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Recurrent Carotid Stenosis
Results of the Asymptomatic Carotid Atherosclerosis Study

Wesley S. Moore, MD; Richard F. Kempczinski, MD; J.J. Nelson, PhD;
James F. Toole, MD; for the ACAS Investigators

Background and Purpose—We sought to determine the incidence of recurrent carotid stenosis in patients in the Asymptomatic Carotid Atherosclerosis Study (ACAS) who had undergone carotid endarterectomy and were prospectively followed with Doppler ultrasound for up to 5 years.

Methods—The ACAS database was interrogated to determine the rate of recurrent carotid stenosis (≥60%) based up angiogram-validated Doppler data, with a 90% and a 95% positive predictive value, as well as information concerning the technologists' interpretation of percent stenosis. These 3 parameters are reported for each of 3 time intervals: within 3 months of operation (residual disease), between 3 and 18 months (early restenoses), and between 18 and 60 months (late restenosis).

Results—Of the 825 patients randomized to the surgical arm of the study, 720 actually underwent carotid endarterectomy, and 645 had complete ultrasound data. The aggregate incidence of residual and recurrent carotid stenosis for all time intervals ranged from 12.7% to 20.4%, depending on the positive predictive value confidence level desired. Residual disease occurred in 4.1% to 6.5%; true, early restenosis was found in 7.6% to 11.4%; and late restenosis occurred in 1.9% to 4.9%. None of the traditional risk factors showed a statistically significant effect on recurrent stenosis. The use of patch angioplasty closure reduced overall risk of restenosis from 21.2% to 7.1%, from 16.7% to 4.6%, and from 27.4% to 8.2%, depending on the PPV confidence level desired ($P<0.001$). Of the 136 patients judged to have recurrent stenosis, only 8 (5.9%) underwent reoperation (only 1 for symptoms). There was no correlation between late stroke and recurrent stenosis.

Conclusions—Carotid endarterectomy is a durable procedure with a low rate of true restenosis, particularly when patch angioplasty is used to close the arteriotomy. **(*Stroke*. 1998;29:2018-2025.)**

Key Words: angioplasty ■ carotid endarterectomy ■ carotid stenosis ■ prospective studies

Carotid endarterectomy (CEA) is now a proven treatment for the prevention of stroke in both asymptomatic and symptomatic patients with hemodynamically significant stenoses.[1–4] The intermediate and long-term durability of the procedure may be affected by the incidence of recurrent carotid stenosis due to either myointimal hyperplasia or recurrent atherosclerosis. The incidence of recurrence has been quite variable, ranging from <2.0% to as much as 30%.[5–12] However, most reports have been retrospective analyses. The Asymptomatic Carotid Atherosclerosis Study (ACAS) had as one of its primary objectives to define the true incidence and consequence of recurrent carotid stenosis after CEA.[13] Thus, data acquisition concerning recurrence is prospective and is made possible by the use of preoperative and follow-up Doppler ultrasound studies in validated laboratories. Machine-specific cut points were defined, yielding information with both 90% and 95% positive predictive value (PPV) concerning stenoses of ≥60%.[14–16] The follow-up protocols also provide for surveillance of recurrent symptoms and the need, if any, for reoperation as a result of recurrent carotid stenosis. The objective of this report will be to document the true incidence of restenosis and frequency of reoperation secondary to recurrent carotid stenosis. In addition, we have analyzed risk factors, including technical considerations, that may correlate with recurrent stenosis.

Subjects and Methods

Participation in ACAS required that each institution have the individual Doppler instruments in their vascular laboratories validated by a single group of experts in ultrasound, biostatistics, and arteriography. This was accomplished by submitting 50 consecutive angiograms from patients with carotid stenoses together with the corresponding Doppler velocity data. These data made it possible to assign machine-specific Doppler cut points for both 90% and 95% PPV to correlate with a diameter-reducing stenosis of ≥60%. The variability of Doppler cut points among participating institutions has

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TABLE 1. Number of ACAS Patients Randomized to Surgery, Receiving Surgery, and Having Doppler Measurements on ACAS-Validated Doppler Machine

No. Randomized	90% PPV Cut Point	95% PPV Cut Point	Technician-Estimated Stenosis
No. randomized to surgery	825	825	825
No. randomized to surgery and receiving CEA	720	720	720
No. randomized to surgery and receiving study CEA and having a DU value* at baseline	664	609	681
No. randomized to surgery and receiving study CEA and having a DU value* at baseline plus ≥1 DU value* during follow-up	645	591	667

DU indicates Doppler ultrasound.
*Obtained with an ACAS-validated machine.

previously been reported.[17] However, the cut point consistency for individual institutions has been validated, thus emphasizing the importance of an individual institution to establish and validate its own Doppler data as criteria for diagnosing hemodynamically significant carotid stenosis. The 95% PPV Doppler cut point was used as a single entry criterion for patients in ACAS, whereas the 90% PPV Doppler-specific cut point was used in combination with a positive Gee-oculopneumoplethysmography study for patient entry. All patients randomized to the surgical arm of the study also had a carotid angiogram confirming that a lesion of ≥60% stenosis was present. Therefore, a preoperative Doppler value confirmed by angiography was available for each patient. After CEA, all patients were required to have a follow-up Doppler study within 3 months of operation, every 6 months thereafter for the next 2 years, then annually for years 3 through 5.[13,14] If a patient's Doppler data failed to normalize after CEA, we defined that as residual disease or incomplete CEA. Recurrent carotid stenosis was diagnosed for patients whose Doppler data returned to normal after CEA but who, during the course of follow-up, developed a Doppler velocity profile that reached or exceeded the machine-specific cut point for patients at that institution. This would indicate that the patient had developed a recurrent diameter-reducing stenosis of ≥60%.

We then accessed the ACAS database with the following questions: (1) What was the total number of CEAs performed in the study? (2) Of the total number of patients undergoing CEA, how many had an initial postoperative Doppler study that failed to normalize after CEA? (3) What was the total number of patients with normalized postoperative Doppler data who developed a recurrent carotid stenosis within 18 months of follow-up as well as during the interval between 18 and 60 months? (4) Of the patients who developed recurrent carotid stenosis, how many became symptomatic in the distribution of the recurrent stenotic lesion? (5) Of the patients who developed recurrent carotid stenosis, how many required reoperation for either symptoms or continued progression to a high-grade lesion? (6) In both unifactorial and multifactorial analyses comparing patients with and without recurrent stenosis, were there any correlations with the following parameters: age, sex, hyperlipidemia, continued cigarette smoking, diabetes mellitus, hypertension, peripheral vascular disease, contralateral carotid stenosis, or operation? In addition, were there any correlations with the following technical features: patch closure, distal endarterectomy tacking sutures, or shunt versus no shunt? (7) Of the patients who reached an end point in the study, either from stroke or death during the course of follow-up, how many had residual lesions after CEA, and how many developed recurrent carotid stenoses?

The ACAS database provided information regarding recurrent carotid stenosis based on validated Doppler data, with 90% and a 95% PPV confidence levels. In addition, information was provided concerning the technologists' interpretation of percent stenosis. These 3 parameters are reported for each of 3 time intervals: within 3 months of operation (residual disease), between 3 and 18 months (early restenosis), and between 18 and 60 months (late restenosis).

The statistical methods used are as follows: For univariate analysis, we used both analysis of proportions and analysis of rates. For categorical variables, the percentage of patients with recurrent stenosis was compared with and without a specified characteristic and was tested with Fisher's exact test. For continuous variables, the mean of standard deviation of the characteristic was compared for patients with and without recurrent stenosis and tested for significance with a Student *t* test. In addition to exploring differences in proportions, we tested the difference of these rates for patients with and without a specified characteristic with a χ^2 statistic. In this formulation the statistic is based on an underlying Poisson distribution. Furthermore, for categorical variables we compared the difference in the probability of recurrent stenosis by Kaplan-Meier (product-limit) survival analysis for patients with and without a specified characteristic. Here, survival refers to nonrecurrence of stenosis. Statistical significance was tested with the log-rank statistic. After determining univariate associations of factors with recurrent stenosis, we performed multivariate analysis to determine independence of associations. For analysis of proportions, we used logistic regression to calculate the odds ratio and a 95% CI of developing recurrent stenosis for each factor identified from the univariate analysis as potentially predictive, first controlling for age and sex only and then, in multivariate mode, simultaneously controlling for all potential predictors. Similarly, for rates, we used proportional hazard regression to calculate the rate ratio or risk ratio and the 95% PPV confidence level of developing recurrent stenosis for each factor identified from the univariate analysis as potentially predictive, controlling for age and sex, and then, in a separate model for all factors, simultaneously controlling for all potential predictors.

Results

Eight hundred twenty-five patients were randomized to the surgical arm of the study. Of these, 724 were prepared to proceed with operation. Four patients suffered a major stroke

TABLE 2. Number and Percentage of Patients With Recurrent Stenosis at Overall Follow-Up for 2 PPV Scenarios and Estimate of Stenosis by Doppler Technician

Doppler Scenario	No. at Risk	With Recurrent Stenosis	
		No.	Percentage
90% PPV	645	103	16.0
95% PPV	591	75	12.7
Estimate of stenosis by technician	667	136	20.4

*A patient is counted only once regardless of number of times Doppler measurements exceed the cut point.

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TABLE 3. Number and Percentage with Residual and Recurrent Stenosis, by Follow-Up Period, for 2 PPV Scenarios and Estimate of Stenosis by Doppler Technician

	Period 1: From Date of Surgery to 3 mo of Postsurgery Follow-Up			Period 2: From 3 mo of Postsurgery Follow-Up to 18 mo			Period 3: From 18 mo of Postsurgery Follow-Up to 60 mo		
Doppler Scenario	No. at Risk	No. With Residual Stenosis	Percentage With Residual Stenosis	No. at Risk*	No. With Recurrent Stenosis*	Percentage With Recurrent Stenosis*	No. at Risk*	No. With Recurrent Stenosis*	Percentage With Recurrent Stenosis*
90% PPV	645	37	5.7	591	50	8.5	495	16	3.2
95% PPV	591	24	4.1	550	42	7.6	466	9	1.9
Estimate of stenosis	667	43	6.5	606	69	11.4	495	24	4.9

*Does not include patients with recurrent stenosis in the previous time period(s).

as a result of preoperative angiography and did not proceed with surgery. Therefore, 720 patients actually underwent CEA. Six hundred sixty-seven patients completed sufficient follow-up to evaluate recurrent stenosis on the basis of technician estimate: 645 on the basis of 90% PPV and 591 on the basis of 95% PPV.

Table 1 summarizes information concerning patients who were randomized to the surgical arm and met criteria for

TABLE 4. Percentage of Surgical Group Patients With Recurrent Stenosis, by Characteristic, for 2 PPV Scenarios and Estimate of Stenosis by Doppler Technician

		90% PPV Cut Point			95% PPV Cut Point			Estimated Stenosis		
Characteristic	Category	No. in Category	Percentage With Recurrent Stenosis	*P*	No. in Category	Percentage With Recurrent Stenosis	*P*	No. in Category	Percentage With Recurrent Stenosis	*P*
Previous contralateral CEA	No	511	16.4	0.60	468	13.9	0.095	526	20.5	0.91
	Yes	134	14.2		123	8.1		141	19.9	
Physician-diagnosed hypertension	No	229	14.9	0.65	213	12.2	0.90	236	19.5	0.69
	Yes	416	16.6		378	13.0		431	20.9	
Hypertension medication	No	37	16.2	1.00	33	15.2	.60	37	18.9	1.00
	Yes	379	16.6		345	12.8		394	21.1	
Physician-diagnosed diabetes	No	485	16.3	0.80	449	12.9	0.89	502	21.1	0.44
	Yes	160	15.0		142	12.0		165	18.2	
Diabetes medication	No	25	16.0	1.00	24	16.7	0.49	26	15.4	0.79
	Yes	135	14.8		118	11.0		139	18.7	
Current smoker	No	470	16.0	1.00	429	12.6	0.89	482	21.2	0.45
	Yes	175	16.0		162	13.0		185	18.4	
Previous contralateral CEA	No	506	16.0	1.00	463	13.6	0.23	521	20.0	0.64
	Yes	139	15.8		128	9.4		146	21.9	
Endarterectomy side	L	320	15.0	0.52	291	12.7	1.00	332	20.2	0.92
	R	325	16.9		300	12.7		335	20.6	
Patch	No	405	21.2	<0.001	395	16.7	<0.001	424	27.4	<0.001
	Yes	240	7.1		196	4.6		243	8.2	
Shunt	No	302	16.2	0.92	293	14.7	0.175	312	21.8	0.44
	Yes	340	15.9		295	10.9		352	19.3	
Sutures	No	428	17.8	0.11	407	15.2	0.0043	442	21.5	0.47
	Yes	209	12.4		178	6.7		217	18.9	
Sex	F	215	19.1	0.14	191	15.7	0.15	226	25.7	0.02
	M	430	14.4		400	11.3		441	17.7	
Derived hypertension	No	124	17.5	0.68	115	12.2	1.00	128	19.5	0.90
	Yes	521	16.3		476	12.8		539	20.6	
Derived hyperlipidemia 1	≤250 mg/dL	466	16.5	0.63	427	13.1	0.68	484	21.5	0.28
	>250 mg/dL	179	14.5		164	11.6		183	17.5	
Derived hyperlipidemia 2	<90th %ile	573	15.9	0.87	526	12.7	1.00	593	20.7	0.65
	>90th %ile	72	16.7		65	12.3		74	17.6	

Results are by Fisher's exact test comparing percentage with recurrent stenosis among patients with and without various characteristics.

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TABLE 5. Probability of Recurrence of Stenosis and Relative Risk, Comparing Patients With and Without Selected Characteristics for 2 PPV Scenarios and Estimate of Stenosis by Doppler Technician

		90% PPV Cut Point				95% PPV Cut Point				Estimated Stenosis			
Characteristics	Category	Prob	RR	95% CI	*P*	Prob	RR	95% CI	*P*	Prob	RR	95% CI	*P*
Previous contralateral CEA	Yes	0.157	0.870	0.55, 1.39	0.52	0.087	0.47	0.23, 0.96	0.09	0.243	1.06	0.70, 1.60	0.83
	No	0.181				0.184				0.230			
Physician-diagnosed hypertension	Yes	0.176	1.020	0.70, 1.50	0.45	0.140	0.74	0.37, 1.45	0.69	0.241	1.10	0.79, 1.54	0.57
	No	0.173				0.190				0.219			
Hypertension medication	Yes	0.175	0.895	0.42, 1.92	0.96	0.136	0.726	0.31, 17.0	0.65	0.242	1.076	0.53, 2.17	0.85
	No	0.195				0.188				0.225			
Physician-diagnosed diabetes	Yes	0.161	0.893	0.58, 1.36	0.82	0.339	2.38	0.76, 7.39	0.88	0.198	0.81	0.56, 1.18	0.48
	No	0.181				0.143				0.243			
Diabetes medication	Yes	0.161	1.010	0.38, 2.70	0.79	0.332	1.99	0.47, 8.52	0.31	0.206	1.340	0.51, 3.52	0.72
	No	0.160				0.167				0.154			
Current smoking	Yes	0.178	1.017	0.68, 1.53	1.00	0.240	1.792	0.80, 4.01	0.99	0.203	0.82	0.57, 1.19	0.41
	No	0.175				0.134				0.246			
Previous contralateral CEA	Yes	0.175	0.994	0.64, 1.54	0.97	0.100	0.552	0.28, 1.07	0.21	0.260	1.16	0.79, 1.71	0.63
	No	0.176				0.181				0.225			
CEA side	R	0.185	1.111	0.78, 1.59	0.48	0.192	1.319	0.65, 2.69	0.99	0.234	1.012	0.73, 1.40	0.88
	L	0.167				0.146				0.231			
Patch	Yes	0.081	0.348	0.21, 0.58	<0.001	0.053	0.230	0.10, 0.51	<0.001	0.094	0.301	0.19, 0.48	<0.001
	No	0.234				0.229				0.313			
Shunt	Yes	0.176	0.990	0.69, 1.42	0.71	0.168	1.018	0.50, 2.09	0.11	0.207	0.773	0.56, 1.07	0.25
	No	0.178				0.165				0.268			
Sutures	Yes	0.140	0.717	0.47, 1.09	0.063	0.076	0.362	0.18, 0.74	0.004	0.208	0.837	0.60, 1.18	0.371
	No	0.194				0.209				0.249			
Sex	M	0.163	0.807	0.56, 1.16	0.12	0.128	0.532	0.26, 1.11	0.13	0.214	0.785	0.57, 1.08	0.013
	F	0.202				0.241				0.272			
Derived hypertension	Yes	0.179	1.093	0.68, 1.76	0.60	0.177	1.314	0.67, 2.60	0.82	0.236	1.061	0.71, 1.58	0.74
	No	0.164				0.135				0.222			
Derived hyperlipidemia 1	Yes	0.163	0.905	0.60, 1.37	0.47	0.209	1.448	0.62, 3.40	0.54	0.190	0.755	0.52, 1.09	0.16
	No	0.180				0.144				0.251			
Derived hyperlipidemia 2	Yes	0.188	1.078	0.62, 1.88	0.94	0.225	1.603	0.60, 4.27	0.80	0.199	0.839	0.50, 1.42	0.42
	No	0.174				0.141				0.238			

Prob indicates probability; RR, relative risk. 95% CI and *P* values are by log-rank test by Kaplan-Meier survival analysis.

stenoses ≥60%. In addition, the table provides information concerning patients who received ≥1 follow-up Doppler study.

Table 2 provides overall data concerning the combination of residual and recurrent stenosis for all time intervals. The incidence ranged from 12.7% to 20.4% depending on the criterion used.

Table 3 summarizes the number and percentage of patients with residual or recurrent carotid stenosis as a function of the follow-up interval and expresses them for two PPV scenarios and the best estimate of stenosis by the Doppler technician. The incidence of residual carotid stenosis, incompletely treated by operation, ranged from 4.1% to 6.5% depending on the criterion used. The second time interval, which ranges from 3 to 18 months after operation, expresses the incidence of true, early recurrent carotid stenosis, that is, patients who normalized after operation but developed a hemodynamically significant recurrence during this interval. This ranged from 7.6% to 11.4% depending on the criterion used. The final time interval, ranging from 18 to 60 months, includes patients whose Doppler data normalized after operation and who remained normal until this time interval. The percentage of late recurrent stenosis ranged from 1.9% to 4.9% depending on the criterion used.

Table 4 presents the proportion of recurrent stenosis for known risk factors previously reported to be associated with recurrent carotid stenosis. Of the 15 potential risk factors tested, only the use of patch angioplasty made a statistically significant difference in the incidence of recurrent carotid stenosis. At 95% PPV, 16.7% of patients without a patch experienced recurrent carotid stenosis, whereas only 4.6% of patients with patch angioplasty closure experienced the same problem ($P<0.001$). Other previously reported factors related to recurrent carotid stenosis, including continued smoking, female sex, and hyperlipidemia, failed to show statistical significance.

Table 5 shows a similar analysis, but for probability of recurrent carotid stenosis; a Kaplan-Meier statistical analysis compares patients with and without selected characteristics. Comparisons are made for 2 PPV scenarios and an estimate of stenosis by the Doppler technician. None of the traditional factors showed a statistically significant effect on the incidence of recurrent carotid stenosis. Additionally, Table 5 examines technical features associated with CEA, including

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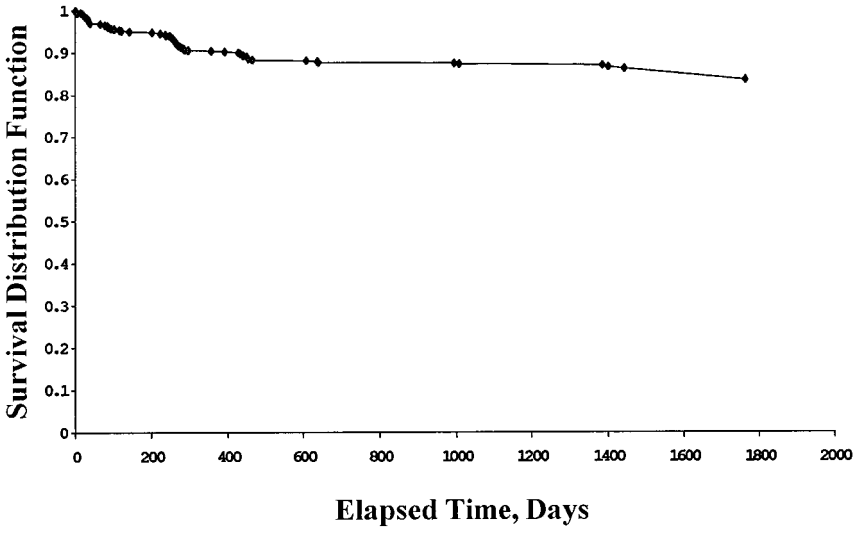

Figure 1. Kaplan-Meier curve documents the probability of nonrecurrence of stenosis after operation at 95% PPV. This represents both residual and recurrent disease.

the use of patch closure, intraluminal shunt, and the placement of tacking sutures at the distal end point. In this instance, 2 factors emerge that demonstrate a statistically significant impact on recurrent carotid stenosis. The use of patch angioplasty closure reduced the overall risk of recurrent carotid stenosis from 21.2% to 7.1% in the 90% PPV category, from 16.7% to 4.6% in the 95% PPV category, and from 27.4% to 8.2% in the Doppler technician's best estimate category. The *P* value for significance of difference was <0.001. The use of distal tacking sutures also appeared to have a trend toward reduction of recurrent carotid stenosis. However, this only reached statistical significance in the 95% PPV category. It did not have statistically significant difference in the 90% PPV category or in the best estimate of stenosis by the Doppler technician. The use of a shunt had no effect on recurrent stenosis.

Figure 1 is a Kaplan-Meier representation of the overall probability of nonrecurrence of stenosis after surgery at 95% PPV. This includes all time intervals including residual as well as recurrent carotid stenosis. Figure 2 is a Kaplan-Meier representation for the initial time interval within the first 90 days at 95% PPV. This is specific for residual disease. Figure 3 is a Kaplan-Meier curve that examines the time interval between 90 days and 18 months for the parameter of recurrent carotid stenosis with 95% PPV. Figure 4 examines the final time interval of 18 months to 5 years with respect to the parameter of recurrent carotid stenosis at 95% PPV. Figure 5 examines the probability of nonrecurrence of stenosis after CEA and compares the outcome of patients undergoing patch angioplasty with those who had CEA and primary closure. This is the only factor that showed a highly statistically significant difference in favor of the patch angioplasty, and that difference is evident in the curve separations.

One hundred thirty-six patients were judged to have recurrent carotid stenosis as best estimate by the Doppler technician. Of these, 8 (5.9%) underwent a second CEA. Only 1 of the 8 patients had experienced symptoms before the second CEA, and this was a stroke 2.5 years before operation. The remaining patients underwent a second CEA for asymptomatic recurrent carotid stenosis. Of the 8 patients undergoing repeat CEA, there were no perioperative deaths or neurological complications.

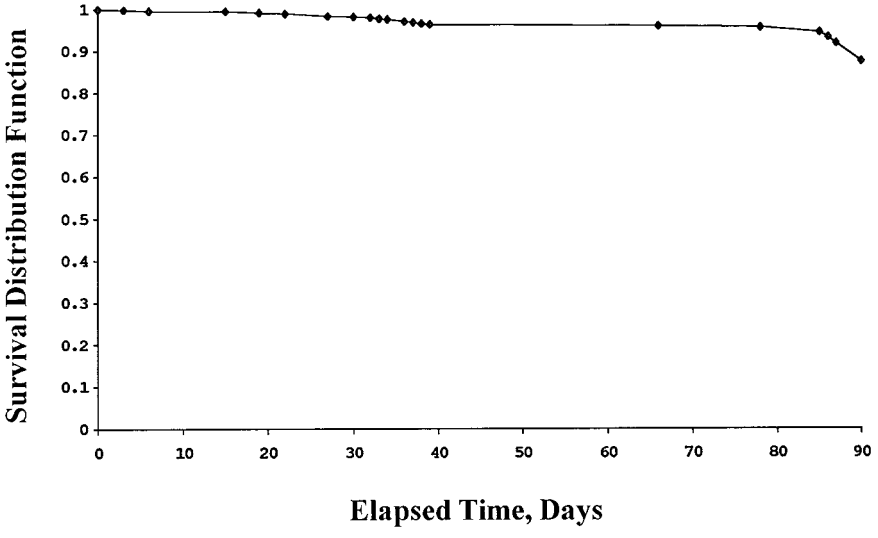

Figure 2. Kaplan-Meier curve documents the probability of nonrecurrent stenosis within the first 90 days after operation at 95% PPV. This represents residual disease.

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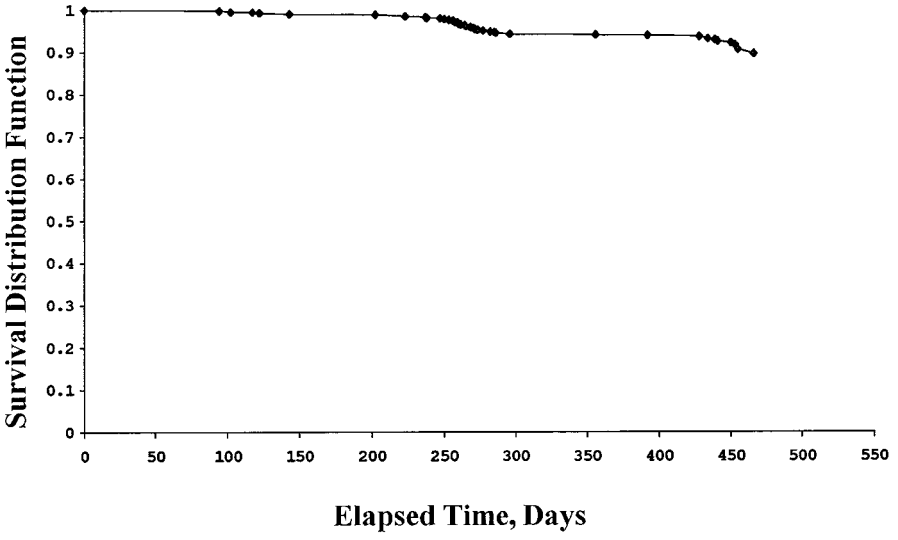

Figure 3. Kaplan-Meier curve documents the probability of nonrecurrent carotid stenosis in the interval 90 days to 18 months after operation at 95% PPV. This is true recurrence, probably due to myointimal hyperplasia.

Table 6 examines the impact of recurrent carotid stenosis with respect to subsequent neurological end points in the form of ipsilateral stroke. Although a higher percentage of patients with recurrent stenosis experienced a stroke compared with those without, the *P* value fails to show a strong association between recurrent carotid stenosis and subsequent ipsilateral stroke, possibly because the number of stroke events is small and the study is potentially statistically underpowered to demonstrate a clear relationship.

Discussion

ACAS has proven that CEA plus best medical management for patients with stenoses ≥60% resulted in fewer fatal and nonfatal strokes than a corresponding group of patients treated with best medical management alone. There was a 5.9% absolute risk reduction and a 53% relative risk reduction in favor of operation.[4] The continuing benefit to patients undergoing CEA will in part be related to the durability of the operation, as evidenced by the incidence of recurrent carotid stenosis and whether those patients who suffer recurrence develop symptoms and the need for further surgical repair.

Continual surveillance of patients after CEA to prospectively assess rates of recurrence was intrinsic to the design of the study. Patients were scheduled for periodic follow-up examination with Doppler assessment of the operated carotid bifurcation performed in validated laboratories and measured against machine-specific cut points, which would find the occurrence or recurrence of hemodynamically significant stenosis in the operated artery.[14] This method of prospective evaluation is in contrast to other reports in the literature, which rely on retrospective data as documented with noninvasive testing in the absence of validation of the test equipment.

The 30-day surgical morbidity and mortality associated with CEA in ACAS has been previously carefully analyzed and reported. The combined mortality and neurological stroke morbidity of patients undergoing CEA was 1.5%.[18,19] The present study has demonstrated that the incidence of recurrent stenosis as measured with a Doppler cut point with 95% PPV was 12.7%. However, evaluation of patients within the immediate postoperative interval indicated that the incidence of postoperative stenosis was 4.1%. Clearly, this is not

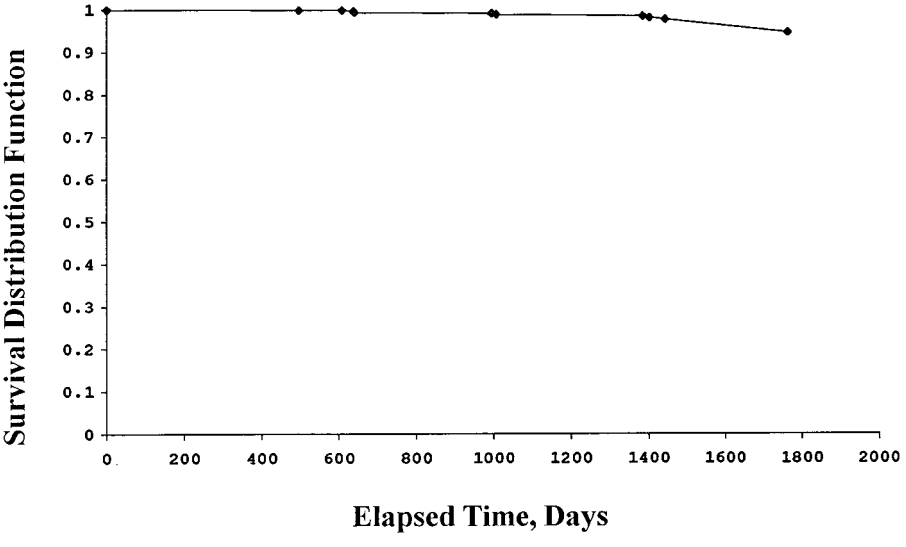

Figure 4. Kaplan-Meier curve documents the probability of nonrecurrent stenosis in the interval between 18 months and 5 years at 95% PPV. This represents the development of a new lesion, probably atherosclerosis.

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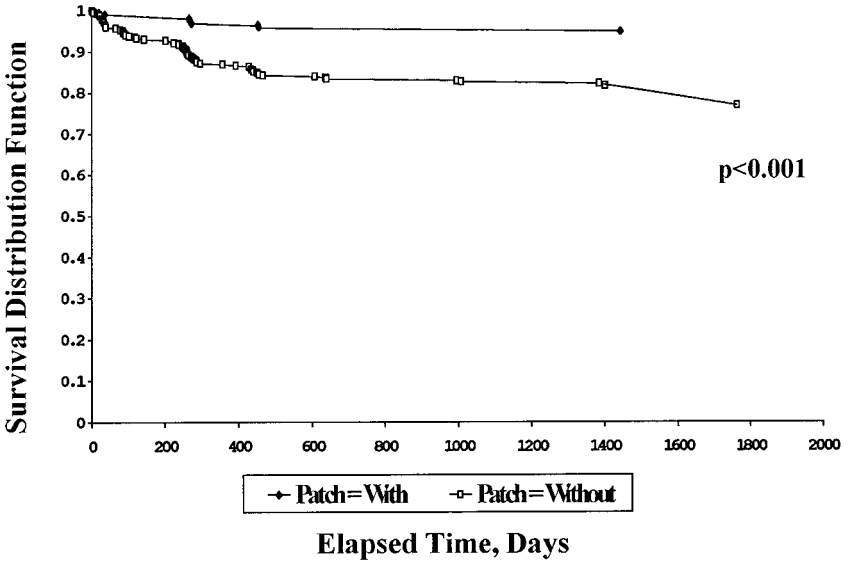

Figure 5. Kaplan-Meier curve compares the probability of nonrecurrent stenosis after operation and compares the incidence in patients in whom the arteriotomy was closed with a patch angioplasty with the incidence in those undergoing primary arterial closure. This summarizes the experience in all time intervals and demonstrates a statistically significant difference in favor of patch closure.

recurrence but represents incomplete CEA, perhaps best defined as residual disease.

The next time interval set in this study was from 3 to 18 months after operation. In this interval the incidence of recurrent carotid stenosis as documented by Doppler data with a 95% PPV was 7.6%. This almost certainly represents the incidence of recurrent carotid stenosis due to myointimal hyperplasia.

The final time interval, defined within the study as 18 to 60 months, showed a recurrent carotid stenosis rate of 1.9% with a Doppler scenario of 95% PPV. In the final time interval we examine the incidence of recurrent carotid stenosis probably due to recurrent atherosclerosis. In absolute terms, 75 patients were documented to have either occurrent or recurrent carotid stenosis with 95% PPV. Eight patients underwent repeated CEA, 7 of which were done for asymptomatic lesions. Therefore, the incidence of recurrent carotid stenosis in the ACAS patients was quite low, and the number of patients actually undergoing repeated CEA was quite small.

Risk factor analysis for recurrent carotid stenosis failed to document any particular characteristic that was associated with a high incidence of recurrence. Previous reports have suggested that female sex, hyperlipidemia, and continued cigarette smoking were associated with an increased incidence of recurrence compared with patients who did not have those factors.[5,20–22] We were unable to confirm this, possibly because of insufficient sample size to reach statistical significance.

Finally, an analysis of technical factors revealed that those patients whose arteriotomies were closed with patch angioplasty had a statistically significant lowering of the incidence of recurrent carotid stenosis compared with those patients undergoing primary arterial closure. When a Doppler cut point with 95% PPV for the presence of a hemodynamically significant stenosis was used, the overall incidence of recurrent carotid stenosis in patients closed with patch angioplasty was 4.52% compared with an incidence of recurrent carotid stenosis of 16.97% in patients undergoing primary arterial closure. This difference was significant at a P value of <0.001. In subset analysis, this difference was apparent at all 3 time intervals. Thus, the percentage of patients with occurrent or residual carotid stenosis, as documented by an abnormal Doppler study within the first 90 days of operation, was 1.1% in patients with patch closure compared with 5.7% in patients with primary closure. At the time interval 30 days to 18 months, the incidence of true recurrent carotid stenosis in patients undergoing patch angioplasty closure was 3.1% compared with 10.2% in patients with primary closure. Finally, in the third time interval, 18 months to 5 years, the

TABLE 6. Rate of Recurrent Stenosis vs Ipsilateral Stroke for 2 Doppler Scenarios

PPV	Ipsilateral Stroke	Recurrent Stenosis	
		No	Yes
90%	No	502	105
	Yes	16	4
		Recurrent stenosis=No	Recurrent stenosis=Yes
Percentage with ipsilateral stroke		3.09	3.67
		Ipsilateral stroke=No	Ipsilateral stroke=Yes
Percentage with recurrent stenosis		17.3	20.0
P=0.76*			

	Ipsilateral Stroke	Recurrent Stenosis	
		No	Yes
95%	No	482	78
	Yes	13	4
		Recurrent stenosis=No	Recurrent stenosis=Yes
Percentage with ipsilateral stroke		2.63	4.88
		Ipsilateral stroke=No	Ipsilateral stroke=Yes
Percentage with recurrent stenosis		13.9	23.5
P=0.28*			

*Fisher's exact test.

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incidence of recurrent carotid stenosis in patients whose arteriotomy was closed with a patch as documented by a Doppler cut point with a 95% PPV was 0.56% compared with 2.8% in patients with primary closure.

The benefit of patch angioplasty closure has been consistently debated in the literature. Some studies have failed to show a difference, while other studies have showed a marked difference in favor of patch closure.[6,8–12,23–25] Others have suggested that the apparent benefit of patch angioplasty is most readily seen in the previously defined high-risk groups, which comprised patients with small arteries, female sex, or continued use of tobacco.[5,26]

This present report suggests that patch angioplasty is beneficial to all groups since we were unable to demonstrate any specific risk factor that was associated with a higher incidence of recurrent carotid stenosis. Specifically, female sex, continued use of tobacco, and other factors, including hyperlipidemia, were not associated with an increased risk of recurrent stenosis in this study. However, all patients had a lower recurrence rate when patch angioplasty was used as opposed to primary closure, even after simultaneous adjustment for age, sex, and other covariables. While some studies involving individual institutions or single surgeons have failed to show a difference between patch angioplasty and primary closure, it is clear that ACAS, which is a multicenter study involving multiple surgeons, provides important data in favor of patch angioplasty that is more generally applicable to the surgical community as a whole.

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