13] We hypothesize that this new synthetic patch shows comparable postoperative results (i.e. neurological events, recurrent stenosis) to venous patches, but with the advantages of synthetic over venous patches as mentioned above (e.g. patch harvesting complications). The present pilot study is the first clinical trial evaluating early and long-term results of CEA with the Fluoropassiv™ thin wall carotid patch as it compares these results to the use of a venous patch.

Materials and Methods

Study design

The study was a prospective randomized clinical trial carried out at a single center between 2000 and 2004. Patients gave informed consent. Randomization was performed by using sealed opaque envelopes containing indication for venous or Fluoropassiv™ patch. An envelop was drawn at the start of surgery and the study controller notified the surgeon of the procedure to be performed. All patients included had symptomatic carotid stenosis (>70%).

Eighty-eight consecutive patients undergoing CEA between September 2000 and March 2004 were eligible for randomization (Fig. 1). Patients were excluded from this trial on the following criteria: known allergies to patch products used, previous ipsilateral carotid surgery, bilateral carotid endarterectomy, progressive neurological events one month prior to surgery (e.g. crescendo transient ischemic attack), and/or hospitalization for heart failure in previous six months. At the beginning of this study, progressive neurological events were still regarded as an indication for delay of CEA, based upon the results of several retrospective studies.[14,15] For uniformity of the present study we continued to exclude such patients, although the discussion on timing of CEA continued. Based on these exclusion criteria, one patient was excluded. Eighty-seven patients were randomized to Fluoropassiv™ patching ($n = 42$) and venous patching ($n = 45$). No crossover was observed during the study. No patients were lost to follow-up. The study was approved by the local medical ethical committee.

Before surgery, all patients underwent carotid duplex ultrasound and angiography to determine carotid stenosis. Baseline preoperative risk factors for cardiovascular disease (e.g. diabetes and hypertension), demographic characteristics and antiplatelet therapy were determined (Table 1). Indications for surgery were categorized into: transient ischemic attack (TIA), amaurosis fugax, regressive stroke and non-regressive stroke.

Operative technique

All patients continued antiplatelet therapy (Dipyridamol (Persantin®) 150 mg twice daily)and Carbasalaatcalcium (Ascal® 80 mg daily) and the patient's usual medication were administered on the morning of surgery. CEAs were performed by two surgeons under general anesthesia and systemic heparin use (usually 5000 units, depending on weight). Intraoperative shunting was used when transcranial doppler (TCD) showed more than 60% reduction in cerebral flow or when Electronic Encephalography (EEG) revealed significant abnormalities during pre-clamping. Endarterectomies were extended beyond grossly diseased intima. Patients randomized to venous patch had a segment of great saphenous vein harvested at the ankle-lower leg, which was judged excellent (i.e. no proximal great saphenous vein was used). Fluoropassiv™ thin wall carotid (8 mm width, 0.1 mm thickness) and venous patches were sutured with 6-0 polypropylene sutures (Prolene, Ethicon, Hamburg, Germany), tacking sutures at the distal endpoint were not used. Thrombin-soaked oxidized cellulose and digital pressure were used to stop any bleeding points prior to closure in the Fluoropassiv™ group. No protamine was given at the end of surgery. Operative and clamping time were recorded. All patients continued antiplatelet therapy postoperatively and Nadroparine calcium (Fraxiparine® 5700 IU/0.6 ml daily) during hospital stay.

Follow-up protocol

All patients were observed by a vascular surgeon and placed postoperatively to a high-dependency unit. Any new neurological deficit lasting longer than 24 hours was classified as stroke by a neurologist. These patients were evaluated by computed tomography and duplex ultrasound scanning. All patients visited the outpatient clinic for clinical vascular examination and neurological evaluation, and received duplex ultrasound 6 weeks and 6, 12 and 24 months after surgery. All examinations were performed by an operator blinded for type of patch used. Recurrent stenosis was defined as Peak Systolic Velocity (PSV) ratio >2.6 or lumen diameter reduction >50%. Lumen diameter at patch location was also followed at the same time for analysis of venous patch dilatation.

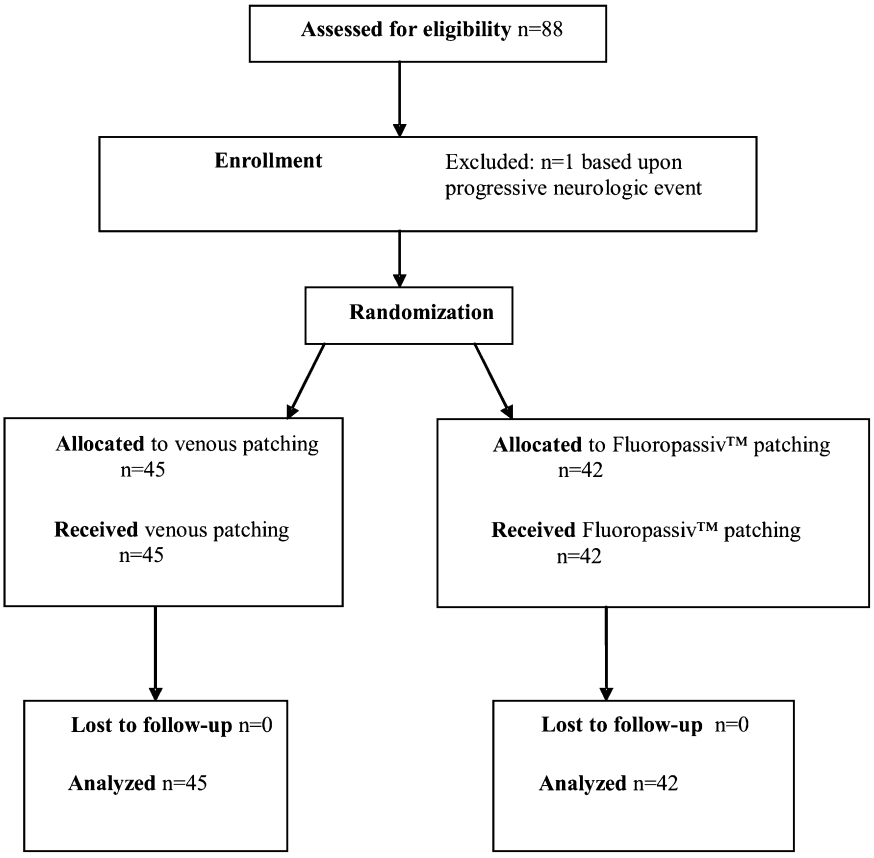

Figure 1 Randomization flow chart.

Complications were death, TIA, (non)regressive stroke, asymptomatic recurrent stenosis/acute thrombosis at CEA location according to the Ad Hoc Committee on Suggested Standards for Reports Dealing with Cerebrovascular Disease, and local wound complications (e.g. nerve damage, infection, pain). Patients were asked to complete a visual analogue score (range 1—10) for neck and ankle pain at six weeks after CEA.

Statistical methods

Comparison between groups was performed with student t-test or Mann-Whitney U test for non-normally distributed variables, and correlations were analyzed with Spearman rank method. Multivariate (logistic) regression analyses were performed to determine independent links of variables with stroke rate. The primary endpoint of this trial was neurological event rates. Secondary endpoints were late recurrent stenosis, acute thrombosis at CEA location, mortality, local wound complications and lumen diameter changes at patch location. Significance was defined as $p < 0.05$.

Results

Baseline

Table 1 summarizes demographic and clinical characteristics. All patients underwent CEA for symptomatic carotid stenosis (>70%). The indication for CEA showed significant differences with more preoperative TIAs in the venous group (77.8% vs 50%, $p = 0.03$) and more regressive strokes in the Fluoropassiv™ group (47.6% vs 17.8%, $p = 0.03$). Approximately 83% of all patients had a carotid stenosis of 80% or more, which was comparable between both groups. The number of patients with bilateral carotid stenosis was almost 3 times higher in the venous group (26.7% vs 9.5%, $p < 0.01$).

Table 2 shows the perioperative characteristics. As noted, mean operation time was 100 minutes in the Fluoropassiv™ group and 93 minutes in the venous group. The clamping time was also comparable, 39 minutes for the Fluoropassiv™ group vs 38 minutes for the venous group. Perioperative intracerebral flow (TCD) was not significantly different between both groups, and four patients in each group received selective shunting.

Perioperative stroke rate was significantly higher in the venous group (8.9%) than in the Fluoropassiv™ group (2.4%; $p = 0.02$; Table 2). Of the four perioperative strokes in the venous group, three were non-regressive and one regressive. One perioperative stroke in both groups was related to acute thrombosis at the site of CEA, and these manifested at the recovery room. All other perioperative strokes manifested 1—4 days after surgery and showed no abnormalities with carotid duplex ultrasound. Multivariate logistic regression analysis showed that perioperative stroke rate was independently related to the presence of bilateral

Table 1 Patient characteristics

	Patch Type		
	Vein ($n = 45$)	Fluoropassiv™ ($n = 42$)	
Age (yr)	67 ± 8	66 ± 8	$p = 0.7$
BMI (kg/m^2)	27 ± 0.4	28 ± 0.4	$p = 0.7$
Gender — male/female (n)	35/10	34/8	$p = 0.6$
CHD (n/%)	26 (58)	24 (57)	$p = 0.6$
PAOD (n/%)	16 (35.6)	13 (31)	$p = 0.5$
Pulmonary disease (n/%)	6 (13.3)	5 (12)	$p = 0.7$
Hyperlipidemia (n/%)	27 (60)	22 (52.4)	$p = 0.4$
Hypertension (n/%)	33 (73)	31 (73.8)	$p = 0.6$
Diabetes mellitus (n/%)	9 (20)	13 (31)	$p = 0.2$
Smoking (n/%)	18 (40)	23 (55)	$p = 0.1$
Preoperative antiplatelet therapy (n/%)	45 (100)	42 (100)	—
CEA Indication:			
Asymptomatic (n/%)	0 (0)	0 (0)	—
TIA or AF (n/%)	35 (77.8)	21 (50)	$p = 0.03$
Regressive stroke (n/%)	8 (17.8)	20 (47.6)	$p = 0.03$
Non-regressive stroke (n/%)	2 (4.4)	1 (2.4)	$p = 0.2$
Degree of carotid stenosis			
70—79% (n/%)	7 (15.6)	7 (16.8)	$p = 0.8$
80—99% (n/%)	38 (84.4)	35 (83.2)	$p = 0.6$
Bilateral carotid stenosis (n/%)	12	4	$p < 0.01$

Mean ± SD; BMI = Body Mass Index; CHD=Coronary Heart Disease; PAOD = Peripheral Arterial Occlusive Disease; TIA = Transient Ischemic Attack; AF = amaurosis fugax; CEA = carotid endarterectomy.

carotid stenosis (odds ratio (OR) 3.4 (95% CI 1,8—4,9)) and to stroke as the indication for CEA (OR 3,1 (95% CI 1,3—4,8); $p < 0.01$). There was no link between perioperative stroke rate and patch type after correction for differences in bilateral carotid stenosis and indication for CEA.

More patients in the Fluoropassiv™ group (14.3%) needed re-exploration for suspected neck hematoma compared to the venous group (6.7%; $p = 0.03$), but no neck infections occurred. Of these nine patients, only two in the venous group and three in the Fluoropassiv™ group actually had

Table 2 Perioperative characteristics and events

	Patch Type		
	Vein ($n = 45$)	Fluoropassiv™ ($n = 42$)	
ASA score 1/2/3/4 (n)	0/8/36/1	0/7/33/2	$p = 0.7$
Total operation time (min)	93 ± 25	100 ± 21	$p = 0.1$
Total clamp time (min)	38 ± 10	39 ± 8	$p = 0.8$
Shunt (n/%)	4 (8.9)	4 (9.5)	$p = 0.9$
Intracerebral flow during clamp (%)[#]	80 ± 20	86 ± 23	$p = 0.4$
Intracerebral flow after clamp (%)[#]	125 ± 20	115 ± 23	$p = 0.3$
Patch length (mm)	35 ± 10.1	34 ± 10.2	$p = 0.8$
Neck re-exploration (n/%)	3 (6.7)	6 (14.3)	$p = 0.03$
Neck hematoma at re-exploration (n/%)	2 (4.4)	3 (7.1)	$p = 0.3$
Transfusion required (n/%)	3 (6.7)	3 (7.1)	$p = 0.8$
Hypoglossus nerve damage (n/%)	2 (4.4)	3 (7.1)	$p = 0.2$
Other local nerve damage (n/%)	0 (0)	0 (0)	—
TIA (n/%)	0 (0)	0 (0)	—
Regressive stroke (n/%)	1 (2.2)	0 (0)	$p = 0.3$
Non-regressive stroke (n/%)	3 (6.7)	1 (2.4)	$p = 0.02$
Hypertensive crisis (n/%)	2 (4.4)	1 (2.4)	$p = 0.6$
Occlusion (n/%)	1 (2.2)	1 (2.4)	$p = 0.8$
Mortality (n/%)	1 (2.2)	0 (0)	$p = 0.3$
Median day discharge (95% CI)	3 (3.1—3.5)	3 (3.2—3.5)	$p = 0.7$

Mean ± SD; ASA = American Association Anesthetist score; TIA = transient ischemic attack.
[#] Flow measured with transcranial doppler as a ratio to flow before clamping.

Table 3 Week 6 postoperative complications and lumen diameters

	Patch Type		
	Vein ($n = 45$)	Fluoropassiv™ ($n = 42$)	
Neck infection (n/%)	0 (0)	0 (0)	
New neurological deficits (n/%)	0 (0)	0 (0)	
Recurrent stenosis (n/%)	0 (0)	0 (0)	
Thrombosis CEA location (n/%)	0 (0)	0 (0)	
Mean lumen diameter at patch location (mm ± SD)	11.6 ± 2.1	10.5 ± 1.9	$p = 0.01$
Wound healing disturbance at ankle (n/%)	5 (11.1)	–	
Pain at ankle (n/%)	10 (22.2)	–	
Median neck VAS score (95% CI)	1 (1.1–1.5)	1 (1.0–1.6)	$p = 0.9$
Median ankle VAS score (95% CI)	3 (3.3–3.5)	–	

Recurrent stenosis = Peak Systolic Velocity Ratio > 2.6 of lumen reduction >50%; New neurological deficits are transient ischemic attacks and/or stroke; VAS = visual analog score (1–10).

a hematoma. Other neck swellings were related to diffuse edema. Patch type did not influence requirements for treating early postoperative hypertension, transfusion requirements or time to hospital discharge.

Six weeks follow-up

No TIAs or strokes occurred during the next 6 weeks of follow-up (Table 3). All survivors underwent carotid duplex ultrasound 6 weeks after CEA. There were no patients with carotid recurrent stenosis or acute thrombosis in either group (all PSV ratio <2.6 and lumen reduction <50% at patch location). Mean diameter at the location of the patch was significantly higher in the venous group (11.6 ± SD 2.1 mm) compared to the Fluoropassiv™ group (10.5 ± 1.9 mm, $p = 0.01$).

In the venous group 22.2% complained of pain at the ankle wound. Approximately 11% of them had wound healing abnormalities at the ankle (e.g. infection, delayed healing). Multivariate regression analysis showed that smoking, presence of diabetes mellitus and a history of peripheral artery occlusive disease were independently related to wound healing abnormalities at the ankle ($p < 0.01$). There were no cervical wound complication in both groups. The median analogue score for neck pain was 1 (95% CI 1.0–1.6) in the venous group and 1 (95% CI, 1.1–1.5) in the Fluoropassiv™ group. The median analogue

Table 4 Thromboembolic events and mortality during follow-up

Follow-up	Patch Type				
	Period		Cumulative		
	Vein ($n = 45$)	Fluoropassiv™ ($n = 42$)	Vein ($n = 45$)	Fluoropassiv™ ($n = 42$)	
6 months					
TIA (n/%)	0 (0)	0 (0)	0 (0)	0 (0)	–
Stroke (n/%)	0 (0)	0 (0)	4 (8.9)	1 (2.4)	$p = 0.02$
Recurrent stenosis (n/%)	0 (0)	0 (0)	0 (0)	0 (0)	–
Thrombosis CEA location (n/%)	0 (0)	0 (0)	1 (2.2)	1 (2.4)	$p = 0.8$
Mortality (n/%)	0 (0)	0 (0)	1 (2.2)	0 (0)	$p = 0.3$
12 months					
TIA (n/%)	2 (4.4)	0 (0)	2 (4.4)	0 (0)	$p = 0.09$
Stroke (n/%)	0 (0)	0 (0)	4 (8.9)	1 (2.4)	$p = 0.02$
Recurrent stenosis (n/%)	0 (0)	0 (0)	0 (0)	0 (0)	–
Thrombosis CEA location (n/%)	0 (0)	0 (0)	1 (2.2)	1 (2.4)	$p = 0.8$
Mortality (n/%)	0 (0)	0 (0)	1 (2.2)	0 (0)	$p = 0.3$
24 months					
TIA (n/%)	1 (2.2)	0 (0)	3 (6.6)	0 (0)	$p = 0.05$
Stroke (n/%)	1 (2.2)	1 (2.4)	5 (11)	2 (4.8)	$p = 0.06$
Recurrent stenosis (n/%)	0 (0)	0 (0)	0 (0)	0 (0)	–
Thrombosis CEA location (n/%)	0 (0.0)	1 (2.4)	1 (2.2)	2 (4.8)	$p = 0.8$
Mortality (n/%)	1 (2.2)	2 (4.8)	2 (4.4)	2 (4.8)	$p = 0.9$

Cumulative is including direct postoperative events; TIA = Transient Ischemic Attack; Recurrent stenosis = Peak Systolic Ratio > 2.6 or lumen reduction >50%; *p*-values for cumulative data.

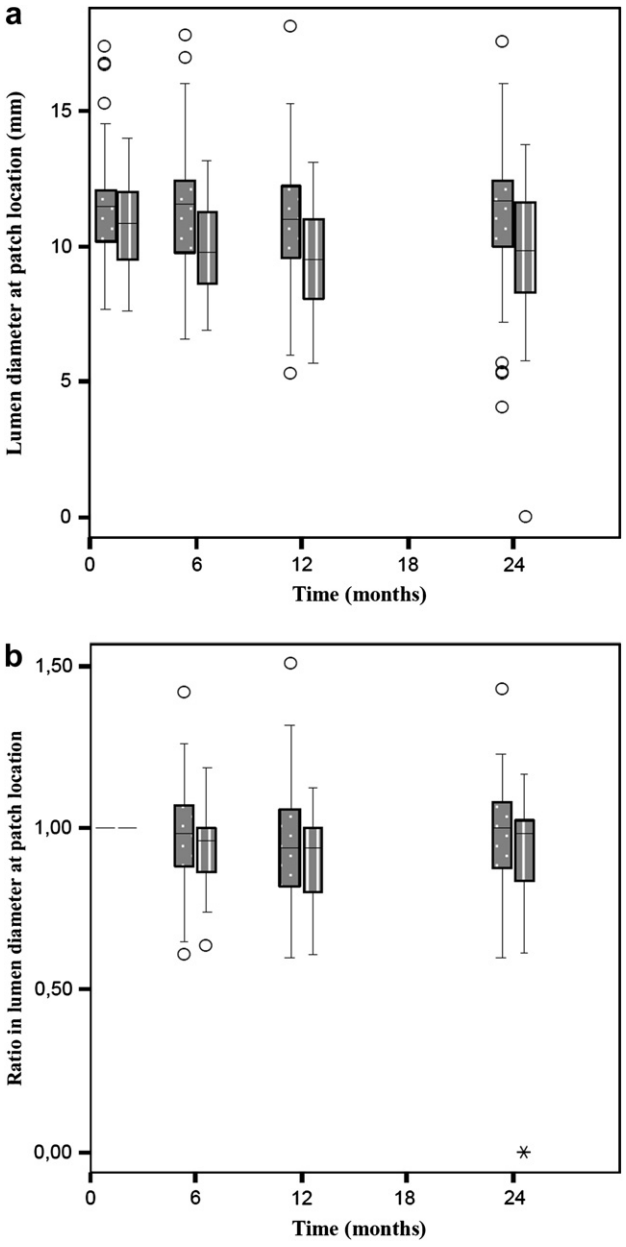

Figure 2 (a) Box plots of lumen diameter (mm) at patch location during duplex ultrasound surveillance for 2 years follow-up, (b) box plots of the ratio of lumen diameter at patch location is the lumen diameter at a specific time compared to the diameter at 6 weeks follow-up. At the specific times, the box plots on the left (filled with dots) show the venous group results; the box plots on the right (filled with stripes) show the results of the Fluoropassiv™ group. Box plots also show outliers.

score for ankle pain was 3 (95% CI 3.3—3.5) in the venous group.

Long-term follow-up

Table 4 shows the results of the two year follow-up period. No patients were lost to follow-up. The overall survival rate, including perioperative events, was 95.4%. The cumulative survival rate after two years follow-up was 95.6% in the venous group and 95.2% in the Fluoropassiv™ group. There were no significant differences in stroke rate between both patch types, except for TIAs. Patients who received a venous patch had more ipsilateral TIAs after one and two years follow-up compared to those who received the Fluoropassiv™ patch. One of these patients in the venous group developed a stroke after two years. The ultrasound duplex analysis of these patients showed no abnormalities (i.e. no recurrent stenosis/thrombosis or aneurysmatic dilatation). There were no obvious differences in patient characteristics compared to the whole venous group either. There was one late thrombosis of the internal carotid artery in the Fluoropassiv™ group, which also resulted in an ipsilateral non-regressive stroke. Previous duplex ultrasound analysis in this patient showed a nonsignificant recurrent stenosis of 40%. No late hemorrhage, patch infection or patch rupture occurred.

Figure 2 shows the results of the lumen diameter analysis at patch location. In both groups there was a minimal reduction in mean lumen diameter (mean reduction of $<10\%$). To further analyze changes in diameter, the lumen diameters were compared as a ratio to the diameter at 6 weeks follow-up (initial postoperative duplex ultrasound measurement). The highest reduction in lumen diameter was 40%, as observed in three patients from the venous group and three patients from the Fluoropassiv™ group. A few patients in the venous group developed an increase in lumen diameter at patch location of up to 150%. There were no patients in either group with a late recurrent stenosis (PSV ratio >2.6).

Discussion

Several studies have shown that CEA with patch angioplasty is superior to primary closure.[5] A systematic review by the Cochrane Collaboration showed that a policy of routine patching results in a threefold to fourfold excess reduction in perioperative and postoperative stroke and recurrent stenosis. Much debate remains regarding the type of patch to be used though.[6] Most randomized trials to date have shown that venous patches are not ''safer'' than synthetic patches (especially PTFE) in terms of neurological events.[6—8,16—18] However, one trial by Aburahma *et al.* shows a benefit of PTFE over polyester in terms of 30-days stroke rate and postoperative recurrent stenosis.[19] The present study has shown no evidence that the early (6-week) risk for thrombogenic complications is higher in the Fluoropassiv™ patch than in the venous patch.

The perioperative stroke rate in the Fluoropassiv™ group is comparable to reports on most other synthetic patches and even lower compared to (Hemashield) polyester patches.[12,20] However, the perioperative stroke rate in the venous group seems high. Multivariate analysis showed that both bilateral carotid stenosis and stroke as indications for CEA were related to the risk of perioperative stroke. Halm *et al.* have shown that these clinical factors indeed increase the risk for perioperative complications (stroke and death) with a comparable odds ratio as described in our study.[21] This might explain the high rate of perioperative stroke in

the venous group, since bilateral carotid stenosis was 3 times more prevalent in the venous group compared to the Fluoropassiv™ group. There was no link between perioperative stroke rate and patch type after correction for differences in bilateral carotid stenosis and indication for CEA.

Furthermore, all patients in this trial had symptomatic carotid stenosis, high comorbidity scores and high degrees of carotid stenosis. As a consequence, they were at a ''high'' risk for complications. A Cochrane analysis in 2002 concluded that there was not enough evidence to support or refute routine use of shunting during CEA.[22] In the present study, patients did receive selectively a shunt, based upon TCD measurements and EEG monitoring for cerebral perfusion analysis. However, TCD velocity measurements and EEG monitoring are not always a reliable indicator of clamping ischemia.[23,24]

There were no differences in stroke and mortality rates between both groups during long-term follow-up. Other randomized trials have concluded the same when comparing vein to prosthetic material.[20,25] Naylor *et al*. showed that there is more to preventing postoperative strokes than debates on patching and shunting, such as antiplatelet therapy.[26] Hayes *et al*. hypothesized that thromboembolic events are not entirely patch-related, but are also a measure of a patient's prothrombotic state.[27,28] Importantly, there is more debate on the risk for late recurrent stenosis in patients receiving vein or prosthetic patches. Naylor *et al*. showed a higher risk for recurrent stenosis in patients receiving Dacron patches compared to venous patches, while Rahma *et al*. showed a higher risk in patients with venous patches compared to PTFE patches.[7,20] In our study, patients were serially followed-up by duplex ultrasound for two years. No patients in the venous or the Fluoropassiv™ group developed a late recurrent stenosis. Importantly, the one patient in the Fluoropassiv™ group with a late thrombosis showed no abnormalities (significant recurrent stenosis) on preceding duplex ultrasound surveillance. On the other hand, the mean lumen diameter was higher in the venous group, and some patients showed an increase in lumen diameter of up to 150%. Wheeler *et al*. showed previously that with use of venous material the lumen diameter may indeed increase with time.[29] Yamamoto *et al*. even demonstrated that aneurysmatic dilatation may lead to new thromboembolic events, i.e. TIA or stroke.[10] Although some of our patients developed TIAs in the venous group after 2 years follow-up, none of them had an aneurysmatic dilatation of the patch.

Patch type had no influence on mortality, operation and clamping time, cranial nerve injury, neck wound pain, neck hematoma and time to hospital discharge. No patients sustained patch rupture or infection during follow-up. However, there were more early re-explorations of the neck for swelling in the Fluoropassiv™ group (14.3%). These were not related to a higher rate of neck hematoma in this group. In some of the patients with neck swelling the wound was re-explored and found to be hemostatic without evidence for hematoma, but subcutaneous tissues were markedly edematous. Two patients in the Fluoropassiv™ group used angiotensin-converting enzyme (ACE) inhibitors, and the use of ACE inhibitors has been described to be related to angioedema after CEA and other head-neck procedures.[30]

Other wound complications observed were those at the ankle for venous harvesting. In the present study, over 22% of the patients still complained about pain at the ankle/lower leg, six weeks after surgery. Athanasiou *et al*. analyzed wound healing disturbances in minimally invasive vein harvesting for coronary bypass surgery.[31] In a meta-analysis of prospective randomized trials, they reported comparable numbers of patients with ankle wound complications as in our study (hematoma, skin necrosis, edema). Patients in need of coronary bypass surgery or CEA are of course those with systemic atherosclerosis which makes them liable to wound complications, especially at the ankle. Smoking, presence of diabetes mellitus and a history of peripheral artery occlusive disease were all independently related to wound complications at the ankle in our study.

A limitation of the present study is a possible lack in power to detect differences in stroke rates. The differences in incidence of perioperative and long-term stroke are probably too small between different types of patches, as concluded e.g. by the Cochrane systematic review.[6] Any study to reliably detect such a difference would have to be quite vast, and the clinical relevance would probably be small. Power analyses by others have also confirmed that trials intended to show clinically relevant differences between different types of patches would need a very large population and long-term inclusion.[25] Importantly, this study was not intended to show a superior effect of the Fluoropassiv™ patch compared to a venous patch. We conducted this pilot study to test the safety of the new Fluoropassiv™ patch in CEA.

In conclusion, this first clinical study with the Fluoropassiv™ thin wall carotid patch showed no enhanced thrombogenicity in the early and long-term postoperative period compared to a venous patch. The Fluoropassiv™ patch is not related to a higher rate of postoperative bleeding events either, as previously observed by PTFE patches. A continuing analysis of this new patch in daily practice may help identify its benefits compared to other patches in CEA.

Conflict of Interest

There is no conflict of interest. The authors are not related in any way to Vascutek, a Terumo Company, Scotland, UK.

References

1 Halliday A, Mansfield A, Marro J, Peto C, Peto R, Potter J, et al. Prevention of disabling and fatal strokes by successful carotid endarterectomy in patients without recent neurological symptoms: randomised controlled trial. *Lancet* 2004;**363**:1491–502.

2 Mast H, Chambless LE, Mohr JP, Toole JF. Indications for endarterectomy in asymptomatic stenoses of the internal or common carotid artery—results of the North American ACAS Study. *Zentralbl Chir* 1996;**121**:1033–5.

3 Randomised trial of endarterectomy for recently symptomatic carotid stenosis: final results of the MRC European Carotid Surgery Trial (ECST). *Lancet* 1998;**351**:1379–87.

4 Beneficial effect of carotid endarterectomy in symptomatic patients with high-grade carotid stenosis. North American Symptomatic Carotid Endarterectomy Trial Collaborators. *N Engl J Med* 1991;**325**:445–53.

5 Bond R, Rerkasem K, AbuRahma AF, Naylor AR, Rothwell PM. Patch angioplasty versus primary closure for carotid endarterectomy. *Cochrane Database Syst Rev*; 2004:CD000160.

6 Bond R, Rerkasem K, Naylor R, Rothwell PM. Patches of different types for carotid patch angioplasty. *Cochrane Database Syst Rev*; 2004:CD000071.

7 AbuRahma AF, Robinson PA, Saiedy S, Kahn JH, Boland JP. Prospective randomized trial of carotid endarterectomy with primary closure and patch angioplasty with saphenous vein, jugular vein, and polytetrafluoroethylene: long-term follow-up. *J Vasc Surg* 1998;**27**:222—32.

8 Allen PJ, Jackson MR, O'Donnell SD, Gillespie DL. Saphenous vein versus polytetrafluoroethylene carotid patch angioplasty. *Am J Surg* 1997;**174**:115—7.

9 Borazjani BH, Wilson SE, Fujitani RM, Gordon I, Mueller M, Williams RA. Postoperative complications of carotid patching: pseudoaneurysm and infection. *Ann Vasc Surg* 2003;**17**:156—61.

10 Yamamoto Y, Piepgras DG, Marsh WR, Meyer FB. Complications resulting from saphenous vein patch graft after carotid endarterectomy. *Neurosurgery* 1996;**39**:670—5.

11 AbuRahma AF, Stone PA, Welch CA, Hofeldt MJ, Hass SM, Perry W. Prospective study of carotid endarterectomy with modified polytetrafluoroethylene (ACUSEAL) patching: early and late results. *J Vasc Surg* 2005;**41**:789—93.

12 AbuRahma AF, Hopkins ES, Robinson PA, Deel JT, Agarwal S. Prospective randomized trial of carotid endarterectomy with polytetrafluoroethylene versus collagen-impregnated dacron (Hemashield) patching: late follow-up. *Ann Surg* 2003;**237**: 885—92.

13 Rhee RY, Gloviczki P, Cambria RA, Miller VM. Experimental evaluation of bleeding complications, thrombogenicity and neointimal characteristics of prosthetic patch materials used for carotid angioplasty. *Cardiovasc Surg* 1996;**4**:746—52.

14 Pritz MB. Timing of carotid endarterectomy after stroke. *Stroke* 1997;**28**:2563—7.

15 Giordano JM. The timing of carotid endarterectomy after acute stroke. *Semin Vasc Surg* 1998;**11**:19—23.

16 AbuRahma AF, Khan JH, Robinson PA, Saiedy S, Short YS, Boland JP, et al. Prospective randomized trial of carotid endarterectomy with primary closure and patch angioplasty with saphenous vein, jugular vein, and polytetrafluoroethylene: perioperative (30-day) results. *J Vasc Surg* 1996;**24**:998—1006.

17 Bernstein EF. Saphenous versus prosthetic patch materials for carotid endarterectomy. *J Vasc Surg* 1992;**15**:869—70.

18 Grego F, Antonello M, Lepidi S, Bonvini S, Deriu GP. Prospective, randomized study of external jugular vein patch versus polytetrafluoroethylene patch during carotid endarterectomy: perioperative and long-term results. *J Vasc Surg* 2003;**38**:1232—40.

19 AbuRahma AF, Hannay RS, Khan JH, Robinson PA, Hudson JK, Davis EA. Prospective randomized study of carotid endarterectomy with polytetrafluoroethylene versus collagen-impregnated Dacron (Hemashield) patching: perioperative (30-day) results. *J Vasc Surg* 2002;**35**:125—30.

20 Naylor R, Hayes PD, Payne DA, Allroggen H, Steel S, Thompson MM, et al. Randomized trial of vein versus dacron patching during carotid endarterectomy: long-term results. *J Vasc Surg* 2004;**39**:985—93.

21 Halm EA, Hannan EL, Rojas M, Tuhrim S, Riles TS, Rockman CB, et al. Clinical and operative predictors of outcomes of carotid endarterectomy. *J Vasc Surg* 2005;**42**:420—8.

22 Bond R, Rerkasem K, Counsell C, Salinas R, Naylor R, Warlow CP, et al. Routine or selective carotid artery shunting for carotid endarterectomy (and different methods of monitoring in selective shunting). *Cochrane Database Syst Rev*; 2002:CD000190.

23 Limoni P, Comani V. Carotid endarterectomy with TCD and EEG monitoring. *Stroke* 1993;**24**:1762—3.

24 Bond R, Rerkasem K, Rothwell PM. Routine or selective carotid artery shunting for carotid endarterectomy (and different methods of monitoring in selective shunting). *Stroke* 2003;**34**:824—5.

25 O'Hara PJ, Hertzer NR, Mascha EJ, Krajewski LP, Clair DG, Ouriel K. A prospective, randomized study of saphenous vein patching versus synthetic patching during carotid endarterectomy. *J Vasc Surg* 2002;**35**:324—32.

26 Naylor AR. There is more to preventing stroke after carotid surgery than shunt and patch debates. *Eur J Vasc Endovasc Surg* 2005;**29**:329—33.

27 Hayes PD, Allroggen H, Steel S, Thompson MM, London NJ, Bell PR, et al. Randomized trial of vein versus Dacron patching during carotid endarterectomy: influence of patch type on postoperative embolization. *J Vasc Surg* 2001;**33**:994—1000.

28 Hayes PD, Box H, Tull S, Bell PR, Goodall A, Naylor AR. Patients' thromboembolic potential after carotid endarterectomy is related to the platelets' sensitivity to adenosine diphosphate. *J Vasc Surg* 2003;**38**:1226—31.

29 Wheeler JM, Wright I, Pugh N, Lane IF. Is there carotid artery aneurysm formation following saphenous vein patch endarterectomy? *Cardiovasc Surg* 2000;**8**:47—50.

30 Marrocco-Trischitta MM, Melissano G, de Dominicis D, Chiesa R. Angiotensin-converting enzyme inhibitor-induced angioedema following carotid endarterectomy misdiagnosed as cervical hematoma. *Ann Vasc Surg* 2006;**20**:145—7.

31 Athanasiou T, Aziz O, Skapinakis P, Perunovic B, Hart J, Crossman MC, et al. Leg wound infection after coronary artery bypass grafting: a meta-analysis comparing minimally invasive versus conventional vein harvesting. *Ann Thorac Surg* 2003; **76**:2141—6.