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Liesker, David J; Gareb, Barzi; Looman, Rick S; Donners, Simone J A; de Borst, Gert Jan; Zeebregts, Clark J; Saleem, Ben R

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Patch angioplasty during carotid endarterectomy using different materials has similar clinical outcomes

David J. Liesker, MD[1]; Barzi Gareb, MD, DMD, PhD[2]; Rick S. Looman, Bsc[1]; Simone J.A. Donners, MD[3]; Gert J. de Borst, MD, PhD[3]; Clark J. Zeebregts, MD, PhD[1]; Ben R. Saleem, MD, PhD[1]

Departments of Surgery (Division of Vascular Surgery)[1] and Oral and Maxillofacial Surgery[2], University Medical Center Groningen, University of Groningen, Groningen, The Netherlands

Department of Surgery (Division of Vascular Surgery)[3], University Medical Center Utrecht, Utrecht, The Netherlands

(Post-publication) corresponding author:

David J. Liesker

Department of Surgery, Division of Vascular Surgery

University of Groningen, University Medical Center Groningen

PO Box 30.001

9700 RB Groningen, The Netherlands

Tel: +31-50 361 3382

E-mail: d.j.liesker@umcg.nl

Article highlights

Type of Research: Single-center retrospective cohort study.

Key Findings: Cox analyses showed no significant differences between carotid endarterectomy with bovine pericardial patch (n=254) or polyester (n=163) on the following outcomes with long-term follow-up: transient ischemic attack or cerebrovascular accident, restenosis, reintervention, or all-cause mortality. Patch infection was rare, while completely absent in the bovine pericardial patch group.

Take home Message: Long-term outcomes of bovine pericardial patch and polyester patch angioplasty during carotid endarterectomy are comparable.

Table of Contents Summary

This large retrospective study showed no significant differences between carotid endarterectomy with bovine pericardial patch and polyester on the following outcomes with a long-term follow-up: transient ischemic attack or cerebrovascular accident, restenosis, reintervention, and all-cause mortality.

Abstract

Objective

Patch angioplasty during carotid endarterectomy is commonly used to treat carotid artery stenosis. However, the choice of which patch to use is still a matter of debate. Autologous venous material has disadvantages such as wound-related problems at the harvest site and a prolonged intervention time. These limitations can be bypassed when synthetic or biological patches are used. Both materials have been associated with divergent advantages and disadvantages. Therefore, the aim of our study was to compare the long-term follow-up outcomes in patients who received carotid endarterectomy and closure with either bovine pericardial patch or polyester patch.

Methods

A retrospective cohort study was conducted, including all patients who underwent primary carotid endarterectomy and closure with bovine pericardial patch or polyester patch between January 2010 and December 2020 at our tertiary referral center. In 2015, bovine pericardial patch was introduced as an alternative for polyester. The primary outcome was the occurrence of transient ischemic attack or cerebrovascular accident during follow-up and secondary outcomes included restenosis, reintervention, all-cause mortality, and patch infection. Cox proportional hazard models were utilized and hazard ratios with 95%-confidence interval were used to predict the above-mentioned outcomes.

Results

417 carotid endarterectomy patients were included. 254 (61%) patients received bovine pericardial patch and 163 received (39%) polyester. The mean age was 70.2 ± 8.7 and 67% were male. The

median follow-up time was 15 (12-27) months for bovine pericardial patch and 42 (16-60) months for polyester ($p<0.001$). Postoperative hematoma (≤30 days) was significantly lower in the bovine pericardial patch cohort (2% bovine pericardial patch vs 6% polyester; $p=0.047$). No other significant differences on short-term outcomes were found. Univariable cox regression analyses showed no significant differences between the effect estimates of polyester and bovine pericardial patch on transient ischemic attack or cerebrovascular accident ($p=0.106$), restenosis ($p=0.211$), reintervention ($p=0.549$), and all-cause mortality ($p=0.158$). No significant differences were found after adjusting for confounders in the multivariable analyses: transient ischemic attack or cerebrovascular accident, ($p=0.939$), restenosis ($p=0.057$), reintervention ($p=0.193$) and all-cause mortality ($p=0.742$). Three patients with a polyester patch had patch infection compared to none of the patients in the group who received a bovine pericardial patch.

Conclusion

This large retrospective study showed comparable safety and durability of both bovine pericardial patch and polyester suggesting that both patch types can be safely applied for carotid endarterectomy with patch angioplasty. Patch infection was rare while absent in the bovine pericardial patch group.

Key words:

Carotid endarterectomy, patch angioplasty, bovine pericardial patch, polyester.

Conflict of interest statement: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Introduction

Stenosis of the internal carotid artery (ICA) is one of the major causes of ischemic stroke.[1,2] In order to reduce the risk of stroke in both symptomatic and asymptomatic carotid stenosis carotid endarterectomy (CEA) with patch angioplasty may be performed. For patients undergoing CEA, routine patch closure is recommended, rather than primary closure.[3] A variety of materials are available, including autologous veins (e.g., the saphenous vein), synthetic patches (e.g., polytetrafluoroethylene [PTFE] or polyester), and biological patches (e.g., bovine pericardial patches [BPP]).[4–6] However, the choice of which patch to use is still a matter of debate.[3] Although saphenous vein patches are often used and deliver good results, many disadvantages exist. This results in a prolonged intervention time and an additional incision must be made which in turn increases the risk of developing wound complications at the harvest site, especially in vascular patients due to poor wound healing and higher risk of infection.[1,7] These limitations can be bypassed when synthetic or biological patches are used, which are usually readily available. However, synthetic patches may be more thrombogenic, carry a higher risk of infection, and have an increased risk of bleeding when compared to autologous venous patches.[8] In recent years, the use of BPP has become more popular. A recently published network meta-analysis did not find significant differences between BPP and polyester patch regarding 30-day stroke/death rate and late restenosis.[9] In 2021, a Cochrane review demonstrated that BPP material may decrease the incidence of fatal stroke, infection, and death when compared to other graft materials.[1] However, the quality of evidence was low due to the small numbers of events. Though these studies showed promising short-term outcomes for BPP, long-term outcomes for most patch types are still unknown and there are still insufficient high quality data to make recommendations in guidelines. Therefore, the aim of our study was to evaluate the difference between BPP versus polyester in long-term follow-up outcomes (i.e., transient ischemic attack [TIA] or cerebrovascular accident [CVA], restenosis, reintervention, all-cause mortality, or patch infection in patients who received a CEA with patch angioplasty).

Methods

Study design

All consecutive patients who underwent primary CEA with patch closure using bovine pericardium or polyester between January 2010 and December 2020 at our tertiary referral center were included in this study. In 2015, BPP was introduced as an alternative for polyester. In the following year, BPP surpassed polyester as the most used patch for CEA in our center. Patients who underwent CEA with primary closure or closure with other patch types than BPP/polyester were excluded from the current study.

The Institutional Review Board approved dispensation in accordance with Dutch law on patient-based medical research (WMO) obligations (registration no. METc 2021/493). Consequently, informed consent was not obtained. All patient related data were processed anonymously and stored electronically in agreement with the Declaration of Helsinki – Ethical principles for medical research involving human subjects.[10]

Patient characteristics and definitions

Baseline characteristics that were obtained from the electronic patient file included age at surgery in years, sex, body mass index (BMI), tobacco use, hypertension, hyperlipidemia, diabetes mellitus, and cardiac-, pulmonary- and renal disease. Tobacco use was defined as current use or less than one year of abstinence. Hypertension, hyperlipidemia, cardiac-, pulmonary-, and renal disease were classified by the Society for Vascular Surgery system (class 0-3) according to the Ad Hoc Committee on Reporting Standard.[11,12] These comorbidities were scored positive if the status was ≥ 1. Symptomatic carotid stenosis (>50% internal carotid artery stenosis) was defined as ipsilateral CVA, TIA, or ocular symptoms (amaurosis fugax) ≤ 6 months before surgery. Asymptomatic stenosis was defined as asymptomatic internal carotid artery stenosis of >50% or as symptomatic carotid stenosis >6 months ago (following the Reporting standards for carotid interventions from the Society for Vascular Surgery (SVS) and the European Society for Vascular Surgery guidelines).[3,13] Furthermore, symptoms at presentation, antiplatelet therapy, anticoagulation use, and statin use were collected. Grade of preoperative ipsilateral stenosis as seen on the duplex ultrasonography was noted. We used the following peak systolic velocities (PSV) for the internal carotid artery: <125 cm/s for a <50% stenosis, ≥125 cm/s for 50-69% stenosis, ≥230 cm/s for 70-89% stenosis, and ≥400 cm/s for >90% stenosis (but not near-occlusion).[14] The presence of contralateral occlusion of the internal carotid artery, as shown on duplex ultrasound, was noted.

Surgical procedure

Details of surgical procedure have been published previously.[15,16] Prior to surgical treatment, patients received a statin and antiplatelet therapy (aspirin 100 mg/day and/or clopidogrel 75 mg/day) unless they were already using anticoagulants. Before clamping the carotid artery, patients received 5000 IU heparin i.v. Intraoperative monitoring was performed using electro-encephalography (EEG) and transcranial Doppler (TCD). Intraoperative shunting was performed if there were significant EEG and/or TCD-changes. Longitudinal arteriotomy was closed using a patch made of bovine pericardium (XenoSure Biologic Vascular Patch; LeMaitre, Burlington, MA, USA) or polyester (Hemagard Carotid Patch; Getinge, Göteborg, Sweden). Protamine was not routinely administered. Postoperative mono-antiplatelet or anticoagulant therapy was continued.

The following intra-operative variables were collected: operation side (left/right), type of anesthesia (regional or total), blood loss (ml), clamping time (minutes), shunting (yes/no), and patch type (BPP or polyester).

Postoperative length of hospital stay was noted. Standard antiplatelet therapy was given following CEA and surveillance duplex was performed 6 weeks postoperatively, followed once a year thereafter.

Outcome

The primary outcome measure was the occurrence of ipsilateral TIA/CVA during follow-up. This was based on evaluation by a neurologist and confirmation with cerebral imaging. Secondary outcomes included ipsilateral restenosis, ipsilateral reintervention, all-cause mortality, and patch infection. A PSV-threshold of >213 cm/s was used for diagnosing a restenosis >50%.[3] Restenosis was scored positive if >50%. Reintervention was defined according to the Reporting standards for carotid interventions from the SVS as any postprocedural adjunctive maneuvers (i.e. management of access site complications and management of postoperative stroke).[13] Patch infection was diagnosed according the Management of Aortic Graft Infection group (MAGIC) classification (with at least one major criterion and one minor criterion from another category).[17]

In addition, short-term results within 30 days after CEA were also considered consisting of peripheral nerve damage, cardiac complication (myocardial infarction, angina pectoris, arrhythmia, or heart failure), delirium, urinary tract infection, wound infection, cervical hematoma (defined according to the SVS Reporting standards for carotid interventions; SVS class 1-3 were scored as positive), restenosis, TIA/CVA, and mortality.[13]

Statistical analysis

Distribution of continuous data were checked visually and supplemented by the Shapiro-Wilk test. Mean and standard deviations of normal distributed continuous variables were calculated. Skewed distributed data were presented as median and interquartile range (IQR). Student's T-tests were used to compare normal distributed variables and Mann-Whitney U tests were used to compare variables with a skewed distribution between both patch types. Fisher's exact test was performed to compare categorical variables. Kaplan-Meier survival curves were plotted to visualize the effect of patch types on the primary and secondary outcome(s). Survival analysis was performed using Cox proportional hazard model with stepwise backward elimination calculating hazard ratio (HR) with 95%-confidence interval (CI). Univariable Cox regression models were fitted to assess the crude effect of patch type on time to the occurrence of TIA/CVA, restenosis, reintervention, all-cause mortality, and patch infection. Subsequently, multivariable models were fitted for each outcome. The eligible variables for the adjusted models were selected whenever the univariable analyses between both patch types yielded a $p<0.10$. A variable was considered a confounder whenever the regression coefficient of the patch type changed ≥10%. Confounders remained included in the multivariable models. Effect modification by diabetes mellitus and hypertension was also tested by including an interaction term (e.g., patch type*diabetes mellitus and patch type*hypertension). All models yielded an estimated regression coefficient (β) with a corresponding HR and 95% CI. The Cox regression model assumptions were tested and fulfilled. Statistical analysis was performed in R, version 4.0.5 (R Foundation for Statical Computing, Vienna, Austria), using the *survival*, *survminer*-, and *ggplot2*-packages. In all analyses, $p<0.05$ was considered statistically significant.

Results

In total, 417 CEA patients were included. Two hundred and fifty four (61%) patients received BPP and 163 received (39%) polyester. The mean age of the total group was 70.2 ± 8.7 and 67% were male. In Table I, baseline characteristics and comorbidities per patch type are listed. Patients with a polyester patch were more likely to have hypertension (p=0.004), cardiac disease (p=0.001), and renal disease (p=0.003). No other differences between patch types were found.

There is a significant difference in the distribution of preoperative presentation (ipsilateral symptoms) in both groups ($p<0.001$). There were no statistically significant differences in preoperative medication (antiplatelet, anticoagulation, and statin use), grade of stenosis, or presence of contralateral occlusion of the internal carotid artery. See Table II.

Intra-operative variables are shown in Table II. Clamping time was 33 ± 8 minutes in BPP patients and 34 ± 9 in patients with a polyester patch (p=0.165). Operation time was significantly longer in the group with CEA with polyester compared to BPP, 184 ± 32 compared to 148 ± 35 minutes (p<0.001). Thirty-one (12%) BPP patients underwent shunting and 15 (9%) polyester patients (p=0.333).

Median postoperative length of hospital stay was 3 (3-4) days for both patch types. Median follow-up time was 15 (12-27) months for BPP and 42 (16-60) months for polyester (p<0.001). Other postoperative characteristics are shown in Table II.

Short-term complications (≤30 days post-procedure)

Short-term (≤30 days) postoperative complications are summarized in Table III. Peripheral nerve damage occurred in 15 (6%) patients with BPP and 16 (10%) patients with polyester (p=0.136). Three patients (1%) with BPP and 2 (1%) with polyester developed a wound infection (p=1.000). Clinical symptoms that were observed were fever, redness, localized pain, and swelling. All patients got antibiotic therapy (oral or i.v.) and three patients (2 BPP and 1 polyester) were treated with incision and drainage. None of the patients developed a patch infection. There were significantly less BPP patients with a postoperative cervical hematoma compared to polyester patients (5 (2%) vs. 9 (6%), p=0.047). There were no significant differences on short-term (ipsilateral) restenosis, TIA/CVA, and mortality between in BPP and polyester patients. Two (1%) vs. 2 (1%) patients had a restenosis (p=1.000), 7 (3%) vs. 10 (6%) had a TIA or CVA (p=0.088), and 0 (0%) vs. 2 (1%) patients died within 30 days postoperative (p=0.152).

Long-term outcome

An overview of the number of adverse events per patch type is shown in Figure 1. The univariable Cox regression analyses showed no significant differences between the effect estimates of polyester and BPP on TIA/CVA (p=0.106), restenosis (p=0.211), reintervention (p=0.549), and all-cause mortality (p=0.158; Table IV and Figure 2). After adjusting for confounders in the multivariable Cox regression analyses, no significant differences were found between patch types on TIA/CVA (p=0.939), restenosis (p=0.057), reintervention (p=0.193), and all-cause mortality (p=0.742); Table IV). Effect modification by diabetes mellitus and hypertension was not observed in any model (all p>0.073).

Peripheral nerve damage

One (7%) of the 15 BPP patients and 3 of the 16 (19%) polyester patients with (short-term) peripheral nerve damage had persistent symptoms at one year follow-up (p=0.600).

Patch infection

Three patients had a suspected graft infection in the total follow-up period. Two patients, with a polyester patch, presented with a pseudo-aneurysm (after 57 and 37 months, respectively). The first patient underwent replacement surgery with an autologous venous patch and the second patient was treated conservatively. This patient was not fit enough for surgery and was treated with antibiotics alone. Diagnosis was based on clinic, intra-operative view, and imaging. Materials cultured during surgery were negative, however probably due to long antibiotic use before surgery. The third patient presented (6 months postoperative) with a fistula which extended from the (polyester) patch to the skin (Supplemental Figure 1). This infected graft was also replaced by an autologous venous patch. Intra-operative cultures were positive for *staphylococcus aureus*.

Discussion

In this retrospective study, we investigated short- and long-term outcomes between BPP and polyester for CEA. With 417 CEA patients, of which 254 (61%) BPP, this is one of the largest retrospective studies comparing BPP with a synthetic alternative.[18] Our results showed that there were no statistically significant differences between both patch types regarding to TIA/CVA, restenosis, reintervention, and all-cause mortality on multivariable analyses. These long-term outcomes without significant differences between both patch materials are comparable with previous published studies.[4,7,18,19]

Graft infection was rare and occurred in three patients with a polyester patch only, while none of the BPP patients were affected. A similar lower infection rate (0.59%) of BPP compared to synthetic patches was found previously.[19] The hypothesis is that BPP is an acellular xenograft, making it less susceptible to infection compared to synthetic patches.[1] This acellular material of collagen may provide a natural environment for host cell migration and proliferation, which causes reendothelialization.[20] The possible infection resistant property was also demonstrated by several reports on BPP used in cardiovascular (graft) infection.[21–24]

Our study demonstrated significantly less BPP patients with short-term (≤30 days) cervical hematoma compared to polyester patients (p=0.047). A possible explanation for this difference may be the fact that the total suture line bleeding is significantly less with BPP compared to polyester (after adjustment for activated clotting time).[25] In this previously published study, bleeding at three and four minutes after carotid cross-clamp removal was observed. Furthermore, blood loss was quantified by weighing the sponge used to tamponade the bleeding. Suture line bleeding may be an explanation for the longer operation time that we found in the polyester group.

A previously published study did not show differences in 30-day hematoma (which required reintervention) between BPP and other materials (polyester, venous, primary closure, and other techniques).[18]

This study has limitations. First of all, the retrospective design of the study causes a lower level of evidence compared to prospective studies and causes a heterogenous sample with variety of follow-up periods. Since BPP was introduced in 2015, this type of patch had a shorter median follow-up time compared to polyester in our study. However, the medical management, the diagnostic criteria, and the surgical procedure remained the same throughout the study period (2010-2020). Since this study compares one type of BPP and one type of polyester, the results may differ when compared to patches from other manufacturers. Furthermore, the number of adverse events (longer term outcomes) were scarce, so comparison between two groups requires a large amount of patients to reduce type II error. In particular, the trends observed on the differences of short-term TIA/CVA (p=0.088) and restenosis (p=0.057) in the multivariable analysis deserve to be further investigated using a larger sample size. However, this is one of the largest retrospective studies comparing BPP with polyester on longer term outcomes.

Conclusion

This study showed comparable safety and durability of both BPP and polyester, making both options acceptable for CEA with patch angioplasty. Patch infection was rare and only three patients with a polyester patch were affected, while absent in the BPP group. On the short term, there were significantly less BPP patients with a postoperative hematoma compared to polyester patients. The choice between patch types remains depending on the experience of the surgical team.[3] Future studies with a larger sample will have to determine if there is a difference in the risk of getting (graft) infection between BPP and polyester.

References

1 Orrapin S, Benyakorn T, Howard DP, Siribumrungwong B, Rerkasem K. Patches of different types for carotid patch angioplasty. *Cochrane Database Syst Rev*2021;2:CD000071.

2 Flaherty ML, Kissela B, Khoury JC, Alwell K, Moomaw CJ, Woo D et al. Carotid artery stenosis as a cause of stroke. *Neuroepidemiology*2012;40:36–41.

3 Naylor AR, Rantner B, Ancetti S, de Borst GJ, De Carlo M, Halliday A et al. European society for vascular surgery (ESVS) 2023 clinical practice guidelines on the management of atherosclerotic carotid and vertebral artery disease. *Eur J Vasc Endovasc Surg*2022;May Online:In press.

4 Texakalidis P, Giannopoulos S, Charisis N, Giannopoulos S, Karasavvidis T, Koullias G et al. A meta-analysis of randomized trials comparing bovine pericardium and other patch materials for carotid endarterectomy. *J Vasc Surg*2018;68:1241-1256.e1.

5 Muto A, Nishibe T, Dardik H, Dardik A. Patches for carotid artery endarterectomy: current materials and prospects. *J Vasc Surg*2009;50:206–213.

6 Rerkasem K, Rothwell PM. Systematic review of randomized controlled trials of patch angioplasty versus primary closure and different types of patch materials during carotid endarterectomy. *Asian J Surg*2011;34:32–40.

7 Ho KJ, Nguyen LL, Menard MT. Intermediate-term outcome of carotid endarterectomy with bovine pericardial patch closure compared with Dacron patch and primary closure. *J Vasc Surg*2012;55:708–714.

8 Ren S, Li X, Wen J, Zhang W, Liu P. Systematic review of randomized controlled trials of

different types of patch materials during carotid endarterectomy. *PLoS One*2013;8:e55050.

9 Lazarides MK, Christaina E, Argyriou C, Georgakarakos E, Tripsianis G, Georgiadis GS. Editor's choice – network meta-analysis of carotid endarterectomy closure techniques. *Eur J Vasc Endovasc Surg*2021;61:181–190.

10 WMA declaration of Helsinki - ethical principles for medical research involving human subjects. https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles for-medical-research-involving-human-subjects/ (accessed February 1, 2022).

11 Rutherford RB, Baker JD, Ernst C, Johnston KW, Porter JM, Ahn S et al. Recommended standards for reports dealing with lower extremity ischemia: revised version. *J Vasc Surg*1997;26:517–538.

12 Evans GHC, Stansby G, Hamilton G. Suggested standards for reporting on arterial aneurysms. *J Vasc Surg*1992;15:456.

13 Timaran CH, McKinsey JF, Schneider PA, Littooy F. Reporting standards for carotid interventions from the Society for Vascular Surgery. *J Vasc Surg*2011;53:1679–1695.

14 Oates CP, Naylor AR, Hartshorne T, Charles SM, Fail T, Humphries K et al. Joint Recommendations for Reporting Carotid Ultrasound Investigations in the United Kingdom. *Eur J Vasc Endovasc Surg*2009;37:251–261.

15 Visser L, Vries BMW De, Mulder DJ, Uyttenboogaart M, Veen S van der, Zeebregts CJ et al. The influence of the metabolic syndrome on the short- and long-term outcome after carotid endarterectomy. *Angiology*2017;68:306–314.

16 Meerwaldt R, Hermus L, Reijnen MMPJ, Zeebregts CJ. Carotid endarterectomy: current consensus and controversies. *Surg Technol Int*2010;20:283–91.

17 Lyons OTA, Baguneid M, Barwick TD, Bell RE, Foster N, Homer-Vanniasinkam S et al. Diagnosis of Aortic Graft Infection: A Case Definition by the Management of Aortic Graft

Infection Collaboration (MAGIC). *Eur J Vasc Endovasc Surg*2016;52:758–763.

18 Oldenburg WA, Almerey T, Selim M, Farres H, Hakaim AG. Durability of carotid endarterectomy with bovine pericardial patch. *Ann Vasc Surg*2018;50:218–224.

19 Léonore F-T, Elsa F, David P-C, Ludovic C, Pascal B, Charles Henri M-A et al. Short- and long-term outcomes following biological pericardium patches versus prosthetic patches for carotid endarterectomy: a retrospective bicentric study. *Ann Vasc Surg*2021;72:66–71.

20 Li X, Guo Y, Ziegler KR, Model LS, Eghbalieh SDD, Brenes RA et al. Current Usage and Future Directions for the Bovine Pericardial Patch. *Ann Vasc Surg*2011;25:561–568.

21 McMillan WD, Leville CD, Hile CN. Bovine pericardial patch repair in infected fields. *J Vasc Surg*2012;55:1712–1715.

22 Kreibich M, Siepe M, Morlock J, Beyersdorf F, Kondov S, Scheumann J et al. Surgical treatment of native and prosthetic aortic infection with xenopericardial tube grafts. *Ann Thorac Surg*2018;106:498–504.

23 Jones JM, Sarsam MA. Partial mitral valve replacement for acute endocarditis. *Ann Thorac Surg*2001;72:255–257.

24 David TE. The surgical treatment of patients with prosthetic valve endocarditis. *Semin Thorac Cardiovasc Surg*1995;7:47–53.

25 Marien BJ, Raffetto JD, Seidman CS, LaMorte WW, Menzoian JO. Bovine pericardium vs dacron for patch angioplasty after carotid endarterectomy: a prospective randomized study. *Arch Surg*2002;137:785–788.

Table I. Patient characteristics associated with type of patch

Patient Characteristics	**Bovine N (%) or mean ± SD**	**Polyester N (%) or mean ± SD**	***P*-value**
No. of patients	254 (61)	163 (39)	-
Age in years	69.6 ± 8.6	71.2 ± 8.9	0.076
Sex (males)	169 (67)	111 (68)	0.740
BMI in kg/m^2	27.2 ± 4.1	27.5 ± 5.1	0.518
Tobacco use	115 (45)	63 (39)	0.199
Hypertension	168 (66)	129 (79)	**0.004**
Hyperlipidaemia	211 (83)	139 (85)	0.550
Diabetes mellitus	55 (21)	48 (29)	0.072
Cardiac disease	85 (33)	80 (49)	**0.001**
Pulmonary disease	37 (15)	30 (18)	0.298
Renal disease	45 (18)	49 (30)	**0.003**

Abbreviations: SD=standard deviation.

Table II. Pre-, intra- and postoperative characteristics

Characteristic	**Bovine** N (%) or mean ± SD or median (IQR)	**Polyester** N (%) or mean ± SD or median (IQR)	***P*-value**
Preoperative			
Ipsilateral symptoms			**<0.001**
CVA	89 (35)	74 (45)	
TIA	101 (40)	51 (31)	
Ocular	57 (22)	22 (13)	
Asymptomatic	7 (3)	16 (10)	
Antiplatelet therapy	236 (93)	145 (89)	0.160
Anticoagulation	32 (14)	26 (19)	0.334
Statin use	219 (86)	137 (84)	0.540
Stenosis grade			0.680
<50%	1 (0)	0 (0)	
50-69%	56 (22)	34 (21)	
70-89%	176 (69)	119 (73)	
>90% (but not near-occlusion)	21 (8)	10 (6)	
Contralateral occlusion	13 (5)	12 (7)	0.400

Intra-operative			
Operation side (right)	112 (44)	70 (43)	0.817
Intervention time (min)	148 ± 35	184 ± 32	**<0.001**
Clamping time (min)	33 ± 8	34 ± 9	0.165
Shunt use	31 (12)	15 (9)	0.333
Postoperative			
Length of hospital stay (days)	3(3-4)	3 (3-4)	0.580
Antiplatelet therapy	244 (96)	152 (93)	0.252
Use of anticoagulation	33 (13)	24 (15)	0.662

Abbreviations: SD=standard deviation, IQR= interquartile range (IQR is written as: first quartile-third quartile), min=minutes.

Table III. Post-operative short-term adverse outcomes

Characteristic	**Bovine** **N (%)**	**Polyester** **N (%)**	***P*-value**
Peripheral nerve damage	15 (6)	16 (10)	0.136
Cardiac complication*	4 (2)	6 (4)	0.198
Delirium	4 (2)	4 (2)	0.717
Urinary tract infection	3 (1)	2 (1)	1.000
Wound infection	3 (1)	2 (1)	1.000
Cervical hematoma (Class 1-3**)	5 (2)	9 (6)	**0.047**
Restenosis	3 (1)	2 (1)	1.000
TIA or CVA	7 (3)	10 (6)	0.088
Mortality	0 (0)	2 (1)	0.152

Abbreviations: -

*defined as: myocardial infarction, angina pectoris, arrhythmia, or heart failure.

**according to the Society of Vascular Surgery Reporting standards for carotid interventions.

Table IV. Uni- and multivariable Cox regression analyses of the effect of patch type on TIA/CVA, restenosis, re-intervention, and all-cause mortality after 5-year follow-up.

Outcome	**Predictor**	**β (95% CI)**	**HR (95% CI)**	***P***
TIA or CVA (ipsilateral)	Polyester (ref: Bovine)	0.68 (-0.14-1.50)	1.97 (0.87-4.47)	0.106
	Polyester (ref: Bovine)[1]	-0.03 (-1.05-0.97)	0.96 (0.35-2.63)	0.939
Restenosis (ipsilateral)	Polyester (ref: Bovine)	-0.38 (-0.98-0.22)	0.68 (0.37-1.24)	0.211
	Polyester (ref: Bovine)[2]	-0.74 (-1.50-0.02)	0.48 (0.22-1.02)	0.057
Re-intervention (ipsilateral)	Polyester (ref: Bovine)	-0.22 (-0.94-0.50)	0.80 (0.39-1.65)	0.549
	Polyester (ref: Bovine)[3]	-0.62 (-1.56-0.32)	0.54 (0.21-1.37)	0.193
All-cause mortality	Polyester (ref: Bovine)	0.45 (-0.17-1.07)	1.57 (0.84-2.93)	0.158
	Polyester (ref: Bovine)[4]	0.13 (-0.62-0.88)	1.13 (0.54-2.40)	0.742

[1]adjusted for age, hypertension, renal disease, cardiac disease, symptoms ipsilateral, intervention time, shunt use.

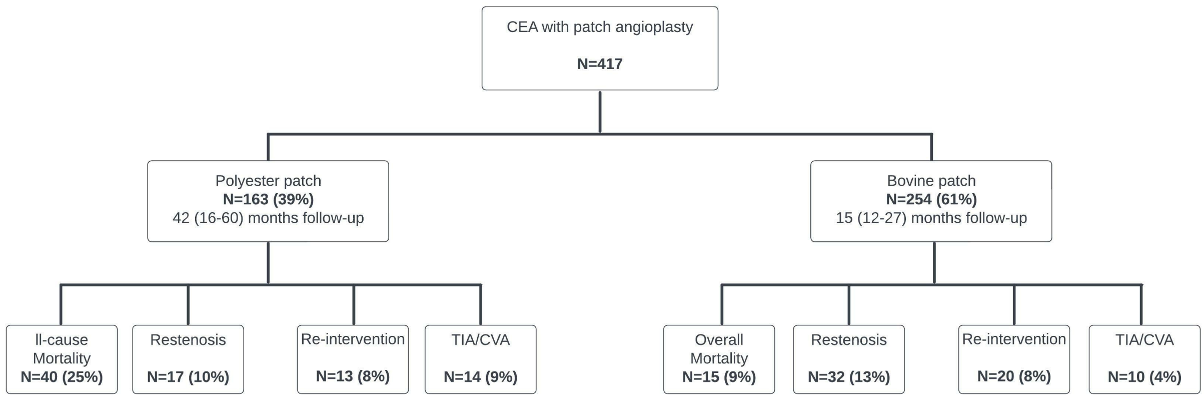
[2] adjusted for intervention time.

[3]adjusted for intervention time, shunt use.

[4]adjusted for age, diabetes mellitus, renal disease, intervention time, shunt use, symptoms ipsilateral.

(tested: age, sex, hypertension, diabetes mellitus, cardiac disease, renal disease, intervention time, symptoms ipsilateral, shunt use).

Abbreviation: ref=reference.


CEA with patch angioplasty
N=417
Polyester patch
N=163 (39%)
42 (16-60) months follow-up
Bovine patch
N=254 (61%)
15 (12-27) months follow-up
ll-cause Mortality
N=40 (25%)
Restenosis
N=17 (10%)
Re-intervention
N=13 (8%)
TIA/CVA
N=14 (9%)
Overall Mortality
N=15 (9%)
Restenosis
N=32 (13%)
Re-intervention
N=20 (8%)
TIA/CVA
N=10 (4%)

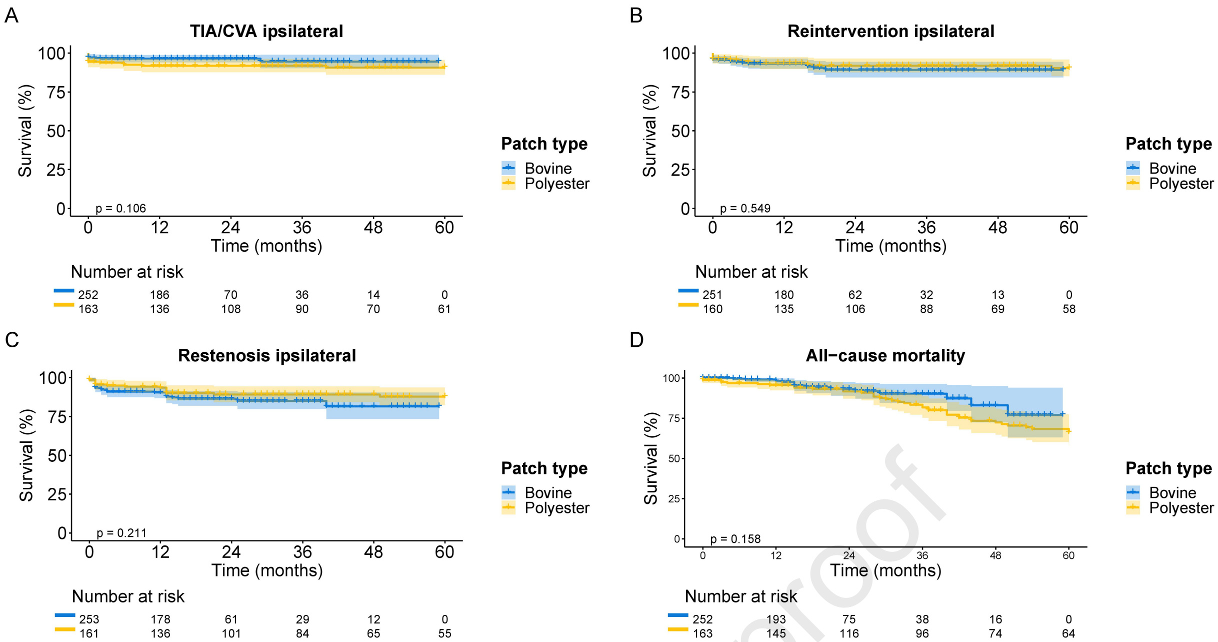

A
TIA/CVA ipsilateral
Survival (%)
p = 0.106
Time (months)
Patch type
Bovine
Polyester
Number at risk
252 186 70 36 14 0
163 136 108 90 70 61
B
Reintervention ipsilateral
Survival (%)
p = 0.549
Time (months)
Patch type
Bovine
Polyester
Number at risk
251 180 62 32 13 0
160 135 106 88 69 58
C
Restenosis ipsilateral
Survival (%)
p = 0.211
Time (months)
Patch type
Bovine
Polyester
Number at risk
253 178 61 29 12 0
161 136 101 84 65 55
D
All−cause mortality
Survival (%)
p = 0.158
Time (months)
Patch type
Bovine
Polyester
Number at risk
252 193 75 38 16 0
163 145 116 96 74 64

Figure legends

Figure 1.

Total number of adverse events in patients with BPP and polyester patch.

Figure 2.

Survival curves per patch type for different outcomes (**2A**: TIA/CVA ipsilateral, **2B**: reintervention ipsilateral, **2C**: restenosis ipsilateral, **2D**: all-cause mortality).

Supplemental Figure 1.

Fistula which extended to the skin of the patient.