Selective management of abdominal aortic aneurysms in a prospective measurement program

Peter M. Brown, MD, FRCSC, Ruth Pattenden, Cathy Vernooy, David T. Zelt, MD, FRCSC, and **John R. Gutelius, MD, FRCSC,** *Kingston, Ontario, Canada*

Purpose: The purpose of this study was to clarify the treatment of patients with small abdominal aortic aneurysms (AAAs) less than 5 cm in diameter and those believed to be unfit for operation with AAAs 5 cm diameter or greater.
Methods: Four hundred ninety two patients with AAAs less than 5 cm when first seen were entered in a prospective measurement program by ultrasonography or computed tomography scan (exclusively after 1988) every 6 months. A decision regarding operative fitness was made when the AAA was 5 cm. Patients then underwent operation if fit or continued follow-up if their AAA was larger than 5 cm but they were unfit. A further group of 91 patients with aneurysms 5 cm or greater when first seen but unfit for repair were entered in the prospective measurement program.
Results: In the group with AAAs less than 5 cm at entry, operation was performed in 201 patients as a result of increase in AAA size to 5 cm or greater (157), AAA expansion of more than 0.5 cm in 6 months (24), or for other reasons (20). Of those with AAAs smaller than 5 cm at entry, 291 have not undergone operation at a mean follow-up of 42 months. Expansion was significantly related to aneurysm size at entry and was highest in the 4.5 to 4.9 cm group at 0.7 cm/year. In the group of patients deemed unfit for operation with 5 cm AAAs [as a graduate of the less than 5 cm group at entry (85 patients) or first seen with AAA greater than 5 cm (91 patients)], 10 ruptures have occurred. Of these patients with ruptured AAAs, six had AAAs between 5.0 and 5.6 cm.
Conclusions: Because of the risk of rupture demonstrated in our series in AAAs 5 cm or slightly greater and the progressive increase in expansion to a mean of 0.7 cm/year in those AAAs between 4.5 and 4.9 cm at entry, recommendation for elective operation in patients with AAAs between 4.5 and 5.0 cm should be strongly considered in a fit patient. (J VASC SURG 1996;23:213-22.)

The management of small abdominal aortic aneurysms (AAAs) continues to be controversial. A number of authors have reported studies recommending conservative treatment for those patients with AAAs smaller than 5 cm.[1-4] Scott et al.[5] have suggested, however, that surgical repair is potentially detrimental until the AAA is 6 cm in diameter. In contrast, a subcommittee of the Joint Council of the Society for Vascular Surgery and the North American Chapter of the International Society for Cardiovascular Surgery recommended operation for fit individuals with AAAs greater than 4 cm in diameter.[6] Furthermore it has been suggested not only that operation prolongs life in the patient with AAA between 4 and 5 cm[7] but also that operation is cost-effective in this group.[8] Because of the controversy some authors have suggested that only randomized trials can provide answers, and at present in Great Britain and in the American Veterans Administration trials are underway.[9,10] The purpose of this study is to clarify the treatment of this perplexing group of patients by means of a prospective series of patients with serial radiologic diameter measurements and selective operation.

From the Division of Vascular Surgery, Kingston General Hospital, and Queen's University.
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Reprint requests: Peter M. Brown, MD, FRCSC, Division of Vascular Surgery, Kingston General Hospital, Kingston, Ontario, Canada.

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Table I. Size at entry, rate of expansion, and percent undergoing operation in patients with abdominal aortic aneurysm <5 cm at entry (n = 492)

Entry size (cm)	*Patients entered*	*Mean expansion rate (cm/yr)*	*SD (± cm)*	*Percent undergoing operation*
2.0-2.4	6	0.17	0.11	0
2.5-2.9	26	0.22	0.27	12
3.0-3.4	105	0.33	0.59	20
3.5-3.9	106	0.41	0.53	34
4.0-4.4	162	0.54	0.54	50
4.5-4.9	87	0.71	0.78	68

Table II. Comparison data between nonsurgical and surgical groups in patients with abdominal aortic aneurysm <5 cm at entry (n = 492)

Category	*Overall*	*No operation*	*Operation*
No. of patients	492	291	201
Mean entry age (yr ± SD)	68.4 (7.7)	69 (8.0)	67.1 (6.9)
Mean entry AAA size (cm ± SD)	3.8 (0.6)	3.6 (0.6)	4.1 (0.5)
Mean follow-up (mo ± SD)		42.2 (28)	29 (22)
Mean no. of visits (scans ± SD)	5.2 (3.2)	5.7 (3.4)	4.6 (2.8)
Mean expansion rate (cm/yr ± SD)	0.48 (0.64)	0.23 (0.28)	0.83 (0.75)

PATIENTS AND METHODS

All patients with no symptoms and AAAs smaller than 5 cm on ultrasonography or computed tomography (CT) scan were entered into the prospective measurement program. Those with AAAs 5 cm or greater underwent operation unless they were considered to have too high of a risk for operation, in which case they were monitored as a separate "high risk" group.

Four hundred ninety-two patients with aneurysms less than 5 cm were entered into the study between September 1976 and December 31, 1992. The follow-up was continued until December 31, 1994. An additional 91 patients with AAAs 5 cm or greater in maximum diameter were entered for conservative treatment because of high surgical risk. All patients were studied by either serial ultrasonography or CT scans. Ultrasonography was used primarily between 1976 and 1982, because it was accepted as the standard technique for aneurysm follow-up.[11] Of the 492 patients with AAAs smaller than 5 cm at entry, 380 were monitored exclusively by CT, and 112 were monitored by ultrasonography. Two hundred ten of 492 patients were entered into the study before 1988, when serial CT scanning became standard. Of the 91 patients with AAAs greater than 5 cm at entry, 79 were monitored by CT, and 12 were monitored by ultrasonography.

All patients with AAAs smaller than 5 cm in diameter were entered into the study. No assessment of operability was made initially or during the serial follow-up, unless the criteria for potential operation were met. The criteria for operation for patients deemed to be fit included an increase in AAA size to 5 cm, AAA expansion of more than 0.5 cm in 6 months, development of aneurysm-related symptoms or signs (pain, peripheral emboli), and aortoiliac occlusive disease requiring treatment. Follow-up including patient visits and radiologic measurements was done by the aneurysm study authors. Abdominal aortic measurements were not done by referring physicians. All patients with AAAs reaching 5 cm did not undergo operation. Relative contraindications included recent myocardial infarction, severe angina that was unmanageable surgically or medically, congestive heart failure, severe pulmonary insufficiency, significant residuum from stroke, significant renal failure (creatinine greater than 300 μmol/L), metastatic malignancy, and extreme old age.

The second group of patients was a higher risk population having AAAs equal to or greater than 5 cm and deemed unfit for operation with AAA at that size. This group consisted of 176 patients. Eighty-five were "graduates" from the group of 492 patients with AAAs less than 5 cm at entry and were believed to be at unacceptable risk for operation when their AAA increased to 5 cm or more. A further 91 patients at high risk were entered into the study for conservative treatment with AAAs 5 cm or greater.

Table III. Average lengths of follow-up of patients with abdominal aortic aneurysms < 5 cm at entry (follow-up group, n = 291)

Length of follow-up (mo)	*No. of patients*	*Average length of follow-up (mo ± SD)*
0-12	28	8.9 (2.6)
13-24	63	19.2 (3.9)
25-36	63	30.2 (3.9)
37-48	43	42.5 (3.8)
49-60	31	53.8 (3.9)
61-84	35	71.5 (6.3)
85-108	17	97.1 (6.6)
109-132	10	113.6 (3.9)
133+	1	137

Table IV. Average lengths of follow-up for patients with abdominal aortic aneurysm < 5 cm at entry (operation group, n = 201)

Length of follow-up (mo)	*No. of patients*	*Average length of follow-up (mo ± SD)*
0-12	74	8.0 (2.2)
13-24	41	17.5 (3.4)
25-36	39	29.9 (4.0)
37-48	19	41.9 (3.7)
49-60	16	55.3 (3.8)
61-84	9	75.3 (6.2)
85-108	2	100.5 (6.4)
109-132	1	125

Table V. Expansion of abdominal aortic aneurysm in follow-up and surgical groups with abdominal aortic aneurysm < 5 cm at entry (n = 492)

	Follow-up group (n = 291)		*Surgical group (n = 201)*		
Entry size (cm)	*No. of patients*	*Mean expansion (cm/yr ± SD)*	*No. of patients*	*Mean expansion (cm/yr ± SD)*	*p**
2.0-2.4	6	0.17 (0.11)	0	–	–
2.5-2.9	23	0.15 (0.14)	3	0.81 (0.35)	<0.0001
3.0-3.4	84	0.18 (0.19)	21	0.91 (1.10)	<0.0001
3.5-3.9	70	0.23 (0.22)	36	0.76 (0.74)	<0.0001
4.0-4.4	80	0.27 (0.29)	82	0.81 (0.59)	<0.0001
4.5-4.9	28	0.38 (0.52)	59	0.87 (0.83)	0.003

**p* Values calculated with standard two-sample *t* test comparing differences in expansion between follow-up groups and surgical groups stratified by size at entry.

These patients were entered into the study between October 1977 and December 31, 1993, with follow-up to December 31, 1994. AAA size at entry in this high-risk group was 5.0 to 5.4 cm (130 patients), 5.5 to 5.9 cm (25 patients), 6.0 to 6.4 (18 patients), and 6.5 to 6.9 (3 patients). Follow-up in this group was similar with CT scans every 6 months. The criteria for operation (other than rupture) were less precise than for the group with AAAs smaller than 5 cm but included continued expansion and improvement in patient condition.

All statistical analyses comparing rates of expansion were done with two-sample *t* tests for populations of equal variance. The comparison of patients' chances of undergoing operation, factoring their age and size of aneurysm at entry, was performed with Pearson's χ^2 tests with Yate's continuity correction. The time until rupture was calculated by Kaplan-Meier testing.

RESULTS

Four hundred ninety-two patients were entered into the study with AAAs smaller than 5 cm when first seen. Their AAA size at entry, rate of AAA

Table VI. Comparison of means and medians of expansion rates for abdominal aortic aneurysms <5 cm at entry into study (n = 492)

Entry size (cm)	*Mean expansion rate (cm/yr)*	*SD (± cm/yr)*	*Median expansion rate (cm/yr)*	*First quartile (cm/yr)*	*Third quartile (cm/yr)*
2.5-2.9	0.22	0.27	0.14	0.05	0.27
3.0-3.4	0.33	0.59	0.19	0.05	0.33
3.5-3.9	0.41	0.53	0.26	0.12	0.48
4.0-4.4	0.54	0.54	0.34	0.17	0.72
4.5-4.9	0.71	0.78	0.44	0.21	0.86

Table VII. Significance of the comparison of expansion rates stratified by abdominal aortic aneurysm size at entry (<5 cm at entry study)

	2.5-2.9 cm	*3.0-3.4 cm*	*3.5-3.9 cm*	*4.0-4.4 cm*	*4.5-4.9 cm*
2.5-2.9 cm					
3.0-3.4 cm	0.1953				
3.5-3.9 cm	0.0429	0.1431			
4.0-4.4 cm	0.0016	0.0009	0.0186		
4.5-4.9 cm	0.00105	0.000062	0.000684	0.0252	

Table VIII. Entry age and rates of operation for patients with abdominal aortic aneurysms <5 cm at entry (n = 492)

Age at entry (yr)	*No. of patients*	*Percent undergoing operation*
40-49	4	0
50-59	59	49
60-69	208	45
70-79	184	38
80-89	37	19

expansion, and percent undergoing operation are shown in Table I. Ages, follow-up, and mean expansion rates (492 patients) and the categories of those continuing follow-up without operation (291) and undergoing operation (201) are shown in Table II. A detailed breakdown of the average (mean) length of follow-up for the 291 patients in the group with AAAs smaller than 5 cm at entry and not undergoing operation is shown in Table III. A detailed breakdown of follow-up in the 201 patients with AAAs smaller than 5 cm at entry and undergoing operation is shown in Table IV.

The expansion rates in the follow-up and surgical groups of the 492 patients with AAAs less than 5 cm at entry are shown in Table V. Those undergoing operation had significantly greater expansion rates at all entry sizes, as shown in Table V. Further comparisons of mean and median expansion rates and expansion rates of the first and third quartile for the entire group with AAAs smaller than 5 cm at entry are shown in Table VI. As demonstrated in Table VII, the larger the diameter of the AAA at entry was, the greater the rate of expansion was. Of particular importance is the rate of expansion in the group with AAAs 4.5 to 4.9 cm and a growth rate of 0.7 cm/year, which is significantly greater than that of all other groups.

The details showing the ages of the patients at entry and rate of operation are shown in Table VIII. The chances of patients undergoing operation at 80 years of age or greater at time of entry were significantly less than if they were younger than 80 years of age ($p = 0.005$) at entry. Furthermore if age and size at entry are combined, the chances of requiring operation were even more dramatically different. Patients 70 years of age or greater with AAAs less than 4 cm in diameter are far less likely to ever undergo operation in a selective management program than those younger than 70 years of age with AAAs equal to or greater than 4 cm in diameter, as shown in Table IX.

Of the 492 patients with AAAs less than 5 cm at entry, 291 patients were monitored without operation. Seventy patients were removed from the study after an average follow-up of 47 months for reasons of advanced age (18), refusal of follow-up (16), move to another center (14), terminal malignancy (8), multisystem failure (5), and other reasons (9). A total of 66 deaths occurred in this follow-up group of 291 patients, as shown in Table X. In two of these patients (with last AAA diameter measurements of 3.3 and 4 cm) we were unable to determine a cause of death.

Table IX. A comparison of surgical rates combining patient age at entry (<70 years or ≥70 years) and abdominal aortic aneurysm size at entry (<4 cm or ≥4 cm)

	Operation	*No operation*
Aneurysm ≥4 cm, age <70 yr	92	45
Aneurysm <4 cm, age ≥70 yr	29	81

Pearson's χ^2 test with Yates' continuity correction.
Null hypothesis: The groups are homogeneous.
$\chi^2 = 39.0055$, df = 1, $p = 0.0000000000000000053$.

Table X. Deaths in aneurysm follow-up group with abdominal aortic aneurysms <5 cm at entry (n = 66)

Cardiac	29
COPD	13
Malignancy	9
Stroke	6
Renal	3
Suicide	1
Rupture	1*
Other	2
Unknown	2

COPD, Chronic obstructive pulmonary disease.
*Patient who died of rupture had just had computed tomography scan showing increase in abdominal aortic aneurysm to 5 cm and was awaiting surgical assessment.

Table XI. Reasons for operation in group entering study with abdominal aortic aneurysms <5.0 cm (n = 201)

AAA reached 5 cm	157
Expansions of greater than 0.5 cm in 6 months	24
Symptoms of pain or signs of peripheral emboli	8
Occlusive disease	5
Large iliac aneurysm	4
Patient concern	1
Aortic bleb	1
Rupture	1*

AAA, Abdominal aortic aneurysm.
*This patient entered the study with abdominal aortic aneurysm at 4 cm and at 5 cm was considered unfit for operation. She had rupture when aneurysm was 5.1 cm.

The causes of deaths were determined by autopsy (4), hospital record examination (16), family physician plus immediate family (7), and family physician alone (40). One patient in this group died of a rupture. A CT scan was performed 3 weeks before rupture/death occurred; this CT indicated the AAA was 5 cm. The patient was waiting to be assessed for operation.

The 201 patients undergoing operation in the group with AAAs smaller than 5 cm had operations for the reasons shown in Table XI. The vast majority had operations for an AAA increase to 5 cm or greater. Of the 24 who had an increase in AAA of 0.5 cm or more in 6 months, 19 of 24 had aneurysms between 4.5 and 4.9 cm. Of the 157 patients who underwent operation for an aneurysm greater than 5 cm, 45 were in the delayed "higher" risk group because of being considered unfit for operation when their AAA first increased to 5 cm or greater. One of these operations in the high-risk group was for rupture. This patient entered the study with an AAA at 4 cm, but when her AAA was 5 cm, she was considered unfit for operation because of her renal failure and obesity. She had a rupture (and survived operation) when her AAA was 5.1 cm. The rate of AAA expansion in the patients undergoing operation was significantly greater than that of the follow-up group, as shown in Table V. Four perioperative deaths occurred in the 201 patients, giving a perioperative mortality rate of 2%.

The higher risk group of 176 patients consisted of 85 patients who entered the study with AAAs less than 5 cm and 91 patients entering the study with AAAs 5 or greater and believed to be unsuitable for operation with AAA at that size. Ninety-three patients in this group have not undergone operation with the reasons for extended follow-up shown in Table XII. Fifty of these 93 patients have been removed from follow-up for the following reasons: refusal of follow-up (22), multiple medical problems preventing attendance at clinics (11), advancing age preventing travel (11), terminal malignancy (5), and moving to a distant location (1). In addition, 24 known deaths occurred in the nonoperative group including cardiac (14), rupture (4), malignancy (2), chronic obstructive pulmonary disease (2), cerebrovascular accident (1), and other (1). The average length of follow-up in these patients was 13 months, with details shown in Table XIII. Eighty-three patients in this higher risk group have undergone operation, with rupture as an indication in six patients. Five operative deaths occurred. Three of those 5 patients had rupture for an indication.

The patients with rupture in this higher risk group of 176 patients require further examination. A

Table XII. Reasons for extended follow-up in patients not undergoing operation (group with abdominal aortic aneurysms >5 cm, n = 93)

Reason for extended follow-up	*No. of patients (n = 93)**
Recent MI	6
Severe angina	7
Other cardiac problems	27
Pulmonary insufficiency	23
Stroke	7
Terminal cancer	7
Advanced age	17
Other	
Prostate cancer	2
Depression	1
Moved away	1
Delay on waiting list	1
Operation refused	8
Renal insufficiency	4
Alcoholism	2
Obesity	2

MI, Myocardial infarction.
*Note that each patient may have multiple indications for extended follow-up over 5 cm.

summary of their ages, aneurysm size at last measurement, the intervals between measurement and time of rupture, clinical summary, and confirmation of rupture are shown in Table XIV. In all patients with ruptured AAAs smaller than 6 cm, the interval between CT scan and rupture was 5 months or less (mean 2 months), suggesting that these measurements closely approximate those at rupture. The six patients with rupture smaller than 6 cm are from a group of 155 patients monitored for an average of 15 months. The annual risk of rupture in this group with AAA 5.0 to 5.9 cm is thus 3.4%. The time until rupture in this group of six patients with rupture as calculated by the Kaplan-Meier method is shown in Fig. 1.

DISCUSSION

Widespread agreement has existed for many years that AAA 6 cm or greater should be repaired except in individuals with major coexisting disease, which makes long-term survival unlikely.[12-14] Nevertheless the annual risk of rupture in this group is unknown. Since the report by Szilazyi[13] was published in 1966, AAAs greater than 6 cm have been considered lethal. In our study only 21 patients were in the group with AAAs greater than 6 cm, and little can be added with the small numbers in this study to the natural history of patients with AAAs greater than 6 cm in diameter. The risk of AAA rupture greater than 5 cm has been discussed by a number of authors, all of whom found a significant risk of rupture.[2,3,15-17] These authors did not distinguish, however, between AAAs of 5.0 to 5.9 cm and those 6 cm or greater. In our series seven patients with AAAs between 5.0 and 5.9 cm had rupture, one patient with AAA at 5 cm in the low-risk group awaiting assessment had rupture, and six patients in the higher risk group with AAAs greater than 5 cm had rupture. The annual risk of rupture of 3.4% found in the 155 patients with AAAs between 5.0 and 5.9 cm may have to be considered the lower limit of rupture, because some of the "cardiac" deaths could have been related to ruptured AAA in spite of all attempts at accurate follow-up. The annual risk of rupture in this group outweighs the operative mortality rate of 2% in our center. We cannot recommend conservative treatment for fit individuals with AAAs between 5.0 and 5.9 cm.

Significant information is available on the natural history of AAAs between 4.0 and 4.9 cm. A number of authors did not find any AAA to be smaller than 5 cm at time of rupture.[2,15,17] Other authors had patients with ruptures between 4.0 and 4.9 cm, but the intervals between the last scan and event were either prolonged or unstated,[3,12,16,18] allowing question of the actual size at rupture. No patient in our series of 492 patients entering the study with AAA less than 5 cm had rupture while the AAA was still less than 5 cm. The sole patient in the "low-risk" group had AAA increase to 5 cm and had rupture before undergoing surgical assessment. On the basis of our experience, the risk of rupture in the group of patients with AAAs 4.0 to 4.9 cm is negligible as long as selective operation for rapid expansion is performed. The rate of expansion of AAA was shown to be related to size at entry as shown in Tables I, VI, and VII. The expansion rate in the 4.5 to 4.9 cm AAA group of 0.7 cm per year was significantly greater than that of all other groups. Other authors have also found a relationship between aneurysm size and expansion rate.[2,16,17,19] Limet et al.[16] found a rate of expansion of 0.69 cm/year in a group of 41 patients in a 4.0 to 4.9 cm AAA group, corresponding to our work. Gadowski et al.[19] demonstrated that large aneurysms (greater than 5 cm) that rupture show more rapid expansion than those that remain intact. Our selective policy of operating on those AAAs with expansion of more than 0.5 cm in 6 months may well have contributed to the absence of ruptures in patients while their AAAs were still smaller than 5 cm.

Our work reinforces four central assumptions. First, AAAs greater or equal to 5 cm are indeed prone

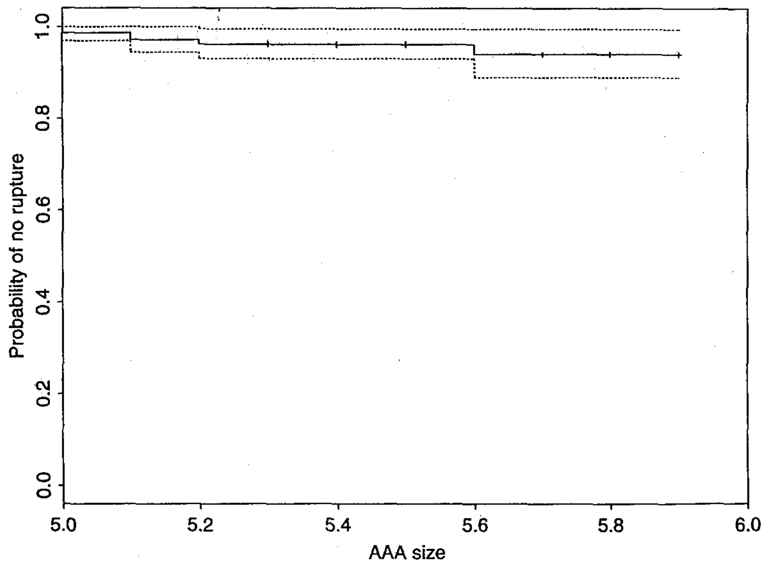

Fig. 1. Kaplan-Meier probability estimate of no rupture on a group of 155 patients monitored with abdominal aortic aneurysm *(AAA)* size between 5.0 and 5.9 cm. The probability estimate of no rupture decreases with increasing AAA size from 98.7% at 5 cm to 94.1% at 5.6 cm.

Table XIII. Average lengths of follow-up for patients with abdominal aortic aneurysms >5 cm at entry (follow-up patients, n = 93)

Length of follow-up (mo)	*No. of patients*	*Average length of follow-up (mo ± SD)*
0-6	38	0.9 (2.1)
7-12	12	9.6 (2.3)
13-24	27	18.4 (3.6)
25-36	11	28.2 (3.1)
37-48	3	40.3 (2.1)
49-60	2	53.5 (2.1)

Table XIV. Ruptures in the group with abdominal aortic aneurysms >5 cm (n = 10)

Size of last computed tomography scan (cm)	*Interval between last measurement and rupture (mo)*	*Age at rupture/death (yr)*	*Clinical summary*	*Confirmation of rupture*
5.0	1	78	Died after operation	At operation
5.0	5	68	Died after operation	Autopsy
5.0	4	76	Died without operation	Autopsy
5.1	0	59	Survived operation	At operation
5.2	0	69	Survived operation	At operation
5.6	1	83	Died after operation	At operation
6.2	8	79	Died at home	Attending physician
6.5	6	86	Died after operation	Autopsy
6.8	1	73	Survived operation	At surgery
7.5	0	83	Died without operation	CT scan

CT, Computed tomography.

to rupture. Second, AAAs smaller than 5 cm are unlikely to rupture, if they are monitored closely and if operation is performed for AAA expansion greater than 0.5 cm in 6 months. Third, AAAs between 4.5 to 4.9 cm expand fairly rapidly with a mean rate of 0.7 cm/year. Fourth, most younger patients (younger than 70 years) with AAAs greater or equal to 4 cm will undergo operation in a selective program within

2 years of entry into the study. Because of these findings, we believe that operation should be offered to fit individuals with aneurysms 4.5 to 4.9 cm in diameter. However, we do not deem it necessary to proceed to operation when the AAA is smaller than 4.5 cm, unless evidence is seen of other factors such as rapid expansion.

Two major prospective trials are currently randomizing patients 50 to 79 years of age with AAA between 4.0 and 5.4 cm[9] or patients 60 to 76 years of age with AAA between 4.0 and 5.5 cm[14] to either operation or conservative treatment. No doubt exists that if these trials are continued, significant important data will be provided. On the basis of our data, however, the necessity of operating on a 76-year-old patient with a 4 cm aneurysm could be questioned. We would also be concerned about the fit 50-year-old patient with a 5.4 cm AAA randomized to follow-up. On grounds of our observations we found that asymptomatic AAAs of 4.5 to 4.9 cm in diameter in fit individuals should receive the same therapeutic considerations as aneurysms of a larger size.

REFERENCES

1. Brown PM, Pattenden R, Gutelius JR. The selective management of small abdominal aortic aneurysms: the Kingston study. J VASC SURG 1992;15:21-7.
2. Glimaker H, Holmberg L, Elvin A, et al. Natural history of patients with abdominal aortic aneurysm. Eur J Vasc Surg 1991;5:125-30.
3. Guirguis EM, Barber GG. The natural history of abdominal aortic aneurysms. Am J Surg 1991;162:481-3.
4. Hallett JW, Naessens JM, Ballard DJ. Early and late outcome of surgical repair for small abdominal aortic aneurysms: a population-based analysis. J VASC SURG 1993;18:684-91.
5. Scott RA, Wilson NM, Kay DN. Is surgery necessary for abdominal aortic aneurysm less than 6 cm in diameter? Lancet 1993;342:1395-6.
6. Hollier LH, Taylor LM, Ochsner J. Recommended indications for operative treatment of abdominal aortic aneurysms. Report of a subcommittee of the joint council of the Society for Vascular Surgery and the North American Chapter of the International Society for Cardiovascular Surgery. J VASC SURG 1992;15:1046-56.
7. Katz DA, Littenberg B, Cronenwett JL. Management of small abdominal aortic aneurysms: early surgery vs watchful waiting. JAMA 1992;268:2678-86.
8. Katz DA, Cronenwett JL. The cost-effectiveness of early surgery versus watchful waiting in the management of small abdominal aortic aneurysms. J VASC SURG 1994;19:980-91.
9. Lederle FA, Wilson SE, Johnson GR, et al. Design of the abdominal aortic aneurysm detection and management study. J VASC SURG 1994;20:296-303.
10. Powell JT, Greenhalgh RM, Ruckley CV, Fowkes FGR. Prologue to a surgical trial. Lancet 1993;342:1473-4.
11. Bernstein EF, Dilley RB, Goldberger LE, Gosink BB, Leopold GG. Growth rates of small abdominal aortic aneurysms. Surgery 1976;80:765-73.
12. Bernstein EF, Chan EL. Abdominal aortic aneurysms in high-risk patients. Outcome of selective management based on size and expansion rate. Ann Surg 1984;200:255-63.
13. Szilagyi DE, Smith RF, DeRusso FJ, Elliott JP, Sherrin FW. Contribution of abdominal aortic aneurysmectomy to prolongation of life. Ann Surg 1966;164:678-99.
14. Fine LG. Abdominal aortic aneurysm. Report of a meeting of physicians and scientists, University College London Medical School. Lancet 1993;341:215-20.
15. Johansson G, Nydahl S, Olofsson P, Swendenborg J. Survival in patients with abdominal aortic aneurysms. Comparison between operative and nonoperative management. Eur J Vasc Surg 1990;4:497-502.
16. Limet R, Sakalihassan N, Albert A. Determination of the expansion rate and incidence of rupture of abdominal aortic aneurysms. J VASC SURG 1991;14:540-8.
17. Nevitt MP, Ballard DJ, Hallett JW. Prognosis of abdominal aortic aneurysms: a population-based study. N Engl J Med 1989;321:1009-14.
18. Cronenwett JL, Murphy TF, Zelenock GB, et al. Actuarial analysis of variables associated with rupture of small abdominal aortic aneurysms. Surgery 1985;98:472-83.
19. Gadowski GR, Pilcher DB, Ricci MA. Abdominal aortic aneurysm expansion rate: effect of size and beta-adrenergic blockage. J VASC SURG 1994;19:727-31.

DISCUSSION

Dr. Jack L. Cronenwett (Lebanon, N.H.). Today the Kingston group has updated their experience with the conservative management of small aneurysms, which they initially presented at this meeting 4 years ago. Now, with nearly double the number of patients, they continue to avoid rupture in aneurysms smaller than 5 cm. Before we adopt this approach, however, which would seem to be appropriate, I would like to ask Dr. Brown to clarify several questions.

First of all, how confident are you that only one of these small aneurysms ruptured, when 24% of these patients were lost to follow-up? Furthermore, if autopsies were not performed in the 10% of patients who died of cardiac causes, could these not have masked cases of aneurysm rupture?

Second, even if we accept that no aneurysms ruptured when less than 5 cm, it is disconcerting that six aneurysms ruptured between 5.0 and 5.2 cm. Thus, there appears to be a fine line between safety and danger. If these aneurysms were known to have reached 5 cm, why were they not repaired? Does this reflect a problem with compliance, which would have to be nearly perfect in this type of strategy?

Third, I note in your manuscript that you have switched from ultrasonography to CT scan surveillance, presumably to increase your accuracy. Do you think that this is cost-effective, or do you think that the implied accuracy of CT scanning actually exceeds the precision of our knowledge of natural history at this point in time?

Finally, rather than applying a uniform size criterion to all patients, we have adopted a selective approach for managing small aneurysms. By using decision analysis techniques, we have concluded that good-risk patients younger than 70 years of age will benefit from repair of 4 to 5 cm aneurysms, if they have other risk factors for aneurysm rupture besides size, such as hypertension, chronic pulmonary disease, or a positive family history. I wonder if you have analyzed any of these other potential risk factors for rupture, or whether you believe that size is the only factor that we should consider?

In summary, the data that we have heard today is really not discordant with our own opinions, using two different techniques, and I think that we are both coming to the same point, that is, that we can safely, selectively treat patients with 4 to 5 cm aneurysms perhaps at the 4.5 cm mark.

Dr. Peter M. Brown (Kingston, Ontario, Canada). As far as the 24% loss to follow-up, there were 70 patients who were deleted from follow-up, after a mean follow-up, however, of almost 5 years. Many of these patients were simply too old and frail, and follow-up was simply impossible. However, of these 70, there was significant follow-up for a long period of time.

I would agree that, in a second point, with the real risk of danger at 5 cm. I think that something dangerous does occur at 5 cm. The patients in that group were in the higher risk group of patients, and they were believed to be unsuitable for surgery. But I agree that 5 cm is too close to danger, particularly when we have an increase of 0.7 cm per year in that 4.5 to 4.9 group. We thus feel that our policy of waiting to 5 cm has to be modified, and we have to go to 4.5 cm to virtually eliminate the risk of rupture while monitoring patients at low risk.

As far as cost effectiveness of CT scans, we went to it about 7 years ago. We have so much better results with our CT scans that we would not consider going back to ultrasonography.

Dr. Hugh G. Beebe (Toledo, Ohio). I am not sure, I may have missed it, did you answer the question about the blood pressure, which was also part of my question? And the other part of my question is, do you have any information about patients in your series who were taking β-blockers?

Dr. Brown. We have not analyzed the information regarding smoking, hypertension, β-blockers, and other risk factors. When we started this study, it was done prospectively, and those factors were not considered important at that time. We found that despite blood pressure, cigarette history, or other factors, by using the criteria of 4.5 cm, it would be safe whether they were hypertensive, smokers, or whatever.

Mr. John H. N. Wolfe (London, U.K.). I have just got one comment to make first, which is Allen Scott's randomized screening program from Chichester of 15,000 patients, where he has a policy of never operating below 6 cm aneurysms, and he is yet to lose a patient with that policy in his screening program. And therefore my follow-up question to you is, have you looked at your data, assuming that your mortality rate was more like the national average? You have gotten outstandingly good results, but if you look to the mortality rate for most of the counties in this room of about 5% or 6% for elective aneurysm repair, would you still be able to suggest that we should be operating on 4.5 cm aneurysms?

Dr. Brown. I'm aware of the operative results in Ontario, with a very large percentage of well-trained vascular surgeons, our overall mortality is 3.8% within Ontario, and so our results are quite consistent throughout the province. There is no doubt, like carotid surgery, that where aneurysm surgery is appropriate is dependent on an operative mortality rate. If a person has a rather higher operative mortality rate than this, they would have to shift the numbers. It may not be quite as clear-cut as in carotid surgery, but I think that analogy also occurs with aneurysm surgery.

Dr. Mellick T. Sykes (San Antonio, Tex.). It sounds as if we may be trying to apply too fine a line to this area of aneurysms between 4 and 4.5 or 5 cm. Depending on the results of your own aneurysm surgery, the mortality may be roughly equivalent between observation and surgery, depending on what risk factors the patient has.

In most areas in which this situation prevails, what we would do is to ask the patient what line he or she is most comfortable in. That is, if patients have had a father or a friend die of a ruptured aneurysm, they are often very anxious to have it repaired. On the other hand, if they have had a friend or relative who has died at surgery, they often will take their chances with Mother Nature and will not want to have anything to do with surgery.

In the Canadian system, with your protocol, is the patient's comfort level with surgery or observation accommodated?

Dr. Brown. I would say that we have a frank and open discussion with these patients. And when they are aware that we followed this number of patients with no loss between 4 and 4.5 cm, we have yet to have a patient who is rushing and urgent for surgery. Most people are quite the opposite. There are occasionally patients, certainly, who have had relatives with problems; however, they have been reassured in our system with a full and open explanation of the results of our study.

Dr. John W. Hallett (Rochester, Minn.). I have one comment and a couple of questions. Your data on the number of patients with rupture in the 5 to 6 cm range are very interesting. In the Rochester, Minnesota, project where we looked at 180 patients, 13 of our 16 ruptured AAAs were more than 6 cm. So these data you present today are new and interesting.

My questions pertain to what happens to the graft once it is placed in the patient with a small aneurysm? Can you give us any information on graft-related complications that occur subsequently and on the survival of these patients?

Dr. Brown. I can give you information on graft-related complications in that in this specific group there are no long-term graft-related complications such as infection or aortoenteric fistula. As far as their long-term survival, I could not comment on that offhand.

I would also note in many of the groups, although 6 cm has classically been used as the borderline for a large aneurysm, when you look at the data, often the 5 to 5.9 cm data are quite unclear, and I really wonder if the 5 cm should be a more modern equivalent of the large abdominal aortic aneurysm.