

## LONG-TERM OUTCOMES OF IMMEDIATE REPAIR COMPARED WITH SURVEILLANCE OF SMALL ABDOMINAL AORTIC ANEURYSMS

THE UNITED KINGDOM SMALL ANEURYSM TRIAL PARTICIPANTS\*

**ABSTRACT**

**Background** Two clinical trials, one British and one American, have shown that early, prophylactic elective surgery does not improve five-year survival among patients with small abdominal aortic aneurysms. We report long-term outcomes in the United Kingdom Small Aneurysm Trial.

**Methods** We randomly assigned 1090 patients, 60 to 76 years of age, with small abdominal aortic aneurysms (diameter, 4.0 to 5.5 cm) to one of two groups: 563 were assigned to undergo early elective surgery, and 527 were assigned to undergo surveillance by ultrasonography. Patients were followed in the trial until June 1998 and thereafter until August 2001; the mean duration of follow-up was 8 years (range, 6 to 10).

**Results** The mean duration of survival was 6.5 years among patients in the surveillance group, as compared with 6.7 years among patients in the early-surgery group ( $P=0.29$ ). The adjusted hazard ratio for death from any cause in the early-surgery group as compared with the surveillance group was 0.83 (95 percent confidence interval, 0.69 to 1.00;  $P=0.05$ ). The 30-day operative mortality in the early-surgery group (5.5 percent) led to an early disadvantage in terms of survival. The survival curves crossed at three years, and at eight years, mortality in the early-surgery group was 7.2 percentage points lower than that in the surveillance group ( $P=0.03$ ). There was no evidence that age, sex, or the initial size of the aneurysm modified the hazard ratio or that delayed surgery in the surveillance group increased 30-day postoperative mortality. Death was attributable to a ruptured aneurysm in 19 of the 411 men who died (5 percent) and in 12 of the 85 women who died (14 percent) ( $P=0.001$ ). The rate of early cessation of smoking was higher in the early-surgery group than in the surveillance group.

**Conclusions** Among patients with a small abdominal aortic aneurysm, we found no long-term difference in mean survival between the early-surgery and surveillance groups, although after eight years, total mortality was lower in the early-surgery group. This difference may be attributed in part to beneficial changes in lifestyle adopted by members of the early-surgery group. (N Engl J Med 2002;346:1445-52.)

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**R**UPTURE of an abdominal aortic aneurysm is associated with a high fatality rate and is an important cause of sudden death. Low rates of rupture of small abdominal aortic aneurysm were observed among patients enrolled in the United Kingdom Small Aneurysm Trial and the Aneurysm Detection and Management Trial in the United States — 1.0 percent and 0.6 percent per year, respectively.<sup>1,2</sup> These low rates of rupture may explain in part why these trials did not demonstrate a five-year survival benefit for patients who were randomly assigned to undergo early elective surgery. Operative mortality rates of 5.8 percent in the British trial and 2.7 percent in the U.S. trial also contributed to the finding of a lack of benefit from early surgery. Moreover, the British trial demonstrated that a policy of early surgery was more costly than a policy of ultrasonographic surveillance.<sup>3</sup>

When active follow-up in the United Kingdom Small Aneurysm Trial was closed in June 1998, only 305 of the 1090 patients had died (28 percent). Therefore, in 1998, we decided to undertake a further analysis when 100 surviving patients would have reached nine years of follow-up and approximately half the original cohort would have died. Such an analysis could also illuminate some of the late complications of aneurysmal disease.<sup>4,5</sup> Here we report the results of this long-term survival analysis.

**METHODS****Study Patients**

The study patients and methods have been described previously.<sup>1,6</sup> Briefly, between September 1991 and October 1995, 1276 patients 60 to 76 years of age from 93 hospitals in the United Kingdom were identified as having an asymptomatic infrarenal abdominal aortic aneurysm of 4.0 to 5.5 cm in diameter. Written informed consent for random assignment to either early elective surgery or a period of ultrasonographic surveillance was obtained for 1090 of these patients.

**Surgery and Follow-up**

Patients in the surveillance group were offered surgery when the diameter of the aneurysm exceeded 5.5 cm, when the aneurysm expanded by more than 1 cm per year, when the aneurysm became

The Writing Committee (A.R. Brady, L.C. Brown, F.G.R. Fowkes, R.M. Greenhalgh, J.T. Powell, C.V. Ruckley, and S.G. Thompson) assumes overall responsibility for the content of the manuscript. Address reprint requests to Dr. Powell at University Hospitals of Coventry and Warwickshire, Clifford Bridge Rd., Walsgrave, Coventry CV2 2DX, United Kingdom, or at janet.powell@wh-tr.wmids.nhs.uk.

\*The participants in the United Kingdom Small Aneurysm Trial are listed in the Appendix.

tender or symptomatic, or when repair of a proximal or iliac aneurysm was scheduled. The patients' records at the Office of National Statistics remained flagged to enable continued reporting of the date, place, and cause of death. Patients were followed individually to ascertain whether they had undergone an emergency or elective repair of an abdominal aortic aneurysm (by open, endovascular, or laparoscopic surgery) between July 1998 and August 2001.

### Statistical Analysis

Analyses were performed as previously described,<sup>1</sup> except that the presence or absence of nonproportional hazards was assessed by a test for a nonzero regression slope of scaled Schoenfeld residuals plotted against the logarithm of the time.<sup>7</sup> We used a log-rank test to compare the Kaplan–Meier curves for the duration of survival from randomization. We used Cox proportional-hazards regression to estimate hazard ratios and to adjust for sex, smoking status, initial diameter of the aneurysm, mean of left and right ankle–brachial pressure indexes, forced expiratory volume in one second (FEV<sub>1</sub>), use or nonuse of aspirin, source of referral, regional center, and type of hospital (teaching or district). Tests of interaction in the Cox regression analyses were used to assess whether age, sex, or initial diameter of the aneurysm affected the overall hazard ratio. Rupture rates were calculated on the basis of the time at risk until the repair of the aneurysm or death.

We also analyzed, in a subgroup enrolled during the first 18 months of the trial, whether smoking status had changed during the first 12 months after randomization; this analysis involved the comparison of the plasma cotinine concentration measured after 1 year of follow-up (available only for patients enrolled early in the trial) with that measured at the time of randomization. Patients were classified as smokers if the cotinine concentration was higher than 0 nmol per liter and as nonsmokers otherwise, with no intermediate category for passive smoking. Logistic regression was used to determine the relation between smoking status at one year and repair of an abdominal aortic aneurysm, with adjustment for smoking status at base line as well as for the variables listed above. All P values are two-tailed.

## RESULTS

### Study Patients

Of the 1090 patients (902 men and 188 women) who consented to undergo randomization, 563 (52 percent) were assigned to undergo early elective surgery and 527 (48 percent) to undergo ultrasonographic surveillance. The mean ( $\pm$ SD) age of the patients assigned to early elective surgery (468 men and 95 women) was  $69.3 \pm 4.4$  years; the mean initial diameter of the aneurysm was  $4.63 \pm 0.40$  cm.<sup>1</sup> The mean age of the patients assigned to ultrasonographic surveillance (434 men and 93 women) was  $69.2 \pm 4.4$  years; the mean initial diameter of the aneurysm was  $4.61 \pm 0.37$  cm.<sup>1</sup>

### Aneurysm Repair

By the end of the trial (June 30, 1998), 520 of the patients in the early-surgery group (92 percent) and 327 of those in the surveillance group (62 percent) had undergone surgical repair of an abdominal aortic aneurysm (Fig. 1). A total of 289 patients in the surveillance group (55 percent) had undergone surgery according to protocol; in the other 38 patients, the repair represented a protocol violation.

By the end of August 2001, an additional 6 patients in the early-surgery group (1 percent) and 62 in the surveillance group (12 percent) had undergone repair of an aneurysm, including one ruptured abdominal aortic aneurysm (Fig. 1). Only 4 of 140 patients who were alive with unrepaired aneurysms as of June 1998 (3 percent) were lost to follow-up. Treatment between the end of the trial and August 2001 did not necessarily adhere to the initial trial protocol, and an increasing proportion of the patients underwent endovascular repair of an aneurysm (13 of the 68 patients who underwent repair between July 1998 and August 2001 [19 percent], as compared with 14 of the 847 patients who underwent repair between randomization and July 1998 [2 percent]), but only 1 patient underwent repair for an asymptomatic abdominal aortic aneurysm of less than 5.5 cm in diameter. About one fifth of the patients in the surveillance group (105 of 527) died without having undergone repair of the aneurysm. The cumulative proportion of patients who underwent repair of an aneurysm is shown in Figure 2. Since only 39 patients who have not undergone repair of the abdominal aortic aneurysm remain alive, future changes to this curve will be minor.

### Mortality

The 30-day mortality associated with elective procedures was 5.4 percent (49 of 905 patients). An additional 10 patients (7 in the surveillance group and 3 in the early-surgery group) underwent emergency surgery for a ruptured aneurysm. Only 2 of these patients (both in the surveillance group) survived, bringing the total 30-day mortality, including deaths due to rupture, to 6.2 percent: 5.5 percent in the early-surgery group (29 of 526 patients) and 7.2 percent in the surveillance group (28 of 389 patients) ( $P=0.30$ ).

After a mean follow-up of 8 years (range, 6 to 10), there had been 254 deaths in the surveillance group and 242 in the early-surgery group. As of August 2001, the unadjusted hazard ratio for death in the early-surgery group as compared with the surveillance group was 0.84 (95 percent confidence interval, 0.70 to 1.00;  $P=0.05$  by the log-rank test) (Fig. 3); after adjustment for two sets of base-line covariates, the hazard ratios were similar, at 0.81 and 0.83 (Table 1).

Survival was initially worse in the early-surgery group and was subsequently worse in the surveillance group; the survival curves crossed at about three years (Fig. 3). There was evidence of nonproportional hazards between the two groups over time ( $P=0.002$ ). During the first six months after randomization, the rate of death in the early-surgery group was about two and a half times that in the surveillance group; thereafter, among those who survived at least six months, the rate of death in the early-surgery group was about three quarters of that in the surveillance group (Ta-

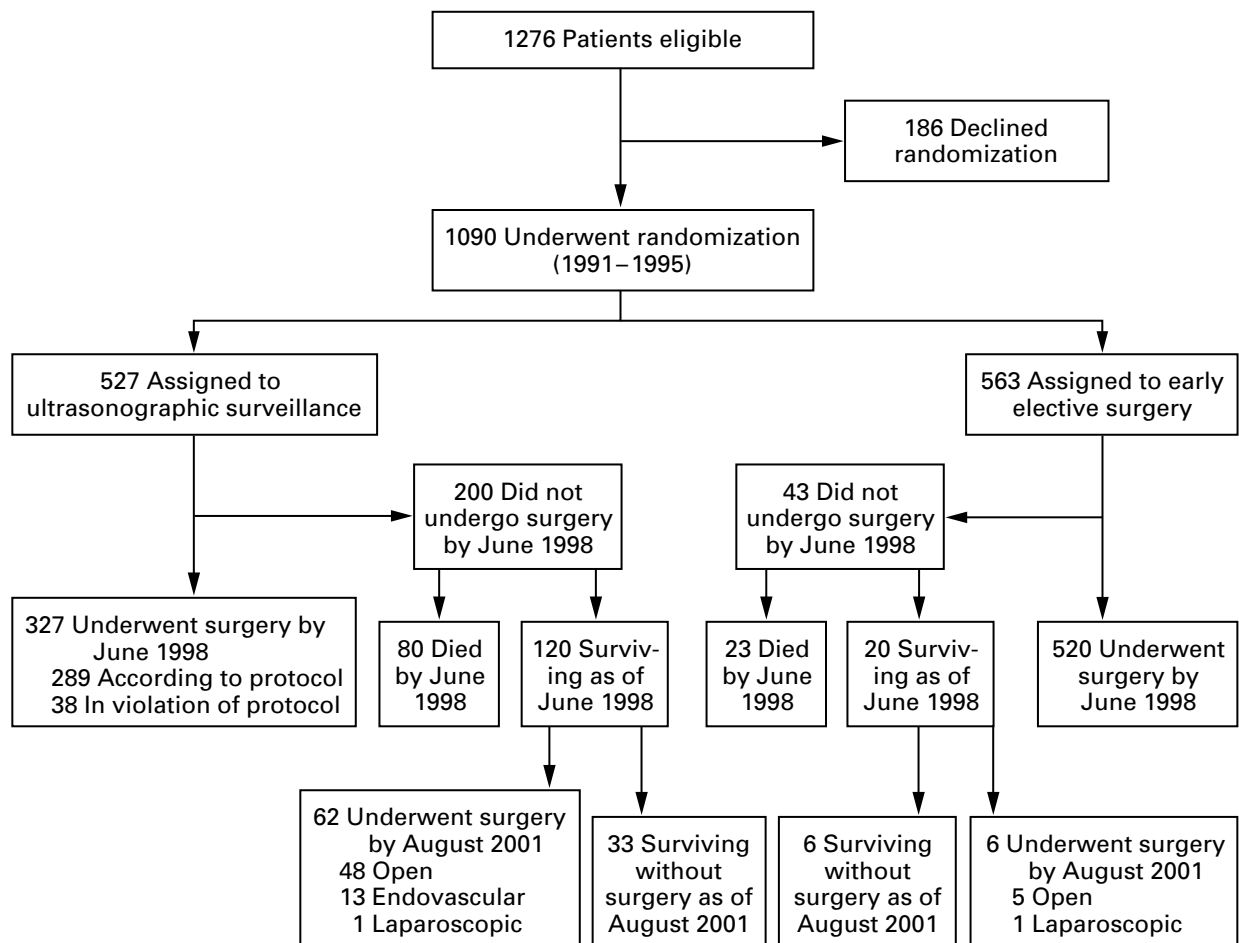


Figure 1. Patients, Randomization, and Outcomes.

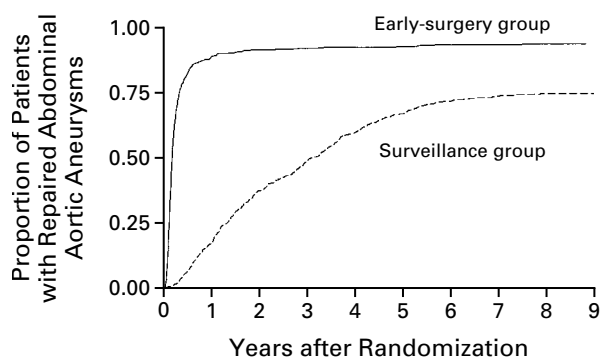
ble 1). At two years, the estimated risk of death was 1.9 percentage points higher in the early-surgery group than in the surveillance group ( $P=0.33$  by the z-test); at four years, the risk was 1.4 percentage points lower in the early-surgery group than in the surveillance group ( $P=0.58$ ); at six years, it was 4.2 percentage points lower ( $P=0.15$ ); and at eight years, it was 7.2 percentage points lower ( $P=0.03$ ). The adjusted hazard ratios tended toward a greater benefit of surgery among younger patients, men, and those with larger aneurysms, but these trends were not significant according to tests of interaction (Table 1). The restricted mean duration of survival<sup>8</sup> (the area under the survival curve) at 9 years was 6.5 years among patients in the surveillance group, as compared with 6.7 years among patients in the early-surgery group ( $P=0.29$ ).

The numbers of deaths from various causes are shown in Table 2. More deaths from ruptured aneu-

rysms were reported among patients in the surveillance group than among those in the early-surgery group. More deaths from cancer were reported in the early-surgery group than in the surveillance group (23 percent vs. 17 percent). Other causes of death were distributed evenly between the two groups.

#### Smoking

Older age, larger diameter of the aneurysm, lower ankle-brachial pressure index, and worse lung function (lower  $FEV_1$ ) were all independently related to an increased risk of death (Table 3). Patients who reported current smoking had a higher risk of death than did former smokers (Table 3). Data on cotinine concentrations at randomization and one year after randomization were available for 130 patients in the early-surgery group and 97 patients in the surveillance group. A total of 124 of these 227 patients (55 per-



**Figure 2.** Kaplan–Meier Estimates of the Cumulative Proportion of Patients Who Underwent Surgery for Aneurysm Repair, According to Treatment-Group Assignment.

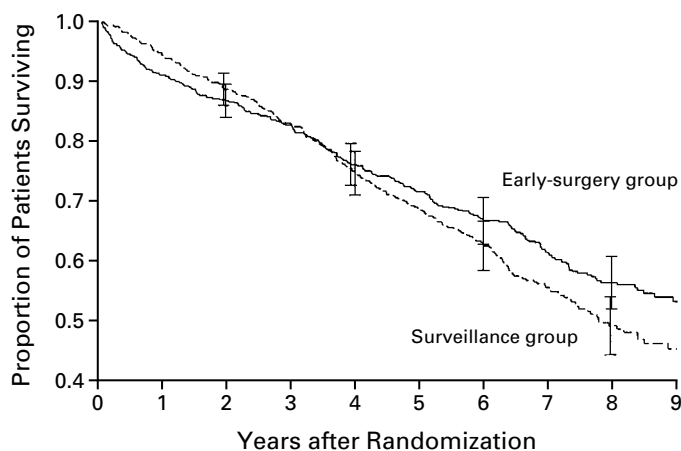
Data were not censored at the time of death.

cent) were classified as current smokers on the basis of the plasma cotinine concentration at the time of randomization; 71 of the patients in the early-surgery group were smokers (55 percent), as were 53 patients in the surveillance group (55 percent). One year after randomization, 37 of the patients in the early-surgery group (28 percent) and 47 of the patients in the surveillance group (48 percent) were still smokers ( $P=0.002$  by the chi-square test). The only factor that was independently associated with smoking cessation was repair of an abdominal aortic aneurysm (odds ratio for smoking cessation, 12.8; 95 percent confidence

interval, 4.2 to 38.9;  $P<0.001$ ). Age, sex, size of the aneurysm, ankle–brachial pressure index, FEV<sub>1</sub>, and the use or nonuse of aspirin therapy were not related to the likelihood of cessation. The death rate among those who continued to smoke was 12.0 per 100 patient-years; the death rate among those who stopped smoking was 3.8 per 100 patient-years (adjusted hazard ratio for death, 3.23; 95 percent confidence interval, 1.73 to 6.03).

**Operative Mortality**

To address the hypothesis that the risk of death increased in the surveillance group with the delay before elective repair of an abdominal aortic aneurysm, we compared the 30-day postoperative mortality rate during the period between randomization and June 30, 1998 (the end of the trial), with the rate between that date and August 31, 2001. A total of 389 patients in the surveillance group had undergone repair of an aneurysm by August 31, 2001; 355 of these repairs (91 percent) were recorded as elective open operations. The 30-day mortality associated with elective open surgery during the period before June 30, 1998, was 6.2 percent (19 of 308 patients), and the 30-day postoperative mortality between July 1998 and August 2001 was 4.3 percent (2 of 47 patients) ( $P=1.0$  by Fisher’s exact test). Logistic-regression analysis of 30-day outcomes according to the time to repair of an abdominal aortic aneurysm also failed to demonstrate that delaying surgery altered the 30-day postoperative mortality (odds ratio for postoperative death, 1.12



No. AT RISK	0	1	2	3	4	5	6	7	8	9
Surveillance group	527	497	468	437	394	363	316	173	97	41
Early-surgery group	563	513	489	465	429	402	371	253	154	66

**Figure 3.** Kaplan–Meier Estimates of Overall Survival According to Treatment-Group Assignment.  $P=0.05$  by the log-rank test. I bars represent the 95 percent confidence intervals for the point estimates.

TABLE 1. DEATHS FROM ANY CAUSE IN THE TWO TREATMENT GROUPS.\*

VARIABLE	DEATHS		ADJUSTED HAZARD RATIO (95% CI)†	P VALUE (TEST FOR INTERACTION)
	SURVEILLANCE GROUP (N=527)	EARLY-SURGERY GROUP (N=563)		
	no./no. of patients (no./100 patient-yr)			
All patients	254/527 (8.3)	242/563 (7.1)	0.83 (0.69–1.00)‡	
Months after randomization				
0–6	12/527 (4.6)	31/563 (11.4)	2.52 (1.20–5.33)	
>6	242/515 (8.7)	211/532 (6.7)	0.77 (0.63–0.93)	
Age				0.18
60–66 yr	68/181 (6.1)	56/183 (4.7)	0.72	
67–71 yr	94/180 (9.5)	76/183 (6.7)	0.74	
72–76 yr	92/166 (9.8)	110/197 (10.0)	1.00	
Sex				0.40
Male	210/434 (8.3)	201/468 (7.1)	0.80	
Female	44/93 (8.4)	41/95 (7.3)	0.99	
Diameter of aneurysm				0.28
4.0–4.4 cm	93/213 (7.4)	91/214 (7.1)	0.95	
4.5–4.8 cm	78/169 (7.9)	73/175 (6.7)	0.84	
4.9–5.5 cm	83/145 (10.4)	78/174 (7.5)	0.70	

\*There were 3048 patient-years of follow-up in the surveillance group, and 3410 in the early-surgery group. For age and diameter of aneurysm, the patients were divided into three groups of approximately equal size.

†Hazard ratios are for the early-surgery group relative to the surveillance group and were adjusted for the following base-line variables: age, sex, smoking status, initial aneurysm diameter, average of left and right ankle-brachial pressure index, forced expiratory volume in one second (FEV<sub>1</sub>), and use or nonuse of aspirin, as well as for the source of referral (general practice, other clinic, or other), regional center, and type of hospital (teaching or district general). CI denotes confidence interval.

‡The unadjusted hazard ratio was 0.84 (95 percent confidence interval, 0.70 to 1.00), and the hazard ratio adjusted only for the base-line age, sex, smoking status, aneurysm diameter, average of left and right ankle-brachial pressure index, FEV<sub>1</sub>, and use or nonuse of aspirin was 0.81 (95 percent confidence interval, 0.68 to 0.98).

per 1-year delay; 95 percent confidence interval, 0.87 to 1.44;  $P=0.40$ ). Adjustment for the age of the patient at the time of repair did not alter the results. Inclusion of the additional patients who underwent elective open surgery after June 1998 weakened the previously reported<sup>9</sup> relation between the age at the time of repair and the 30-day outcome (adjusted odds ratio for postoperative death, 1.61 per 10-year increment in age; 95 percent confidence interval, 0.77 to 3.39;  $P=0.21$ ).

#### Endovascular and Laparoscopic Repair

It is possible that the results were affected by the fact that, in the period after June 1998, some patients in the surveillance group underwent endovascular repair of an aneurysm at a time when clinicians had relatively little experience with this technique. Among the study patients, 27 endovascular repairs of abdominal aortic aneurysms were reported by August 2001, and one patient died within 30 days after such a repair. Two additional patients underwent laparoscopic repair, and one died within 30 days after the repair.

When the data for patients who underwent an endovascular or laparoscopic repair were censored at the time of repair, the shapes of the survival curves and the significance of the difference between them were unchanged ( $P=0.05$  by the log-rank test).

#### Rupture and Aneurysm-Related Deaths

We assessed the total rupture rate (including ruptures of aneurysms larger than 5.5 cm in diameter) for two periods. The total rupture rate (including non-fatal ruptures) was 1.6 percent per year before June 1998 and 3.2 percent per year between July 1998 and August 2001 ( $P=0.08$ ). Fatal ruptures were more common among women than among men, causing 12 of the 85 deaths in women (14 percent) and 19 of the 411 deaths in men (5 percent,  $P=0.001$ ). The risk of rupture of an abdominal aortic aneurysm was four times as high among women as among men (hazard ratio, 4.0; 95 percent confidence interval, 2.0 to 7.9;  $P<0.001$ ).

In addition to 3 deaths from the rupture of an abdominal aortic aneurysm after open surgery for repair

**TABLE 2.** CAUSES OF DEATH (1991–2001) ACCORDING TO TREATMENT GROUP.\*

CAUSE OF DEATH	SURVEILLANCE GROUP	EARLY-SURGERY GROUP
	no. (%)	
Any	254	242
Cardiovascular causes		
Total	172 (68)	146 (60)
Myocardial infarction	48 (19)	42 (17)
Stroke	12 (5)	9 (4)
Ruptured thoracic aortic aneurysm	11 (4)	5 (2)
Ruptured AAA†	21 (8)	10 (4)
Secondary AAA rupture‡	3 (1)	0
AAA repair§	25 (10)	27 (11)
Other	52 (20)	53 (22)
Cancer		
Total	44 (17)	56 (23)
Lung	13 (5)	20 (8)
Other	31 (12)	36 (15)
Other	37 (15)	38 (16)
Unknown¶	1 (<1)	2 (1)

\*Autopsies were performed in 130 cases (26 percent). AAA denotes abdominal aortic aneurysm.

†In a minority of patients the diameter of the aneurysm exceeded 5.5 cm and the patient had either refused surgery or become unfit for surgery; this was the case for 7 of the 21 in the surveillance group and 3 of the 10 in the early-surgery group.

‡Data are for ruptures after repair of an abdominal aortic aneurysm.

§Repair was considered the underlying cause of death, which occurred within 14 days after repair.

¶Data are for patients who died abroad.

of the aneurysm, there were 4 deaths from an aortoduodenal fistula and 12 deaths from a ruptured thoracic aortic aneurysm after open surgery for repair of an abdominal aortic aneurysm. Of these deaths from aneurysm-related disorders after the repair of an abdominal aortic aneurysm, 15 occurred in the surveillance group and 4 in the early-surgery group, resulting in rates of 9.5 per 1000 patient-years and 1.3 per 1000 patient-years, respectively ( $P < 0.001$ ).

## DISCUSSION

Discussions between clinicians and patients concerning the prognosis of patients with life-threatening disorders, such as abdominal aortic aneurysm, commonly focus on the five-year survival rate. Neither our trial nor the Aneurysm Detection and Management Study demonstrated that early surgical intervention for small abdominal aortic aneurysms improved five-year survival.<sup>1,2</sup> Both trials showed that eventually about three quarters of the patients in the surveillance group undergo aneurysm repair. Does improvement in survival depend on the timing of surgery?

We tested the hypothesis that early elective surgery for small abdominal aortic aneurysms would confer a survival benefit at five years, resulting in 71 percent survival with early surgery and 62 percent survival with surveillance. Only much later in the follow-up period was there weak evidence to suggest a benefit of early elective surgery: nine-year survival was 53 percent in the early-surgery group and 45 percent in the surveillance group. There was no evidence that the number of life-years gained (mean duration of survival) was improved significantly by a policy of early surgery.

We considered the possibility that the small late survival advantage (at nine years) in the early-surgery group could have resulted from the larger size of the aneurysms and the older age of the patients who underwent delayed surgery, which might have led to an increased risk of postoperative death. There was no evidence to support this hypothesis. We also considered the possibility that after the trial had formally ended (in June 1998) and there was no longer the same rigorous surveillance by the trial coordinators, increased rates of aneurysm rupture and of surgery that did not adhere to the trial protocol could have accounted for the survival disadvantage in the surveillance group. Again, there was no strong evidence for these hypotheses. Only eight ruptures occurred between July 1998 and August 2001, mostly in men with aneurysms more than 5.5 cm in diameter or in women; the risk of rupture was four times as high among women as among men. The small increase in the rate of rupture was not significant, and the proportion of all deaths that were caused by the rupture of an unrepaired abdominal aortic aneurysm was very low (6 percent). Although there was increasing use of endovascular or laparoscopic surgery between July 1998 and August 2001, censoring the data of patients at the time of these procedures did not alter the long-term survival advantage of the early-surgery group. Therefore, there must be other explanations for the small late survival advantage in the early-surgery group.

Early surgery could have beneficial biologic or life-style-related effects. In the early-surgery group, patients' perceptions of their health were improved 12 months after randomization.<sup>3</sup> There was evidence of a higher rate of smoking cessation among patients who underwent early surgery, according to an analysis of a subgroup of patients who were recruited early in the trial. In this subgroup, patients who were motivated to stop smoking had much better survival than those who continued smoking. Major surgery is recognized as an important stimulus to smoking cessation, the survival benefits of which do not become apparent for five or more years.<sup>10-12</sup> Smoking cessation results in a particular reduction in mortality from cardiovascular causes,<sup>13</sup> and such an effect is consistent with

**TABLE 3.** CRUDE DEATH RATES AND ADJUSTED HAZARD OF DEATH ACCORDING TO BASE-LINE FACTORS.\*

FACTOR	DEATHS	CRUDE DEATH RATE	ADJUSTED HAZARD RATIO (95% CI)	ADJUSTED P VALUE
	no./no. of patients	no./100 person-yr		
Age			1.06 (1.03–1.08)	<0.001
60–66 yr	124/364	5.4	per 1-yr increment	
67–71 yr	170/363	8.0		
72–76 yr	202/363	9.9		
Sex			1.23 (0.94–1.60)	0.14
Male	411/902	7.7	1.00	
Female	85/188	7.8		
Smoking status			1.25 (1.03–1.53)	0.06
Current smoker	204/404	9.0	1.00	
Former smoker	259/620	6.9		
Never smoked	32/64	8.2		
Diameter of the aneurysm			1.46 (1.15–1.86)	0.002
4.0–4.4 cm	184/427	7.2	per 1-cm increment	
4.5–4.8 cm	151/344	7.3		
4.9–5.5 cm	161/319	8.8		
Ankle–brachial pressure index†			0.52 (0.32–0.84)	0.008
0.2–0.9	202/354	10.4	per 1-unit increment	
0.9–1.1	137/354	6.2		
1.1–1.9	139/354	6.4		
FEV <sub>1</sub>			0.80 (0.70–0.92)	0.002
0.3–1.8 liters	195/377	9.3	per 1-liter increment	
1.9–2.5 liters	161/373	7.2		
2.6–4.4 liters	117/313	5.8		

\*Hazard ratios and P values were determined by Cox proportional-hazards regression analysis and were adjusted for base-line age, sex, smoking status, aneurysm diameter, average of left and right ankle–brachial pressure index, forced expiratory volume in one second (FEV<sub>1</sub>), and use or nonuse of aspirin, as well as for the source of referral (general practice, other clinic, or other), regional center, type of hospital (teaching or district general), and treatment-group assignment. For age, diameter of the aneurysm, ankle–brachial pressure index, and FEV<sub>1</sub>, the patients were divided into three groups of approximately equal size. CI denotes confidence interval.

†Data are for the average of the left and right ankle–brachial pressure indexes.

the smaller number of deaths from myocardial infarction and stroke in the early-surgery group. Moreover, patients who reported that they were former smokers had a lower risk of death than those who reported that they were current smokers. Favorable biologic results of early surgery could include a reduction in circulating interleukin-6, a marker of cardiovascular risk.<sup>14</sup> Two thirds of the 496 deaths were attributed to a cardiovascular cause. The diameter of the aneurysm is an independent marker of the risk of cardiovascular disease.<sup>15</sup> Thus, a combination of lifestyle-related and biologic effects of early repair of an abdominal aortic aneurysm could underlie the long-term survival benefit of early surgery.

Patients with small abdominal aortic aneurysms, like surgeons, need information to guide decisions about the timing of surgery. Early surgery is associated with a significant risk of operative death, although taking this risk could lead to a long-term survival advantage. However, neither five-year survival nor the mean du-

ration of survival is improved by early surgery. Given these findings, patients are likely to inquire about their own risk of death after surgery and the surgeon's audited outcome data. However, there is no prospectively validated, simple means of assessing the risk associated with surgery to repair an abdominal aortic aneurysm that would permit the confident identification of patients with a low risk of death.

Coexisting conditions are important in patients with abdominal aortic aneurysms. Comparison of the patients enrolled in the British and U.S. small aneurysm trials reveals that the British patients had significantly worse lung and renal function (mean FEV<sub>1</sub>, 0.38 liter lower; mean serum creatinine concentration 0.08 mg per deciliter [7.1 μmol per liter] higher) as well as significantly higher systolic blood pressure and serum cholesterol than the U.S. cohort.<sup>2</sup> The overall survival among the British patients was worse than that in the U.S. cohort. Lung and renal function have important effects on the risk of postoperative death<sup>9</sup>

and might affect outcomes in both treatment groups.

Since the publication of the results of our trial,<sup>1,3</sup> surgical practice in much of Europe has changed in favor of refraining from the prophylactic repair of small abdominal aortic aneurysms. Results from the Aneurysm Detection and Management Trial support this change in practice: even with low operative mortality among low-risk patients, early surgery did not improve five-year survival. Unlike the U.S. trial (conducted through Veterans Affairs medical centers), the United Kingdom trial included a considerable proportion of women (17 percent), for whom the threshold of 5.5 cm in diameter for the repair of an aneurysm may have been too high, although our data do not enable us to specify the diameter at which surgery should be recommended. At least for men, surveillance remains a justifiable policy until the threshold of 5.5 cm in diameter is reached.

Supported by grants from the Medical Research Council and the British Heart Foundation to Imperial College and the University of Edinburgh and by the BUPA Foundation.

#### APPENDIX

The following centers and investigators participated in the trial (the number of patients enrolled at each center is given in parentheses): **Southwestern England and South Wales** — Royal United Hospital (29): M. Horrocks (regional trial director), J. Budd; Bristol Royal Infirmary (22): R.N. Baird, P. Lamont; Derriford Hospital (9): D.C. Wilkins, S. Ashley; Dorset County Hospital (9): K. Flowerdew; Frenchay Hospital (7): A. Baker; Gloucester Royal Infirmary (7): J. Earnshaw, B. Heather; Morrilton Hospital (14): C. Gibbons; Neville Hall Hospital (8): R.L. Blackett; New Royal Bournemouth General Hospital (30): S.D. Parvin; North Devon District General Hospital (1): D.R. Harvey; Princess of Wales Hospital (1): R. Hedges; Princess Margaret Hospital (8): D. Finch, D.B. Hocken; Southampton General Hospital (5): G.E. Morris, C.P. Shearman; Southmead Hospital (4): P. Lear; Torbay Hospital (5): P. Lewis; Yeovil District General Hospital (5): R.J. Clarke; **Scotland and Northeastern England** — Edinburgh Royal Infirmary (29): C.V. Ruckley (regional trial director), A.M. Jenkins; Aberdeen Royal Infirmary (57): G.G. Cooper, J. Engeset, R. Naylor; Ayr Hospital (16): G. Stewart; Dryburn Hospital, Durham (10): J. Cumming; Dumfries and Galloway Royal Infirmary (8): J. McCormick; Dunfermline and West Fife Hospital (15): A. Howd, A. Turner; Falkirk and District Infirmary (11): D.R. Harper, R.C. Smith; Freeman Hospital (24): J. Chamberlain, A.G. Jones, M.G. Wyatt; Gartnavel General Hospital (13): A.J. McKay; Ninewells Hospital (36): J.C. Forrester, P. McCollum, P.A. Stonebridge; Perth Royal Infirmary (2): A.I.G. Davidson; Queen Elizabeth Hospital (4): R. Baker; Royal Victoria Infirmary (9): J.L.R. Forsythe, D. Lambert; Royal Northern Infirmary (11): J.L. Duncan; **The Midlands** — Leicester Royal Infirmary (26): P.R.F. Bell (regional trial director), D. Ratliff; Derbyshire Royal Infirmary (33): K.G. Callum, J.R. Nash; Glenfield General Hospital (7): D.S. McPherson; Kettering and General District Hospital (9): R.E. Jenner, R. Stewart; Kidderminster General Hospital (8): P.R. Armitstead; Leicester General Hospital (5): W.W. Barrie; Northampton General Hospital (11): D.B. Hamer, S. Powis; Northern General Hospital (9): L.D. Coen, J. Michaels, C.L. Welsh; Nottingham Queen's Medical Centre (19): B.R. Hopkinson, P.W. Wenham; Royal Hallamshire Hospital (25): J. Beard; Sandwell District General Hospital (3): A. Auckland; Worcester Royal Infirmary (16): J. Black, R. Downing, N.C. Hickey; **London and Southeastern England** — Charing Cross Hospital (46): R.M. Greenhalgh (regional trial director), A.H. Davies, D. Nott; Colchester General Hospital (33): A.R.L. May; Epsom District Hospital (11): R. McFarland; Guy's Hospital (15): P. Taylor; Hillingdon Hospital (12): J.W.P. Bradley, T. Paes; Ipswich Hospital (7): A.E.P. Cameron; Joyce Green Hospital (18): A. McIrvine; Lewisham Hospital (14): D. Negus, P.R. Taylor; Medway Hospital (3): C.M. Butler, R.W. Hoile; Newham General Hospital (11): B. Pardy; Princess Alexandra Hospital (9): J. Ackroyd; Royal Free Hospital (4): G. Hamilton; Royal Hampshire County Hospital (1): R. Lane; Royal Surrey County Hospital (21): A.E.B. Giddings; St. George's

Hospital (14): J. Dormandy, R. Taylor; St. Peter's Hospital (18): M. Thomas; St. Thomas' Hospital (7): K.J. Burnand; University College Hospital (3): M. Adiseshiah; West Middlesex Hospital (1): P. Pattison; West Norwich Hospital (17): J. Clarke, J. Colin; Wexham Park Hospital (4): P. Rutter; Whipps Cross Hospital (15): S. Brearley, M. Pietroni; **Northern England and North Wales** — University Hospital South Manchester (12): C.N. McCollum (regional trial director); Arrowse Park Hospital (9): M.G. Greaney, D. Reilly; Blackburn Royal Infirmary (1): W.G. Paley; Blackpool, Victoria Hospital (16): M. Lambert; Burnley General Hospital (16): R. Hughes; Clatterbridge Hospital (2): S. Blair; Cumberland Infirmary (1): J.E.G. Shand; Grimsby District General Hospital (1): L.A. Donaldson; Hull Royal Infirmary (23): J.M.D. Galloway, A.R. Wilkinson; Leeds District General Hospital (16): M. Gough; Leigh Infirmary (1): J. Mosley; Macclesfield General Hospital (19): D.M. Matheson; Manchester Royal Infirmary (4): M. Walker; Oldham Royal Hospital (4): N. Hulton; Pontefract General Infirmary (5): M.I. Aldoori, C.K. Yeung; Royal Preston Hospital (6): A.R. Hearn; Royal Lancaster Infirmary (18): J. Kelly; Stafford General Hospital (5): D. Durrans, B. Gwynn; Stoke City General Hospital (13): G.B. Hopkinson; Telford General Hospital (18): R.G.M. Duffield; The Infirmary, Rochdale (3): I.G. Schraibman; York District Hospital (7): R. Hall, S.H. Leveson; Glan Clwyd Hospital, Rhyl (26): J. Clark, O. Klimach. **Trial Steering Committee** — R.M. Greenhalgh (chair), J.F. Forbes, E.G.R. Fowkes, J.T. Powell, C.V. Ruckley; **Writing Committee** — J.T. Powell (chair), A.R. Brady, L.C. Brown, E.G.R. Fowkes, R.M. Greenhalgh, C.V. Ruckley, S.G. Thompson; **Trial Monitoring Committee** — P.A. Poole-Wilson (chair), N. Browse, C.J. Bulpitt, K. Burnand, E.C. Coles, A. Fletcher; **Trial Coordinators** — S. Blair, R. Clark, C. Devine, K. Ferguson, S. Hearn, E. Kerracher, S. Logan, A. McCabe, R. Meer-Baloch, M. Mossa, A. Rattray, K. Wilson; **Cotinine Analysis** — R. Mir Hassaine.

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