Surgery versus surveillance for ascending aortic aneurysms in elderly patients

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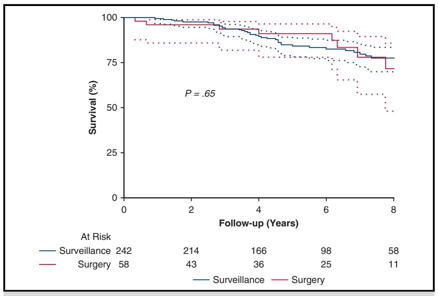
ABSTRACT

Background: Whether elderly patients with aortic root or ascending aortic aneurysm (ATAA) would benefit from the new surgical size threshold of 5.0 cm is unknown. This study aimed to evaluate the natural history of ATAA in elderly patients and to compare long-term outcomes of those who underwent initial surveillance versus surgery.

Methods: Patients age ≥75 years with an ATAA ≥40 mm were categorized into 2 groups: initial surgery and initial surveillance. The primary outcome was all-cause mortality; Kaplan-Meier curves were plotted for survival. A multivariable Cox proportional hazard regression model was used to identify independent predictors of long-term mortality.

Results: The study series comprised 300 patients, including 58 who underwent initial surgery and 242 who received surveillance between July 2010 and September 2022. In the surveillance cohort, the mean aneurysm growth rate was 0.10 cm/year. Comparing surveillance to surgery, at 8 years there was no difference in survival (mean, 77.8 ± 3.4% vs 71.8 ± 9.6%; *P* = .65). For 116 patients with an initial aneurysm diameter ≥5.0 cm, there was no difference in survival between the 2 groups at 8 years (76.5 ± 7.0% vs 68.4 ± 11.3%; *P* = .20). Larger body surface area (hazard ratio [HR], 1.44; 95% confidence interval [CI], 1.09-1.90; *P* = .01) and history of smoking (HR, 2.25; 95% CI, 1.27-3.98; *P* = .01) were identified as predictors of long-term mortality.

Conclusions: In our series of elderly patients with ATAA, there was no difference in 8-year survival between initial surveillance and surgical management, with a high competing risk of nonaortic mortality. Surveillance may be a reasonable alternative to surgery for selected older adults with ATAA <5.5 cm. (JTCVS Open 2024;22:132-43)



Eight-year survival for patients who underwent initial surgery or initial surveillance.

CENTRAL MESSAGE

Elderly patients with aortic root or ascending aortic aneurysm have a high competing risk of nonaortic death, Surveillance may be a reasonable approach for selected older adults with aneurysms <5.5 cm.

PERSPECTIVE

Recent aortic guidelines recommend a surgical threshold of 5.0 cm for patients with aortic root or ascending aortic aneurysm (ATAA) in expert centers with low surgical risk. However, elderly patients with ATAA may have a different natural history, competing risk of nonaortic mortality, and surgical risk profile and might not benefit from earlier intervention.

The goal of management of aortic root or ascending aortic aneurysm (ATAA) is to lower the risk of adverse aortic events over the patient's lifetime, and the treatment recommendation should be based on an assessment of the risk of surgery compared to risk of dissection or rupture during surveillance follow-up. For degenerative ATAAs, the

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Abbreviations and Acronyms

ATAA = aortic root or ascending aortic aneurysm
CI = confidence interval
HR = hazard ratio

2022 American Heart Association/American College of Cardiology guidelines recommend surgery at a maximum aortic diameter of ≥5.5 cm.[1] In addition, for patients with a maximum aortic diameter ≥5.0 cm, the guidelines suggest that surgery is reasonable when performed by experienced surgeons and a multidisciplinary aortic team, reflecting the lower surgical risk observed at high-volume institutions. However, no other qualifiers were recommended based on any patient-specific factors that might change the surgical risk or the cumulative risk of aortic events accrued during follow-up.

For elderly patients, the risk-benefit analysis for prophylactic surgery of ATAAs may be different for a number of reasons. First, the size of the normal thoracic aorta increases with age,[2] and thus the threshold for diagnosis of an aneurysm may be different. Second, the natural history risk of ATAAs has not been well characterized in the elderly; importantly, elderly patients may accrue less long-term risk of adverse aortic events, because they have a higher competing risk of mortality from other causes. Third, advanced age is correlated with more complex comorbidities and associated with higher perioperative risk for surgery, as accounted for in virtually all risk scoring systems.[3,4] Finally, quality of life considerations are paramount for elderly patients, and the potential benefit of prophylactic aortic surgery to prevent aortic events might not be sufficient to offset the potential loss of quality of life and independence following invasive surgery.[5] Therefore, whether elderly patients may benefit from surgical intervention compared to surveillance, particularly at an aneurysm size of 5.0 cm, is unclear.

This study aimed to evaluate the natural history of ATAA in elderly patients and to compare long-term outcome of those treated with an initial surveillance strategy versus those who underwent initial surgery.

METHODS

Patient Population

This retrospective cohort study received Institutional Ethics Research Board approval (protocol 20170400-01H; approved June 29, 2017), and individual patient consent was waived. Between July 2010 and September 2022, 2494 patients were referred to and followed at a dedicated thoracic aortic clinic, the sole referral center for cardiac and aortic surgery in the region. At the study center, the primary indication for intervention for ATAA was a maximal aneurysm diameter of 5.5 cm, unless other risk factors for an adverse aortic event were present. A secondary indication for intervention for ATAA was a maximal aneurysm diameter of 4.5 cm in the setting of concomitant cardiac surgery. Patients were offered surgery if deemed to be of acceptable surgical risk based on standard preoperative assessment of comorbidities, and if surgery was acceptable to the patient after informed consent.

Patients who were age ≥75 years with ATAA ≥40 mm at initial consultation were included and were grouped into those who underwent elective surgery as the initial management strategy (operative cohort) and those who underwent imaging surveillance as the initial management strategy (surveillance cohort). For patients who underwent initial surveillance strategy, selected patients underwent surgery during follow-up if they met the class I indications for surgery at 5.5 cm or had another indication for surgery, such as aortic valve disease or coronary artery disease. Patients with previous aortic dissection in any segment of the aorta were excluded.

Data Collection

Preoperative, intraoperative, and postoperative data for all patients who underwent aortic surgery were collected prospectively in a dedicated database. Clinical and imaging follow-up data were collected through retrospective review of electronic medical records. Imaging parameters were collected retrospectively from computed tomography or echocardiographic reports at the time of referral and during follow-up.

Outcomes

The primary outcome was all-cause mortality during follow-up. Secondary outcomes included in-hospital mortality and perioperative stroke, incidence of acute aortic events, aortic death, elective aortic surgery during follow-up, and aneurysm growth rate. All deaths were adjudicated by reviewing all available clinical, imaging, and autopsy information. Aortic death included "definite" and "possible" aortic death.[6] Definite aortic death was defined as patients with documented aortic pathology causing death (on autopsy, during the operation, or on imaging). Possible aortic death was defined as patients with potential aortic cause but not confirmed on autopsy, or those with sudden death not attributable to other causes. Acute aortic events were defined as aortic dissection, intramural hematoma, or aortic rupture on autopsy, imaging, or direct observation. The mean duration of clinical follow-up was defined as the number of years from the first consultation with the thoracic aortic clinic to the last encounter date on the patient's chart. The mean imaging follow-up was defined as the time between the first and last imaging (via transthoracic echocardiography, computed tomography scan, or magnetic resonance imaging).

Statistical Analysis

Categorical variables are reported as counts and percentages and compared with the χ^2 test or Fisher exact test for variables with low counts (n < 5). Continuous variables are reported as mean ± standard deviation and compared using the Student *t* test if normally distributed or the Wilcoxon rank-sum test if skewed. Kaplan-Meier curves were plotted for survival; differences in survival rates between the groups were tested using the log-rank test. Cumulative incidence function curves for aortic death were plotted using the Gray test of equality, accounting for a competing risk of nonaortic mortality.

A multivariable backward-stepwise Cox proportional hazard regression model was used to identify independent predictors of long-term mortality, which included variables with $P \leq .1$ on univariable analysis, including body surface area and history of smoking (defined as previous or active smoking), as well as prespecified variables including sex, initial aneurysm diameter, aneurysm involvement of aortic root and arch, annual growth rate, and need for surgical intervention on follow-up. Results are reported as hazard ratio (HR) with 95% confidence interval (CI).

A *P* value of < .05 was considered to indicate statistical significance. Missing data were random and infrequent (<2%) and thus were not

TABLE 1. Baseline characteristics of the surveillance versus the surgical cohort

Characteristic	Surveillance cohort (N = 242)	Surgical cohort (N = 58)	*P* value
Demographics			
Male sex, n (%)	157 (64.9)	29 (50.0)	.04
Age at consult, y, mean ± SD	80.0 ± 3.9	79.8 ± 3.3	.71
BSA, m^2, mean ± SD	1.9 ± 0.6	1.8 ± 0.2	.38
Comorbidities, n (%)			
Coronary artery disease	40 (16.5)	19 (32.8)	.01
Hypertension	187 (77.3)	39 (67.2)	.11
Diabetes	28 (11.6)	7 (12.1)	.92
Dyslipidemia	121 (50.0)	22 (37.9)	.10
COPD	16 (6.6)	8 (13.8)	.07
Chronic renal disease	13 (5.4)	4 (6.9)	.65
History of smoking	91 (37.6)	25 (43.1)	.44
Cerebrovascular disease	36 (14.9)	14 (24.1)	.09
Previous PCI	18 (7.4)	4 (6.9)	.89
Previous cardiac surgery	26 (10.7)	1 (1.7)	.03
Previous aortic surgery	4 (1.7)	0 (0.0)	.32
Bicuspid aortic valve	20 (8.3)	11 (19.0)	.02
Medication use, n (%)			
Beta blockers	99 (40.9)	36 (62.1)	<.01
ACEi	73 (30.2)	20 (34.5)	.52
ARB	42 (17.4)	7 (2.3)	.33
Calcium channel blockers	61 (25.2)	18 (31.0)	.37
Statins	135 (55.8)	33 (56.9)	.88
Aortic disease involvement, n (%)			
Aortic root	73 (30.2)	24 (41.4)	.10
Ascending aorta	231 (95.5)	55 (94.8)	.84
Aortic arch	12 (5.0)	21 (36.2)	<.01
Aneurysm characteristics			
Primary aneurysm location, n (%)			.30
Root	22 (9.1)	8 (13.8)	–
Ascending aorta	219 (90.5)	49 (84.5)	–
Arch	1 (0.4)	1 (1.7)	–
Initial aneurysm diameter, cm, mean ± SD	4.7 ± 0.5	5.5 ± 1.0	<.01
Initial aneurysm diameter ≥5.0 cm, n (%)	75 (31.0)	41 (70.7)	<.01
Last aneurysm diameter, cm, mean ± SD	5.0 ± 0.6	–	–
Initial aortic size index, cm/m^2, mean ± SD	2.6 ± 0.4	3.1 ± 0.7	<.01
Last aortic size index, cm/m^2, mean ± SD	2.7 ± 0.5	–	
Duration of imaging follow-up, y, mean ± SD	4.3 ± 2.9	–	–
Growth rate, cm/y, mean ± SD	0.10 ± 0.19	–	–
Surgery on follow-up, n (%)	30 (12.4)	–	–

BSA, Body surface area; *COPD*, chronic obstructive pulmonary disease; *PCI*, percutaneous coronary intervention; *ACEi*, angiotensin-converting enzyme inhibitor; *ARB*, angiotensin 2 receptor blocker.

replaced with imputation, and the sample size was allowed to vary based on analyses. Analyses were performed with SAS version 9.4 (SAS Institute) and Prism 10.1.2 (GraphPad Software).

RESULTS

Patient Characteristics

A total of 300 patients with ATAA who were age ≥75 years at the time of initial consultation between July 2010 and September 2022, were included, of whom 58 underwent initial elective surgery and 242 received conservative management, including management of risk factors and regular imaging surveillance (Figure E1). In the surgical cohort, 44.8% of patients (n = 26) underwent aortic surgery for a primary aortic indication. All patients who underwent aortic surgery for an aneurysm <5.5 cm also had concomitant valvular or coronary disease meeting the criteria for intervention. The baseline characteristics of the surgical and surveillance cohorts are shown in Table 1. The mean patient age was 80.0 ± 3.9 years for the surveillance cohort

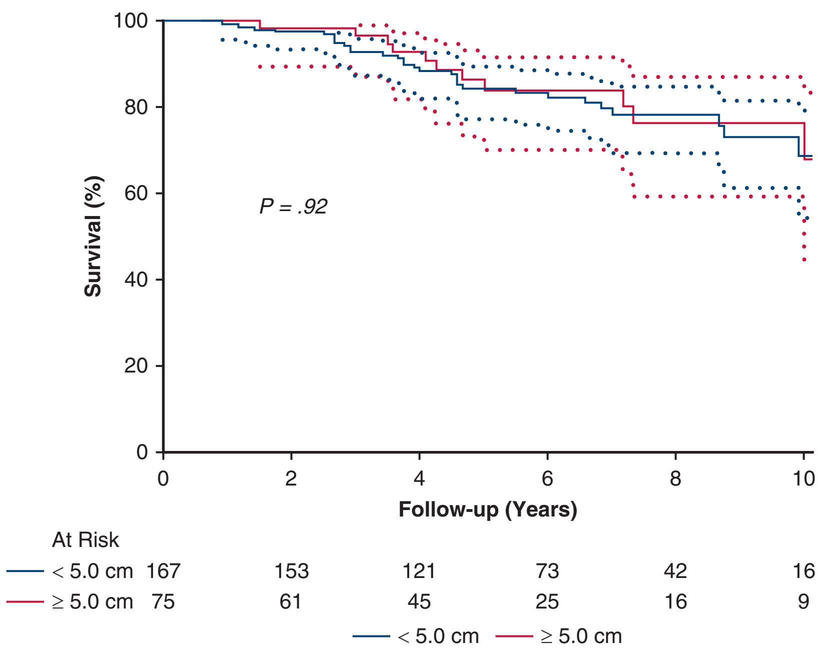

FIGURE 1. Ten-year survival for patients with aneurysm size 4.0 to 4.9 cm and patients with aneurysm size ≥5.0 cm in the surveillance cohort. The *dotted line* indicates 95% confidence interval.

and 79.8 ± 3.3 years for the surgical cohort ($P = .71$). Compared to the surveillance cohort, the surgical cohort had fewer male patients and higher rates of coronary artery disease, bicuspid aortic valve disease, and aneurysmal arch disease ($P < .02$ for all). The surgical patients also had a larger initial maximal aneurysm diameter (mean 5.5 ± 1.0 mm vs 4.7 ± 0.5 mm; $P < .01$) and a higher prevalence of initial aneurysm size ≥5.0 cm (70.7 vs 31.0%; $P < .01$). There was no difference in the location of the primary aneurysm between the 2 groups ($P = .30$).

Surveillance Cohort: Natural History

Of the 242 patients in the surveillance cohort, 167 had an initial aneurysm diameter of 4.0 to 4.9 cm, and 75 had an initial aneurysm diameter ≥5.0 cm (Table E1). Compared to patients with aneurysms of 4.0 to 4.9 cm, patients with aneurysms ≥5.0 cm were older and had more chronic kidney disease, beta-blocker and calcium channel blocker use, and aneurysmal arch disease ($P < .04$ for all).

The mean duration of imaging follow-up for the surveillance cohort was 4.3 ± 2.9 years. Two patients were lost to follow-up (1.2%). The mean aneurysm growth rate was 0.10 cm/year and was higher for patients with an initial aneurysm size ≥5.0 cm compared to those with an aneurysm size of 4.0 to 4.9 cm (0.17 ± 0.31 cm/year vs 0.07 ± 0.11 cm/year; $P < .01$). The incidence of aortic surgery at follow-up also was higher for patients with an initial aneurysm size ≥5.0 cm (24.0 vs 7.2%; $P < .01$). Of the 30 aortic surgeries performed in surveillance patients during follow-up, 19 (63.3%) were done electively

TABLE 2. Intraoperative characteristics and incidence of postoperative stroke and mortality for patients who underwent surgery on presentation or during follow-up (N = 58)

Characteristic	Value, n (%)
Urgency	
Elective	54 (93.1)
Urgent	3 (5.2)
Emergent	1 (1.7)
Primary aortic indication (diameter ≥5.5 cm)	26 (44.8)
Aortic root intervention	14 (24.1)
Aortic valve repair	28 (48.3)
Aortic valve replacement	18 (31.0)
Ascending aortic replacement	57 (98.3)
Hemiarch replacement	29 (50.0)
Total arch replacement	2 (3.5)
TEVAR	1 (1.7)
CABG	13 (22.4)
Mitral valve intervention	6 (10.3)
Postoperative outcomes	
Stroke	1 (1.7)
In-hospital mortality	0 (0.0)

TEVAR, Thoracic endovascular aortic repair; *CABG*, coronary artery bypass grafting.

after reaching a size threshold of 5.5 cm, 10 (33.3%) were performed for nonaortic indications, and 1 (3.3%) was performed emergently for acute intramural hematoma. At 10 years, there was no difference in mean survival between patients with aneurysms of 4.0 to 4.9 cm and those with aneurysms ≥5.0 cm (68.7 ± 6.4% vs 68.0 ± 10.1%; P = .92) (Figure 1). Of the 43 patients who died during follow-up in the surveillance cohort, 34 (79.1%) died from noncardiac causes, 4 (9.3%) died of cardiac but nonaortic causes, and 5 (11.6%) represented a definite or possible aortic death. One patient developed acute intramural hematoma during follow-up and was successfully treated with surgery.

For patients in the surveillance cohort with an initial aneurysm diameter of 5.0 to 5.5 cm, 61.3% (n = 46) reached aneurysm diameter of ≥ 5.5 cm during the follow-up period, of which 34.8% (n = 16) underwent surgery, and 65.2% (n = 30) did not. At 8 years, there was no difference in survival between those who had surgery on follow-up versus those who did not (76.6 ± 8.4% vs 78.1 ± 11.7%; P = .75).

Surgical Cohort: Perioperative Outcomes

In the initial surgery cohort, 54 patients (93.1%) underwent elective surgery was performed for of the patients, while 5.2% (n = 3) were urgent, and 1.7% (n = 1) were emergent for a rapidly expanding aneurysm (Table 2). The most common aortic procedures were ascending aorta replacement (n = 57; 98.3%) and hemiarch replacement (n = 29; 50.0%); 22.4% of patients underwent concomitant coronary artery bypass grafting, and 10.3% underwent concomitant mitral valve intervention. There was no in-hospital mortality, and stroke occurred in 1 patient.

Surgery Versus Surveillance as Initial Management Strategy

The mean duration of clinical follow-up for the entire cohort was 5.8 ± 3.2 years. At 8 years, there was no difference between the surveillance and surgical cohorts in mean survival (77.8 ± 3.4% vs 71.8 ± 9.6%; P = .65) or mean cumulative incidence of aortic death (4.1 ± 1.7% vs 2.4 ± 2.4%; P = .57) (Figure 2). Of the 51 deaths that occurred during follow-up in the entire cohort, 37 (72.5%) were noncardiac deaths, 7 (13.7%) were cardiac but nonaortic deaths, and 7 (13.7%) were definite or possible aortic deaths.

Among the 116 patients with an initial maximal aneurysm diameter ≥5.0 cm, 75 (64.7%) underwent initial surveillance and 41 (35.3%) underwent initial surgery. The surgical cohort had less patients with previous cardiac surgery, more arch involvement, and higher mean initial aneurysm diameter (all P < .03) (Table 3). For patients in the surveillance cohort, the mean aneurysm growth rate was 0.17 cm/year, and 18 patients (24.0%) underwent aortic surgery during follow-up. At 8 years, there was no difference in survival between initial the surveillance and initial surgery cohorts (76.5 ± 7.0% vs 68.4 ± 11.3%; P = .20) (Figure 3).

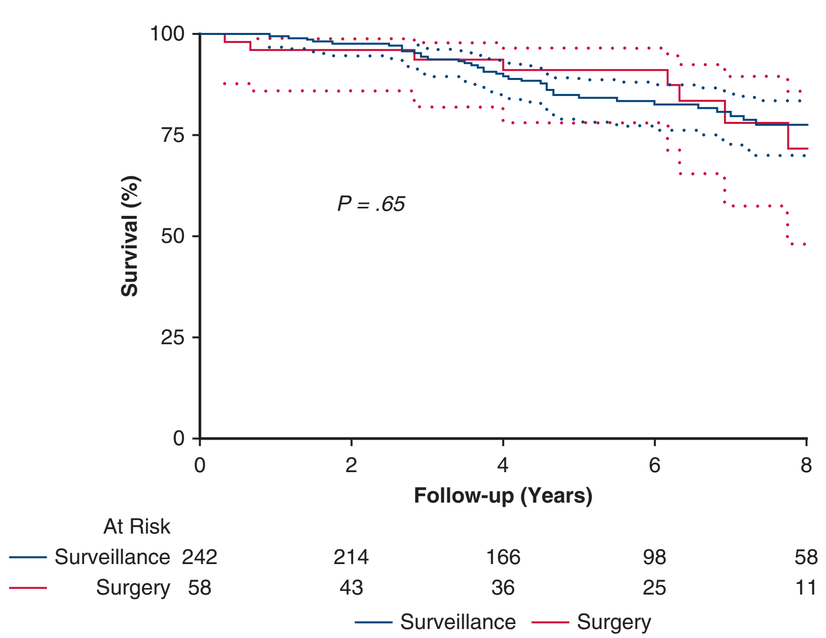

FIGURE 2. Eight-year survival for patients who underwent initial surgery versus patients who received initial surveillance. The *dotted line* indicates 95% confidence interval.

TABLE 3. Baseline characteristics of patients with aneurysm ≥5.0 cm in the surgical versus surveillance cohort

Characteristic	Surveillance cohort (N = 75)	Surgery cohort (N = 41)	*P* value
Demographics			
Male sex	43 (57.3)	20 (48.8)	.38
Age at consult, y, mean ± SD	81.3 ± 4.1	80.1 ± 3.5	.12
BSA, m^2, mean ± SD	1.8 ± 0.2	1.8 ± 0.2	.38
Comorbidities, n (%)			
Coronary artery disease	15 (20.0)	12 (29.3)	.26
Hypertension	58 (77.3)	30 (73.2)	.62
Diabetes	5 (6.7)	4 (9.8)	.55
Dyslipidemia	35 (46.7)	16 (39.0)	.43
COPD	8 (10.7)	8 (19.5)	.19
Chronic renal disease	8 (10.7)	3 (7.3)	.56
History of smoking	27 (36.0)	20 (48.8)	.18
Cerebrovascular disease	13 (17.3)	10 (24.4)	.36
Previous PCI	8 (10.7)	1 (2.4)	.11
Previous cardiac surgery	12 (16.0)	1 (2.4)	.03
Previous aortic surgery	3 (4.0)	0 (0.0)	.19
Bicuspid aortic valve	7 (9.3)	5 (12.2)	.63
Medication use, n (%)			
Beta blockers	38 (50.7)	25 (61.0)	.29
ACEi	28 (37.3)	14 (34.2)	.73
ARB	12 (16.0)	4 (9.8)	.35
Calcium channel blockers	26 (34.7)	13 (31.7)	.75
Statins	40 (53.3)	20 (48.8)	.64
Aortic disease involvement, n (%)			
Aortic root	20 (26.7)	16 (39.0)	.17
Ascending aorta	74 (98.7)	41 (100.0)	.46
Aortic arch	8 (10.7)	20 (48.8)	<.01
Aneurysm characteristics			
Primary aneurysm location, n (%)			.60
Root	4 (5.3)	4 (9.8)	–
Ascending aorta	70 (93.3)	36 (87.8)	–
Arch	1 (1.3)	1 (2.4)	–
Initial aneurysm diameter, cm, mean ± SD	5.3 ± 0.4	5.9 ± 0.9	<.01
Last aneurysm diameter, cm, mean ± SD	5.6 ± 0.5	–	–
Initial aortic size index, cm/m^2, mean ± SD	2.9 ± 0.4	3.3 ± 0.6	<.01
Last aortic size index, cm/m^2, mean ± SD	3.1 ± 0.5	–	
Duration of imaging follow-up, y, mean ± SD	3.3 ± 2.9	–	–
Growth rate, cm/y, mean ± SD	0.17 ± 0.31	–	–
Surgery on follow-up, n (%)	18 (24.0)	–	–

BSA, Body surface area; *COPD*, chronic obstructive pulmonary disease; *PCI*, percutaneous coronary intervention; *ACEi*, angiotensin-converting enzyme inhibitor; *ARB*, angiotensin 2 receptor blocker.

Predictors of All-Cause Mortality

The Cox proportional hazard model identified greater body surface area (HR, 1.44; 95% CI, 1.09-1.90; *P* = .01) and history of smoking (HR, 2.25; 95% CI, 1.27-3.98; *P* = .01) as predictors of long-term mortality (Table 4). Conversely, aneurysm location, growth rate, and diameter (including initial aneurysm diameter or maximal aneurysm diameter), as well as aortic surgery on follow-up, were not predictive of long-term mortality.

DISCUSSION

The natural history of ATAA and a comparison of surgical and surveillance outcomes specifically for elderly patients has not yet been reported in the literature. In the present study, for patients age ≥75 years managed in adherence with a guideline-recommended surgical threshold of 5.5 cm and standard screening for appropriateness for surgery, we report a size-dependent aneurysm growth rate with low aortic death rates in the surveillance cohort, low surgical risk for selected elderly patients who underwent

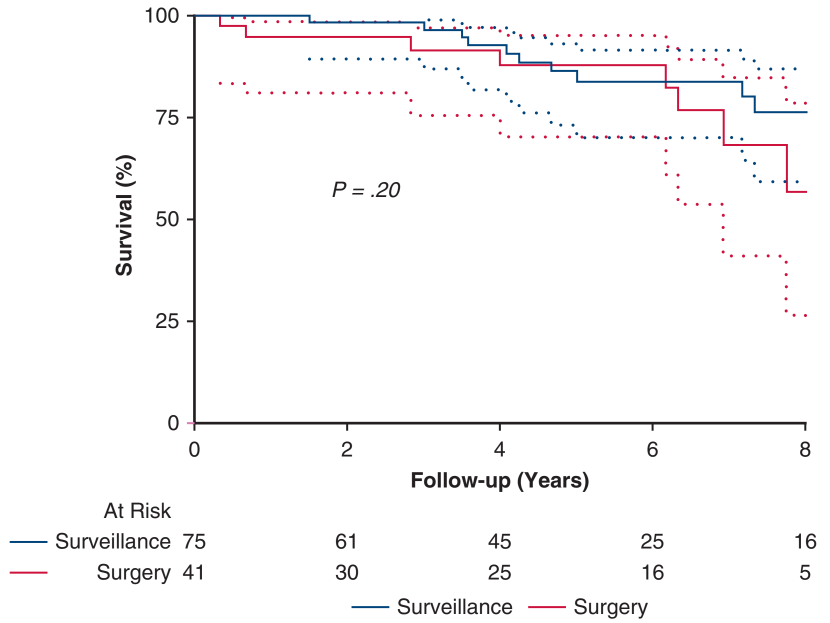

FIGURE 3. Eight-year survival for patients with an initial aneurysm diameter of ≥5.0 cm who received initial surveillance versus those who underwent initial surgery. The *dotted line* indicates 95% confidence interval.

aortic surgery, and, importantly, similar survival at 10 years with either initial surveillance strategy or initial surgical management (Figure 4).

In elderly patients, when followed in a dedicated aortic clinic in which surgical decisions are based on guideline recommendations and clinical expertise, patients selected to undergo surveillance did not experience excess death, and patients selected to undergo surgery had safe outcomes, with long-term survival similar to that in patients followed for smaller aneurysms. On the other hand, competing risks of nonaortic death are high, and aortic surgery at a lower size threshold of 5.0 cm might not lead to improved outcomes. In our study, >85% of patients treated with an initial surveillance strategy died of nonaortic-related causes over a mean follow-up of 5.8 years. In addition, aneurysm size and aortic surgery on follow-up were not predictive of long-term survival. Current studies on the natural history of thoracic aortic aneurysm were based on a cohort with a mean age of 60 to 67 years, with few patients older than 75 years.[7-9] Wu and colleagues[6] recently reported advanced age as a predictor of adverse aortic events in conjunction with aneurysm size; however, the age of the patients with adverse aortic events was the age at which the event occurred, not the age at initial consultation. In this regard, older patients in that cohort had more time to accrue aortic events compared to the younger cohort. Therefore, elderly patients with an initial aneurysm size <5.5 cm may be well served with an initial surveillance strategy if other risk factors for adverse aortic events are absent.

For elderly patients with small to moderate proximal thoracic aortic aneurysms (4.0 to 4.9 cm), the growth rate, need for aortic surgery, and incidence of aortic-related death on follow-up were low. This is consistent with a growth rate of 0.04 to 0.06 cm/year for patients with aneurysms <5.0 cm at referral centers reported in one study,[10] as well as an average growth rate of 0.01 cm/year among a non-referral-based patient population with a median age of 74 years reported in a recent study by Weininger and colleagues.[11] For patients with abdominal aortic aneurysm, elderly status (≥80 years) and initial aneurysm size <5.0 cm were associated with slower aneurysm growth, and octogenarians were significantly less likely to reach the surgical size threshold.[12] Furthermore, octogenarians with abdominal aortic aneurysm who reached the surgical size threshold were significantly less likely to undergo repair. Therefore, for elderly patients with ATAA, a discussion with the patient regarding the benefits and risks of surgery may be warranted at an early phase to determine whether the cost of inconvenience associated with ongoing imaging follow-up would be beneficial.

Postoperative mortality and stroke for elderly patients who underwent surgery were low; however, patient selection was important to achieving good outcomes. Reported outcomes for elderly patients undergoing thoracic aortic surgery are variable in the literature, with some studies reporting comparable outcomes to younger cohorts but

TABLE 4. Predictors of long-term mortality on Cox proportional hazard analysis

Predictor	Univariable	*P* value	Multivariable	*P* value
Body surface area	1.45 (1.10-1.90)	.01	1.44 (1.09-1.90)	.01
History of smoking	2.41 (1.39-4.22)	<.01	2.25 (1.27-3.98)	.01
Age at consultation	1.07 (1.00-1.16)	.06		
Male sex	0.76 (0.44-1.32)	.76		
Coronary artery disease	0.68 (0.32-1.45)	.32		
Hypertension	0.65 (0.34-1.23)	.19		
Diabetes	1.74 (0.84-3.57)	.13		
Dyslipidemia	0.98 (0.56-1.70)	.94		
COPD	1.83 (0.78-4.31)	.17		
Chronic kidney disease	2.08 (0.82-5.24)	.12		
Cerebrovascular accident	0.84 (0.38-1.87)	.67		
Previous PCI	1.09 (0.39-3.02)	.87		
Previous cardiac surgery	0.92 (0.36-2.31)	.85		
Bicuspid aortic valves	0.54 (0.17-1.74)	.30		
Beta-blockers use	1.03 (0.59-1.79)	.92		
ACEi use	1.31 (0.74-2.32)	.35		
ARB use	0.66 (0.29-1.47)	.31		
Calcium channel blockers use	0.75 (0.39-1.44)	.39		
Statin use	0.66 (0.38-1.14)	.14		
Root involvement	0.86 (0.47-1.57)	.62		
Ascending aorta involvement	0.79 (0.19-3.24)	.79		
Arch involvement	1.06 (0.45-2.48)	.90		
Initial aneurysm diameter	1.13 (0.73-1.77)	.58		
Initial aortic size index	0.96 (0.54-1.80)	.96		
Last aneurysm diameter	1.09 (0.73-1.60)	.68		
Last aortic size index	1.00 (0.59-1.68)	.99		
Growth rate	2.19 (0.61-7.93)	.23		
Initial surgical intervention	0.94 (0.41-2.00)	.86		
Surgical intervention on follow-up	0.63 (0.25-1.59)	.33		

COPD, Chronic obstructive pulmonary disease; *PCI*, percutaneous coronary intervention; *ACEi*, angiotensin-converting enzyme inhibitor; *ARB*, angiotensin 2 receptor blocker.

others reporting elevated mortality and morbidity.[13,14] Selection bias is an important limitation for all of these studies and is difficult to control for; therefore, consideration for institutional experience, nuanced preoperative risk assessment, and shared decision making processes with the patient and family discussing not only the clinical outcomes, but also potential loss of independence and quality of life, are particularly important for this patient cohort.

Despite being one of the larger studies of elderly patients with ATAA, this study has several limitations, including its single-center design, which limits the generalizability of our findings. The limited sample size also may have insufficient power to detect statistical differences in outcomes over the follow-up period. Although the aortic clinic is the only specialized referral clinic in the region, it is possible that some patients were missed owing to lack of referral or to direct referral to another surgeon. Given the study's nonrandomized nature, it is difficult to adjust for differences in baseline characteristics between the comparison groups; in addition, risk factors included in the multivariable regression model included only those collected by the cardiac surgery and cardiac surgery intensive care unit research database; other variables, such as frailty, were not recorded and therefore not included. There also was a limited number of patients with bicuspid valve with aortic root phenotype, and thus the impact of this on the natural history of our patient cohort could not be assessed. Finally, long-term outcomes in this study only included survival and aortic-related

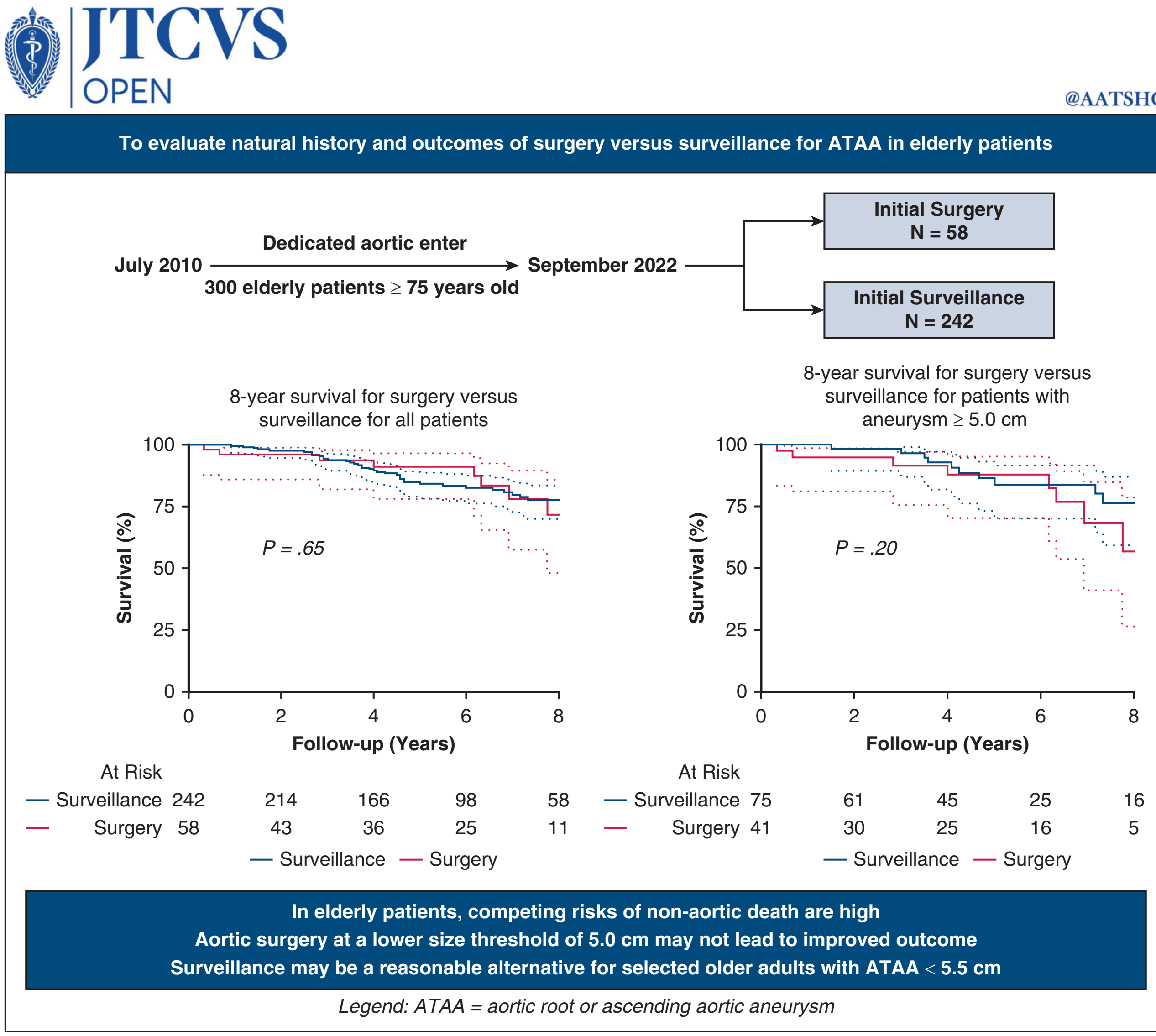

FIGURE 4. Graphical abstract. *ATAA*, Aortic root or ascending aortic aneurysm.

death; other morbidities or quality of life for the patients was not surveyed.

CONCLUSIONS

For elderly adults with aortic root or ascending aortic aneurysm, even with low surgical risk, there was no difference in 8-year survival and freedom from aortic death between an initial surveillance strategy versus surgical management, while the competing risk of mortality was high. Therefore, surveillance may be a reasonable alternative to surgery for selected older adults with proximal aortic aneurysms <5.5 cm. On the other hand, surgery can be performed safely in selected elderly patients with proximal aortic aneurysms ≥5.5 cm.

Conflict of Interest Statement

Dr Boodhwani reported consulting fees from Gore Medical and Edwards Lifesciences. All other authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

References

1. Isselbacher EM, Preventza O, Hamilton Black J III, et al, Peer Review Committee Members. 2022 ACC/AHA Guideline for the Diagnosis and Management of Aortic Disease: a report of the American Heart Association/American College of Cardiology Joint Committee on Clinical Practice Guidelines. *Circulation*. 2022; 146:e334-e482.

2. Erbel R, Eggebrecht H. Aortic dimensions and the risk of dissection. *Heart*. 2006; 92:137-142.
3. Shahian DM, O'Brien SM, Filardo G, et al; Society of Thoracic Surgeons Quality Measurement Task Force. The Society of Thoracic Surgeons 2008 cardiac surgery risk models: part 1–coronary artery bypass grafting surgery. *Ann Thorac Surg*. 2009;88(1 Suppl):S2-S22.
4. Nashef SA, Roques F, Sharples LD, et al. EuroSCORE II. *Eur J Cardiothorac Surg*. 2012;41:734-744.
5. Oda K, Hata M, Kawatsu S, et al. Quality of life in elderly patients following thoracic aortic surgery. *Jpn J Thorac Cardiovasc Surg*. 2004;52:515-523.
6. Wu J, Zafar MA, Liu Y, et al. Fate of the unoperated ascending thoracic aortic aneurysm: three-decade experience from the Aortic Institute at Yale University. *Eur Heart J*. 2023;44:4579-4588.
7. Davies RR, Kaple RK, Mandapati D, et al. Natural history of ascending aortic aneurysms in the setting of an unreplaced bicuspid aortic valve. *Ann Thorac Surg*. 2007;83:1338-1344.
8. Sonsino A, Ellauzi H, Ziganshin BA, Zafar MA, Elefteriades JA. Rapid growth of thoracic aortic aneurysm: reality or myth? *J Thorac Cardiovasc Surg*. 2024;167: 1206-1213.
9. Wu J, Zafar MA, Li Y, et al. Ascending aortic length and risk of aortic adverse events: the neglected dimension. *J Am Coll Cardiol*. 2019;74:1883-1894.
10. Gagné-Loranger M, Dumont É, Voisine P, Mohammadi S, Dagenais F. Natural history of 40-50 mm root/ascending aortic aneurysms in the current era of dedicated thoracic aortic clinics. *Eur J Cardiothorac Surg*. 2016;50:562-566.
11. Weininger G, Mori M, Yousef S, et al. Growth rate of ascending thoracic aortic aneurysms in a non-referral-based population. *J Cardiothorac Surg*. 2022;17:14.
12. Rockley M, Radonjic A, LeBlanc D, Jetty P. The futility of surveillance for old and small aneurysms. *J Vasc Surg*. 2020;72:162-170.e1.
13. Wanamaker KM, Hirji SA, Del Val FR, et al. Proximal aortic surgery in the elderly population: is advanced age a contraindication for surgery? *J Thorac Cardiovasc Surg*. 2019;157:53-63.
14. Guo MH, Tran D, Ahmadvand A, et al. Perioperative and long-term morbidity and mortality for elderly patients undergoing thoracic aortic surgery. *Semin Thorac Cardiovasc Surg*. 2020;32:644-652.

Key Words: aortic root aneurysm, ascending aortic aneurysm, elderly, guideline

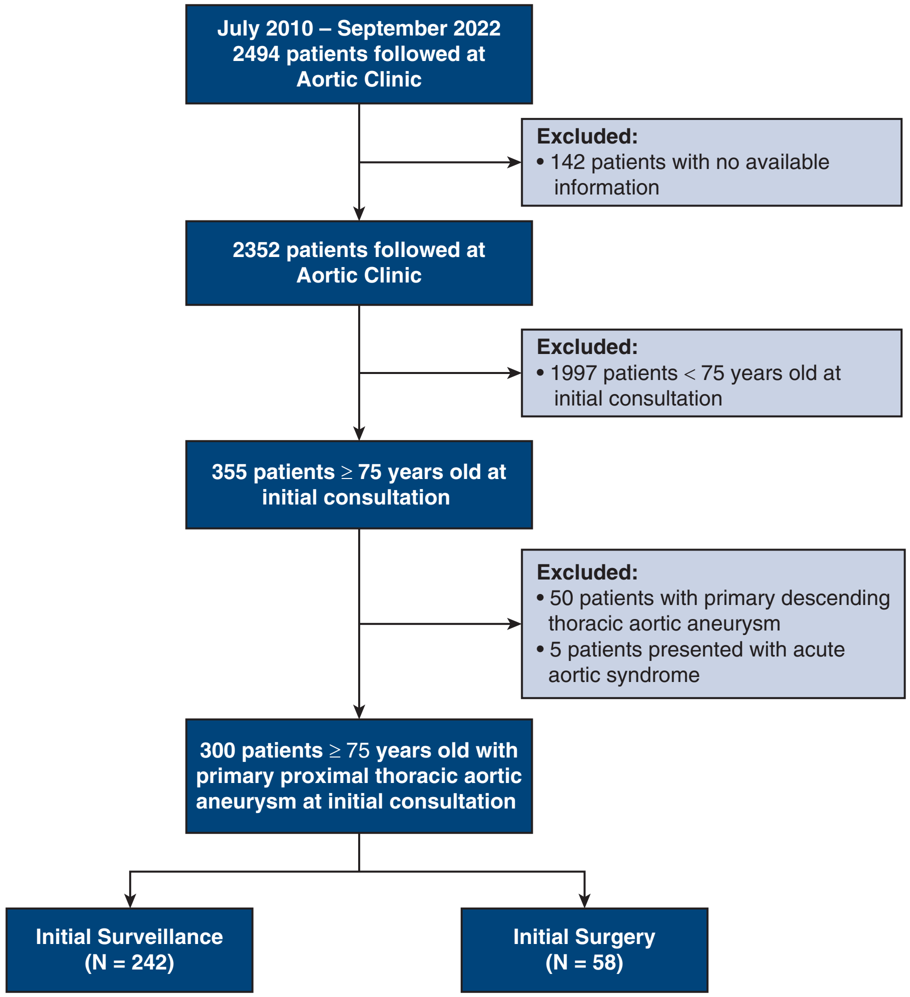

FIGURE E1. Study flowchart.

TABLE E1. Baseline characteristics of patients in the surveillance cohort by aneurysm size

Characteristic	4.0-4.9 cm (N = 167)	≥5.0 cm (N = 75)	*P* value
Demographics			
Male sex, n (%)	114 (68.3)	43 (57.3)	.10
Age at consult, y, mean ± SD	79.4 ± 3.7	81.3 ± 4.1	<.01
BSA, m^2, mean ± SD	1.9 ± 0.7	1.8 ± 0.2	.33
Comorbidities, n (%)			
Coronary artery disease	167 (15.0)	15 (20.0)	.33
Hypertension	129 (77.3)	58 (77.3)	.99
Diabetes	23 (13.8)	5 (6.7)	.11
Dyslipidemia	86 (51.5)	35 (46.7)	.49
COPD	8 (4.8)	8 (10.7)	.09
Chronic renal disease	5 (3.0)	8 (10.7)	.01
History of smoking	64 (38.3)	27 (36.0)	.73
Cerebrovascular accident	23 (13.8)	13 (17.3)	.47
Previous PCI	10 (6.0)	8 (10.7)	.20
Previous cardiac surgery	14 (8.4)	12 (16.0)	.08
Previous aortic surgery	1 (0.6)	3 (4.0)	.06
Bicuspid aortic valve	13 (8.8)	7 (9.3)	.69
Medication use, n (%)			
Beta blockers	61 (36.5)	38 (50.7)	.04
ACEi	45 (27.0)	28 (37.3)	.10
ARB	30 (18.0)	12 (16.0)	.71
Calcium channel blockers	35 (21.0)	26 (34.7)	.02
Statins	95 (56.9)	40 (53.3)	.61
Aortic disease involvement			
Aortic root, n (%)	53 (31.7)	20 (26.7)	.43
Ascending aorta, n (%)	157 (94.0)	74 (98.7)	.11
Aortic arch, n (%)	4 (2.4)	8 (10.7)	.01
Growth rate, cm/y, mean ± SD	0.07 ± 0.31	0.17 ± 0.11	<.01
Surgery on follow-up, n (%)	12 (7.2)	18 (24.0)	<.01

BSA, Body surface area; *COPD*, chronic obstructive pulmonary disease; *PCI*, percutaneous coronary intervention; *ACEi*, angiotensin-converting enzyme inhibitor; *ARB*, angiotensin 2 receptor blocker.