In vivo and mechanical properties of peritoneum/fascia as a novel arterial substitute

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Objective: **This study evaluates the efficacy of bovine peritoneum/fascia as an arterial substitute.**

Methods and Outcome Measures: **Twelve dogs underwent bilateral femoral artery patch angioplasty with a glutaraldehyde-fixed bovine peritoneal/fascial patch (PFA patch) on one side and polyester patch on the contralateral side. Arteriograms were performed just before vessel harvest at 1 and 6 months, and vessels were evaluated for aneurysms and inflammation. Histologic analysis included intima area, media thickness, and lumen area. Immunofluoresence for CD 34 and Factor VIII was done to evaluate endothelialization and α-actin for smooth muscle cell growth. Mechanical strength testing was evaluated in separate PFA patches and compared independently to a commercially available bovine pericardial patch and polyester patch.**

Results: **All vessels examined at both 1 and 6 months were patent with no arteriographic evidence of stenosis. There was no evidence of aneurysm formation in any vessel and no difference between groups in inflammatory reaction. One polyester patch at 1 month developed an infection. Microscopic evaluation of experimental vessels revealed no difference between groups in intima area at 1 month (2.1 ± 1.2 vs 2.2 ± 1.2 mm^2; $P = .5$) and at 6 months (1.81 ± 1.2 vs 1.9 ± 1.2 mm^2; $P = .5$). There was no difference in media thickness, but the PFA patch group had a greater lumen area at 1 month (8.8 ± 2.9 vs 9.8 ± 3.0 mm^2; $P = .02$) and 6 months (10.5 ± 4.2 vs 11.7 ± 5.6 mm^2; $P = .02$). Immunofluoresence for CD34 and Factor VIII demonstrated complete re-endothelialization of all patches. The polyester patch had a chronic inflammatory response, but not the PFA patch. Mechanical strength testing demonstrated that compared to pericardium, the PFA patch had superior ($P < .05$) failure tension, stiffness, and suture pullout strength, whereas extensibility, fatigue tension, relax slope, and creep tests were not different. Polyester demonstrated superior suture pullout, stiffness, relax slope, and failure strain ($P < .05$), but it was not different in failure tension and extensibility than the PFA patch. However, the PFA patch had significantly less creep (0.25 ± 0.25 vs 4.92 ± 0.84; $P < .01$).**

Conclusions: **The PFA patch has similar clot-resistant properties to polyester and is superior to the pericardial patch in mechanical strength. It is a promising endothelial alternative for not only arterial patches but other vascular products. (J Vasc Surg 2005;41:490-7.)**

Clinical Relevance: **The search for an artificial, thromboresistant, and intimal hyperplasia resistant interface between blood and native blood vessels still continues. This study demonstrates the feasibility and proof of concept of the peritoneum's clot-resistant properties. When adding the underlying fascia, it serves as an ideal arterial patch. Other studies are underway evaluating its feasibility as a bypass graft and a "drug coated"–like stent lining.**

Polyester (Dacron) and expanded polytetrafluoroethylene are the mainstay arterial substitutes for open vascular surgical procedures. Biologic substitutes such as bovine pericardial patches, bovine carotid arteries, and human umbilical vein grafts are other alternatives, but they have not gained widespread acceptance. Cadaveric arteries and veins have shown promise,[1] but their long-term durability is suspect, and their costs are prohibitive.

Although blood vessel substitutes have drawn considerable attention, their genesis stems from simpler patches. Arterial patches have been in use since Dos Santos first described thromboendarterectomy,[2] and polyester and autologous vein are the primary choices for arterial patches after carotid endarterectomy.[3] Nonetheless, bovine pericardium has been widely used as an interface between blood and tissue for heart valves, and there has been a recent report of excellent long-term results using bovine pericardial patches for carotid endarterectomy.[4] Tissue has been promoted for use as arterial and venous substitutes because of less chance of infection[5] and potentially less restenosis.[6] Despite these potential benefits, quantity, size, and durability for use as dialysis and bypass grafts or other arterial applications have been suboptimal. Similarly, prosthetic bypass grafts also have inferior results with high levels of restenosis and inferior patency rates.[7]

The optimal arterial substitute has not been found. With limited autogenous vein and poor results of prosthetic arterial substitutes, alternative sources of materials continue to be explored. Peritoneum is the abdominal cavity's embryologic equivalent to endothelium, because it is derived

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from mesenchymal tissue. It is similar to pericardium and pleura in its surface characteristics and functions as "frictionless" interface for visceral surfaces. The following study reports the use of bovine peritoneum with adherent fascia as a novel source for arterial placement.

MATERIAL AND METHODS

Bovine peritoneal/fascia patch tissue harvest and processing. All studies were conducted under Good Laboratory Practice conditions, were approved by the animal review committee, and were performed in accordance with institutional guidelines and the *Guide for the Care and Use of Laboratory Animals*.[8] Bovine weighing between 125 and 130 kg (Robert Mikesell Stock Farm, Frazeysburg, Ohio) were quarantined for a minimum of 3 days; food was withheld for 8 to 12 hours and water for 2 hours before each procedure. Each bovine received benzathine-procaine penicillin (30,000 to 50,000 U/kg intramuscular) preoperatively followed by sedation to deliver isoflurane (2% to 4%). The animals were intubated, and anesthesia was maintained with isoflurane (0.8% to 1.25%). The animal's abdomen and chest were scrubbed with alcohol and betadine, and a longitudinal abdominal incision and two upper and lower abdominal transverse incisions were made to expose the peritoneum/fascia (PFA). The PFA was extracted for tissue processing, and the animal was killed.

After the tissue was harvested, it was placed in a container with 0.9% phosphate buffered saline (PBS; Baxter Healthcare Corporation, Deerfield, Ill) at pH 7.4 and temperature 4.0°C. The tissue was cut into segments, sutured to polyethylene plates, and placed into sterile jars. Further processing for cross-linking and sterilization was done in the following manner. The PFA fixed on the plate was bathed in PBS at room temperature for 1 hour. Next, the tissue was cross-linked by transferring it to 2.5% glutaraldehyde solution (Fisher Scientific, Fairlawn, NJ) for 24 hours. It was then rinsed in PBS for 1 hour and sterilized in 50% reagent ethanol (Labchem Inc, Pittsburgh, Pa) for 24 hours. Subsequent inactivation of prions was done in 1 molar NaOH for 2 hours[9] after rinsing in PBS. The tissue underwent a final rinse in PBS before placing it into its final storage solution of 0.625% glutaraldehyde.

Experimental procedure. Female random source dogs weighing between 25 to 30 kg (Hodgins Kennels, Inc, Howell, Mich) were housed in individual cages in light-dark–cycled, temperature-controlled rooms. Standard food and tap water were offered ad libitum. The canines were quarantined for a minimum of 7 days, and animals were kept without food for 8 to 12 hours and water for 2 hours preceding each procedure. Animals were anesthetized with sodium thiopental (16 to 20 mg/kg, intravenous), intubated, and maintained with 1.5% isoflurane. Each animal received benzathine-procanine pencillin (450,000 U, intramuscular). Femoral regions were prepped and draped in sterile fashion.

Twelve dogs underwent bilateral femoral artery exposure. Before implanting the PFA patch, each patch was rinsed in PBS solution for 5 minutes. The animal was heparinized (80 U/kg), and activated clotting time (ACT) was obtained at 3 minutes; additional heparin administration ensured adequate anticoagulation to maintain the ACT 2 1/2 times the baseline. Patch angioplasty was done by sewing a 0.8 × 3 cm PFA patch on one side and a control polyester patch of similar dimensions on the contralateral side (Hemashield; Boston Scientific, Oakland, NJ) with a continuous 6-0 polyprolene suture (Ethicon, Somerville, NJ). Each animal served as its own control, and left and right sides were alternated. All incisions were closed with 2-0 vicryl sutures (Ethicon). Animals were given buprenorphine (0.01 to 0.02 mg/kg, subcutaneous, twice a day) for postoperative discomfort. Dog's femoral arteries were evaluated for blood vessel patency daily for the first week and then weekly thereafter. End points for vessel harvest were 1 month and 6 months.

Vessel harvest. One half of the canines were killed at 1 month and the other half at 6 months. The animals were heparinzed (80 U/kg), and each dog was anesthetized as described above. The right common carotid artery was exposed for arteriographic access, and bi-planar arteriography was taken by using an OEC 9600 C-arm (GE Medical Systems OEC, Salt Lake City, Utah) in the anterior-posterior and lateral views by injecting 10 mL of intravenous contrast (Hypaque-76; Amersham Health, Princeton, NJ). Patency along with degree of stenosis was documented. After the arteriograms were obtained, the experimental vessels were exposed, and gross evaluation was performed to determine aneurysm formation and inflammation. Inflammation and adhesions were recorded for each vessel by the following scale: 1, mild; 2, mild-moderate; 3, moderate; 4, moderate-severe; 5, severe. Each vessel was harvested after pressure perfusion fixation at 120 mm Hg as previously described.[10] Two liters of PBS and 1 L of 2.5% glutaraldehyde were perfused through each vessel. Each study vessel was harvested 2 cm proximal and distal to each patch and stored in 2.5% glutaraldehyde until histologic processing.

Histologic processing. Representative sections of each artery were obtained at 1.0-cm intervals from the proximal, mid, and distal portions of the vessel and labeled. All tissue sections were dehydrated in a graded series of ethanol and embedded in paraffin. Sections were cut at 4 to 6 μm, mounted, and stained with hematoxylin-eosin and Movat's Pentachrome. Each cross-section was further divided into four quadrants. The patch was at 12 o'clock, and in a clockwise formation labeling the next three quadrants were 3, 6, and 9 o'clock. All four quadrants were measured for intimal thickness, quadrant 6 o'clock was measured for medial thickness, and quadrant 12 o'clock was measured for graft thickness. Lumen area was calculated by measuring by internal elastic lamina in native artery (from 3 o'clock to 9 o'clock) and interface between graft and neointima in graft area (from 9 to 3 o'clock). Total vessel area was determined by measuring the interface between the graft and surrounding external elastic soft tissue between 9 and 3

o'clock and by measuring the external elastic lamina from 9 to 3 o'clock. Intima/vessel wall ratio was defined as [IL area – L area]/[TVA – IL area].

For immunofluoresence, sections were deparaffinized and rehydrated before being microwaved in 10 mmol/L citrate buffer (pH 6.0) for 15 minutes to achieve antigen retrieval. The tissue was blocked in 3% bovine serum albumin for 30 minutes at room temperature and washed three times in PBS. Primary antibodies were applied to recognize smooth muscle α-actin (mouse monoclonal antibody, clone 1A-4), CD34 (mouse monoclonal antibody, clone Ab-1), and Factor VIII (rabbit polyclonal antibody) in the concentration of 1 μg/mL for the monoclonal antibodies and 1:80 dilution for the polyclonal antibody. All primary antibodies were purchased from Neomarkers Inc, Fremount, Calif. After washing in PBS four times, fluorescein isothiocyanate–tagged secondary antibodies were applied (Santa Cruz Biotechnology Inc, Santa Cruz, Calif). Rabbit anti-mouse immunoglobulin G (IgG) was applied to sections stained for smooth muscle actin and CD34 at 5μg/mL, and 5μg/mL of goat anti-rabbit IgG was used on Factor VIII sections. Negative control sections were stained with secondary antibodies alone. For each antibody two sections from each time point of 30 and 180 days in both groups of washed and unwashed were stained. Slides were analyzed with Leica Qwin system (Leica, Wetzlan, Germany) by using Image Pro Plus 5.0 software (Media Cybernetics, Silver Spring, Md).

Mechanical testing. Specimens were compared to a commercially available bovine pericardial patch (Vascuguard; Synovis Life Technologies, St Paul, Minn). Strips of peritoneum with adherent fascia were cut along the principal collagen fiber direction. Mechanical tests were performed by using an Instron 8511 series hydraulic testing frame outfitted with a 22-kg or 11-kg load-cell (Sensotec, Insron; Canton, Mass). All tests were performed in a saline bath heated to 37°C. Tissues were held with delrin clamps (Acetal; Dupont, Wilmington, Del) lined with sandpaper. Propriety software was used for control of the load frame and acquisition of load and displacement data. Preliminary testing demonstrated that a load of 1000 g was well within the linear range of the load displacement curve of the bovine PFA and the pericardial patch and thus suitable for the tensile tests. Tensile tests were conducted at a ramp rate of 4 mm/s up to a load of 1000 g. Each specimen was preconditioned for 10 cycles. This was immediately followed by an elongation test, then by a 100-second stress relaxation test, and finally a failure test. All data were sampled at 200 Hz.

The loads used for each group in the creep test were approximately 20% of the mean failure load for that group as measured in the tensile tests. The bovine PFA was loaded to 1000 g, whereas the pericardium and the Vascuguard specimens were loaded to approximately 450 g. Each specimen was preconditioned for 10 cycles at 4 mm/s and then loaded to 1000 g and held at 1000 g for 1 hour. Data were sampled at 200 Hz for the preconditioning cycles and 10 Hz for the creep test.

During the first suture pullout test, 6-0 prolene suture failed at roughly 700 g and did not affect the tissue. We then switched to a wire suture less than 1 mm in diameter. The specimen was placed so that 2 mm of its length was inside the grip. The suture was than passed through the tissue approximately 2 to 3 mm from the free edge, held at the top, and pulled at 4 mm/s so that the suture would pull perpendicular to the collagen fiber direction. The wire suture did pull through the tissue. Data were collected at 400 Hz.

For mechanical testing, load and displacement data from the elongation and failure tests were converted to tension (load in newtons divided by width in meters) and strain, respectively. The tension versus strain curves were then fit with an exponential function in the toe region and a cubic function in the linear region. From these curves we measured extensibility, stiffness, and failure tensions and strains. The load data from the stress relaxation test were also converted to tension and plotted versus log (time s). The data were fit with a line, and the slope of the line was calculated and reported as the stress relaxation slope. The creep data were plotted as % strain vs time in seconds. The total strain required to maintain the creep load was calculated by subtracting the strain at 60 seconds from the strain at 3600 seconds. The long-term creep rate was calculated by taking the slope of a line fitted to the strain vs time plot from 60 to 3600 seconds. Suture pullout strength was measured as the ultimate load (g) recorded as the wire suture was pulled through the tissue.

Statistical comparisons were conducted with the χ^2 test, Fisher exact test, and paired *t* test where appropriate. All values represent mean ± SD.

RESULTS

Animal experimentation. All animals had palpable femoral pulses at the time of harvest. There was no aneurysm formation, adhesions, and inflammation in either test or control arterial patch. One animal at 1 month developed an infected polyester patch, and no animal in the PFA group developed an infection. Representative angiograms at both 1 and 6 months are shown in Fig 1. All vessels were patent with no evidence of significant stenosis in both the experimental and control groups at both time periods.

Histology. Morphometric histologic evaluation of the vessels is presented in Table I. There was no difference between groups in media thickness or total vessel area at both time periods. There was minimal neointimal hyperplasia in both groups at 1 and 6 months (Fig 2). The neointima area was significantly greater in the polyester patch than in the PFA patch at 1 month (2.05 ± 1.29 vs 1.81 ± 0.74 mm^2; $P = .01$), but there was no difference at 6 months (2.60 ± 1.07 vs 2.42 ± 1.13 mm^2; $P = .50$). Lumen area was significantly greater in the PFA patch group at both 1 month (6.91 ± 2.46 vs 6.01 ± 2.34 mm^2; $P = .02$) and 6 months (11.51 ± 7.1 vs 10.5 ± 2.91 mm^2; $P = .01$). In addition, chronic inflammatory cells such as lymphocytes, macrophages, and multinucleated giant cells were present between the polyester fibers at both 30 and

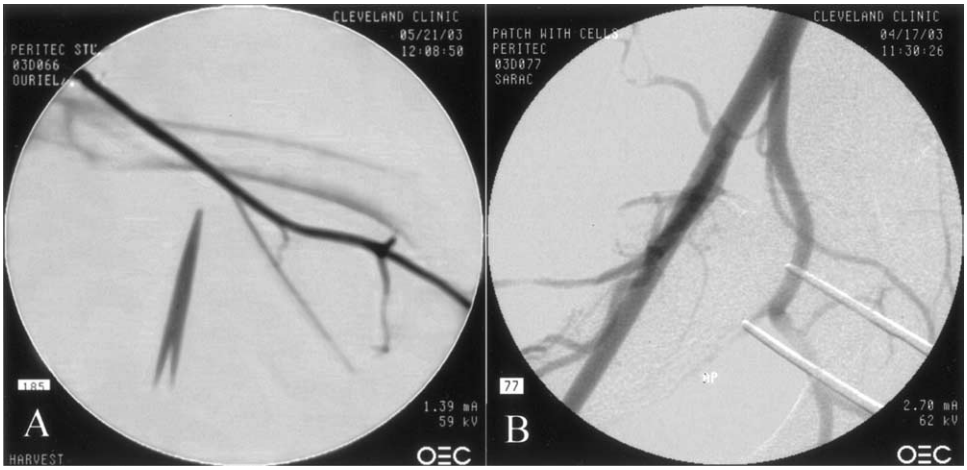

Fig 1. Lateral (**A**) and anterior/posterior (**B**) arteriogram of femoral artery containing PFA patch at 6 months demonstrating patent vessel with no evidence of stenosis or aneurysm.

Table I. Histologic morphometric measurements

	30 Days			*180 Days*		
	PFA patch	*Polyester patch*	P *value*	*PFA patch*	*Polyester patch*	P *value*
Medial thickness	0.29 ± 0.09	0.28 ± 0.08	.35	0.16 ± 0.04	0.17 ± 0.06	.75
Intimal area	1.81 ± 0.74	2.05 ± 1.29	.01	2.60 ± 1.07	2.42 ± 1.13	.50
Lumen area	6.91 ± 2.46	6.01 ± 2.34	.02	11.51 ± 7.1	10.5 ± 2.91	.01
Total vessel area	19.12 ± 5.3	21.02 ± 7.79	.09	28.96 ± 9.31	28.14 ± 6.20	.48

All values are mm^2, mean ± standard deviation.

180 days where minimal chronic inflammation is seen within the PFA patch (Fig 3). Immunohistochemistry staining for CD 34, Factor VIII, and actin is shown in Fig 4. Both the PFA patch and the polyester patch stained the luminal surface heavily with CD34 and Factor VIII at 1 and 6 months in both groups. Immunofluoresence for α-actin was quantified by counting five high-power fields (×400) in both groups at 30 and 180 days and three separate specimens. There was twice the quantity of smooth muscle cells at 180 days compared to 30 days, but there was no difference between the PFA patch and polyester patch at each time point.

Mechanical properties. Results from the tensile tests are summarized in Tables II and III. Compared to the pericardial patch, the PFA patch displayed significantly greater stiffness (60.6 ± 10.5 vs 28.5 ± 17 kN/m; P = .002). In addition, the PFA patch failed at significantly higher failure tensions than the pericardial patch (8.8 ± 2.2 vs 4.2 ± 2.6 kN/m; P = .004) and had a greater relax slope (5.2 ± 0.6 vs 3.1 ± 0.1 N/m/log s; P = .001). Finally, the PFA patch exhibited much greater suture pullout strength than the pericardial patch (3.1 ± 1.6 vs 1.3 ± 0.3 kg; P = .05). There was no difference between the PFA patch and the pericardial patch for failure strain and extensibility (P = not significant). We also compared the PFA patch to the polyester patch for mechanical properties (Table III). Polyester demonstrated superior suture pullout, stiffness, relax slope, and failure strain, but it was not different in extensibility and failure tension. All groups had the same total amount of creep during 1 hour when loaded to approximately 20% of their failure strength. Most of the creep occurred during the first 10 minutes of the test. During the last 50 minutes the PFA patch and pericardial patch did not creep (0.3 ± 0.1 vs 0.3 ± 0.1% strain/h; P = not significant). However, the polyester patch continued to creep (4.9 ± 0.8 vs 0.3 ± 0.3% strain/h; $P < .01$).

DISCUSSION

Peritoneal tissue was first used in the early 1970s by Polish researchers as a graft material to repair the inner lining of blood vessels.[11] In these preliminary experiments, peritoneal tissue was placed on the inside of conventional polyester grafts and produced superior results in the canine aorta compared to controls. Grafts implanted with peritoneum remained patent for a longer period of time than polyester alone. Other researchers have demonstrated the tissue's effectiveness in the venous circulation as a patch and graft in the inferior vena cava.[12,13] Further work has focused on using the peritoneum itself as a bypass in blood vessels that supply the peripheral circulation; however, the tissue proved too thin to be used alone.[14,15]

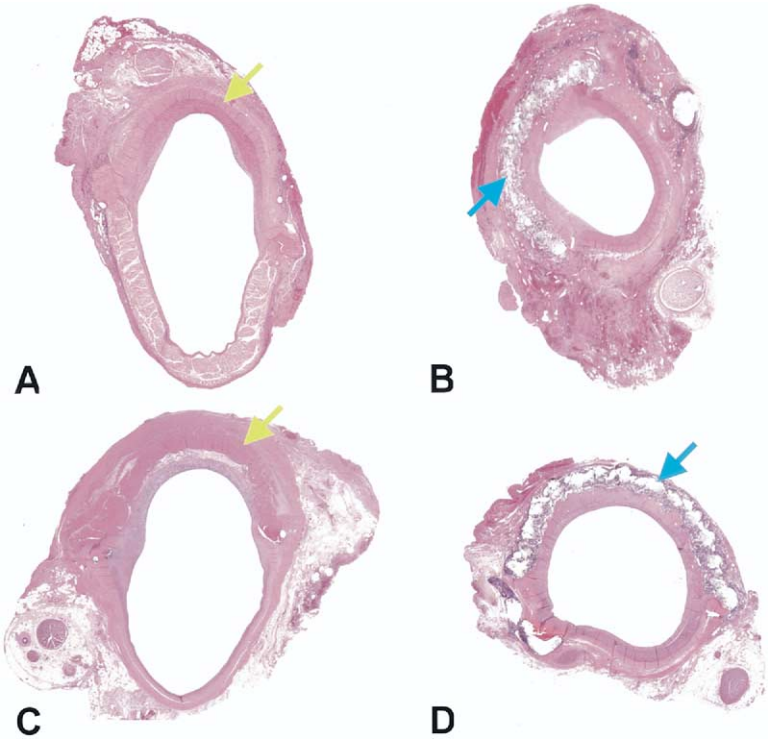

Fig 2. Hematoxylyn-eosin sections from 30 days (**A** and **B**) and 180 days (**C** and **D**) of arterial patches implanted in canine femoral arteries. **A** and **C** are the PFA patch, and **B** and **D** are the polyester patch. The PFA patch (*yellow arrows*) stains similar to native tissue, and the polyester patch (*blue arrows*) does not take up the stain.

Embryologically the peritoneum is very similar to endothelial cells because the coelomic cavity is designed like a tube within a tube. Pericardium is a similar tissue that has been used extensively as valve leaflets for aortic and mitral valve replacement and also has been used for more than 10 years as an arterial patch for carotid endarterectomy. Its usefulness in applications as artificial conduit for bypass grafts and stent linings is limited by its thickness and quantity. Whereas the PFA patch approaches pericardial patch in terms of thickness (1.0 vs 1.2 mm), the peritoneum alone is five times thinner (0.2 mm). The fascia is composed of primarily collagen, which gives it its strength. Peritoneum is composed of confluent sheet of mesothelial cells with an underlying basement membrane. Our data support the concept that its surface characteristics give it its thromboresistant properties as it might serve as a scaffold for re-endothelialization of native cells. Its thin layer makes it potentially an ideal endothelial substitute for application in other vascular conduits such as bypass grafts and stents for which current studies are underway.

We chose the model described in this experiment for several reasons. The first is that using xenogeneic material allows for testing of a source of abundant product, and cross-linking the material eliminates the antigenicity. The main advantage of using glutaraldehyde and alcohol as a fixative stems from glutaraldehyde's ability to cross-link, which not only eliminates xenogeic antigens, but also prevents enzymatic degradation.[16] However, a long-term disadvantage is the potential development of mineralization.[17] Possibly other novel fixatives will alleviate this problem. In addition, we used the dog model because the canine femoral artery approaches the size of human carotid arteries, thus accommodating a typical patch used in clinical settings. Polyester was used as the in vivo control because it is the most widely accepted arterial patch and is considered the gold standard, despite being synthetic.

Mechanical testing of the PFA patch was compared to a commercially available pericardial patch because it is the most widely used tissue patch for blood vessels and serves as a standard for comparison. Mechanical strength testing was undertaken before implantation to determine whether the underlying connective tissue could withstand the forces imposed by continuous pulsatile pressure during long periods of time. The greater failure tension, stiffness, and relax slope of the PFA patch compared to the pericardial patch demonstrate its intrinsic properties that make it an ideal vessel substitute in terms of its ability to tolerate hemodynamic forces in the arterial circulation. Suture pullout strength is the most important basic property that demonstrates proof of concept for use as an arterial patch, because of the strength provided by the adherent underlying fascia. We also compared its strength to a commercially available polyester patch, and as expected the synthetic polyester patch was stronger in several areas. However, it was some-

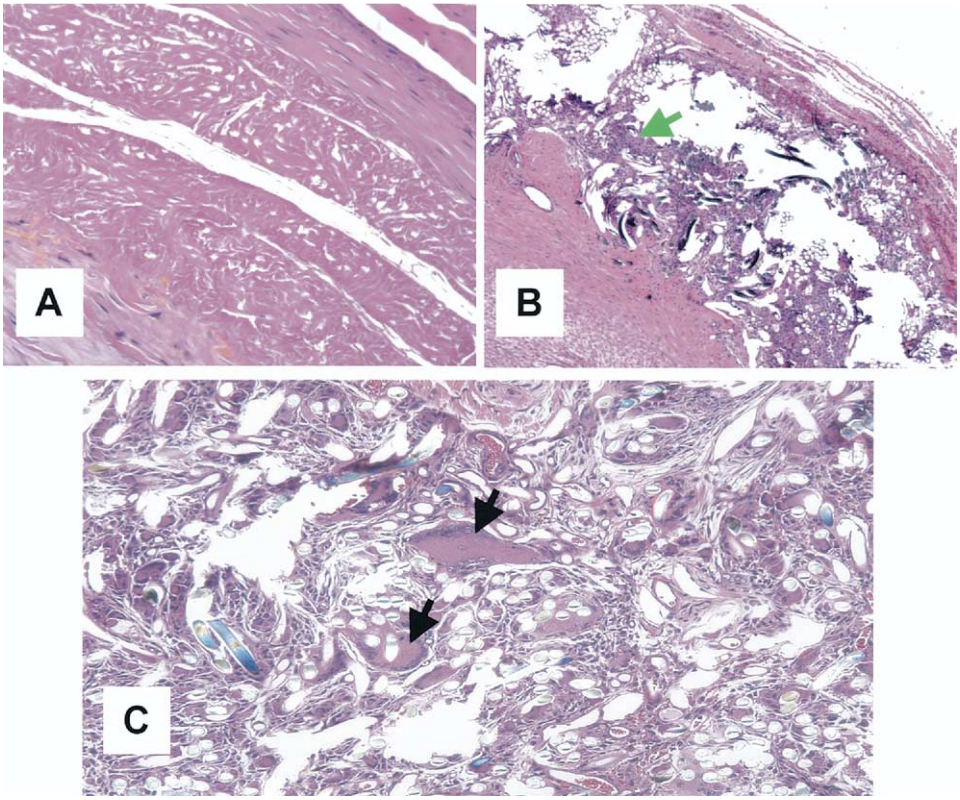

Fig 3. Hematoxylin-eosin stained sections of the peritoneal patch (**A**) and the polyester patch (**B**) from the canine femoral artery model after 180 days. There is severe inflammation between the polyester fibers (*green arrow*), and no inflammation is seen within the peritoneal patch. This inflammation shown under higher power (**C**) is of the foreign body type, consisting of macrophages, giant cells (*black arrows*), and occasional lymphocytes.

what unexpected that the native tissue stopped creeping after a short period of time, and the polyester patch kept moving. This is likely due to the synthetic nature of the woven material.

The in vivo results presented in this article are important for evaluating the tissue's ability to withstand continuous arterial pressure over a length of time and also act as a template for new endothelial cell repopulation. In this regard, the PFA patch withstood up to 6 months of arterial pressure with no aneurysm formation. In addition, it served as an ideal template for re-endothelialization because there was abundant CD34 and Factor VIII staining. There was minimal smooth muscle actin staining at the luminal surface, also complementing the morphometric assessments that showed minimal neointimal hyperplasia. It is possible that the compliance of the tissue in addition to its mesothelial-like properties accounted for its ability to resist extensive intimal hyperplasia. Another potential advantage of using tissue is that it elicits minimal inflammation and adhesions, despite the tissue coming from another species. Fixing the tissue inactivates the actual peritoneal cell, but the inherent properties of a confluent surface allow for laminar flow similar to that of heart valves and arterial patches made of pericardium. More importantly, there was no vessel thrombosis and less stenosis compared to controls as demonstrated by the greater lumen area. Although we did not measure the total length of the patch after implantation at either the gross or microscopic level, there was no gross or microscopic evidence of aneurysm formation. The lumen area of both groups of vessels increased over time. Despite a greater lumen area, the overall vessel area and neointimal area were identical in both groups. It is possible the small but measurable differences in lumen area at both time periods in the PFA patch group were from an overall difference in tissue compliance, a processing area, or a type II error, because there was no difference in intima area. We could not measure overall media area, given that the lumen was interrupted by the patch. However, there were no differences in media thickness at measurable points.

In conclusion, cross-lined bovine PFA has inherent strength and thromboresistant properties in vivo that make it a promising arterial substitute. It acts as a template for re-endothelialization and might be a potential source for artificial endothelial. Current studies are underway evaluating its efficacy in lining stents and as bypass grafts.

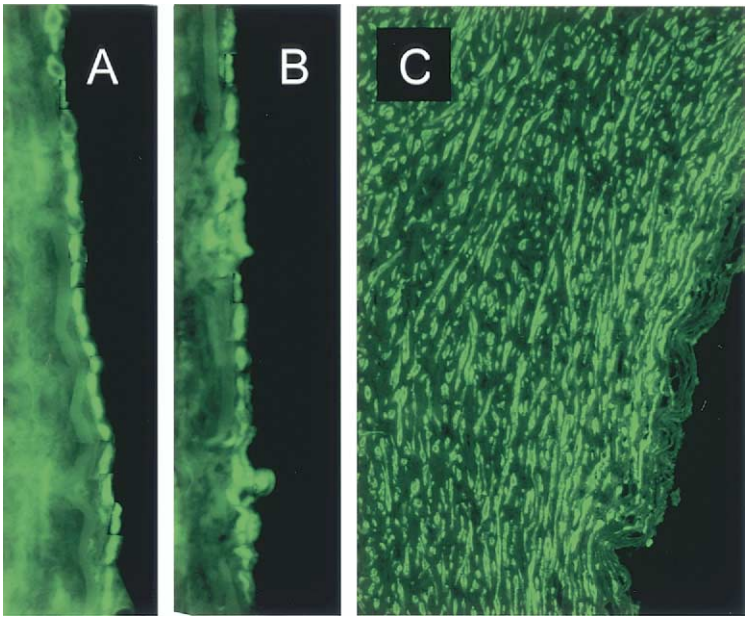

Fig 4. Immunofluoresence staining of patched arteries at 180 days for Factor VIII (**A**), CD34 (**B**), and smooth muscle actin (**C**) in the region overlying the patch.

Table II. Tensile properties of PFA patch vs pericardial patch

Group	*Extensibility (% strain)*	*Failure strain (% strain)*	*Failure tension (kN/m)*	*Relax slope (N/m/log s)*	*Stiffness (kN/M)*	*Suture pullout (g)*
PFA patch	13.3 ± 2.4	31 ± 4.9	8.8 ± 2.2	5.2 ± 0.6	60.6 ± 10.5	3120 ± 1586
Pericardial patch	12.9 ± 7.6	34.1 ± 6.2	4.2 ± 2.6	3.2 ± 0.1	28.5 ± 17.0	1327 ± 267
P value	NS	NS	.004	NS	.002	.005

All values are mean ± standard deviation.
NS, Not significant.

Table III. Tensile properties of PFA patch vs polyester

Group	*Extensibility (% strain)*	*Failure strain (% strain)*	*Failure tension (kN/m)*	*Relax slope (N/m/log s)*	*Stiffness (kN/M)*	*Suture pullout (g)*
PFA patch	11.2 ± 6.0	27.2 ± 7.5	3.6 ± 2.4	5.6 ± 1.1	27.7 ± 7.5	476 ± 191
Polyester	18.9 ± 0.7	180.2 ± 6.1	5.2 ± 0.4	10.8 ± 0.3	11.5 ± 0.4	3116 ± 309
P value	NS	.004	NS	.001	.002	.05

All values are mean ± standard deviation.
NS, Not significant.

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