Computed tomography follow-up after elective proximal aortic surgery: Less is more?

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Abstract

Study objective The added value of computed tomography (CT) follow-up after elective proximal aortic surgery is unclear. We evaluated the benefit of CT follow-up by assessing the incidence of aorta-related complications and reinterventions detected during routine CT follow-up.

Methods Data on 314 patients undergoing first time elective proximal aortic surgery between 2000 and 2015 were collected. The primary study end points were aorta-related complications and reinterventions, detected during routine CT follow-up. Secondary study endpoints included all aorta-related complications and reinterventions, irrespective of the mode of detection and survival.

Results Median CT follow-up time was 6.8 (IQR 4.1-9.8) years, during which a total of 1303 routine follow-up CT-scans (median 4, IQR 3-5) were performed. During CT follow-up, aorta-related complications were detected in 18 (5.7%) patients, of which 6 (1.6%) underwent reintervention. In total, 28 aorta-related complications were observed in 23 (7.3%) patients, of which 9 led to reintervention. In order to detect 1 aorta-related complication leading to reintervention, 218 routine follow-up CT-scans were required. The unadjusted and EuroSCORE II adjusted hazard ratios of not undergoing CT follow-up on mortality were 1.260 (95% CI 0.705-2.251) and 0.830 (95% CI 0.430-1.605), respectively.

Conclusions Following first time elective proximal aortic surgery, aorta-related complications are uncommon, are not always detected during CT follow-up and, if detected, often do not result in reintervention. Therefore, a more conservative CT follow-up protocol could be considered in selected patients to reduce lifetime radiation burden and health care costs. (Am Heart J 2022;249:66–75.)

Following surgery on the thoracic aorta, patients are at risk of developing proximal as well as distal aorta-related complications comprised of progressive aortic dilatation, aortic dissection and anastomotic pseudoaneurysms.[1-7] Respective guidelines recommend structured imaging surveillance to allow early detection and treatment of these complications when indicated.[8,9]

For selected patients with a high risk of developing aorta-related complications, including patients with connective tissue disorders, following acute aortic dissections or after endovascular aortic repair, the need for postoperative imaging surveillance is widely accepted.[10-12] However, in the setting of elective surgery on the proximal aorta and in the absence of known high risk factors, the added value of imaging surveillance is unclear. Little is known about the incidence of aorta-related complications in these low-risk patients and no data on the contribution of imaging surveillance on clinical outcomes are available. Moreover, respective guidelines are unclear with regards to the type of imaging modality [computed tomography (CT), magnetic resonance imaging and/or transthoracic echocardiography] and the surveillance intervals best suited for these patients, with no studies supporting the recommendations made.[8,9] Considering the substantial emotional stress, radiation burden and health care costs associated with structured imaging surveillance, further studies are needed to provide sufficient support and guide improvements in the guidelines recommendations.

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We aim to study the incidence of aorta-related complications and reinterventions after elective proximal aortic surgery and aim to critically evaluate the contribution of structured imaging follow-up on the detection of these complications. As CT is the preferred imaging modality for postoperative surveillance of the aorta, this study will focus on the need for postoperative CT follow-up, specifically.[8,9,14]

Methods

Study design and patient selection

In this single-center cohort study, data on adult patients undergoing first time elective proximal aortic surgery between January 1, 2000, and December 31, 2015, at the Leiden University Medical Center, are reported. Proximal aortic surgery was defined as aortic root replacement, with or without aortic valve replacement, ascending aortic replacement and/or hemi-arch replacement. Patients who underwent previous aortic or aortic valve interventions were excluded from the study. Other exclusion criteria included: aortic dissection, acute infective endocarditis, total aortic arch replacement, connective tissue disorders and congenital aortic abnormalities, all in order to reach a homogenous study population. Preoperative, operative and postoperative data on all patients were retrospectively collected from hospital medical records. For deceased patients, the date and cause of death were obtained from hospital or general practitioner databases, which are directly linked to the national health register (Statistics Netherlands – CBS). Statistics Netherlands registers mortality for all domestically deceased patients and reporting the date and main cause of death to Statistics Netherlands is mandatory by Dutch law. The study was approved by the Leiden University Medical Center Medical Ethics Committee. No extramural funding was used to support this work.

Follow-up

Following surgery, all patients included in the study underwent prospective follow-up at our outpatient clinic and all follow-up CT scans were performed at our institution. Our structured CT surveillance protocol is in accordance with the European Society of Cardiology (ESC) guidelines on the diagnosis and treatment of aortic diseases, and is presented in Figure 1.[8] To be considered for inclusion, at least 1 routine follow-up CT-scan performed at 6 months postoperatively or later was required. CT-scans made for other reasons than structured follow-up of the aorta (eg, clinical CT-scans), were not counted in the total number of routine follow-up CT-scans and aorta-related complications detected on these CT-scans were considered detected by clinical presentation, as they were performed for clinical inquiries, not follow-up of the aorta. Patients were followed until death or the administrative end of study (October 31, 2020).

Definitions

Aorta-related complications were reported when one of the following criteria was met: (1) progressive aortic dilatation, defined as a maximum aortic diameter of ≥55 mm or rapid progressive dilatation of >5 mm/y measured by CT or Magnetic Resonance Imaging, (2) aortic dissection, defined as the presence of an intimal flap in the ascending or descending aorta, (3) pseudoaneurysm, defined as a contrast-filled compartment outside the expected borders of the aorta or prosthesis, which communicated with the aortic lumen or cardiac cavity, or (4) aortic rupture.[8,15] Aortic-valve related complications (including structural biological or mechanical aortic valve prothesis degeneration resulting in stenosis or regurgitation or prosthetic valve endocarditis) were not regarded as aorta-related complications, even if resulting in reintervention, as they were not relevant to CT follow-up. As patients undergoing thoracic aortic surgery are presumably at risk of developing proximal as well as distal aortic complications, the ESC guidelines recommend also imaging remote parts of the aorta.[8] Therefore, complications at all segments of the aorta were included. Indications for reintervention were in accordance with the ESC guidelines, granted patients were adequate surgical candidates, given their comorbidities and clinical condition.

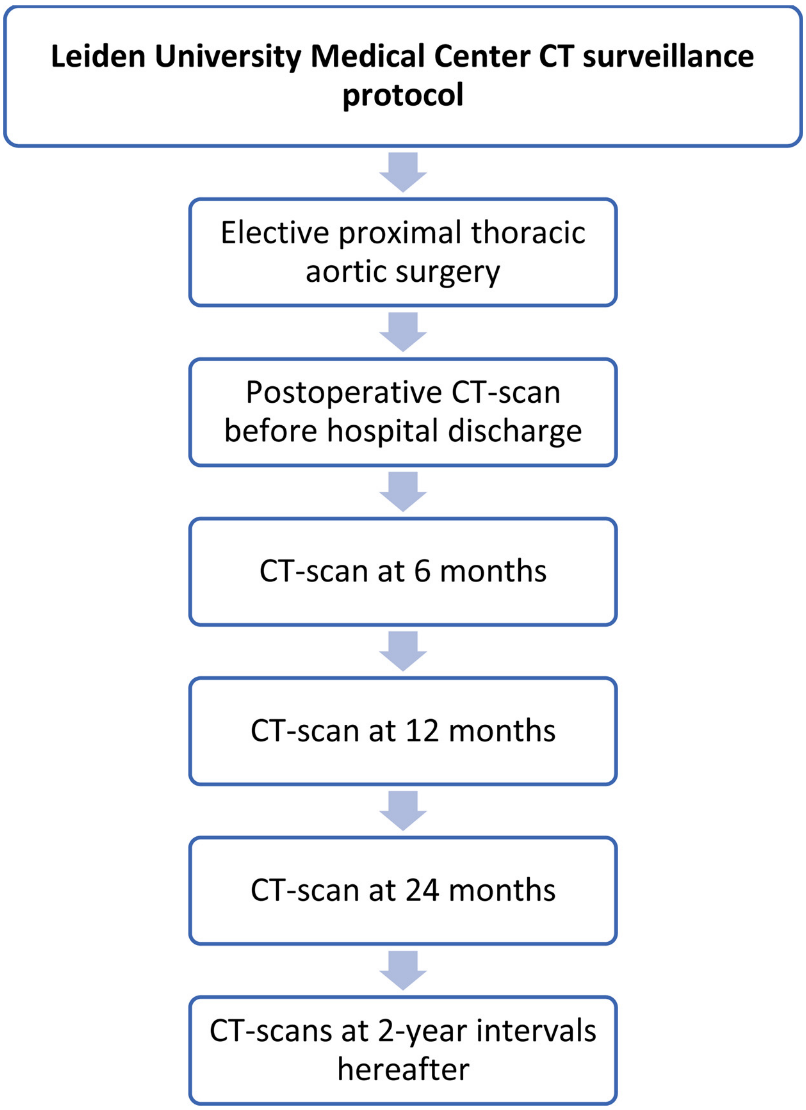
Study end points

The primary study end points were: (1) aorta-related complications detected during routine CT follow-up, and (2) reinterventions as a result these complications. Secondary end points were (1) all aorta-related complications and reinterventions, irrespective of the mode of detection, and (2) overall survival.

Statistical analysis

All statistical analyses were performed using SPSS statistics for Windows version 27.0 (IBM Corp., Armonk, NY) and R Statistical Software (v4.1.3; R Core Team 2021). Normally distributed continuous variables are displayed as mean ± standard deviation, non-normally distributed variables as median and interquartile range. Categorical variables are displayed as numbers and percentages. Cumulative incidence rates were estimated by the Kaplan-Meier method. For freedom from aorta-related complications/reinterventions, the end of follow-up was defined as the date of complication/reintervention or the last CT-scan, as asymptomatic complications hereafter would remain undetected. Fine-Gray cumulative incidence probability analyses following patients until complication/reintervention, death or the administrative end of study are included as Supplementary Material Figures S1 and S2. In case of multiple complications in a single patient, the first complication was included in the statistical analyses, secondary complications were only

Figure 1



Computed Tomography follow-up surveillance protocol after elective proximal aortic surgery at Leiden University Medical Center.

reported in-text. A sub-analysis was performed, comparing overall survival of all patients with and without CT surveillance. A Cox regression analysis, adjusted for EuroSCORE II, was performed for risk-adjusted comparison between these groups. In order to prevent survivorship bias, a blanking period of 6 months after the index surgery was applied for the comparative analysis, as patients who were included in the CT follow-up group inherently survived long enough to undergo surveillance imaging at 6 months, while patients without CT follow-up could have died within this time period. Inter-group comparison of baseline characteristics and operative details can be found in Supplementary Material Tables S1 and S2. Distributions of baseline characteristics among patients with and without CT follow-up were compared using the Student's *t* test or Mann-Whitney *U* test for continuous variables and the χ^2 test or Fisher's exact test for categorical variables. A two-sided *P*-value of <.05 was considered statistically significant.

Results

Patient characteristics and operative details

A total of 314 patients who underwent first time elective proximal aortic surgery and underwent CT follow-up postoperatively were identified from the department

Table I. Characteristics of all included patients who underwent first time elective proximal aortic surgery at our institution and were followed by our CT follow-up protocol

Variables	Total (*n* = 314)
Age at index operation (years), median (IQR)	62.3 (52.8-69.2)
Male gender, n (%)	209 (66.6)
Body Mass Index (kg/m^2), median (IQR)	26.2 (23.9-28.4)
EuroSCORE II, median (IQR)	2.9 (2.2-4.4)
Preoperative NYHA class, n (%)	
I	105 (33.4)
II	140 (44.6)
III	61 (19.4)
IV	3 (1.0)
Hypertension, n (%)	163 (51.9)
Pulmonary hypertension, n (%)	53 (16.8)
History of smoking, n (%)	139 (44.3)
Diabetes, n (%)	19 (6.1)
LVEF function, n (%)	
Good (>50%)	252 (80.3)
Moderately impaired (31%-50%)	58 (18.5)
Poor (<30%)	4 (1.3)
Renal function, n (%)	
eGFR >85 ml/kg/min	184 (58.6)
eGFR >50-85 ml/min	116 (36.9)
eGFR <50 ml/kg/min	11 (3.5)
Aortic valve function, n (%)	
Normal	54 (17.2)
Stenosis	83 (26.4)
Insufficiency	133 (42.4)
Mixed	42 (13.4)
Bicuspid aortic valve, n (%)	153 (48.7)
Indication for surgery, n (%)	
Isolated aortic aneurysm	113 (36.0)
Concomitant to aortic valve intervention	201 (64.0)

Egfr, estimated glomerular filtration rate as calculated by Cockcroft-Gault formula; IQR, interquartile range; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association.

Table II. Intraoperative details of all patients who underwent first time elective proximal aortic surgery at our institution and were followed by our CT follow-up protocol

Variables	Total (*n* = 314)
CBP time (min), median (IQR)	181.0 (147.5-224.0)
Cross-clamping time (min), median (IQR)	143.0 (110.0-180.0)
Circulatory arrest time (min), median (IQR)	25.0 (20.3-29.8)
ACP time (min), median (IQR)	21.0 (15.5-28.00)
Intervention type, n (%)	
Aortic root replacement,	210 (66.9)
Full root replacement	159 (50.6)
Bio-root prosthesis	137 (43.6)
Bentall	22 (7.0)
Valve-sparing aortic root replacement	51 (16.2)
Ascending aorta replacement	243 (77.4)
Open distal anastomosis	20 (6.4)
Hemi-arch replacement	41 (13.1)
Concomitant surgery, n (%)	176 (87.9)
Aortic valve surgery (without aortic root replacement)	85 (27.1)
Biologic aortic valve replacement	23 (7.3)
Mechanical aortic valve replacement	21 (6.7)
Aortic valve repair	41 (12.6)
Coronary artery bypass grafting	47 (15.4)
Mitral valve surgery	37 (11.8)
Tricuspid valve surgery	19 (6.1)
Ablation for atrial fibrillation	28 (8.9)

ACP, antegrade cerebral perfusion; CBP, cardiopulmonary bypass; IQR, interquartile range.

database. Baseline characteristics for the entire cohort at time of the index operation are listed in Table I. Median age was 62.3 (IQR 52.8-69.2) years, 209 (66.6%) patients were men, 163 (51.9%) had hypertension, and 153 (48.7%) had a bicuspid aortic valve. Intraoperative details are summarized in Table II. The aortic root was replaced in 210 (66.9%) patients and the ascending aorta in 243 (77.4%) patients, including 20 (6.4%) patients in whom an open distal anastomosis with deep hypothermic circulatory arrest was performed. Hemi-arch replacement was performed in 41 (13.1%) patients, all under deep hypothermic circulatory arrest.

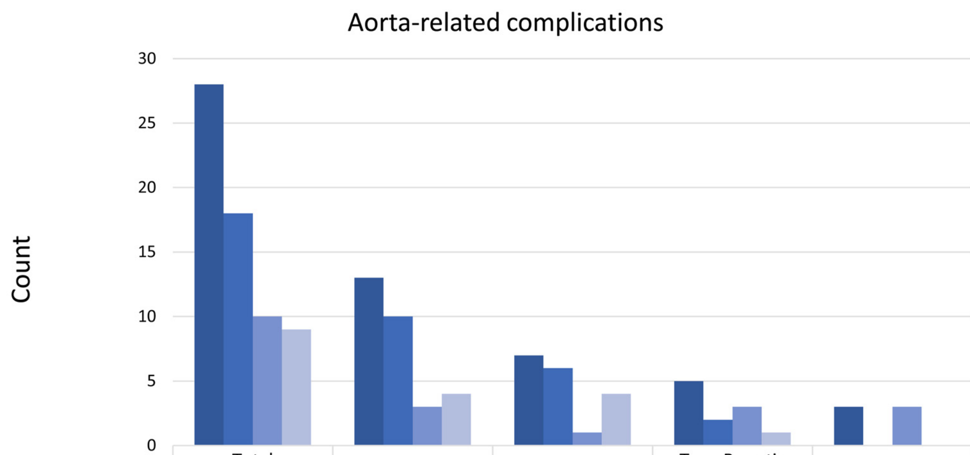
Follow-up

Median CT follow-up time (time from the index operation until the last routine follow-up CT-scan), was 6.8 (IQR 4.1-9.8, maximum 18.8) years, with the duration of follow-up exceeding 5 years in 213 (67.8%) patients and exceeding 10 years in 74 (23.6%) patients. Median clinical follow-up time was 9.2 (IQR 7.0-12.7, maximum 20.8) years, with follow-up duration exceeding 5 years in 290 (92.4%) patients and 10 years in 135 (43.0%) patients.

Aorta-related complications

During follow-up, 23 (7.3%) patients developed a total of 28 aorta-related complications. The most common complication was aortic aneurysm (≥55 mm or progressive dilatation of >5 mm/y), which was detected in 13 (4.8%) patients (2 ascending aortic aneurysms, 3 aortic arch aneurysms, 6 descending aortic aneurysms, and 2 aneurysms involving both the ascending aorta/aortic arch and the descending aorta). Other complications were pseudoaneurysm formation in 7 patients (at the level of the proximal suture line in 3, the distal suture line in 2 and the coronary button in 2 patients), type B aortic dissection in 5 patients, and aortic rupture in 3 patients. Of these complications, 18 (64.3%) were detected during CT follow-up and 10 (35.7%) by clinical presentation. None of the complications were initially detected during echocardiography follow-up. Within the subgroup of ascending aortic replacement with open distal anastomosis or hemiarch replacement, 4 (6.6%) patients developed aorta-related complications. Figure 2 summarizes all aorta-related complications and subsequent reinterventions, with the corresponding mode of detection. The overall freedom from aorta-related complications is presented in Figure 3A and was 94.8% (95% CI 92.3%-

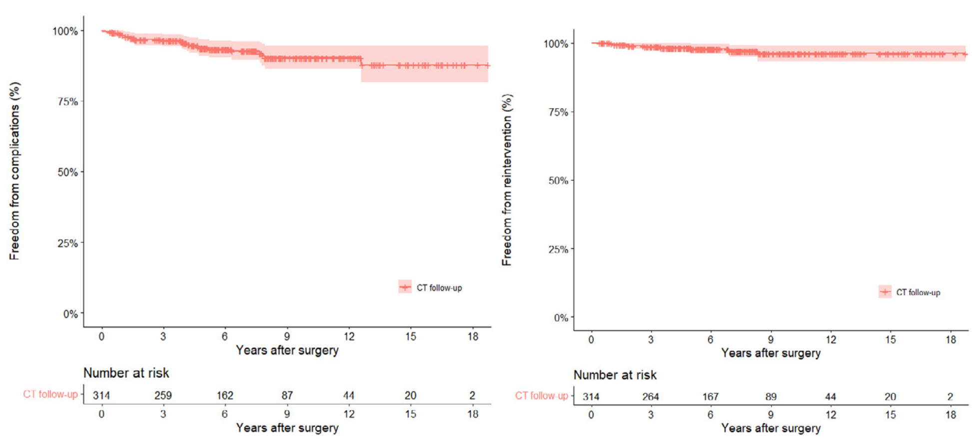
Figure 2



	Total complications	Aortic aneurysm	Pseudoaneurysm	Type B aortic dissection	Aortic rupture
Total complications	28	13	7	5	3
CT-detected	18	10	6	2	0
Detected by clinical presentation	10	3	1	3	3
Reinterventions	9	4	4	1	0

All aorta-related complications and reinterventions throughout the study period, with the corresponding mode of detection. A total of 23 out of 314 patients (7.3%) developed 28 aorta-related complications. Of these complications, 18 were detected by routine CT follow-up (3 were secondary complications after reintervention for previous complications detected by clinical presentation) and 10 by clinical presentation. All aorta-related complications combined resulted in 8 patients (2.5%) undergoing a total of 9 reinterventions.

Figure 3



3A and 3B. Freedom from aorta-related complications and freedom from aorta-related reintervention as a result of these complications. Overall freedom from aorta-related complications is presented in (A) and was 93.7% (95% CI 90.8%-96.6%) and 90.3% (95% CI 86.2%-94.4%) at 5 and 10 years, respectively. Freedom from reintervention as a result of aorta-related complications is presented in (B) and was 98.2% (95% CI 96.6%-99.8%) and 96.1% (95% CI 93.2%-99.0%) at 5 and 10 years, respectively.

Table III. Reinterventions performed for aorta-related complications after first time elective proximal aortic surgery

Reintervention performed	Total (n = 9), n (%)
Aortic root/ascending aorta replacement	3 (33.3)
Thoracoabdominal aorta replacement	3 (33.3)
Aortic arch replacement	2 (22.2)
Aortic root/ascending aorta and aortic arch replacement	1 (11.1)

97.3%) and 92.7% (95% CI 89.6%-95.8%) at 5 and 10 years, respectively.

Aorta-related reinterventions

All complications combined, led to 8 (2.5%) patients undergoing 9 aortic reinterventions. Median time to reintervention was 3.1 (IQR 1.3-6.4) years. Freedom from reintervention as a result of aorta-related complications is presented in Figure 3B and was 98.4% (95% CI 97.0%-99.8%) and 97.1% (95% CI 95.1%-99.1%) at 5 and 10 years, respectively. Within the ascending aortic replacement with open distal anastomosis or hemiarch subgroup, 1 (1.6%) patient underwent aortic reintervention. The type of reinterventions performed are presented in Table III.

Computed tomography-detected complications and reinterventions

During follow-up, a total of 1303 routine follow-up CT scans were performed on which 18 (5.7%) aorta-related complications (10 aortic aneurysms, 6 pseudoaneurysm formation and 2 asymptomatic type B aortic dissections) were detected: 73 CT-scans per detected complication. Of the pseudoaneurysms, 3 were secondary complications after reinterventions performed after the index operation for previous complications detected by clinical presentation.

A total of 6 (1.9%) patients with a complication detected during routine CT follow-up underwent reintervention, which corresponds to 218 CT-scans required to detect 1 aorta-related complication resulting in reintervention. In 6 remaining patients in whom an indication for reintervention was present, the reintervention was not performed because of the high risk of redo surgery or because patients were eventually considered unfit to undergo surgical reintervention. In the other 6 cases, the complications were deemed relatively minor, making conservative treatment the preferred approach. Of these patients, 8 died during follow-up; 1 due to aortic rupture, 5 because of non-aorta-related causes, and 2 because of causes which remained unknown. All CT-detected complications and subsequent reinterventions, with the survival status at the end of follow-up is presented in Table IV.

Survival

Figure 4 presents the overall survival sub-analysis comparing patients with and without CT follow-up. For patients with CT follow-up the 5- and 10-years survival rates were 93% (95% CI 90.3%-95.7%) and 80.5% (95% CI 75.6%-85.4%), respectively. In the group without CT follow-up this correlated to 92.4% (95 CI 85.9%- 98.9%) and 78.5% (95% CI 66.0%-91.0%). The unadjusted and EUROScore adjusted hazard ratios for mortality of not undergoing CT follow-up were 1.260 (95% CI 0.705-2.251) and 0.830 (95% CI 0.430-1.605), respectively.

The hazard ratio within the ascending aortic replacement with open distal anastomosis or hemiarch replacement subgroup was 1.159 (95% CI 0.252-5.327) (Supplementary Material Figure S3).

Discussion

This study demonstrates that following first time elective proximal aortic surgery, aorta-related complications are uncommon and rarely lead to reintervention, raising into question the clinical value of routine CT follow-up. The uncertainty of whether prospective CT follow-up in this selected group of patients is beneficial, is further raised by the observation that no survival benefit was seen when compared to patients with no CT follow-up.

Data about CT surveillance imaging after thoracic aortic surgery is limited and recommendations made by the respective guidelines by the American Heart Association and the ESC lack robust evidence to support them (level of evidence C).[8,9] To date, the majority of studies on this topic have simultaneously studies heterogenous groups of patients, including patients with acute type A aortic dissection, connective tissue disorder, infective endocarditis or chronic aortic aneurysm.[13,15]. The inherent risk of aorta-related complications varies significantly between these populations, rendering combined analysis somewhat ambiguous. Our study contributes to the current body of evidence by focusing on the value of routine CT follow-up in low-risk patients specifically, and shows that in this group generalized surveillance protocols may be redundant.

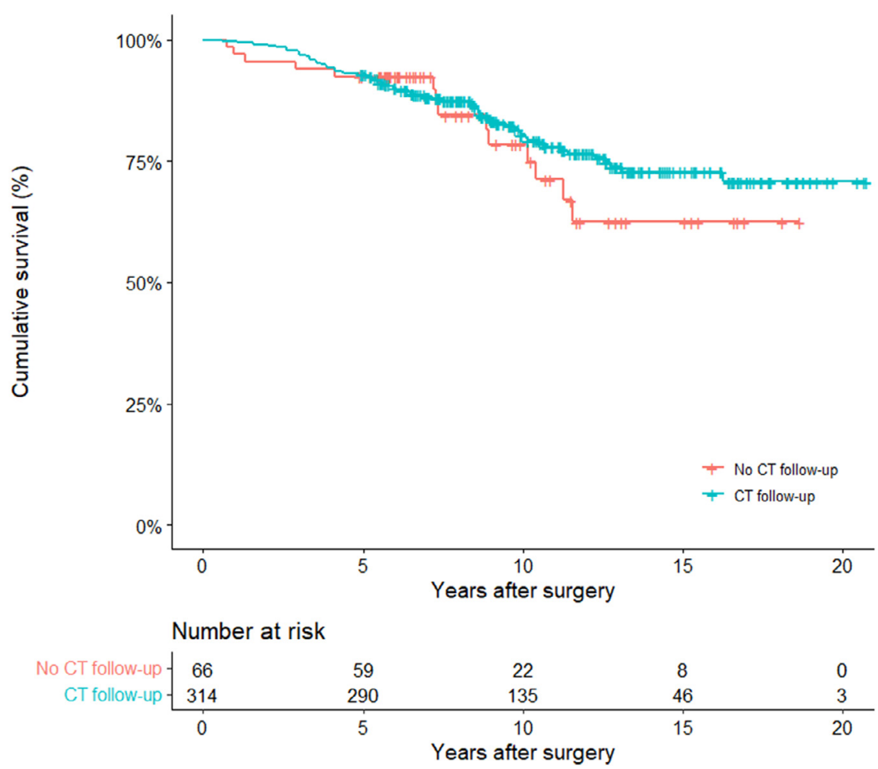
In accordance with our findings, previous studies have reported low reintervention rates, even in populations with known risk factors for aorta-related complications such as type A aortic dissection.[1,13] In a group of patients who had undergone aortic root replacement for various indications, Yamabe et al reported a 10-year cumulative incidence of reinterventions specifically for aorta-related complications of 0.8%. Moreover, Iribarne et al reported an overall reintervention rate of 4.8% over 9 years follow-up after proximal aortic surgery, which also included reinterventions for infective endocarditis and aortic valve insufficiency, which are not relevant to CT follow-up. Admittedly, it is unclear in these studies how many complications did not result in reintervention because of sub-

Table IV. All complications detected during structured CT follow-up, reinterventions as a result of these complications and survival status at the administrative end of the study

Case	Age*	Complication	Reintervention	Survival
1. Male	69	Aneurysm	Yes (1.86 y after surgery)	Alive at follow-up
2. Female	65	Aneurysm	Yes (8.34 y after surgery)	Died of aortic rupture
3. Male	71	Aneurysm	Yes (3.47 y after surgery)	Alive at follow-up
4. Female	74	Aneurysm	No: High risk	Died‡
5. Female	77	Aneurysm	No: stable focal dilatation	Alive at follow-up
6. Female	78	Aneurysm	No: unfit for surgery	Alive at follow-up
7. Female	71	Aneurysm	No: declined surgery, high risk	Died of aortic rupture
8. Male	77	Aneurysm	No: unfit for surgery	Died§
9. Female	70	Aneurysm	No: declined surgery, high risk	Died§
10. Male	73	Aneurysm	No: died before reintervention	Died§
11. Female	63	Pseudoaneurysm	Yes (6.92 y after surgery)	Alive at follow-up
12. Male	60	Pseudoaneurysm	Yes (2.68 y after surgery)	Alive at follow-up
13. Female	61	Pseudoaneurysm†	Yes (7.25 y after surgery)	Died‡
14. Female	46	Pseudoaneurysm†	No: intensified CT surveillance	Alive at follow-up
15. Female	59	Pseudoaneurysm†	No: minor pseudoaneurysm	Alive at follow-up
16. Male	73	Pseudoaneurysm	No: minor pseudoaneurysm	Died‡
17. Female	76	Type-B dissection	No: conservative treatment	Died‡
18. Male	70	Type-B dissection	No: conservative treatment	Died‡

* Age at index operation.
† Secondary complication after reintervention for a previous complication detected by clinical presentation.
‡ Cause of death not aorta-related.
§ Cause of death unknown.

Figure 4



Kaplan-Meier analysis comparing survival rates of patients with and without CT follow-up after first time elective proximal aortic surgery. Survival rates were comparable between patients with and without CT follow-up (log-rank $P = 0.434$). The unadjusted and EuroSCORE II adjusted hazard ratios of absent CT follow-up were 1.260 (95% CI 0.705-2.251) and 0.830 (95% CI 0.430-1.605), respectively.

standard clinical condition, even if a reintervention was indicated. This seems to be of particular importance in daily practice, illustrated by the observation that just 9 out of 28 aorta-related complications in our study resulted in reintervention. In our cohort, this was primarily because patients were deemed too old or otherwise unfit to undergo surgical reintervention by the time complications occurred, or because minor complications did not justify the hazard of aortic reintervention. A question that remains unanswered is whether these reinterventions actually significantly improve survival rates compared to the natural progression of disease, which is especially relevant in reinterventions for asymptomatic CT-detected complications.

As emphasised by the ESC guidelines, patient preferences need to be considered in the treatment decision-making for aortic aneurysms.[8] Many patients with aortic aneurysms experience high levels of stress, fearing that their aorta might rupture.[16] Therefore, when assessing the need for aortic imaging surveillance, the impact of annual screening on quality of life should be taken into account alongside objective clinical outcomes. Currently, there are no studies investigating this topic, but from a clinician and patient point of view it seems that combining clinical evidence on outcomes, the unique clinical state and circumstances of the individual patient, and informed patient preferences results in an optimal shared-decision making process, which generally improves patient-reported outcomes.[16]

Taking this into account, a more individualized patient-tailored approach instead of generalized protocols could be considered for postoperative CT follow-up as well. Adapting postoperative aortic imaging surveillance to disease etiology, patients characteristics, individual circumstances and preferences has the potential to reduce overall lifetime radiation burden and health care costs, while improving patient-reported outcomes.[13,17]

Accurate risk stratification is essential in individualizing and optimizing imaging surveillance protocols. In our study, a low-risk cohort for aortic complications was selected based on disease localization and the underlying pathology of the aortic abnormality. As such, patients with well-known risk factors for aortic complications (eg, type A aortic dissection or connective tissue disorders) were excluded, as lifelong imaging follow-up is justified in this group. On the other hand, we were able to define a low-risk group based on the presumed risk of late complications. An example would be a patient with bicuspid aortic valve who underwent aortic root with us without replacement of the ascending aorta. In these patients, aortic pathology is limited to the proximal aorta and surgical intervention has been shown to limit the progression of postoperative aortic dilatation (even when the ascending aorta is not replaced), being comparable to patients with tricuspid aortic valves.[18,19] Likewise, we observed no cases of progressive aortic arch dilatation in this group, making the value of CT follow-up limited. The appropriateness of our selection, based solely on the ground of pathoethiological factors, is confirmed by our results that mirror results previously reported. As an example, a study by Itagaki et al reported 15-year cumulative ascending aortic aneurysm and intervention rates of just 4.8% and 2.5% after isolated AVR in patients with bicuspid aortic valve.[20] Should postoperative dilatation still occur at the level of the aortic root or ascending aorta, this would likely be captured by means of Transthoracic Echocardiography.

Another group for which routine CT follow-up could be forgone, are elderly patient with limited life expectancy, as the chances of developing aorta-related complications resulting in alteration of clinical policy are slim. This is illustrated in by the small percentage of aorta-related complications actually leading to reintervention in our study, as a result of patients being unfit for surgery by the time complications occur. The value of CT follow-up in patients with higher risk profiles and more extensive aortic pathology remains a topic for debate. Patients undergoing total aortic arch replacement for example, often have adjacent dilatation in the downstream aorta, making the risk of aorta-related complications inherently greater than in the cohort discussed in our study. Therefore, further research into risk factors for aorta-related complications and the value of CT follow-up in distinct subpopulations remains essential in optimizing aortic imaging surveillance in the future.

Finally, with improved outcomes in cardiac surgery and an ageing population, the containment of costs is becoming increasingly important.[21] When balancing risks, benefits and costs of treatment options the consideration of health-related quality of life outcomes is essential to be able to calculate quality adjusted life years. This information in turn can be utilized to calculate the incremental cost-effectiveness ratio and assess whether a particular intervention or protocol is worth the investment. Currently, a formal calculation on the cost-effectiveness of postoperative CT surveillance is lacking and therefore unambiguous comments surrounding this subject are unfounded. Nevertheless, as the number of CT-scans needed to detect aorta-related complications, especially those resulting in reintervention, was particularly high, one could question whether prospective aortic surveillance imaging using CT is worthwhile in terms of cost-effectiveness in low-risk patients.

Limitations

Our study is retrospective in nature and subject to flaws inherent to this type of study design and should therefore only be regarded as hypothesis generating. Furthermore, changes in (peri)operative management and imaging techniques during the study period may have influenced complication, reintervention and survival rates.

Moreover, not all patients fully adhered to the CT follow-up protocol as described in Figure 1, which could have influenced the ability of the surveillance protocol to detect complications. Additionally, a slight underestimation of complication rate could be present, as patients who experienced sudden death, for whom the cause of death was unknown and no obduction was performed, aorta-related complications would remain undetected. Intergroup differences in patient characteristics between patients with and without CT follow-up, other than Euroscore II, could have affected the survival comparison. Furthermore, the sample size is small and the comparison of outcomes between groups might not have enough power to detect small differences. Lastly, the conclusions of this article are limited to the reported study population and cannot be extrapolated to all elective thoracic aortic surgery.

Conclusion

Following first time elective proximal aortic surgery, aorta-related complications are relatively uncommon and often do not lead to reintervention. The value of routine CT follow-up is questionable, as CT-detected complications rarely resulted in relevant changes in clinical management and prospective CT follow-up did not impact long-term survival. Therefore, a more conservative CT follow-up protocol could be considered in selected patients to reduce lifetime radiation burden and health care costs.

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Conflict of interest

None reported.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ahj.2022.04.003.

CRediT authorship contribution statement

Delano J. de Oliveira Marreiros: Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft. **Anton Tomšič:** Conceptualization, Data curation, Methodology, Writing – review & editing. **Thomas J. van Brakel:** Conceptualization, Supervision, Methodology, Writing – review & editing. **Jaap F. Hamming:** Supervision, Writing – review & editing. **Arthur J.H.A. Scholte:** Supervision, Writing – review & editing. **Jesper Hjortnaes:** Conceptualization, Supervision, Methodology, Writing – review & editing. **Robert J.M. Klautz:** Supervision, Writing – review & editing.

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