Systematic review of randomized controlled trials of patch angioplasty versus primary closure and different types of patch materials during carotid endarterectomy

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Background: Patch angioplasty during carotid endarterectomy (CEA) may reduce the risk for perioperative or late carotid artery recurrent stenosis and subsequent ischemic stroke. We performed a systematic review of randomized controlled trials to assess the effect of routine or selective carotid patch angioplasty compared with CEA with primary closure, and the effect of different materials used for carotid patch angioplasty.
Methods: Randomized trials were included if they compared carotid patch angioplasty with primary closure in any patients undergoing CEA or use of one type of carotid patch with another.
Results: Thirteen eligible randomized trials were identified. Seven trials involving 1281 operations compared primary closure with routine patch closure, and 8 trials with 1480 operations compared different patch materials (2 studies compared both). Patch angioplasty was associated with a reduction in risk for stroke of any type ($P = .004$), ipsilateral stroke ($P = .001$), and stroke or death during both the perioperative period ($P = .007$) and long-term follow-up ($P = .004$). Patching was also associated with reduced risk for perioperative arterial occlusion ($P = .0001$) and decreased recurrent stenosis during long-term follow-up ($P < .0001$). Seven trials that compared different patch types showed no difference in the risk for stroke, death, or arterial recurrent stenosis either perioperatively or at 1-year follow-up. One study of 180 patients (200 arteries) compared collagen-impregnated Dacron (Hemashield) patches with polytetrafluoroethylene patches. There was a significant increase in risk for stroke ($P = .02$), combined stroke and transient ischemic attack ($P = .03$), and recurrent stenosis ($P = .01$) at 30 days, and an increased risk for late recurrent stenosis greater than 50% ($P < .001$) associated with Dacron compared with polytetrafluoroethylene.
Conclusions: Carotid patch angioplasty decreases the risk for perioperative death or stroke, and long-term risk for ipsilateral ischemic stroke. More data are required to establish differences between various patch materials. (J Vasc Surg 2004;40:1126-35.)

Carotid endarterectomy (CEA) was shown in large randomized controlled trials (RCTs) to reduce the risk for stroke in selected patients with internal carotid artery stenosis.[1-3] Although the basic aims of surgery are always the same, the exact techniques used to achieve them may vary between surgeons.[4] For example, carotid patch angioplasty with either a vein or synthetic patch is believed by some surgeons to be preferable to primary closure, because it may reduce the risk for early and late recurrent stenosis and consequently the long-term risk for ipsilateral ischemic stroke.

There are relatively few good prospective studies of recurrent stenosis after CEA. Furthermore, those studies that do exist are difficult to compare, because of differences in the definition of recurrent stenosis and duration of follow-up. However, it appears that carotid recurrent stenosis greater than 50% diameter reduction, as detected on duplex ultrasound scans, occurs in 6% to 36% of patients during long-term follow-up,[5,6] with most occurring in the first 2 years after surgery.[7] Carotid patch angioplasty may reduce the risk for recurrent stenosis, and thus reduce the long-term risk for recurrent ipsilateral ischemic stroke.[8,9] However, the true value of reducing the rate of recurrent stenosis is uncertain, because the risk for symptomatic recurrent stenosis appears to be much lower than for all recurrent stenosis, about 2% to 4%.[7,10,11] Furthermore, patch angioplasty may also be associated with certain perioperative risks, such as routine patching involving longer carotid occlusion time, 2 suture lines instead of 1, and patch material, all of which may increase the risk for postoperative occlusion, arterial rupture, infection, or pseudoaneurysm formation.[8]

There is considerable debate over the choice of patch material. Vein patches, usually harvested from the saphe-

nous vein and sometimes from the jugular vein, are favored by some, on the basis that they may be better at preventing stroke or death.[12] Vein also has the advantage of being easily available and easy to handle, and having greater resistance to infection. However, there may be morbidity associated with vein harvesting, such as neuralgia, hemorrhage, and infection. Synthetic material, such as Dacron or polytetrafluoroethylene (PTFE), is favored by others, who believe it offers a lower risk for patch rupture[13] and aneurysm dilatation.[14] It also spares the morbidity associated with saphenous vein harvesting, and leaves the vein intact for future use as a conduit for coronary or peripheral bypass grafting. Furthermore, it is possible that one type of synthetic material is better than another. For example, Abu-Rahma et al[15,16] found that PTFE was associated with significantly fewer perioperative carotid thromboses and strokes, compared with collagen-impregnated Dacron (Hemashield) patches. Finally, a number of new materials, such as bovine pericardium,[17] are being introduced, but have yet to be widely tested or accepted.

There is considerable heterogeneity in frequency of use of patch angioplasty at the individual surgeon, national, and international levels.[4] Given the uncertainty implied by such variation in practice, it is clearly important to establish whether routine or selective patching is more effective than and as safe as primary closure. RCTs provide the most reliable evidence on which to base these assessments. We therefore performed a systematic review of all such trials that compared routine or selective patching with primary closure, or the efficacy of various patch materials.

METHODS

The reviewers sought to identify all randomized trials that compared primary closure with either routine (patching attempted in all patients) or selective carotid patch angioplasty with any type of patch, and trials in which one type of patch was compared with another. Trials in which allocation to different treatment regimens was not adequately concealed (eg, allocation by alternation, date of birth, hospital number, day of the week, or with an open random number list) were included in the main analyses, but were also analyzed separately from those trials in which allocation concealment was secure, to check that no bias was being introduced by foreknowledge of treatment allocation.[18]

Trials that included any patients undergoing CEA were considered eligible, whether the initial indication for endarterectomy was symptomatic or asymptomatic carotid disease. We aimed to extract from each trial the number of patients originally allocated to each treatment group, to allow intention-to-treat analysis. End points were 30-day risk for stroke, fatal stroke, all-cause death, and combined stroke and death. Local complications, such as arterial rupture, acute carotid thrombosis, wound infection, cranial nerve injury, return to the operating room for any reason, or development of recurrent stenosis greater than 50%, were also recorded.

To identify all relevant trials between 1980 and 2004, we searched the MEDLINE and Embase databases, and the Cochrane Controlled Trials Register, using a Medical Subject Headings (MeSH) strategy initially developed by the Cochrane controlled trials group. Furthermore, 9 journals were hand-searched for the same period: *Annals of Surgery, British Journal of Surgery, European Journal of Vascular and Endovascular Surgery, Stroke, Journal of Vascular Surgery, Annals of Vascular Surgery, American Journal of Surgery, World Journal of Surgery,* and *Cardiovascular Surgery.* The reference lists from all relevant trials identified with the above methods were also searched, and the abstracts of the following meetings were reviewed: The European Stroke Conference, American Heart Association Stroke Conference, annual general meeting (AGM) of the Vascular Surgical Society (United Kingdom), AGM of the Association of Surgeons of Great Britain and Ireland, and the Annual Meeting of the Society for Vascular Surgery (United States). Two reviewers (R.B., K.R.) independently selected which trials to include in the review. Disagreements were resolved by discussion, and when necessary by arbitration from a third reviewer (P.R.). The same 2 reviewers also assessed the methodologic quality of each trial. Data on the number of outcome events in all patients originally randomized were sought to allow intention-to-treat analysis. All data were independently extracted by 2 reviewers (R.B., K.R.) and cross-checked. In addition, details about the patients included in the trial, inclusion and exclusion criteria, comparability of the treatment and control groups for important prognostic factors, type of patch, type of anesthetic, use of shunts, and use of anti-platelet therapy during follow-up were also extracted. If any of these data were not available from the publication, further information was sought by correspondence with the trialists. However, responses were not always received.

Analysis of outcomes was performed per artery rather than per patient, because this was how most trials presented their results. All of the trials included patients who had undergone bilateral CEA, and in most the artery was randomized to a particular procedure rather than the patient. In these trials it was therefore possible for a patient to have primary closure on 1 side and carotid patching on the other side. In the reporting of these trials the results were given for each artery randomized, rather than for each individual patient. This makes sense for arterial complications such as hemorrhage or occlusion, for ipsilateral events, and for complications within 30 days of surgery, inasmuch as most patients waited at least this long between first and second operations, but is not ideal for patient-related long-term clinical outcome events such as death or any stroke. We therefore also performed intention-to-treat analysis per patient by requesting data from the authors about actual numbers of patients treated. Because the number of bilateral operations was small, there were no significant differences between the 2 analyses, and the per patient analyses are not included here.

Proportional risk reductions were calculated on the basis of a weighted estimate of the odds ratio, with the Peto

method. Because all outcome events assessed were rare, the odds ratios quoted are similar to the relative risk. Absolute risk reductions were calculated from the crude risk for each outcome in all trials combined. Heterogeneity between trial results was tested with the standard χ^2 test.

RESULTS

Fourteen RCTs that fulfilled the eligibility criteria were identified,[14,15,19-31] (Ricco, unpublished data, 1997) but 1 unpublished trial was excluded because of excessive rates of crossovers between randomized groups.[31] The methodologic quality of the 13 included trials varied. For example, inadequate methods of randomization and blinding were used in several trials, and this could have biased the results.[18] Most trials used sealed envelopes as the method of randomization, but in 1 case the envelopes were not numbered or opaque,[24] and in 2 trials allocation was made on the basis of the patient's hospital number[22] or Social Security number.[26]

Most of the patients in all of the trials received antiplatelet or anticoagulant drugs long term after the operation, and all trials used heparin during the operation. However, 1 trial used heparin reversal at the end of surgery in 30% of patients with synthetic closure but in no patients with vein closure.[26] Data on heparin reversal were not available from any of the other trials. During follow-up, recurrent stenosis of the arteries was assessed with duplex ultrasound scanning in all trials, with the addition of intravenous digital subtraction angiography in 2 trials.[15,22]

Trials of routine patch versus primary closure. Seven trials compared routine patching with primary closure. Three trials used only saphenous vein patches,[22-24] and 1 trial used only PTFE patches.[20] Three trials used both vein and synthetic (PTFE or Dacron) patches,[19,21,25] but in 1 of these the results were not recorded by type of patch that the patient received.[19] One of the trials included a group that was allocated to obligate patching without randomization[23]; this group of patients was not included in the analyses. Three trials excluded patients if the arteries were thought too small to close primarily. Myers et al[23] excluded 38 arteries if the vessels were less than 5 mm in diameter, Katz and Kohl[26] excluded 1 of 110 arteries less than 3.5 mm in diameter, and AbuRahma et al[21] excluded 12 of 399 arteries less than 4 mm in diameter. A summary of all meta-analysis results is provided in Fig 1. Data from 7 trials (1193 patients, 1281 operations) were included in this review.[19-25]

Outcomes within 30 days of operation. The overall risk for stroke was 3.2%, and for combined stroke and death was 3.5%. Patching was associated with a significant reduction in risk for any perioperative stroke (odds ratio [OR], 0.33; 95% confidence interval [CI], 0.20-0.71; $P = .004$), ipsilateral stroke (OR. 0.32; 95% CI, 0.16-0.68; $P = .001$; Fig 2), combined stroke or death (OR, 0.39; 95% CI, 0.20-0.78; $P = .007$; Fig 2), perioperative arterial occlusion (OR, 0.12; 95% CI, 0.03-0.40; $P = .0001$), and return to the operating room (OR, 0.35; 95% CI, 0.14-0.76). There was no significant difference between patching and

primary closure for risk of death (OR, 0.76; 95% CI, 0.20-2.70; $P = .6$), or arterial rupture (OR, 1.94; 95% CI, 0.55-6.86). None of the arterial ruptures was associated with a fatal or major stroke. Episodes of local infection and cranial nerve palsy were too few to enable conclusions to be drawn.

Outcomes during long-term follow-up (≥1 year), including events during first 30 days. Six trials followed up patients for longer than 30 days.[19-24] Fifty-three arteries (4%; 27 patch, 26 primary closure) were lost to follow-up. For the purposes of analyses, these patients were assumed to be event free. Patching was associated with a significant reduction in risk for any stroke (OR, 0.31; 95% CI, 0.17-0.63; $P = .0009$), ipsilateral stroke (OR, 0.31; 95% CI, 0.14-0.68; $P = .001$), combined stroke or death (OR, 0.54; 95% CI, 0.42-0.84; $P = .004$; Fig 3), and arterial occlusion or recurrent stenosis (OR, 0.22; 95% CI, 0.13-0.29; $P < .00001$; Fig 3). A similar but nonsignificant reduction was seen in fatal strokes (OR, 0.27; 95% CI, 0.05-1.6; $P = .15$), and death from any cause (OR, 0.69; 95% CI, 0.49-0.99; $P = .1$). No pseudoaneurysms were documented during follow-up of at least 1 year in 1141 arteries.

Description of studies of different patch materials. Seven trials of different patch materials, reporting 1280 operations, were included. Four trials[14,21,25] (Ricco, unpublished data, 1997) compared vein closure with PTFE closure, and 3 trials[26-28,30] compared vein with Dacron. Two trials[21,25] had 3 arms; saphenous vein patching, PTFE patching, and primary closure. Four trials[25-28] compared saphenous vein harvested from the groin with synthetic patches. One used saphenous vein from the ankle,[14] 1 trial alternately used vein from the jugular and from the saphenous vein at the ankle,[21] and 1 trial did not specify a site.[30] All meta-analyses are summarized in Fig 4. Data from the 7 trials (1280 operations) that compared vein with synthetic patch were included.

Outcomes within 30 days of operation. The overall risk for stroke was 1.6%, and for combined stroke and death was 2.4%. The absolute risk for perioperative stroke (1.7%, 19 of 1120), death (1.1%, 12 of 1120), and combined stroke and death (2.4%, 27 of 1120; Fig 5) were all low. No significant difference was seen in risk for all strokes, ipsilateral stroke, combined stroke and death, or all death. Wound infection was nonsignificantly more common in the vein group compared with the synthetic patch group, because of increased risk for groin wound infection. However, there were no patch infections during the perioperative period. Repeat operation for any reason occurred in 2.6% of patients (33 of 1263), and showed a nonsignificant trend toward being more common in the synthetic patch group (OR, 1.77; 95% CI, 0.85-3.57; $P = .17$). Most repeat operations were because of either patch rupture (1 in the PTFE group, 2 in the vein group) or wound hemorrhage (2.30%, 29 of 1263). Two of the 3 patch ruptures were fatal, 1 in each group. There was a nonsignificant tendency for wound hematoma to be more common in the synthetic group (OR, 1.63; 95% CI, 0.77-3.46; $P = .2$)
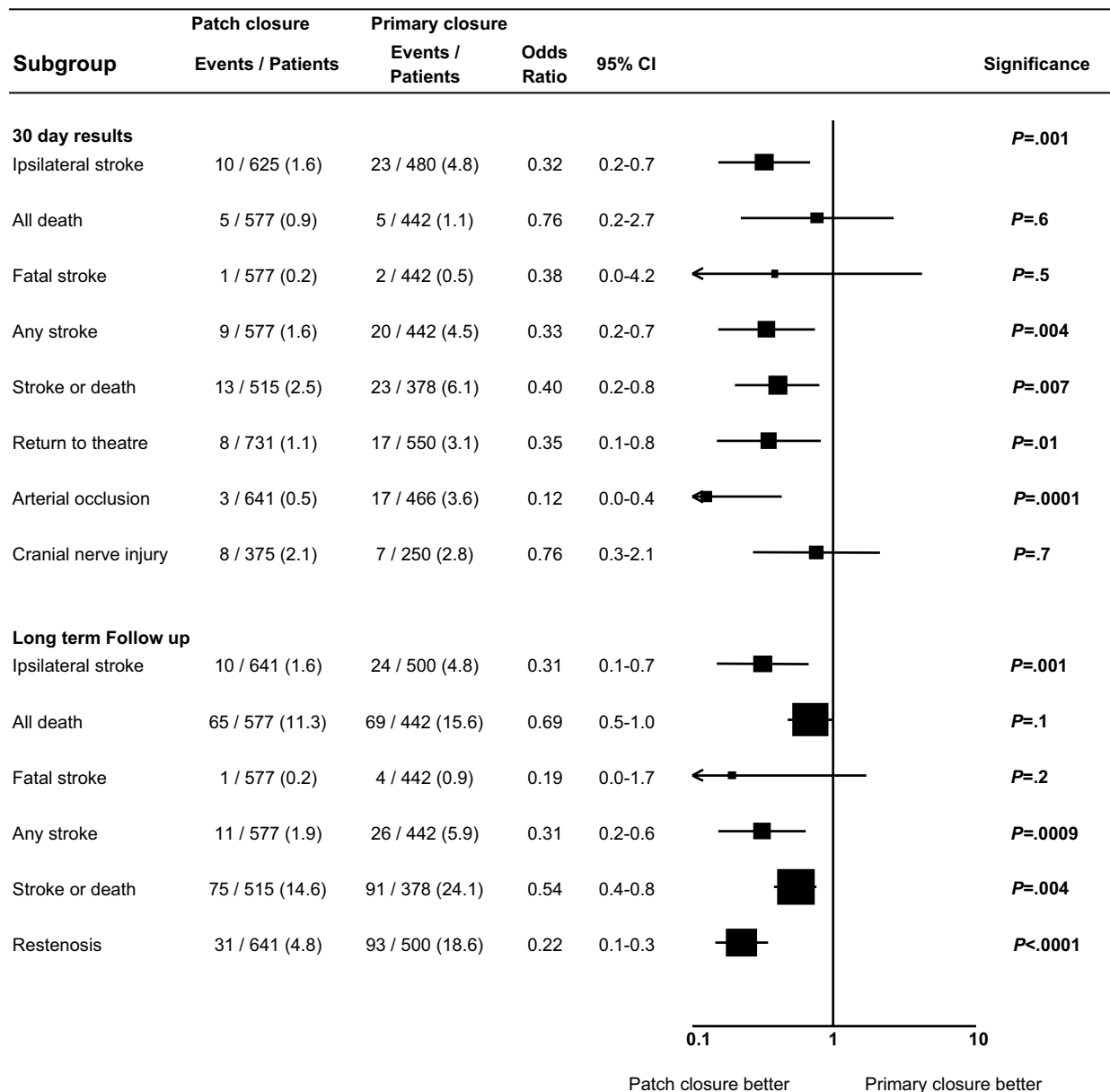
Subgroup	Patch closure	Primary closure	Odds Ratio	95% CI		Significance
	Events / Patients	Events / Patients				
30 day results						**P=.001**
Ipsilateral stroke	10 / 625 (1.6)	23 / 480 (4.8)	0.32	0.2-0.7		
All death	5 / 577 (0.9)	5 / 442 (1.1)	0.76	0.2-2.7		**P=.6**
Fatal stroke	1 / 577 (0.2)	2 / 442 (0.5)	0.38	0.0-4.2		**P=.5**
Any stroke	9 / 577 (1.6)	20 / 442 (4.5)	0.33	0.2-0.7		**P=.004**
Stroke or death	13 / 515 (2.5)	23 / 378 (6.1)	0.40	0.2-0.8		**P=.007**
Return to theatre	8 / 731 (1.1)	17 / 550 (3.1)	0.35	0.1-0.8		**P=.01**
Arterial occlusion	3 / 641 (0.5)	17 / 466 (3.6)	0.12	0.0-0.4		**P=.0001**
Cranial nerve injury	8 / 375 (2.1)	7 / 250 (2.8)	0.76	0.3-2.1		**P=.7**
Long term Follow up						
Ipsilateral stroke	10 / 641 (1.6)	24 / 500 (4.8)	0.31	0.1-0.7		**P=.001**
All death	65 / 577 (11.3)	69 / 442 (15.6)	0.69	0.5-1.0		**P=.1**
Fatal stroke	1 / 577 (0.2)	4 / 442 (0.9)	0.19	0.0-1.7		**P=.2**
Any stroke	11 / 577 (1.9)	26 / 442 (5.9)	0.31	0.2-0.6		**P=.0009**
Stroke or death	75 / 515 (14.6)	91 / 378 (24.1)	0.54	0.4-0.8		**P=.004**
Restenosis	31 / 641 (4.8)	93 / 500 (18.6)	0.22	0.1-0.3		**P<.0001**

0.1   1   10

Patch closure better   Primary closure better

Fig 1. Summary estimates of treatment effect from all meta-analysis outcomes from 7 trials that compared patch angioplasty versus primary closure. Review included 1193 patients (1281 operations).

Cranial nerve palsy occurred in 3.0% of patients (19 of 630). There was no suggestion that it was more common in either group. The absolute risk for arterial occlusion was 0.6% (6 of 1068). There was a nonsignificant trend to suggest that acute occlusion was more common in arteries patched with synthetic material (OR, 2.57; 95% CI, 0.59-11.20; P = .2).

Outcomes during long-term follow-up (≥1 year), including events during first 30 days. Two trials[25,26] did not follow up patients for at least 1 year. There was no significant difference between PTFE and vein patching in

risk for stroke (OR, 1.31; 95% CI, 0.70-2.52; P = .71), ipsilateral stroke (OR, 1.43; 95% CI, 0.70-2.96; P = .75), death from all causes (OR, 0.89; 95% CI, 0.58-1.49; P = .95), or combined stroke or death (OR, 1.04; 95% CI, 0.69-1.5; P = .99; Fig 5). However, confidence intervals were wide in each case. Sixty-six arteries (7.3%) became restenosed or occluded during follow-up, with no trend favoring synthetic or vein patching (OR, 1.0; 95% CI, 0.0.6-1.62; P = .93; Fig 5). In 1 artery with a PTFE patch an infected false aneurysm developed at 7 months, which was successfully excised. There were no other late graft infections.
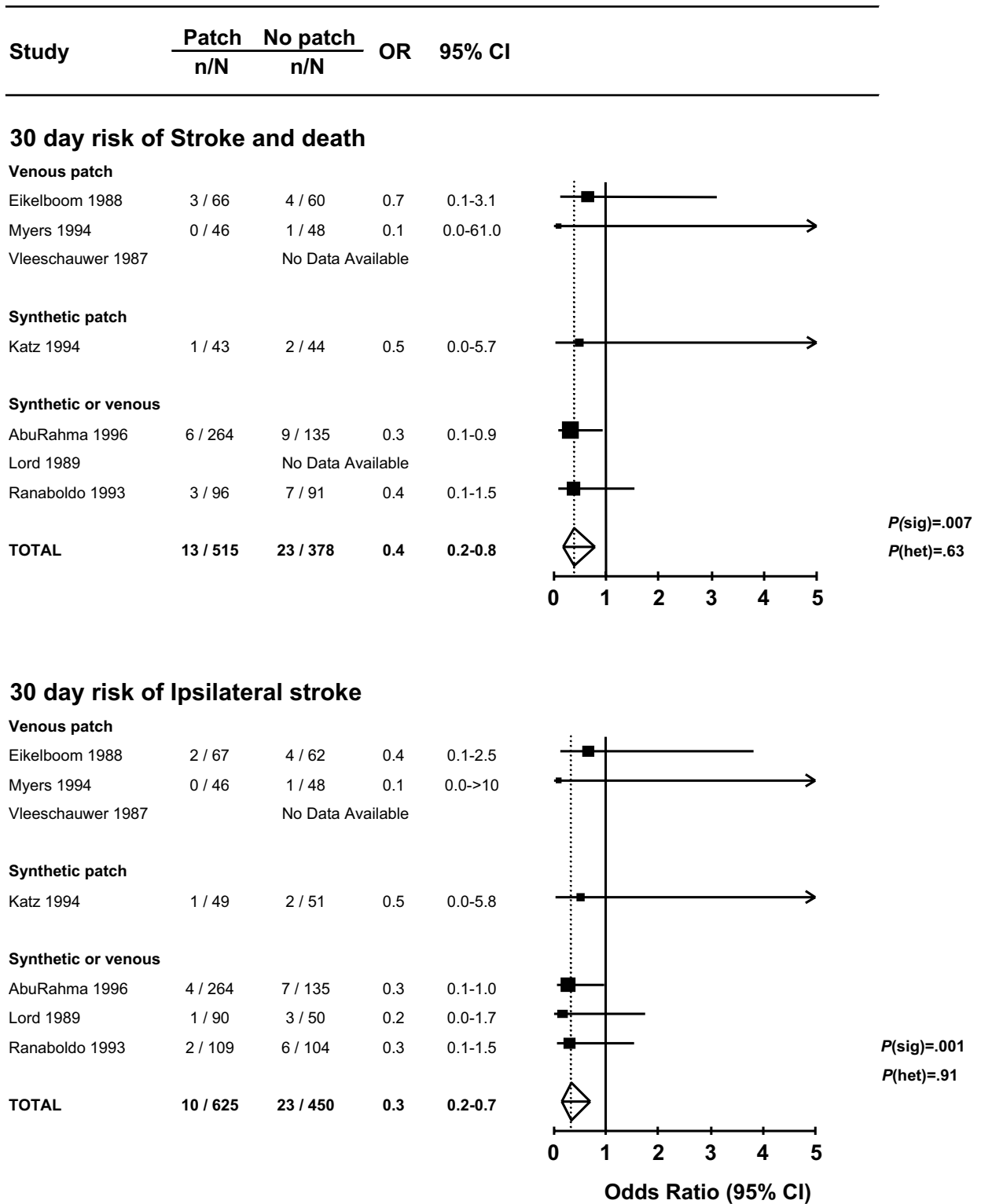
Study	Patch n/N	No patch n/N	OR	95% CI

30 day risk of Stroke and death

Venous patch

Eikelboom 1988	3 / 66	4 / 60	0.7	0.1-3.1
Myers 1994	0 / 46	1 / 48	0.1	0.0-61.0
Vleeschauwer 1987		No Data Available		

Synthetic patch

Katz 1994	1 / 43	2 / 44	0.5	0.0-5.7

Synthetic or venous

AbuRahma 1996	6 / 264	9 / 135	0.3	0.1-0.9
Lord 1989		No Data Available		
Ranaboldo 1993	3 / 96	7 / 91	0.4	0.1-1.5
TOTAL	**13 / 515**	**23 / 378**	**0.4**	**0.2-0.8**

P(sig)=.007
P(het)=.63

0   1   2   3   4   5

30 day risk of Ipsilateral stroke

Venous patch

Eikelboom 1988	2 / 67	4 / 62	0.4	0.1-2.5
Myers 1994	0 / 46	1 / 48	0.1	0.0->10
Vleeschauwer 1987		No Data Available		

Synthetic patch

Katz 1994	1 / 49	2 / 51	0.5	0.0-5.8

Synthetic or venous

AbuRahma 1996	4 / 264	7 / 135	0.3	0.1-1.0
Lord 1989	1 / 90	3 / 50	0.2	0.0-1.7
Ranaboldo 1993	2 / 109	6 / 104	0.3	0.1-1.5
TOTAL	**10 / 625**	**23 / 450**	**0.3**	**0.2-0.7**

P(sig)=.001
P(het)=.91

0   1   2   3   4   5

Odds Ratio (95% CI)

Fig 2. Thirty-day combined odds ratios for selected outcomes in patients undergoing patch versus primary closure during carotid endarterectomy according to type of patch used. Not all end points were reported by all trials; therefore denominators (number of operations) vary between end points.

Study	Patch n/N	No patch n/N	OR	95% CI

Re-stenosis (>50%) during long-term follow up

Venous patch

Eikelboom 1988	8 / 67	17 / 62	0.4	0.1-0.9
Myers 1994	2 / 62	2 / 64	1.0	0.1-7.6
Vleeschauwer 1987	1 / 90	9 / 84	0.1	0.0-0.8

Synthetic patch

Katz 1994	0 / 49	3 / 51	0.0	0.0-17.4

Synthetic or venous

AbuRahma 1996	14 / 264	45 / 135	0.1	0.1-0.2
Ranaboldo 1993	6 / 109	17 / 104	0.3	0.1-0.8
TOTAL	**31 / 641**	**93 / 500**	**0.2**	**0.1-0.3**
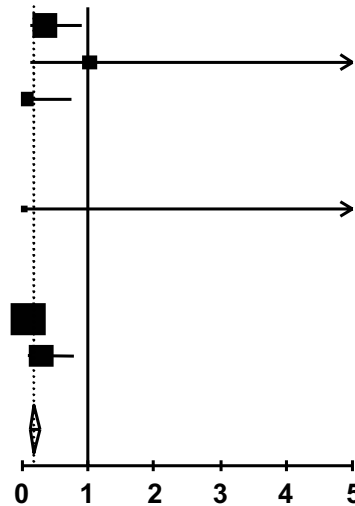
P(sig) <.0001
P(het) = .071

Stroke and death during long-term follow up

Venous patch

Eikelboom 1988	23 / 66	21 / 60	1.0	0.5-2.1
Myers 1994	12 / 46	22 / 48	0.4	0.2-1.0
Vleeschauwer 1987		No Data Available		

Synthetic patch

Katz 1994	8 / 43	12 / 44	0.6	0.2-1.7

Synthetic or venous

AbuRahma 1996	25 / 264	19 / 135	0.6	0.3-1.2
Ranaboldo 1993	7 / 96	17 / 91	0.3	0.1-0.9
TOTAL	**75 / 515**	**91 / 378**	**0.6**	**0.4-0.8**
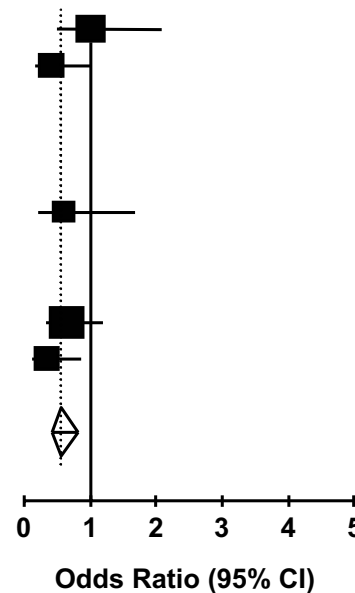
P(sig) =.004
P(het) =.436

Odds Ratio (95% CI)

Fig 3. Long-term (>1 year) combined odds ratios for selected outcomes in patients undergoing patch versus primary closure during carotid endarterectomy according to type of patch used. Several trials included in review reported early (30-day) and late follow-up results in separate publications. In some cases they reported different outcomes in each. Consequently there may be greater numbers of a specific end point available during long-term follow-up than at 30 days.
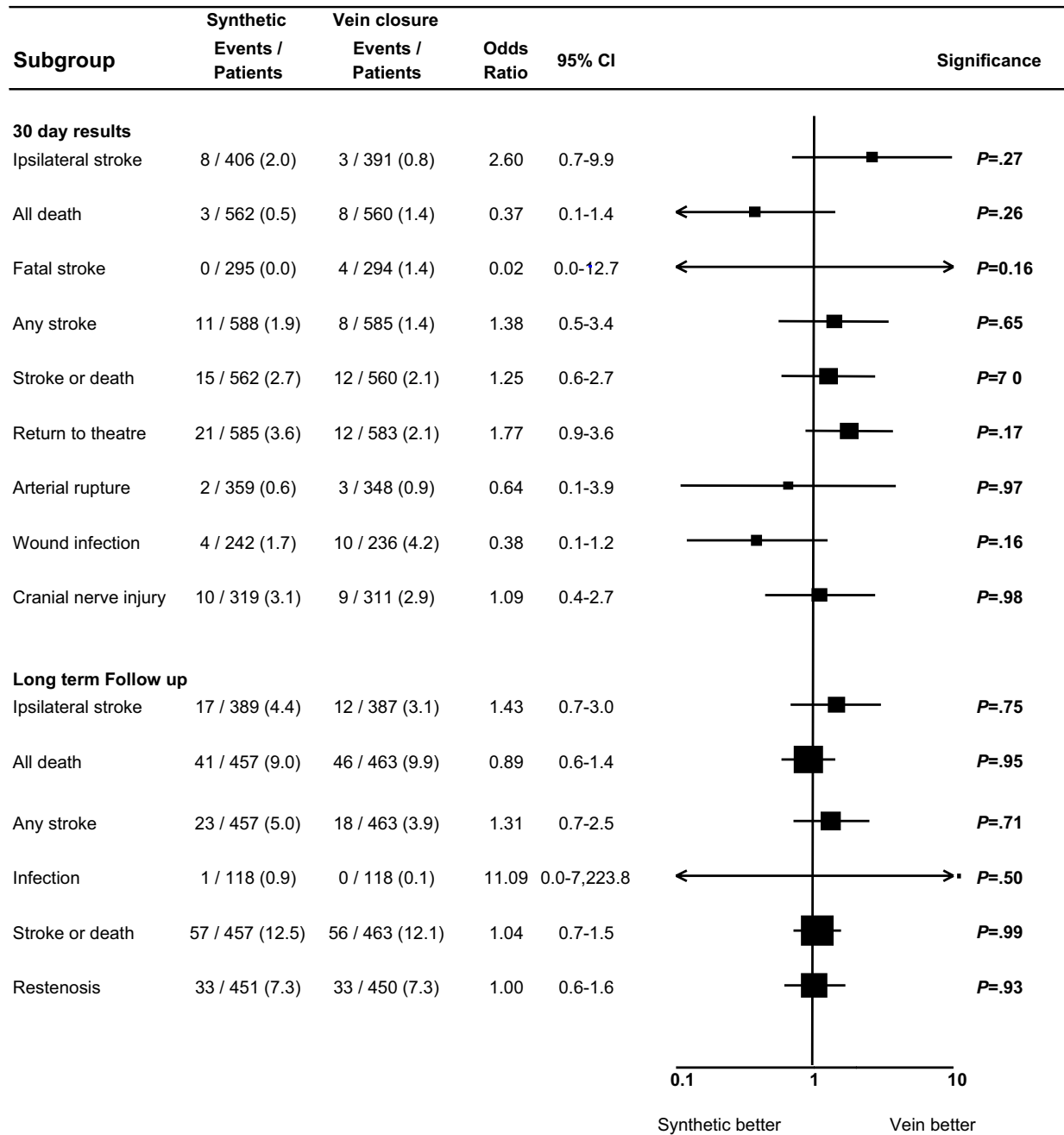
Subgroup	Synthetic Events / Patients	Vein closure Events / Patients	Odds Ratio	95% CI	Significance
30 day results					
Ipsilateral stroke	8 / 406 (2.0)	3 / 391 (0.8)	2.60	0.7-9.9	P=.27
All death	3 / 562 (0.5)	8 / 560 (1.4)	0.37	0.1-1.4	P=.26
Fatal stroke	0 / 295 (0.0)	4 / 294 (1.4)	0.02	0.0-12.7	P=0.16
Any stroke	11 / 588 (1.9)	8 / 585 (1.4)	1.38	0.5-3.4	P=.65
Stroke or death	15 / 562 (2.7)	12 / 560 (2.1)	1.25	0.6-2.7	P=7 0
Return to theatre	21 / 585 (3.6)	12 / 583 (2.1)	1.77	0.9-3.6	P=.17
Arterial rupture	2 / 359 (0.6)	3 / 348 (0.9)	0.64	0.1-3.9	P=.97
Wound infection	4 / 242 (1.7)	10 / 236 (4.2)	0.38	0.1-1.2	P=.16
Cranial nerve injury	10 / 319 (3.1)	9 / 311 (2.9)	1.09	0.4-2.7	P=.98
Long term Follow up					
Ipsilateral stroke	17 / 389 (4.4)	12 / 387 (3.1)	1.43	0.7-3.0	P=.75
All death	41 / 457 (9.0)	46 / 463 (9.9)	0.89	0.6-1.4	P=.95
Any stroke	23 / 457 (5.0)	18 / 463 (3.9)	1.31	0.7-2.5	P=.71
Infection	1 / 118 (0.9)	0 / 118 (0.1)	11.09	0.0-7,223.8	P=.50
Stroke or death	57 / 457 (12.5)	56 / 463 (12.1)	1.04	0.7-1.5	P=.99
Restenosis	33 / 451 (7.3)	33 / 450 (7.3)	1.00	0.6-1.6	P=.93

0.1   1   10

Synthetic better   Vein better

Fig 4. Summary estimates of treatment effect from all meta-analysis outcomes from 7 trials (1280 operations) that compared vein with synthetic patch angioplasty.

Dacron vs PTFE. One trial compared collagen-impregnated (Hemashield) Dacron with PTFE (180 patients, 200 operations).[15,16] In the perioperative period (30 days) there were 7 strokes in the Dacron group, all ipsilateral, compared with none in the PTFE group ($P = .02$). There was also increased risk for combined stroke and transient ischemic attack ($P = .47$) with Dacron compared with PTFE. There were 2 deaths in the Dacron patch group, and

none in the PTFE group ($P = .3$). There were no fatal strokes in either group. No cranial nerve palsies or wound infections were reported. A nonsignificantly longer operation time ($P = .08$), but significantly longer hemostasis time ($P < .001$) was found in patients who received the PTFE patch rather than the Dacron patch. Seven patients required repeat operation, 6 in the Dacron group and 1 in the PTFE group ($P = .09$). All repeat explorations were
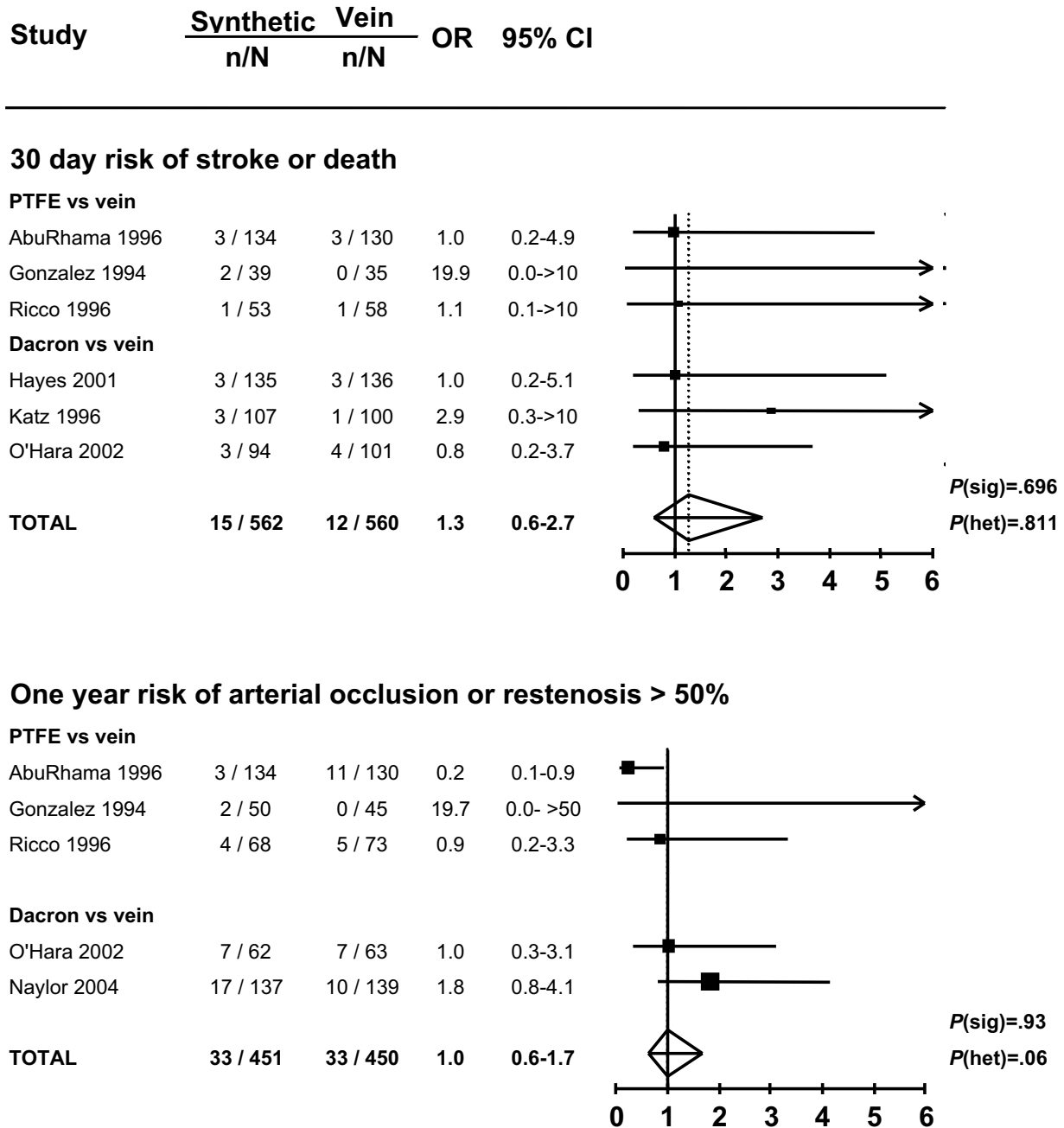
Study	Synthetic n/N	Vein n/N	OR	95% CI
30 day risk of stroke or death				
PTFE vs vein				
AbuRhama 1996	3 / 134	3 / 130	1.0	0.2-4.9
Gonzalez 1994	2 / 39	0 / 35	19.9	0.0->10
Ricco 1996	1 / 53	1 / 58	1.1	0.1->10
Dacron vs vein				
Hayes 2001	3 / 135	3 / 136	1.0	0.2-5.1
Katz 1996	3 / 107	1 / 100	2.9	0.3->10
O'Hara 2002	3 / 94	4 / 101	0.8	0.2-3.7
TOTAL	**15 / 562**	**12 / 560**	**1.3**	**0.6-2.7**

P(sig)=.696
P(het)=.811

Study	Synthetic n/N	Vein n/N	OR	95% CI
One year risk of arterial occlusion or restenosis > 50%				
PTFE vs vein				
AbuRhama 1996	3 / 134	11 / 130	0.2	0.1-0.9
Gonzalez 1994	2 / 50	0 / 45	19.7	0.0- >50
Ricco 1996	4 / 68	5 / 73	0.9	0.2-3.3
Dacron vs vein				
O'Hara 2002	7 / 62	7 / 63	1.0	0.3-3.1
Naylor 2004	17 / 137	10 / 139	1.8	0.8-4.1
TOTAL	**33 / 451**	**33 / 450**	**1.0**	**0.6-1.7**

P(sig)=.93
P(het)=.06

Fig 5. Thirty-day and long-term (>1 year) combined odds ratios for selected outcomes in patients undergoing synthetic patch angioplasty versus vein patch closure during carotid endarterectomy.

because of suspected or proved carotid thrombosis or occlusion. A significant risk for recurrent stenosis or occlusion at 30 days ($P = .01$) and a nonsignificant increased risk for perioperative carotid thrombosis ($P = .1$) was found with Dacron compared with PTFE. Mean follow-up was 25.5 months (range, 1-40 months), during which greater than 50% recurrent stenosis developed in 30% of patients with

Dacron patches compared with 3% of patients with PTFE pataches ($P < .001$)

DISCUSSION

The results of this systematic review show a significant and potentially clinically important trend in favor of routine patching versus primary closure in terms of both short-term

and long-term reduction in risk for ipsilateral stroke, any stroke, and any stroke or death. However, the results may still be unreliable, because of the presence of significant methodologic flaws in many of the included trials. The trials were also generally too small to achieve adequate statistical power, and none could be analyzed on a true intention-to-treat basis, in part because there were significant losses to follow-up. However, there were no significant differences in numbers lost to follow-up between treatment groups in any of the studies. Consequently, our assumption that patients who were lost to follow-up did not have an outcome event should not have introduced major bias. Furthermore, analysis of quasi-randomized trials separately from truly randomized studies did not significantly influence any results.

Patching also appears to significantly reduce the risk for acute occlusion and long-term recurrent stenosis, compared with primary closure. However, these findings may be less useful than data on clinically important outcomes such as stroke. Acute occlusion, though undesirable, is not always associated with stroke. Similarly, recurrent stenosis detected at routine duplex scanning may not be clinically important. In some cases remodeling of the arterial wall after endarterectomy can be mistaken for stenosis, and in other cases spontaneous regression of duplex ultrasound scan–defined stenosis has occurred.[19,32] Moreover, recurrent stenosis may be associated with lower risk for neurologic symptoms, compared with primary stenosis.[32]

Most surgeons agree that carotid patching has a role in CEA, because they are faced with situations in which this type of closure is either unavoidable or positively desirable (eg, artery with very narrow internal diameter or very long plaque).[22] However, it is unclear how frequently such situations arise, and how narrow an artery should be before it must be patched. For example, only 3 trials in this review excluded narrow arteries on the grounds that they must be patched. In the other trials, crossover from primary closure to patching was required in few patients because the artery was deemed too narrow for primary closure. There is divided opinion on how often patching is required; some surgeons use it all the time, others use it rarely or never.[4] The trials of patch versus no patch included in this review tested the policy of routinely patching all arteries against a policy of never patching in those patients with no definite indication for a patch. A policy of selective patching of only those arteries thought to require a patch at the time of operation compared with no patching has not been tested in RCTs. It is possible that if patching is effective its benefit may be restricted to narrow arteries. It was not possible to test this hypothesis, because the results of the trials were not reported according to degree of narrowing of the artery.

Despite more than 1200 patients randomized, there were still insufficient data to enable definite conclusions about the optimal patch type. There are no obvious differences in the risk for stroke or death in patients receiving synthetic or vein patches, either perioperatively or during long-term follow-up, or evidence to support the belief that synthetic patches are associated with lower risk for patch

rupture. The risk for major arterial complications such as rupture or infection was low (<1%) in both groups. Any trials designed to reliably detect reduction in risk for rupture with synthetic patches would therefore need to be enormous, and even if the risk for rupture were less with synthetic patches, the absolute benefits would be small. For example, if we assume a baseline risk for rupture of 0.6%, more than 10,000 arteries would be needed for an 80% chance of detecting a 50% reduction in the relative risk for rupture, and this would still prevent only 1 rupture in every 350 operations.

Although there is little reliable evidence to guide surgeons as to which patch material to use, synthetic patches offer the advantage of sparing the morbidity (eg, poor wound healing, pain) and time associated with vein harvesting and ensure that vein is available for future coronary bypass grafting if required. However, use of PTFE in patching may increase operation time by several minutes, mainly because of increased bleeding through the suture holes. This may be less of a problem with Dacron patches.[33] In addition, the trial by Carney and Lilly[33] suggests that surgeons prefer the handling qualities of Dacron or vein to PTFE, which they found less compliant. Dacron may therefore be preferable to PTFE, although some believe it carries a greater risk for thrombosis[25] and may be more prone to infection.[34] Furthermore, the newer versions of PTFE may be more hemostatic than previously, and the only good, quality randomized trial that has compared the use of PTFE and Dacron in CEA found a significant benefit of PTFE over collagen-impregnated (Hemashield) Dacron grafts in terms of 30-day stroke rate, combined transient ischemic attack and stroke rate, and recurrent stenosis and long-term recurrent stenosis rates.[15,16] However, it also noted longer hemostasis time with PTFE (14.4 minutes vs 3.4 minutes; $P < .001$).

At present, most vascular surgeons do not routinely use patching in all patients undergoing CEA. However, despite the limitations of the data, the results of this review appear to support a recommendation in favor of routine patching, although more conclusive evidence is required because numbers are still small. Individual surgeons, and patients, may still interpret the evidence differently, and therefore it is up to each surgeon to decide whether to patch routinely.

It is also relevant to note that many surgeons are now performing eversion CEA as opposed to the "standard" longitudinal arteriotomy technique. This technique removes the need for patching, and should be borne in mind during design of further trials of carotid patching. This technique has not been studied in this review, to prevent overly confusing the results.

The use of selective patching (eg, in very narrow arteries) has not been studied in RCTs; thus, although it is likely to be required on occasion, no clear indications for selective patching can be given. The results of this review do not support the use of vein over synthetic patch material in CEA. The decision as to which type of patch to use, if any, remains a matter of individual preference. However, if synthetic material is used, the currently available (limited)

evidence from a single trial appears to show benefits from PTFE as opposed to Dacron material.

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