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Survival after surgery of the ascending aorta: a matched cohort study

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Key question

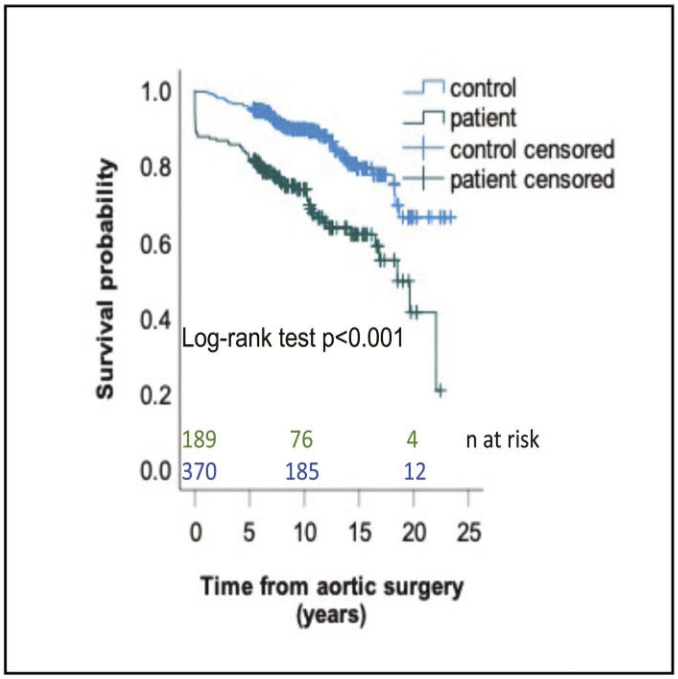
What is the survival among patients going through surgery of the ascending aorta compared to matched controls?

Key finding(s)

The total survival, as well as short-and long-term survival is reduced among patients compared to matched controls.

Take-home message

Patients need life-long surveillance after aortic surgery.



Abstract

OBJECTIVES: Surgery of ascending aortic aneurysms is performed prophylactically or acute. The expected survival after surgery is uncertain. The goal of this study was to compare mortality in people with aortic surgery with matched controls.

METHODS: All patients undergoing ascending aortic surgery at Umeå University Hospital from 1988 to 2012, who previously participated in 1 of 3 population-based health surveys, were matched to 2 randomly selected controls from the same health survey and followed until death or until censoring on 24 August 2017, whichever came first. Mortality was calculated using the Kaplan-Meier method and the log-rank test. Cox regression analyses were made for all-cause mortality, adjusted for traditional cardiovascular risk factors. Deaths during the first 90 days after surgery and at >90 days postoperatively were studied separately.

RESULTS: The median follow-up time was 9.2 years. A total of 61 of 189 patients and 51 of 370 controls died [hazard ratio (HR) 2.77, 95% confidence interval (CI) 1.91–4.01]. Mortality was increased during the first 90 days post-surgery (HR 43.4, 95% CI 5.83–323), as well as after the first 90 days (HR 1.90, 95% CI 1.25–2.88) and after acute surgery (HR 6.05, 95% CI 2.92–12.56) as well as after elective surgery (HR 2.10, 95% CI 1.35–3.27). Among 57 surgical patients with information about cause of death, 23 (40%) died of aortic disease.

CONCLUSIONS: During follow-up, more patients died than matched controls. Findings were consistent when adjusting for traditional cardiovascular risk factors and across subgroups. Both short-term and long-term postoperative deaths were increased as well.

Keywords: Thoracic aorta • survival • surgery • aortic aneurysm • aortic dissection

ABBREVIATIONS

aHR	Adjusted hazard ratio
CI	Confidence interval
HR	Hazard ratio
ICD	International Statistical Classification of Disease and Related Health Problems
MONICA	The northern Sweden MONItoring of trends and determinants in CArdiovascular disease survey
MSP	Mammary screening program
SD	Standard deviation
VIP	Västerbotten intervention program

INTRODUCTION

The incidence of thoracic aortic dissection in Sweden has been reported to be 7.2/100,000/year. About 1 in 3 patients dies before reaching hospital and 1 in 5 of those admitted to the hospital die within 30 days [1]. To prevent dissection, prophylactic surgery is recommended at certain diameters, taking hereditary aortic disease, comorbidities and aortic growth rate into consideration [2, 3].

In a recent multicentre study, the perioperative mortality among patients having elective surgery of the proximal aorta was 2.2% [4]. However, studies comparing survivors to matched controls, which is essential to account for background risk, are sparse. Van Duffel *et al.* presented a small study of 72 patients who had elective surgery for an aneurysm of the ascending aorta. The 30-day mortality was 9.7% and the 10-year survival was 81%, compared to 85.2% for randomly selected controls, matched for age and sex [5].

We assessed survival among patients who had surgery of the ascending aorta compared to matched controls. Short- and long-term survival data were studied separately in a landmark analysis at 90 days post-surgery, and the impact of clinical presentation was explored in subgroup analyses.

MATERIALS AND METHODS

This paper is based on a data set constructed for a previous case-control study assessing risk factors for the development of heart valve disease and ascending aortic disease [6]. To assess if surgery restored normal life expectancy, we compared survival among patients having surgery of the ascending aorta to survival among matched controls.

Ethical considerations

The study was approved by the regional ethics committee of the Department of Medical Science, Umeå University, 07-174M (2008-02-19) and 2015/107-31 (2015-04-07). Informed and written consent for future research was obtained at the baseline survey. During admission at the Department of Cardiothoracic Surgery, Umeå University Hospital, patients were informed by public announcements that the procedures were registered in the local quality register.

Population

All patients who had ascending aortic surgery at the Department of Cardiothoracic Surgery, Umeå University Hospital from March 1988 to December 2012 and who had participated in 1 of 3 population-based health surveys, the Västerbotten Intervention Programme (VIP), the northern Sweden MONItoring of trends and determinants in CArdiovascular disease (MONICA) survey and the mammary screening program (MSP), were included in the study [7–10].

At the time of surgery, 2 randomly selected controls with prior participation in 1 of the 3 health surveys were matched for sex, age (±2 years), type of health survey (MONICA, VIP or MSP), date of health survey (±4 months) and geographical area. No exclusion of patients or controls was made except for controls with surgery for valvular heart disease and surgery of the ascending aorta. Beyond variables reported from the health surveys, the medical status of the controls was unknown. The surveys and the subjects' characteristics at the time of the survey are further described in supplementary materials (Web appendix).

Clinical data at surgery

Data from preoperative assessments were extracted manually from hospital health records. If hypertension and/or diabetes mellitus was mentioned or medications indicating treatment of these diagnoses were listed, patients were categorized accordingly. Similarly, patients were categorized as smokers, ex-smokers or non-smokers. A coronary artery angiogram was performed in 85% of the patients. Coronary artery disease was defined as stenosis ≥50% in any coronary artery. The majority of patients with missing preoperative angiography or echocardiography had emergency surgery of the ascending aorta [6].

Outcome data

Vital status through 24 August 2017 was reported from the Swedish population register held by the Swedish tax authorities. The register has full coverage of Swedish residents. By using the unique Swedish personal identity numbers, it was possible to cross-link the Swedish population register and the study population.

Cause of death

International Statistical Classification of Disease and Related Health Problems codes for causes of death were extracted from the National Board of Health and Welfarés cause of death register for patients undergoing surgery. These codes for the main and underlying causes of death were assessed.

Data analysis

A time-to-event analysis was performed using the Kaplan-Meier method. Deaths among the patients were compared to deaths among the controls, using the log-rank test.

The observational time was counted from the date of the operation until death or censoring. Patients and controls still alive on 24 August 2017 were censored on that date. Median follow-up time was calculated using the reversed Kaplan-Meier method.

A Cox regression analysis was performed for all-cause mortality, adjusted for the categorical cofactors smoking and hypertension and the continuous cofactors, diastolic blood pressure, body mass index and total serum cholesterol. Systolic blood pressure was excluded because diastolic blood pressure has a larger impact on cardiovascular diseases at the age at which the participants took the survey than does systolic blood pressure [11].

No participants were excluded due to missing data. To minimize the impact of missing values on the adjusted hazard ratios (aHRs) and to preserve statistical power, multiple imputation was performed. The following variables were imputed: total serum cholesterol, smoking, hypertension and diastolic blood pressure, based on the "missing at random" assumption. To reduce sampling variability, 20 imputed data sets were created. The variables used for imputation were body mass index, hypertension, diastolic blood pressure, smoking habits, serum cholesterol, vital status, survival time and case/control.

Landmark analyses were performed to study short-term, i.e. ≤90 days, and long-term, i.e. > 90 days, postoperative survival separately. By separating death during the first 90 days from death over the long term, i.e. 90 days post-surgery, one can assess mortality without impact from perioperative complications [12]. When analysing mortality 90 days post-surgery and forward, the Cox regression analysis was further adjusted for sex and the age at which the patient took the survey to compensate for the loss of matching of patients and controls.

Analyses were stratified based on whether ascending aortic surgery was the primary indication for surgery or not and whether the surgery was acute or elective. Furthermore, in the group in whom the aorta was the primary indication, we performed an ad hoc analysis separating acute surgery from elective surgery. Analyses of short-term and long-term deaths after acute and elective surgery were performed as well.

Due to missing values for several covariates from the MSP cohort, a sensitivity analysis was performed from which subjects from the MSP cohort were excluded. To detect a potential improvement in survival over time, a sensitivity analysis was performed in which the date of surgery was divided at the median. To assess the impact of age at surgery on mortality, a sensitivity analysis was performed in which the ages the patients were when the surgery was performed were divided at the median.

All analyses were performed using IBM SPSS statistics 26 software (IBM Corp, Armonk, NY, USA).

RESULTS

Patient characteristics

Of 189 patients undergoing ascending aortic surgery, 161 had participated in VIP, 10 in MONICA and 18 in MSP. One hundred eighteen patients had surgery of the ascending aorta as the primary indication and 71 patients had another primary indication for surgery; 41 patients had acute surgery whereas 148 had prophylactic surgery.

Sixty-nine patients (37%) were women; the mean age at surgery was 62.2 (standard deviation, 9.4) years. Forty-eight patients (30%) had significant coronary artery stenosis and 31 patients (16%) underwent concomitant coronary artery bypass graft surgery. With few exceptions, the characteristics at surgery were similar between the subgroups (Table 1). In the group in which the ascending aortic operation was the secondary indication, aortic stenosis was the most common concomitant surgical procedure. As expected, aortic regurgitation was the most common cause of concomitant surgery if the aorta was the primary indication.

Thirteen out of 189 of the cases had undergone a prior aortic operation. The corresponding number among controls was 10 out of 370. Characteristics at the time of the survey are presented in the Web appendix (eTable 1).

Survival

The median follow-up time after surgery was 10.6 years [95% confidence interval (CI) 10.1–11.0]. During this period, 61 out of 189 patients and 51 out of 370 controls died, resulting in an aHR during the complete follow-up period of 2.72 (95% CI 1.86–3.99) (Fig. 1a). Survival data are presented in Table 2 and Figures 1–3.

Causes of death

The cause of death was known for 57 of 61 patients who died. In total, 40 patients died of cardiovascular diseases; 23 had aortic disease as the main cause of death. Nine patients had aortic disease as a contributing cause of death. Three of those died of myocardial infarction, 2 of cerebrovascular disease and 2 of aortic valvular disease; only 2 died of non-cardiovascular disease. All 21 patients who died during the first 90 days post-surgery died of cardiovascular disease; 17 died of aortic disease and 2 were reported to have aortic disease as a contributing cause of death. Among patients surviving >90 days, 19 of 36 patients died of cardiovascular diseases; 6 died of aortic disease, 3 died of aortic valvular disease and 4 died of endocarditis. Seven patients had aortic disease as a contributing cause of death. Among patients having elective surgery who died within 90 days, 2 died of aortic disease, 1 of endocarditis, 1 of aortic stenosis, 1 of pericardial disease not further specified and 1 of acute myocardial infarction. Among those having elective surgery who survived the first 90 days, 5 died of aortic disease. Fourteen died of other cardiovascular diseases.

Sensitivity analyses

The hazard ratio for death was 2.93 (95% CI 1.85–4.63), aHR 2.85 (95% CI 1.77–4.58) for surgery before February 2007 and 2.46 (95% CI 1.13–4.65), aHR 2.16 (95% CI 1.09–4.26) for surgery after February 2007.

The exclusion of the MSP cohort changed results only marginally: hazard ratio (HR) 2.92 (95% CI 1.95–4.37) and aHR 2.80 (95% 1.82–4.30).

Further, age at surgery younger than the median was associated with slightly more deaths, HR of 3.77 (95% CI 1.79–7.93) and aHR 3.98 (95% CI 1.83–8.64), compared with older patients: HR 2.68 (1.73–4.15) and aHR 2.38 (95% CI 1.50–3.76).

Table 1. Characteristics at surgery

	In total	Aorta as primary indication	Aorta as secondary indication	Acute surgery	Elective surgery	Valid
N	189	118	71	41	148	189
Female sex, n (%)	69 (37)	47 (40)	22 (31)	14 (34)	55 (37)	189
Age at surgery, years (SD)	62.2 (9.4)	62.0 (9.3)	62.6 (9.7)	60.3 (9.1)	62.8 (9.5)	189
Diabetes mellitus, n (%)	6(3.2)	3 (2.5)	3 (4.2)	2 (5.3)	4 (2.7)	186
Hypertension, n (%)	99 (53)	67 (57)	32 (45)	21 (51)	78 (53)	188
BMI, kg/m^2 (SD)	26.6 (4.1)	26.5 (3.9)	26.8 (4.4)	26.8 (3.9)	26.6 (4.1)	170
Smoking, n (%)						178
Never smoker	83 (47)	52 (48)	31 (44)	11 (32)	72 (50)	–
Current smoker	24 (14)	16 (14)	8 (11)	7 (21)	17 (12)	–
Ex-smoker	71 (40)	40 (37)	31 (44)	16 (47)	55 (38)	–
Coronary artery stenosis ≥50%, n (%)	48 (30)	26 (29)	22 (31)	9 (22)	39 (27)	160
Stroke volume, mL (SD)	97.0 (30.6)	97.5 (32)	96.3 (29.6)	91.1 (18.7)	97.3 (31.2)	140
LVEDD, mm (SD)	54.3 (8.8)	53.2 (7.0)	55.7 (10.5)	53.4 (6.4)	54.4 (9.0)	157
LVESD, mm (SD)	37.2 (9.9)	35.3 (8.4)	39.7 (11.1)	37.3 (7.7)	37.2 (10.1)	125
Atrial fibrillation, n (%)	20 (11)	13 (12)	7 (10)	3 (9)	17 (12)	178
Concomitant surgery n (%)						189
AS	65 (34)	19 (16)	45 (63)	0 (0)	65 (44)	
AR	63 (33)	41(35)	20 (28)	9 (22)	54 (37)	
MR	1 (0.5)	0 (0)	1 (1.4)	0 (0)	1 (0.7)	
CABG	31 (16)	15 (13)	3 (4.2)	3 (7.3)	28 (19)	
Other	8 (4.2)	6 (5.2)	2 (2.8)	3 (7.3)	5 (3.4)	
Concomitant medication, %						
Beta blockers, n (%)	65 (35)	43 (37)	22 (31)	13 (33)	52 (35)	188
ACEi, n (%)	51 (27)	32 (27)	19 (27)	11 (28)	40 (27)	187
ARB, n (%)	24 (13)	15(13)	9 (13)	3 (7.5)	21 (14)	187
Spironolactone, n (%)	6 (3.2)	2 (1.7)	4 (5.7)	0 (0)	6 (4.1)	187
Diuretics, n (%)	42 (23)	26 (22)	16 (23)	5 (13)	37 (25)	187
Digoxin, n (%)	4 (2.1)	2 (1.7)	2 (2.9)	0(0)	4 (2.7)	187
Calcium-channel blockers, n (%)	37 (20)	26 (22)	11 (16)	10 (25)	27 (18)	187
Aspirin, n (%)	44 (24)	25 (21)	19 (27)	9 (23)	35 (24)	187
Warfarin, n (%)	20 (11)	12 (10)	8 (11)	0 (0)	20 (14)	187
Statins, n (%)	38 (20)	24 (21)	14 (21)	5 (13)	33 (22)	187
Clopidogrel n (%)	8 (4.3)	2 (1.7)	6 (8.6)	1 (2.5)	7 (4.8)	187

ACEi: angiotensin-converting enzyme inhibitor; ARB: angiotensin II receptor antagonist; AR: aortic regurgitation; AS: aortic stenosis; BMI: body mass index; CABG: coronary artery bypass graft; LVEDD: left ventricular end diastolic diameter; LVESD: left ventricular end systolic diameter; MR: mitral regurgitation.

DISCUSSION

Ascending aortic surgery improves the prognosis for patients with an aneurysm or acute dissection. However, our findings indicate that patients undergoing surgery do not regain normal life expectancy. During follow-up, mortality was higher among cases than controls, findings that were consistent when adjusting for traditional risk factors for cardiovascular disease and across subgroups. Also, the landmark analyses showed increased mortality among patients during the first 90 days post-surgery, as well as after 90 days post-surgery, indicating that perioperative complications are unlikely to explain the entire increase in mortality among the patients. These observations are further supported by the fact that more than 25% of patients who underwent aortic surgery and survived the perioperative period had aortic disease as a contributing cause of death during the long-term follow-up period. The sensitivity analysis indicates that young patients have a worse outcome than older patients. One can speculate whether those younger patients more often had genetic disorders, causing a more aggressive aortic disease.

A larger proportion of patients than controls had prior coronary surgery. Previous cardiac surgery has been reported as a risk factor for aortic dissection [13]. One can also expect patients with prior coronary artery disease to be diagnosed with aortic aneurysms to a greater extent than healthy persons due to more frequent echocardiographic examinations.

The higher proportion of patients who had prior coronary surgery may have impacted the higher mortality, but more than 25% of patients who underwent aortic surgery and survived the perioperative period, had aortic disease as a contributing cause of death during long-term follow-up.

Comparison with previous studies

There are few studies assessing survival in patients undergoing surgery of the ascending aorta compared to matched controls. Compared to previous studies, our study is relatively large and well-matched, including most cardiovascular risk factors in addition to age and sex [5, 14, 15].

In our study, patients surviving the first 90 days had an excess mortality rate of 1.90 (CI 95% 1.25–2.88). Our findings are supported by results from the Australian and New Zealand Society of Cardiac and Thoracic Surgeons database, in which long-term survival after aortic root replacement, including both acute and elective surgery, was estimated to be 84% and 69% at 5 and 10 years, respectively [16]. In contrast, Hernandez-Vaqueros *et al.* found normal survival among patients having elective surgery of the ascending aorta and surviving the post-operative period [15].

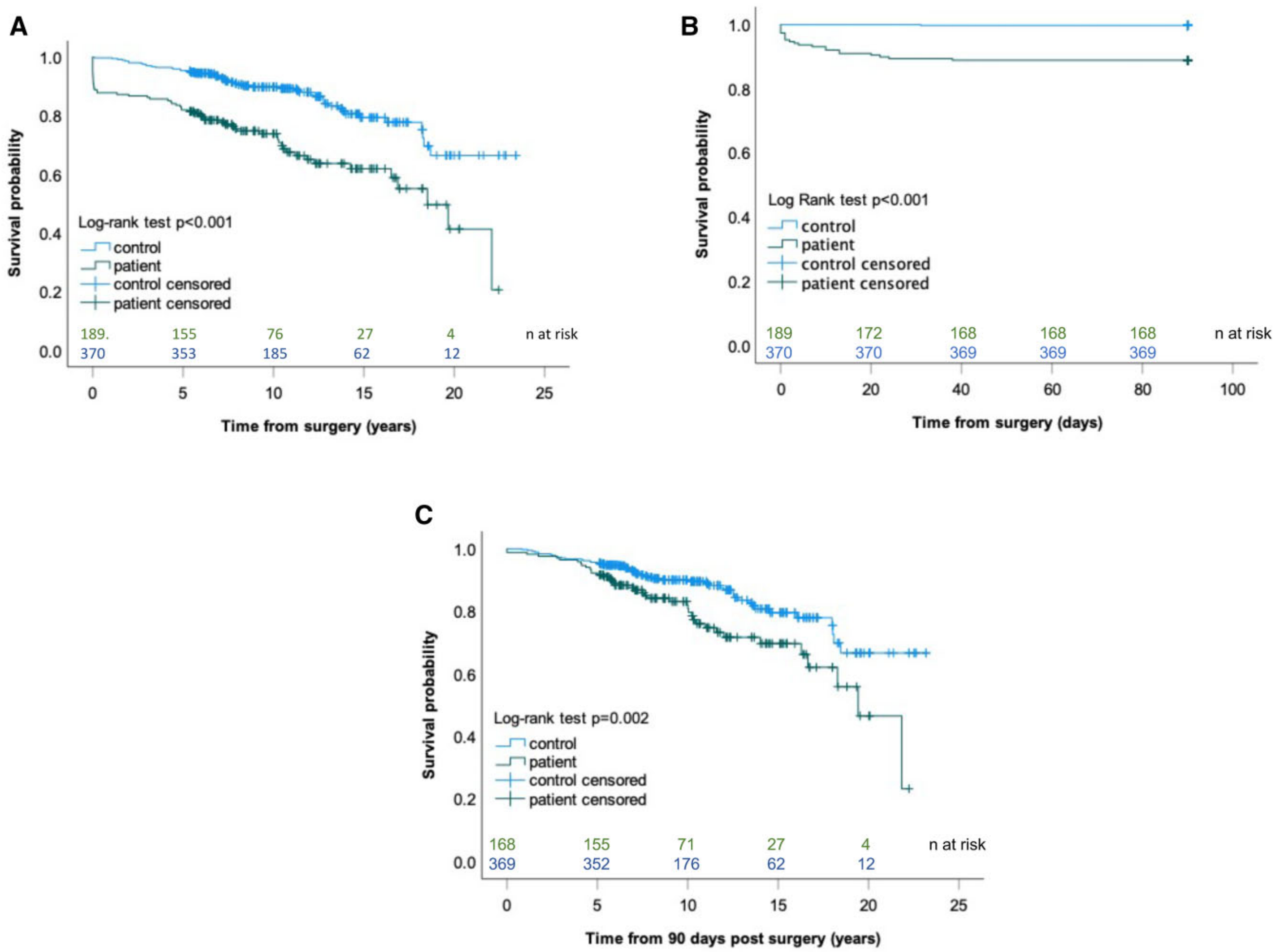


Figure 1. Kaplan-Meier curves for survival among patients after surgery of the ascending aorta and controls. (**a**) Survival during total follow-up time [median follow-up time 10.6 years (95% confidence interval 10.1–11.0)]. (**b**) Survival during the first 90 days post-surgery. (**c**) Survival from 90 days post-surgery and forward.

Also, van Duffel *et al.* found non-inferior 10-year survival among patients going through elective surgery of the ascending aorta from 1998 to 2012 [5]. Although our study includes older data compared to these studies, our results were consistent in sensitivity analysis stratified by year of surgery. The fact that 25% of the patients surviving the first 90 days had aortic disease as a contributing cause of death supports the idea that the patients in our study were not cured of aortic disease. Our study also contributes with information related to mortality in acute and elective surgery. Higgins *et al.* reports a tenfold increase in 30-day mortality among patients having acute surgery and an odds ratio of 1.5 among those having elective surgery [17]. Pan *et al.*, on the other hand, did not find any differences in long-term survival among those who survived the first 30 days, regardless of whether the surgical indication was acute or elective [18]. Our findings are in agreement with those of Higgins, with excess mortality after acute surgery, both during the first 90 days and >90 days [17].

Limitations

Our study has some limitations: (i) The fact that the study was done in a single centre may impair the generalizability of the results. (ii) This is a retrospective observational study. The study question does not allow randomization. Even though the controls are randomly selected and the analyses are adjusted for traditional risk factors for cardiovascular disease, there is a risk of residual confounding. No differences were noticed among factors potentially impacting outcome, i.e. calendar time is studied in a subgroup analysis, but unmeasured confounding cannot be completely ruled out. The study may also suffer from selection bias because patients and controls had to participate in a health survey prior to the date of the patients' surgery. The health surveys were voluntary; not everyone who was invited agreed to participate in the study. (iii) Missing data for cofactors were handled by multiple imputation. Because missing data occurred mostly among the MSP cohort, our assumption that data are missing at random can be questioned. To assess the impact of this assumption, we performed a sensitivity analysis in which the MSP cohort was excluded—the results were not altered significantly. (iv) We lack information about hereditary conditions and underlying genetic disorders, such as Loeys-Dietz and Marfan syndromes, known to be associated with a shorter life expectancy. Conditions such as preoperative renal failure, preoperative cerebrovascular disease, chronic obstructive pulmonary disease, peripheral vascular disease and descending or thoracoabdominal aortic surgery have also been associated with decreased survival of up to 8 years after aortic surgery [17, 19]. Unfortunately, our material did not include information about any of these conditions, except for creatinine, for which levels did not differ

Table 2. Mortality rate, hazard ratios and adjusted hazard ratios for aortic surgery in total and in subgroups

Mortality after surgery of the ascending aorta	Cases (n/N)	Referents (n/N)	Hazard ratio (95% CI)	Adjusted hazard ratio (95% CI)
In total	61/189	51/370	2.77 (1.91-4.01)	2.72 (1.86-3.99)
Acute surgery	21/41	12/82	6.05 (2.92-12.6)	4.24 (1.79-10.09)
Elective surgery	40/148	39/288	2.10 (1.35-3.27)	2.20 (1.40-3.45)
Aorta, primary indication	42/118	33/234	3.14 (1.99-4.95)	3.05 (1.89-4.91)
Aorta, secondary indication	19/71	18/136	2.13 (1.12-4.06)	2.11 (1.09-4.08)
Aorta, primary indication, elective surgery	21/77	21/152	2.06 (1.13-3.78)	2.26 (1.21-4.22)
≤90 days				
In total	21/189	1/370	43.4 (5.80-323)	40.2 (5.36-301)
Acute surgery	15/41	0/82	N/A	N/A
Elective surgery	6/148	1/288	11.9 (1.40-99.0)	13.54 (1.58-116)
Primary indication	17/118	1/234	36.0 (4.80-271)	31.5 (4.11-240)
2nd indication	4/71	0/136	N/A	N/A
Primary indication, elective surgery	2/77	1/152	4.00 (0.36-44.1)	N/A
>90 days				
In total	40/168	50/369	1.90 (1.25-2.88)	2.01 (1.30-3.11)
Acute surgery	6/26	12/82	2.20 (0.81-5.97)	1.91 (0.52-7.04)
Elective surgery	34/142	38/287	1.84 (1.16-2.92)	1.94 (1.20-3.13)
Aorta, primary indication	25/101	32/233	2.01 (1.19-3.40)	2.21 (1.25-3.91)
Aorta, secondary indication	15/67	18/136	1.69 (0.85-3.35)	1.62 (0.80-3.29)
Aorta, primary indication, elective surgery	19/75	20/151	1.96 (1.05-3.68)	2.20 (1.12-4.31)

≤90 represents mortality during the first 90 days post-surgery. >90 days represents mortality 90 days post-surgery and going forward.
CI: confidence interval. N/A: not applicable.

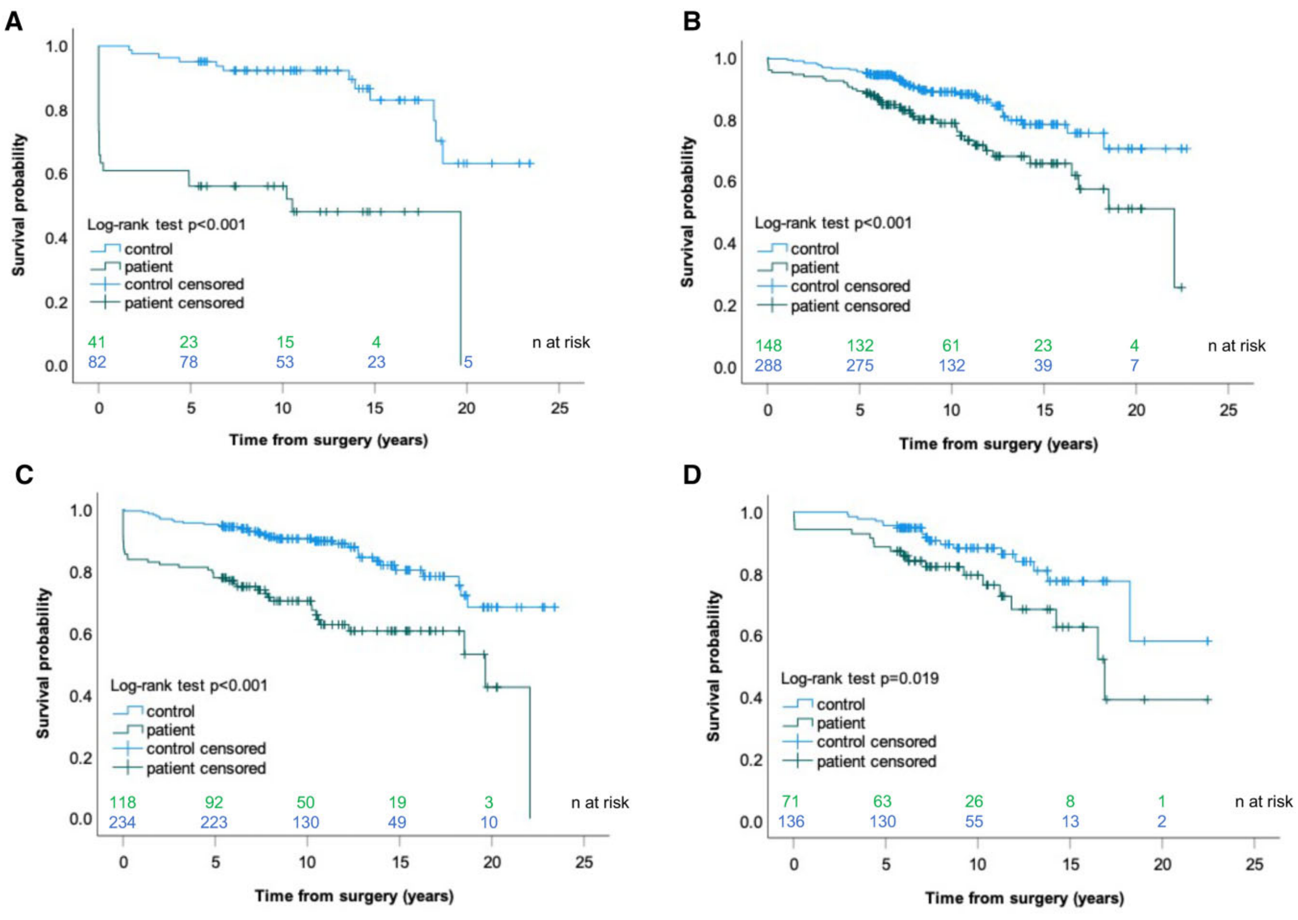


Figure 2. Kaplan-Meier curves for survival among patients after surgery of the ascending aorta and controls. (**a**) Survival after acute surgery. (**b**) Survival after elective surgery. (**c**) Aortic surgery as the primary indication. (**d**) Aortic surgery as a secondary indication.

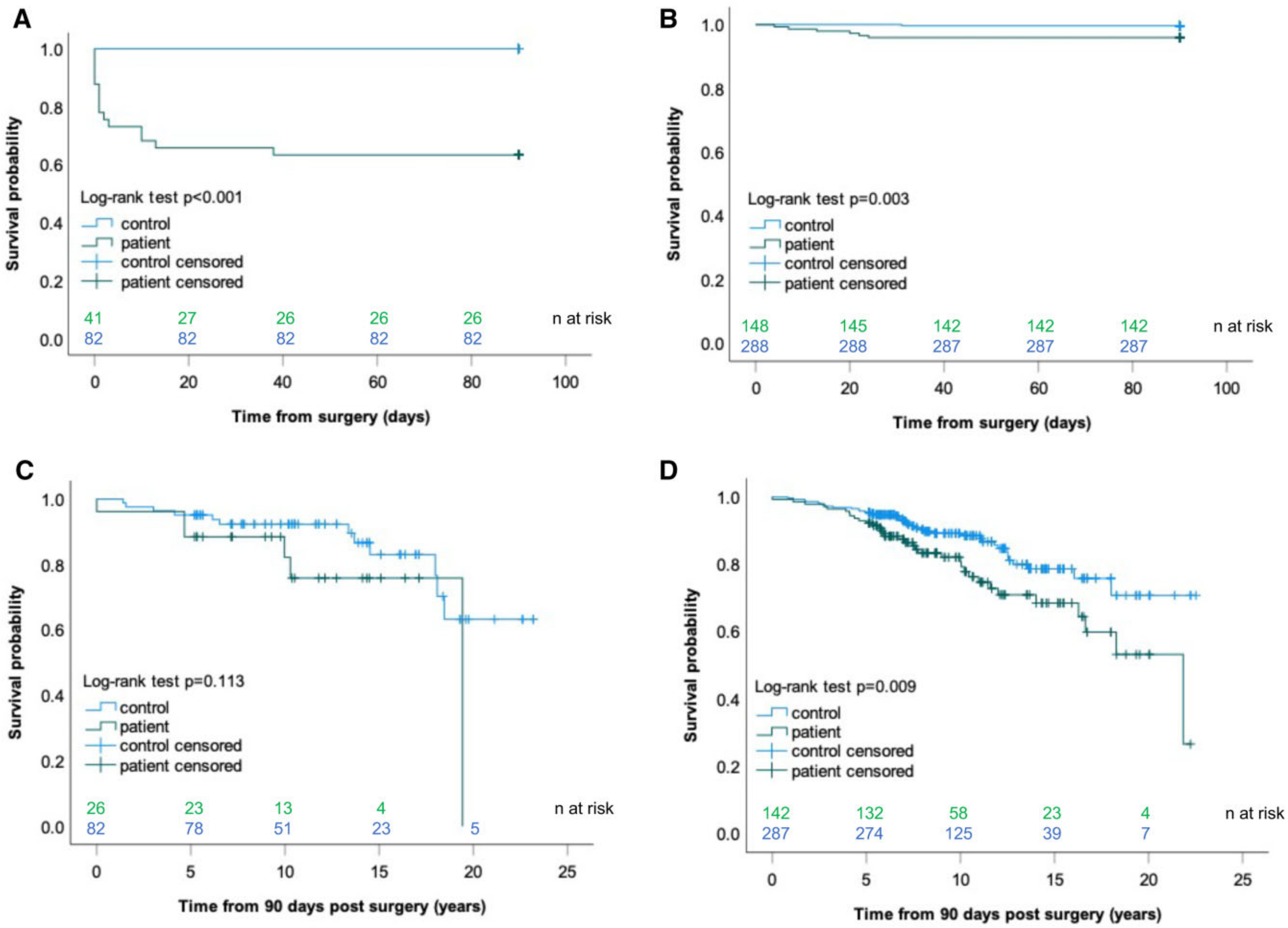


Figure 3. Kaplan-Meier curves for survival after surgery of the ascending aorta and controls. (**a**) Survival during the first 90 days after acute surgery. (**b**) Survival during the first 90 days after elective surgery. (**c**) Survival from 90 days post-surgery and forward, acute surgery. (**d**) Survival from 90 days post-surgery and forward, elective surgery.

between cases and controls. (v) The mean lag time between the collection of risk factor data (survey) and the start of follow-up (surgery) was 10 years (standard deviation, 5.8). It is possible that risk factor patterns changed in different ways in patients and controls during this time period, resulting in unbalanced groups, and that these changes were not captured by adjustment for the covariates included here. (vi) Subjects included in the VIP survey are expected to have affected the age distribution of patients, because the ages of those included in this study are 30, 40, 50 and 60 years. Thus, patients not included in this age span have been missed, limiting the generalizability of our findings among older patients going through aortic surgery and also among younger patients who are more prone to have syndromes causing the aortic disease. (vii) Umeå University Hospital is a small centre, and the requirement of prior participation in one of the health surveys for matching purposes further limits the number of eligible patients. The analyses based on subgroups include relatively few subjects and should be interpreted carefully. Finally, the study participants are not limited to patients with isolated aortic disease; they also included patients with combined valvular and coronary diseases. This group reflects the spectrum of patients having aortic surgery at this specific university hospital, meaning the generalizability of the results to other thoracic centres may be limited.

Clinical implications

Prophylactic surgery of ascending aortic aneurysms and acute surgery of aortic dissections improve the prognosis for patients with ascending aortic disease. However, after surgery, the patients cannot be considered cured. Their remaining life span is reduced compared to that of matched controls.

Our findings indicate that aortic disease is progressive even after surgery. This observation is important both for physicians and patients to keep in mind when making decisions about surgery. It also tells us that it is important to have reasonable expectations of what one can accomplish with surgery and that surveillance of patients who have been operated on is important.

Future directions

The higher mortality among patients with ascending aortic disease remains despite prophylactic surgery. The knowledge of causes of death is limited. In agreement with our findings, Olson *et al.* have shown that cardiac, aortic and cerebrovascular diseases are the main causes of long-term mortality after surgery of the ascending aorta [20]. It has earlier been shown that among patients going through replacement of the aortic root, progression of the aortic disease is the major cause of long-term mortality [21]. Knowledge of how to counteract this excess mortality is needed.

It has previously been shown that the 30-day survival after aortic dissection has improved [1]. It remains to be seen if the recent improvement in short-term survival after aortic dissection will persist through the long-term follow-up and after elective surgery.

The impact of associated conditions could not be assessed in this study due to the small case numbers. Future analyses with larger numbers of participants, allowing more granular analyses, would be of great interest.

CONCLUSIONS

The survival of patients having ascending aortic surgery is reduced compared to that of the controls. This is true for both short-term and long-term survival, meaning it is not perioperative mortality that causes the excess mortality. Furthermore, our findings are similar for acute and prophylactic surgery and for ascending aortic surgery as the primary indication or as a secondary indication.

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Conflicts of interest: Stefan Söderberg receives speaker honoraria from Actelion and is a member of advisory boards of Actelion and Novartis outside the present work.

Data Availability Statement

Ethical approval for this study does not support sharing the underlying data publicly.

Author contributions

Linn Skoglund Larsson: Conceptualization; Formal analysis; Funding acquisition; Methodology; Project administration; Visualization; Writing—original draft; Writing—review & editing; **Johan Ljungberg**: Data curation; Investigation; Writing—review & editing; **Lars Johansson**: Conceptualization; Methodology; Writing—review & editing; **Bo Carlberg**: Conceptualization, Methodology; Writing—review & editing; **Stefan Söderberg**: Conceptualization; Data curation; Funding acquisition; Investigation; Supervision; Writing—review & editing. **Mattias Brunström**: Conceptualization; Formal analysis; Funding acquisition; Methodology; Project administration; Supervision; Visualization; Writing—original draft; Writing—review & editing.

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