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Burden and causes of readmissions following initial discharge after aortic syndromes

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Article Highlights

Type of research

Retrospective, population-based study.

Key findings

Out of a total of 117 patients with diagnosis of aortic syndrome (AS) who survived the index event, 79 patients (68%) experienced at least one readmission following initial discharge. The median time to first any-cause, cardiovascular and aortic readmission was 143, 861 and 171 days, respectively. The cumulative incidence of any-cause readmissions at 2, 4 and 10 years was 45%, 55% and 69%, respectively. The cumulative incidence of cardiovascular readmissions at 2, 4 and 10 years was 15%, 20% and 28%, respectively. The cumulative incidence of aortic readmissions at 2, 4 and 10 years was 38%, 46% and 59%, respectively.

Take-home message

Readmissions following initial discharge after diagnosis of AS are common and not different across specific disease types. While aortic-related rehospitalization occur in more than half of patients but tend to be earlier, cardiovascular-related rehospitalizations tend to happen later in about one third of subjects.

Table of Contents Summary

In a population-based study of patients with diagnosis of aortic syndrome (AS), readmissions following initial discharge after diagnosis of AS are common and not different across specific disease types. While aortic-related rehospitalization occur in more than half of patients but tend to be earlier, cardiovascular-related rehospitalizations tend to happen later in about one third of subjects. This may suggest the need for early follow-up focused on aortic complications while later follow-up should address cardiovascular events.

Abstract

Introduction

Aortic syndromes (AS), including aortic dissection (AD), intramural hematoma (IMH), and penetrating aortic ulcer (PAU), carry significant morbidity and mortality; little data exist regarding burden and causes of related rehospitalizations following initial discharge.

Methods

The study was conducted using the Rochester Epidemiology Project (REP). All adult residents (age≥18 years) with an incident diagnosis of AD/IMH/PAU (1995-2015) were identified from the REP using the International Classification of Disease (ICD), 9th and 10th revision, codes and Hospital Adaptation of the ICD, 2nd edition, codes. Assessment of any-cause (aortic+cardiovascular), aortic-related, or cardiovascular-related readmissions was determined following date of hospital discharge or diagnosis date (i.e. the index event).

Results

A total of 117 patients out of 130 cases of AD/IMH/PAU included in the initial study population survived the index event and were evaluated. The median age of diagnosis was 74 years and 70 (60%) were male. A total of 79 patients (68%) experienced at least one readmission. The median time to first any-cause, cardiovascular and aortic readmission was 143, 861 and 171 days, respectively. The cumulative incidence of any-cause readmissions at 2, 4 and 10 years was 45%, 55% and 69%, respectively. The cumulative incidence of cardiovascular readmissions at 2, 4 and 10 years was 15%, 20% and 28%, respectively. The cumulative incidence of aortic readmissions at 2, 4 and 10 years was 38%, 46% and 59%, respectively. Overall survival for the entire cohort at 2, 4 and 10 years was 84%, 75% and 50%, respectively.

Conclusion

Readmissions following initial discharge after diagnosis of AS are common and not different across specific disease types. While aortic-related rehospitalization occur in more than half of patients but tend to be earlier, cardiovascular-related rehospitalizations tend to happen later in about one third of subjects. This may suggest the need for early follow-up focused on aortic complications while later follow-up should address cardiovascular events.

Keywords

Aortic syndrome; Readmissions: Epidemiology; Population-based.

Introduction

Aortic syndromes (AS), which include aortic dissection (AD), intramural hematoma (IMH), and penetrating aortic ulcer (PAU) are uncommon aortic pathologies with an incidence of 7.7 per 100,000 person-years[1]. Although rare, they are associated with significant aortic and cardiovascular morbidity and mortality[2]. Depending on the location and type of AS, acute management may be surgical, endovascular or medical. Following the acute management, lifelong surveillance is advocated since secondary aortic procedures are common over time, especially after aortic dissection. However, there is a paucity of data regarding burden and causes of hospitalizations following initial diagnosis of these pathologies. Previous work has shown mortality rate after AS diagnosis has remained relatively similar over the past several decades. Additionally, over 60% of deaths are attributable to cardiac or aortic causes. To improve the longitudinal care of patients with AS, understanding the cause for recurrent hospitalizations may identify patterns and etiologies for targeted intervention. Thus, the study aim was to evaluate the burden and pattern of readmissions following an initial diagnosis of AS using a population-based approach.

Methods

Study design

The present study was part of a retrospective, population-based study aimed to assess AS (AD/IMH/PAU) in Olmsted County, Minnesota (MN). The study was conducted using the

Rochester Epidemiology Project (REP), a medical record linkage system that includes virtually all residents and local health care providers in Olmsted County, MN. Because of the unique isolated nature of the region and few providers, billing data on all medical services are collated through the REP[3, 4]. This enables identification of incident diagnosis of medical conditions and permits review of treatments, evaluations, autopsy reports, and death certificates for decedents. The Mayo Clinic and Olmsted Medical Center Institutional Review Boards approved this study and granted a consent waiver for minimal risk. In addition, per Minnesota statutes, each patient identified with AS had provided authorization for the use of their medical record for research. No patients with AS were excluded because of lack of research authorization.

Cohort identification

Cohort identification has been previously described[1]. Briefly, all adult residents (age≥18 years) with an incident diagnosis of AD/IMH/PAU over two decades (1995 - 2015) were identified from the REP using the International Classification of Disease (ICD), 9th and 10th revision, codes and Hospital Adaptation of the International Classification of Diseases, 2nd edition, codes. To be included in the study, the diagnosis must be confirmed by imaging or, for immediate decedents, AS had to have been confirmed by autopsy or be listed on the death certificate as the main/primary diagnosis. AD/IMH/PAU were defined using current clinical practice guidelines[5]. All identified pathologies that met the inclusion criteria were evaluated regardless of the acuity of presentation. The AS was defined as acute if diagnosed and/or treated within 14 days of the onset of symptoms. Thereafter, it was defined as sub-acute between 2 weeks and 3 months, and chronic after 3 months.

For the present study only the patients surviving the index event/hospitalization were included. Comorbidities and medical events known before the index AS event were considered pre-existing, and subsequent events were defined as the outcome events. For assessment of comorbidities, the Charlson Comorbidity Index (CCI) was implemented[6]. For identification of the CCI comorbidities, the ICD and Hospital Adaptation of the International Classification of Diseases diagnostic codes were used. To be assigned as a comorbidity, two instances of the predefined code(s) within 5 years before the AS diagnosis date were necessary, as described in prior publications[7]. Censoring of all patients was done on March 31, 2019.

Events appraisal

Events (readmissions and mortality) assessment was done through two mechanisms. First, the REP data sources were queried for mortality status (with death certificates reviewed for cause) and readmissions. Second, vital status and death date information was queried using an institutionally approved fee-based Internet research location service (Accurint, accurint.com) to ensure that vital status was complete for all included subjects. If death occurred outside Minnesota, death certificates were retrieved as permissible by the vital records statutes within the state in which the decedent passed away. Events were classified as aortic (because of new-onset acute complications from AS or need for secondary treatment of AS-related complications either planned or not), cardiovascular (myocardial infarction MI, new-onset congestive heart failure CHF, new-onset atrial fibrillation AF, stroke, deep venous thrombosis/pulmonary embolism DVT/PE or cardiac arrest), or because of other reasons. In the case of acute thoracic pain leading to hospitalization, the event was classified as aortic if appropriate diagnostic tests ruled out cardiovascular events as above defined without any further evidence for alternate cause.

Assessment of any-cause (aortic and cardiovascular), aortic-related, or cardiovascular-related readmissions was determined following date of hospital discharge or diagnosis date (i.e. the index event).

Statistical analysis

Baseline characteristics were assessed overall with categorical data reported as number and percentage while continuous data was reported as median and IQR. In the time-to-event analyses, only the first readmission was considered. The cumulative incidence of readmissions was estimated while considering the competing risk of death. Discharge date or diagnosis date for those not admitted to hospital was considered as time 0. Analysis was conducted at 30 days, 90 days and 1 year. Trends in readmission (total number of readmission per year/total number of patients eligible per year) was assessed using univariate linear regression. Frequency of readmissions was grouped by patient's diagnosis year (i.e. time 0); if there was either death in first year or less than 1 year of follow-up, patient's readmissions were not included. Factors associated with readmissions were assessed using univariate Cox proportional hazard regression. Covariates for the models were entered before analysis, with only those considered to be most relevant based on current literature included (age, gender, type of AS, acuity of disease, Charlson Comorbidity Index CCI, previous cerebrovascular disease, initial management, in-hospital complications). Two, four, and ten-year survival was estimated using the Kaplan-Meier method. All statistical analyses were performed with the SAS statistical software (SAS 9.4, SAS Institute, Cary, NC, USA). A 2-sided P-value <0.05 was considered statistically significant.

Results

Study cohort

A total of 117 patients out of 130 included in the initial study population survived the index AS event and were included into the study. The median age of diagnosis was 74 years (IQR 61-80, range 28-93) and 70 (60%) were male (**Table 1**). Overall, AD was identified in 65 (56%), followed by PAU in 32 (27%) and IMH in 20 (17%). The median CCI for the entire cohort was 2 (IQR1-4, range 0-11) and the initial management was medical in 85 (73%).

Number, causes, and frequency of readmissions

A total of 79 patients (68%) experienced at least one readmission with a median time to first any-cause readmission of 143 days (IQR 15-1244, range 1-5664). The percentage of the cohort experiencing first any-cause readmission at 30 days, 90 days and 1 year was 26%, 32% and 41%, respectively. Pain and complications (from disease or treatment) were the main causes for readmission at 30 and 90 days (**Table 2 & Appendix Table 1**). A cardiovascular readmission was noted in 37 patients (32% of the entire cohort) with a median time to first cardiovascular readmission of 861 days (IQR 111-3006, range 1-5664). The percentage of the cohort experiencing first cardiovascular readmission at 30 days, 90 days and 1 year was 2%, 8% and 14%, respectively. An aortic readmission was noted in 66 patients (56% of the entire cohort) with a median time to first aortic readmission of 171 days (IQR 15-1213, range 1-5686). The percentage of the cohort experiencing first aortic readmission at 30 days, 90 days and 1 year was 22%, 26% and 33%, respectively. Frequency of readmissions is reported in **Table 3**. Analysis of trends in readmissions showed that during the study period there was no significant decrease in the median number of overall readmissions (-0.04 per year, SE 0.03, p=.28), cardiovascular

readmissions (-0.02 per year, SE 0.02, p=.27), or aortic readmissions (-0.015 per year, SE 0.03, p=.64).

Cumulative incidence of readmissions

With death as competing risk, the cumulative incidence of any-cause readmissions at 2, 4 and 10 years was 45% (95%CI 36-55), 55% (95%CI 46-65) and 69% (95%CI 60-79), respectively (**Figure 1**). The cumulative incidence of cardiovascular readmissions at 2, 4 and 10 years was 15% (95%CI 10-23), 20% (95%CI 14-29) and 28% (95%CI 20-38), respectively (**Figure 2**). The cumulative incidence of aortic readmissions at 2, 4 and 10 years was 38% (95%CI 30-48), 46% (95%CI 37-56) and 59% (95%CI 50-69), respectively (**Figure 3**).

Factors associated with readmissions

Univariate Cox Proportional Hazard showed that in-hospital complications were associated with both any-cause readmissions (HR 2.0, 95%CI 1.2, 3.2, p=.007) and aortic readmissions (HR 1.9, 95%CI 1.1, 3.2, p=.02), but not for cardiovascular readmissions (HR 1.5, 95%CI 0.7, 3.0, p=.30) (**Appendix Table 2**). Similarly, initial management (p=.04) was associated with any-cause readmissions (Open: HR 1.9, 95%CI 1.2, 3.0, p=.01 and Endo: 1.7, 95%CI 0.4, 6.9, p=.48, each vs. Medical) and aortic readmissions (p=.01) (Open: HR 2.2, 95%CI 1.3, 3.6, p=.003 and Endo: HR 2.1, 95%CI 0.5, 8.9, p=0.30), but not for cardiovascular readmissions (p=0.31). Conversely, CCI was associated with cardiovascular readmissions (HR 1.2, 95%CI 1.1, 1.3, p=.004), but not for any-cause readmissions (HR 1.0, 95%CI 0.9, 1.1, p=.68) or aortic readmissions (HR 1.0,

95%CI 0.9, 1.1, p=.71). Type of AS and acuity of disease (at index presentation) were not significantly associated with any-cause, cardiovascular or aortic readmissions.

Overall survival

Overall survival for the entire cohort at 2, 4 and 10 years was 84% (95%CI 77, 91), 75% (95%CI 67, 83) and 50% (95%CI 40, 62), respectively (**Supplementary Figure 1**). Univariate Cox Proportional Hazards showed that age (HR 1.7, 95%CI 1.3, 2.2, p<.001), CCI (HR 1.1, 95%CI 1.0, 1.2, p=.02), and CVD (HR 2.17, 95%CI 1.22, 3.87; p=.008). were associated with death (**Appendix Table 3**).

Discussion

Despite the advancement in medical and surgical management of aortic disease, AS (including AD, IMH and PAU) still carry a significant risk of early and long-term morbidity and mortality, which has remained substantially unchanged over the last 20 years[4]. They require lifelong clinical and imaging surveillance to detect secondary adverse events and address subsequent reinterventions during follow-up. Thus, rehospitalizations following initial discharge are a common event during the lifespan of AS patients and represent a significant cost for both patients and society. However, detailed data on the causes and burden of readmissions are lacking but will potentially highlight ways to improve the longitudinal care of this patients' group.

In this contemporary population-based assessment, we examined incidences of, reasons for, and factors associated with, readmissions after initial diagnosis of AS or discharge for AS. The following main findings were evident from this study. First, about two third of all patients with AS will experience at least one readmission during follow-up. Second, although readmissions seem to occur relatively early, as indicated by a median time to the first readmission of 143 days, a bimodal pattern appears to exist. Aortic readmissions were more common in the first year of follow-up, while cardiovascular readmissions mostly cumulated during the second year of follow-up. Third, different factors are associated with different types of readmissions, which may inform on how to tailor specific follow-up protocols according to the individual patient's presentation. Taken altogether, these findings would suggest a pattern of early intensive care for aortic complications and later care needs for cardiovascular events. Furthermore, they are similar to those from a recent series at the University of Bologna (Italy) detailing the long-term follow-up of 242 consecutive patients with final diagnosis of acute AS between 2010-2016, which reported that two thirds of these individuals will eventually develop at least one aortic or non-aortic event during long-term follow-up[8]. We believe follow-up should be based on careful multidisciplinary assessment, to be made on a case by case basis, and eventually lead to a patient-tailored protocol encompassing at least the frequency and consistency of imaging (with a balance to be achieved between the need to detect even subtle changes of the disease pattern and the necessity to keep radiation and contrast exposure as low as reasonable), early referral for intervention and strict management of cardiovascular risk factors.

In this study, neither type of AS (AD/IMH/PAU) nor acuity of disease were associated with aortic readmissions. Conversely, in-hospital complications and open surgery were significantly associated with their occurrence. These data may be attributable to different plausible causes.

First, they could be surrogate markers for more aggressive disease requiring more invasive treatment that lead to increased rate of complications and rehospitalizations. Second, since open surgery is usually reserved for AS involving the ascending aorta and/or aortic arch, this will indicate that, even after successful exclusion of the more proximal disease, AS might not be fully exempt from long-term adverse events. Indeed, a recent Swedish study focusing on long-term survival and frequency of reinterventions of patients undergoing proximal thoracic aortic surgery has showed that while aneurysm surgery normalizes mortality (in comparison with age-matched and sex-matched peers), dissection surgery still carries a high long-term mortality rate caused by disease progression[9]. These findings emphasize the need for close post-operative monitoring of AS patients to promptly address potential complications.

In our cohort, the cause for first readmission within 90 days was aneurysmal degeneration/expansion in 9%, rupture in 6% and planned intervention in 3%. Although difficult to ascertain, these data seem concordant with the existing evidence that incidence of reintervention after thoracic endovascular aortic repair (TEVAR) for AD is relatively high during midterm follow-up (mean rate of 15% at 3 years), with the three most common reasons for reintervention being endoleaks, false lumen perfusion (with/without aortic dilation), and new dissection[10, 11]. In fact, TEVAR has become the mainstay of treatment for AS involving the descending aorta in the presence of anatomic and/or clinical complications, mainly because of the early surgical benefit[12]. Furthermore, a recent statewide study from the California Office of Statewide Hospital Planning Development database reporting outcomes after acute uncomplicated type B AD (9.165 cases, mean age 66 years, 39% female) would suggest an independent survival benefit for TEVAR over medical therapy[13], a finding which may support a paradigm shift towards more aggressive management of acute type B AD even in the absence of

frank complications. However, TEVAR might not be able to prevent all aortic events during follow-up as indicated from the INSTEAD trial data[14] with subsequent consensus document[15] and further confirmed by a recent systematic review[16]. Thus, a more in-depth evaluation of the anatomy and physiology of patients with and without aortic degeneration might provide helpful data to assist with patients' selection, techniques implementation and surveillance strategies that may achieve higher clinical effectiveness and cost effectiveness as compared with "one-fits-all" algorithms[17]. Due to the limited number of patients treated with TEVAR over our 20-years review, we cannot comment on the impact TEVAR has for these aortic pathologies nor on the selection of patients' subgroups that might benefit the most from endovascular treatment.

As previously demonstrated, patients with AS have a significantly higher risk of non-aortic cardiovascular death and first-time non-fatal cardiovascular events as compared with population referents, a risk which did not seem to decrease even after excluding events occurring during the acute priod[18]. The findings from the present study further elucidate the timing and likely predisposing factors of these events. Indeed, cardiovascular readmissions were prevalent in the second year of follow-up and were predicted by higher CCI. Thus, it is likely that a greater burden of comorbidities will predispose this patients' group to higher risk of cardiovascular, but not aortic events. This was also expected to some extent, given that when compared with local controls, patients with AS have higher rates of cardiac, vascular and pulmonary disease, and carry a higher comorbidity burden[4]. Our findings further underline the need for measures aimed at reduction of the overall cardiovascular risk in individuals with AD, a need that has been recognized also in recent clinical practice guidelines from the European Society for Vascular Surgery[5]. Among cardiovascular risk factors, hypertension is the most commonly found in patients with AD and IMH, with a prevalence rate up to 80%, and thought to play a role in the

development and progression of the disease(s)[19, 20]. However, it has also been showed that AD patients may be poorly compliant with their antihypertensive regimen, and further work to improve medication adherence and to understand its impact on disease progression is vital to deliver the best outcomes for ASs patients[21].

Observations coming from this report must also be examined considering previously reported data from the same cohort. Indeed, we had already observed 5-, 10-, and 15-year survival rates of 62%, 43%, and 30%, respectively, with a significantly higher long-term risk of any-cause death for patients with AS compared to population referents even after exclusion of acute deaths[4]. In line with previously reported data[22-24], most patients (32%) in our cohort died of aortic causes, while cardiovascular causes were the primary diagnosis of death in 29% of the study subjects. However, further analysis of non-acute deaths only (>2 weeks following the index event), cardiovascular causes were more common than aortic causes in our cohort[18]. The findings from this study further strengthen these data, as indicated by the fact that only age ad diagnosis and baseline CCI (i.e. baseline comorbidity burden) were independent predictors for death. Although overall management of AS has significantly improved during the last decades, medical therapy and follow-up protocols for AS patients might still not be appropriate or strict enough to prevent the occurrence of aortic and cardiovascular deaths, thereby improving overall life expectancy and need for rehospitalizations. With these data, future work can focus on defining targets to improve the quality of care and prognosis of these complex aortic pathologies.

Epidemiologic studies of AS are usually difficult to conduct, as many reports for patients with AS predominantly come from multicenter registries[25], claims data[26, 27], or single-center series[28], which might bias the findings as more severe cases are generally referred to specialized centers. Furthermore, as patients follow-up might be undertaken at several locations, this could result in

heterogeneous and incomplete data. As a result, these methodologies, although specific may lack sensitivity[29]. In contrast, our results are strengthened by the fact that, within the United States, the REP provides unmatched conditions for the conduct of population-based research. Because Olmsted County is a relatively isolated geographical area, where all main health care providers in the county are included in the REP, virtually all health care delivered to Olmsted County residents can be reliably and consistently captured. Although Olmsted County displays a predominantly white population, previous REP studies showed high comparability in demographic and ethnic characteristics of the Olmsted County residents with those of Minnesota and the upper Midwest, as well as close mortality rates for Olmsted County and the United States overall[30].

Study limitations

Some limitations to our study must be acknowledged. First, owing to the relatively small subgroups of IMH and PAU, we may not have had enough power to detect a difference among these groups. We acknowledge that these are three separate but pathophysiological related pathologies. However, the study aim was to obtain a broad assessment on the burden and pattern of readmissions after initial AS diagnosis. Further studies with larger cohorts are warranted to identify specific subgroups of individuals that may warrant tailored protocols for follow-up and intervention. Owing to the retrospective, population-based nature of the research, the patients were managed by several providersand follow-up protocols were not standardized. Therefore, we could not identify specific shortcomings in the medical management of these patients, which should be the object of future research. Also, we acknowledge that the true autopsy rate in Olmsted County is not known, so it is possible that some patients may have died without

diagnosis. However, this would only impact incidence and not readmissions (as these patients would have been excluded from the present study). Lastly, our composite definition of aortic or cardiovascular readmissions did not allow us to differentiate the relative strength of single pathological entities.

Conclusion

Readmissions following initial discharge after diagnosis of AS are common and not different across specific disease types. While aortic-related rehospitalization occur in more than half of patients but tend to be earlier, cardiovascular-related rehospitalizations tend to happen later in about one third of subjects. This may suggest the need for early follow-up focused on aortic complications while later follow-up should address cardiovascular events.

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Tables

Table 1. Baseline demographics and clinical characteristics.

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Figures

Figure 1. Cumulative Incidence of Any-Cause Readmissions (with Death as a competing risk).

Figure 2. Cumulative Incidence of Cardiovascular Readmissions (with Death as a competing risk).

Figure 3. Cumulative Incidence of Aortic Readmissions (with Death as a competing risk).

Supplementary Figure 1. Kaplan-Meier Estimates for Overall Survival.

Table 1. Baseline demographics and clinical characteristics.

Variable	Total (N=117)
Type of AS	
AD	65 (55.6%)
IMH	20 (17.1%)
PAU	32 (27.4%)
Age at diagnosis	
Median	74.0
Q1, Q3	61.3, 80.3
Range	(27.8-93.4)
Gender	
Male	70 (59.8%)
Female	47 (40.2%)
Acute AS	64 (90.1%)
CCI	
Median	2.0
Q1, Q3	1.0, 4.0
Range	(0.0-11.0)
Previous MI	18 (15.4%)
Previous CHF	22 (18.8%)
Previous PVD	49 (41.9%)
Previous CVD	23 (19.7%)
Previous COPD	29 (24.8%)
Previous DM	21 (17.9%)
Initial management	
Medical	85 (72.6%)

Variable	Total (N=117)
Open	29 (24.8%)
Endovascular	3 (2.6%)

AS: aortic syndrome; AD: aortic dissection; IMH: intramural hematoma; PAU: penetrating aortic ulcer; CCI: Charlson Comorbidity Index; MI: myocardial infarction; CHD: congestive heart failure; PVD: peripheral vascular disease; CVD: cerebrovascular disease; COPD: chronic obstructive pulmonary disease; DM: diabetes mellitus.

Table 2. Number of readmissions within 1 year from start (Discharge date or Diagnosis date).

Readmission Type	**# of patients with readmission in 1 year**	**# of patients with readmission**	**Among those with readmission in 1 year** **Overall**	**Among those with readmission in 1 year** **Alive**	**Among those with readmission in 1 year** **Death**
	N	N	Median (Q1, Q3)	Median (Q1, Q3)	Median (Q1, Q3)
Any	44	78*	1.0 (1.0, 2.0)	1.0 (1.0, 2.0)	1.0 (1.0, 1.0)
CV	14	37	1.0 (1.0, 1.0)	1.0 (1.0, 1.0)	--
Aortic	35	65*	1.0 (1.0, 2.0)	1.0 (1.0, 2.0)	1.0 (1.0, 1.0)

*1 patient with incomplete 1 year of follow-up

DVT: deep venous thrombosis; PE: pulmonary embolism; CHF: congestive heart failure; CV: cardiovascular.

Appendix Table 1. Causes of readmissions.

	Total (N=117)
ANY READMISSION	
Any readmission	
Yes	79 (67.5%)
Days to 1st any readmission (Among those with any readmission)	
Median	143.0
Q1, Q3	15.0, 1244.0
Range	(0.5-5664.0)
Any 30-day readmission	
Yes	29 (25.7%)
Cause for 30-day any readmission – First Cause (Among those with any readmission within 30 days)	
Pain	12 (46.2%)
Aneurysmal degeneration/expansion	2 (7.6%)
Complication	7 (26.9%)
Rupture	2 (7.7%)
Stroke	1 (3.8%)
DVT/PE	1 (3.8%)
Limb Ischemia	1 (3.8%)
Any 90-day readmission	
Yes	36 (31.9%)
Cause for 90-day Readmission – First Cause (Among those with any readmission within 90 days)	
Pain	12 (36.4%)
Aneurysmal degeneration/expansion	3 (9.0%)
Planned Intervention	1 (3.0%)
Complication	8 (24.2%)
Rupture	2 (6.1%)
New-onset CHF	2 (6.1%)
Stroke	2 (6.1%)
DVT/PE	2 (6.0%)
Limb Ischemia	1 (3.0%)

	Total (N=117)
Any 1-year readmission	
Yes	45 (40.9%)
CV READMISSION	
CV readmission	
Yes	37 (31.6%)
Days to 1st CV readmission (Among those with CV readmission)	
Median	861.0
Q1, Q3	111.0, 3006.0
Range	(0.5-5664.0)
CV 30-day readmission	
Yes	2 (1.8%)
CV 90-day readmission	
Yes	9 (8.3%)
CV 1-year readmission	
Yes	14 (13.6%)
AORTIC READMISSION	
Aortic readmission	
Yes	66 (56.4%)
Days to 1st aortic readmission (Among those with aortic readmission)	
Median	171.0
Q1, Q3	15.0, 1213.0
Range	(0.5-5686.0)
Aortic 30-day readmission	
Yes	25 (22.1%)
Aortic 90-day readmission	
Yes	29 (25.9%)
Aortic 1-year readmission	
Yes	36 (33.0%)

Table 3. Frequency of readmissions.

		Any Readmission		CV Readmission		Aortic Readmission	
Year	**N**	**Median**	**Q1-Q3**	**Median**	**Q1-Q3**	**Median**	**Q1-Q3**
1995	4	1.5	0.5, 2.5	0.5	0, 1.5	1.0	0.5, 1.0
1996	6	2.0	1.0, 5.0	0.5	0, 1.0	1.5	0, 3.0
1997	2	0	0, 0	0	0, 0	0	0, 0
1998	7	1.0	0, 5.0	0	0, 0	1.0	0, 1.0
1999	2	1.5	0, 3.0	0.5	0, 1.0	1.0	0, 2.0
2000	3	4.0	1.0, 4.0	0	0, 0	3.0	1.0, 2.0
2001	11	2.0	1.0, 3.0	0	0, 1.0	1.0	1.0, 2.0
2002	9	2.0	1.0, 3.0	0	0, 1.0	1.0	0, 2.0
2003	7	1.0	0, 2.0	1.0	0, 2.0	0	0, 1.0
2004	4	0.5	0, 1.5	0.5	0, 1.0	0	0, 0.5
2005	2	1.0	0, 2.0	0	0, 0	1.0	0, 2.0
2006	8	2.0	0.5, 3.0	0.5	0, 1.0	0.5	0, 2.0
2007	4	2.0	1.0, 3.5	0.5	0, 1.0	1.5	0.5, 3.0
2008	2	1.0	0, 2.0	0	0, 0	1.0	0, 2.0
2009	3	0	0, 1.0	0	0, 0	0	0, 1.0
2010	7	1.0	0, 6.0	0	0, 1.0	1.0	0, 5.0
2011	4	0.5	0, 1.0	0	0, 0	0.5	0, 1.0
2012	7	1.0	1.0, 6.0	0	0, 1.0	1.0	1.0, 2.0
2013	6	0	0, 1.0	0	0, 0	0	0, 0
2014	5	1.0	0, 1.0	0	0, 1.0	0	0, 1.0
2015*	0						

*all patients in 2015 did not have enough follow-up to be considered

Appendix Table 2. Univariate Cox Proportional Hazards Models for Readmissions.

A. Any-Cause Readmission

Variable	HR (95% CI)	p-value
Type of AS		Overall p=0.238
AD	1.0 reference	
IMH	1.33 (0.73, 2.44)	0.349
PAU	0.74 (0.43, 1.26)	0.264
Age at diagnosis (per 10 years)	1.02 (0.87, 1.20)	0.805
Gender		
Male	1.06 (0.67, 1.68)	0.801
Female	1.0 reference	
Acuity of disease		Overall p=0.640
Acute	1.0 reference	
Subacute	1.56 (0.48, 5.11)	0.461
Chronic	0.67 (0.16, 2.78)	0.581
CCI	1.02 (0.94, 1.10)	0.677
CVD		
No	1.0 reference	
Yes	1.38 (0.81, 2.34)	0.238
Initial Management		Overall p=0.039
Medical	1.0 reference	
Open	1.85 (1.15, 3.0)	0.012
Endovascular	1.68 (0.41, 6.93)	0.476
In-Hospital Complications		
None	1.0 reference	
Any Complication	1.96 (1.20, 3.21)	0.007

Median Follow-up for Any-Cause Readmission = 6.95 (2.99, 12.29) years

B. CV Readmission

Variable	HR (95% CI)	p-value
Type of AS		Overall p=0.572
AD	1.0 reference	
IMH	0.58 (0.20, 1.67)	0.310
PAU	0.82 (0.38, 1.78)	0.620
Age at diagnosis (per 10 years)	1.23 (0.95, 1.60)	0.125
Gender		
Male	1.70 (0.82, 3.53)	0.155
Female	1.0 reference	
Acuity of disease		Overall p=0.980
Acute	1.0 reference	
Subacute	0.81 (0.11, 6.09)	0.842
Chronic	0.99 (0.13, 7.43)	0.991
CCI	1.15 (1.05, 1.27)	0.004
CVD		
No	1.0 reference	
Yes	2.35 (1.16, 4.79)	0.019
Initial Management		Overall p=0.314
Medical	1.0 reference	
Open	1.69 (0.86, 3.33)	0.128
Endovascular	--	
In-Hospital Complications		
None	1.0 reference	
Any Complication	1.46 (0.72, 2.96)	0.301

C. Aortic Readmission

Variable	HR (95% CI)	p-value
Type of AS		Overall p=0.107
AD	1.0 reference	
IMH	1.52 (0.81, 2.87)	0.196
PAU	0.67 (0.36, 1.24)	0.202
Age at diagnosis (per 10 years)	0.96 (0.81, 1.14)	0.622
Gender		
Male	1.16 (0.70, 1.92)	0.573
Female	1.0 reference	
Acuity of disease		Overall p=0.507
Acute	1.0 reference	
Subacute	1.98 (0.60, 6.55)	0.264
Chronic	0.82 (0.20, 3.44)	0.789
CCI	0.98 (0.90, 1.07)	0.713
CVD		
No	1.0 reference	
Yes	1.30 (0.73, 2.33)	0.376
Initial Management		Overall p=0.011
Medical	1.0 reference	
Open	2.15 (1.29, 3.57)	0.003
Endovascular	2.13 (0.51, 8.86)	0.300
In-Hospital Complications		
None	1.0 reference	
Any Complication	1.90 (1.12, 3.21)	0.018

AS: aortic syndrome; AD: aortic dissection; IMH: intramural hematoma; PAU: penetrating aortic ulcer; CCI: Charlson Comorbidity Index; CVD: cerebrovascular disease.

Appendix Table 3. Univariate Cox Proportional Hazards Models for Death.

Variable	HR (95% CI)	p-value
Type of AS		Overall p=0.451
Dissection	1.0 reference	
IMH	1.27 (0.60, 2.69)	0.540
PAU	1.47 (0.80, 2.69)	0.216
Age at diagnosis (per 10 years)	1.71 (1.32, 2.21)	<0.001
Gender		
Male	0.64 (0.38, 1.09)	0.102
Female	1.0 reference	
Acuity of Dx		0.803
Acute	1.0 reference	
Subacute	0.72 (0.10, 5.29)	0.743
Chronic	1.51 (0.36, 6.41)	0.577
CCI	1.11 (1.02, 1.20)	0.017
CVD		
No	1.0 reference	
Yes	2.17 (1.22, 3.87)	0.008
Initial Management		Overall p=0.688
Medical	1.0 reference	
Open	0.78 (0.42, 1.44)	0.425
Endovascular	0.67 (0.09, 4.89)	0.672
In-Hospital Complications		
None	1.0 reference	
Any Complication	0.90 (0.49, 1.66)	0.746

Median Follow-up for Death = 11.10 (4.82, 14.14) years

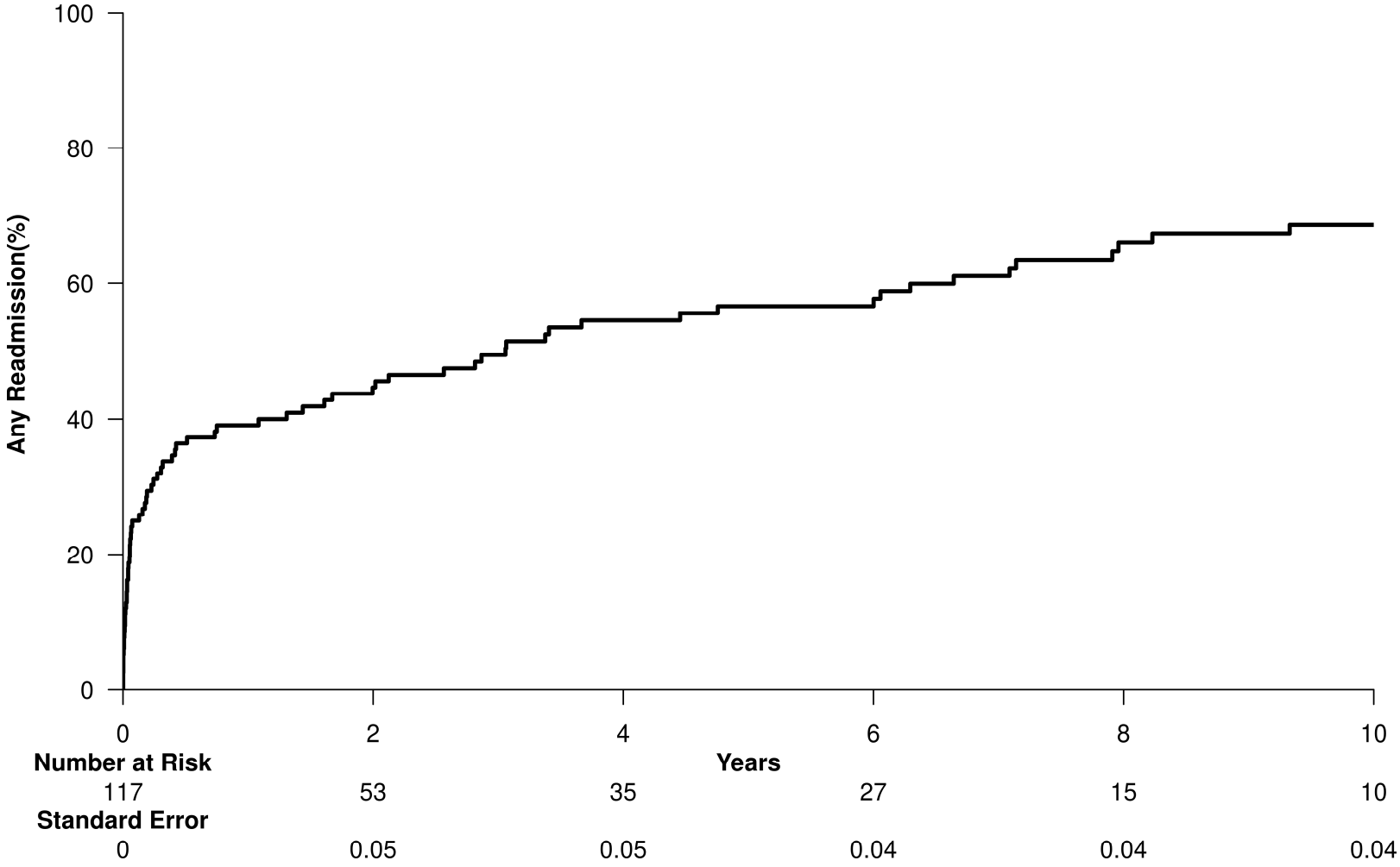
AS: aortic syndrome; AD: aortic dissection; IMH: intramural hematoma; PAU: penetrating aortic ulcer;

CCI: Charlson Comorbidity Index; CVD: cerebrovascular disease.

Table 3. Frequency of readmissions.

		Any Readmission		CV Readmission		Aortic Readmission	
Year	**N**	**Median**	**Q1-Q3**	**Median**	**Q1-Q3**	**Median**	**Q1-Q3**
1995	4	1.5	0.5, 2.5	0.5	0, 1.5	1.0	0.5, 1.0
1996	6	2.0	1.0, 5.0	0.5	0, 1.0	1.5	0, 3.0
1997	2	0	0, 0	0	0, 0	0	0, 0
1998	7	1.0	0, 5.0	0	0, 0	1.0	0, 1.0
1999	2	1.5	0, 3.0	0.5	0, 1.0	1.0	0, 2.0
2000	3	4.0	1.0, 4.0	0	0, 0	3.0	1.0, 2.0
2001	11	2.0	1.0, 3.0	0	0, 1.0	1.0	1.0, 2.0
2002	9	2.0	1.0, 3.0	0	0, 1.0	1.0	0, 2.0
2003	7	1.0	0, 2.0	1.0	0, 2.0	0	0, 1.0
2004	4	0.5	0, 1.5	0.5	0, 1.0	0	0, 0.5
2005	2	1.0	0, 2.0	0	0, 0	1.0	0, 2.0
2006	8	2.0	0.5, 3.0	0.5	0, 1.0	0.5	0, 2.0
2007	4	2.0	1.0, 3.5	0.5	0, 1.0	1.5	0.5, 3.0
2008	2	1.0	0, 2.0	0	0, 0	1.0	0, 2.0
2009	3	0	0, 1.0	0	0, 0	0	0, 1.0
2010	7	1.0	0, 6.0	0	0, 1.0	1.0	0, 5.0
2011	4	0.5	0, 1.0	0	0, 0	0.5	0, 1.0
2012	7	1.0	1.0, 6.0	0	0, 1.0	1.0	1.0, 2.0
2013	6	0	0, 1.0	0	0, 0	0	0, 0
2014	5	1.0	0, 1.0	0	0, 1.0	0	0, 1.0
2015*	0						

*all patients in 2015 did not have enough follow-up to be considered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2
4
6
8
10
Years
Number at Risk
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Standard Error
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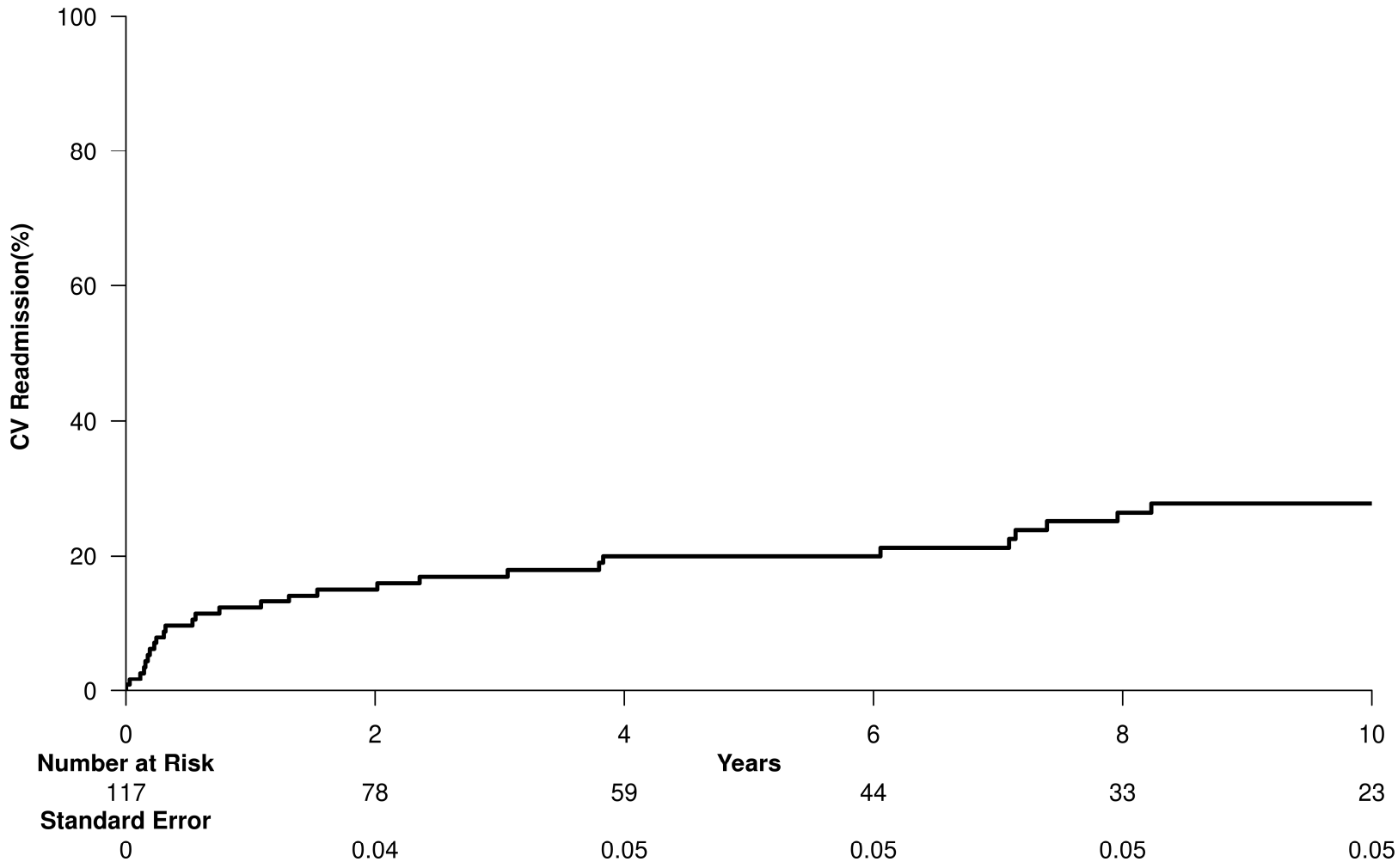
0.04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80
60
40
20
0
CV Readmission(%)
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2
4
6
8
10
Years
Number at Risk
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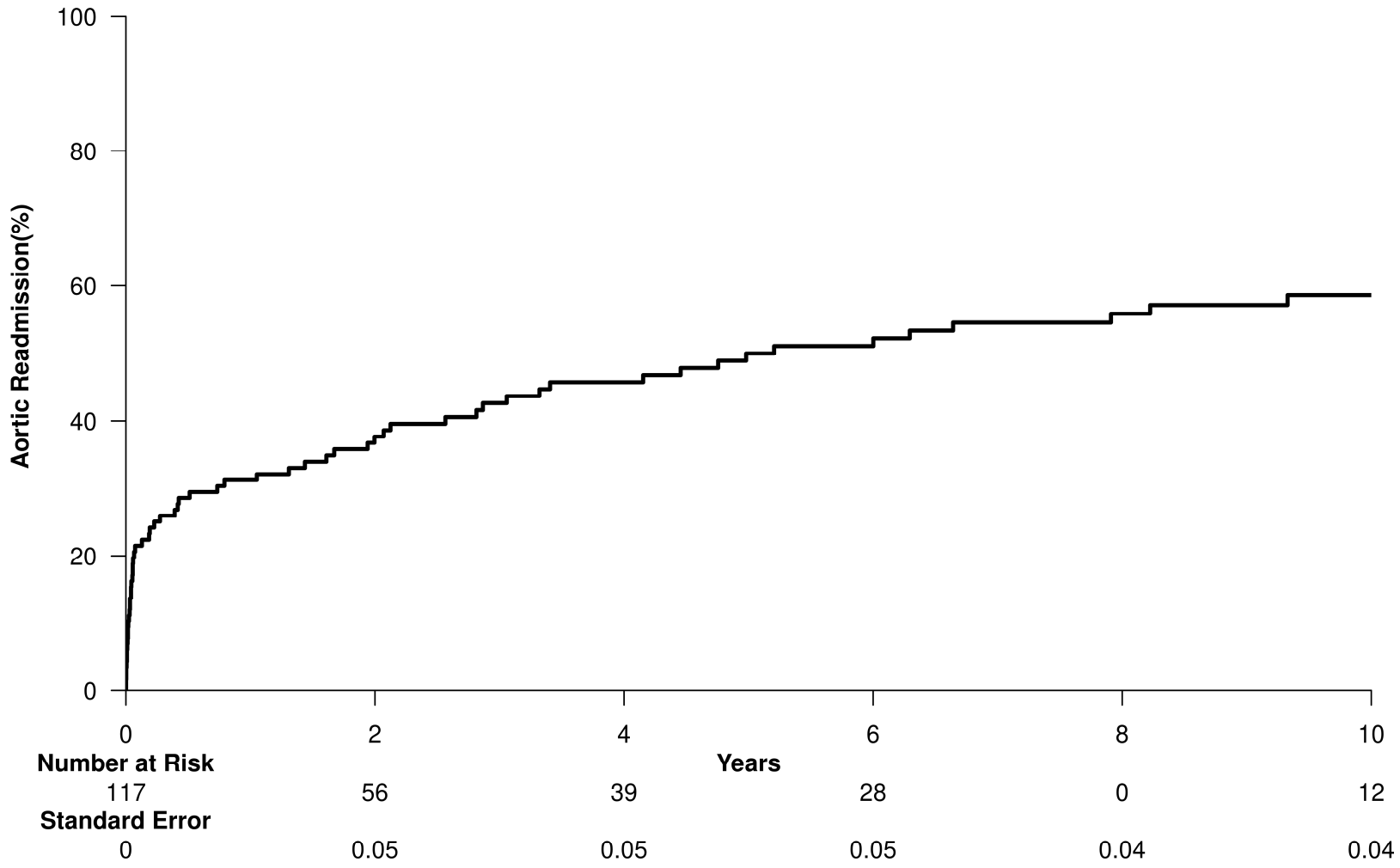
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40
20
0
0
2
4
6
8
10
Years
Number at Risk
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28
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12
Standard Error
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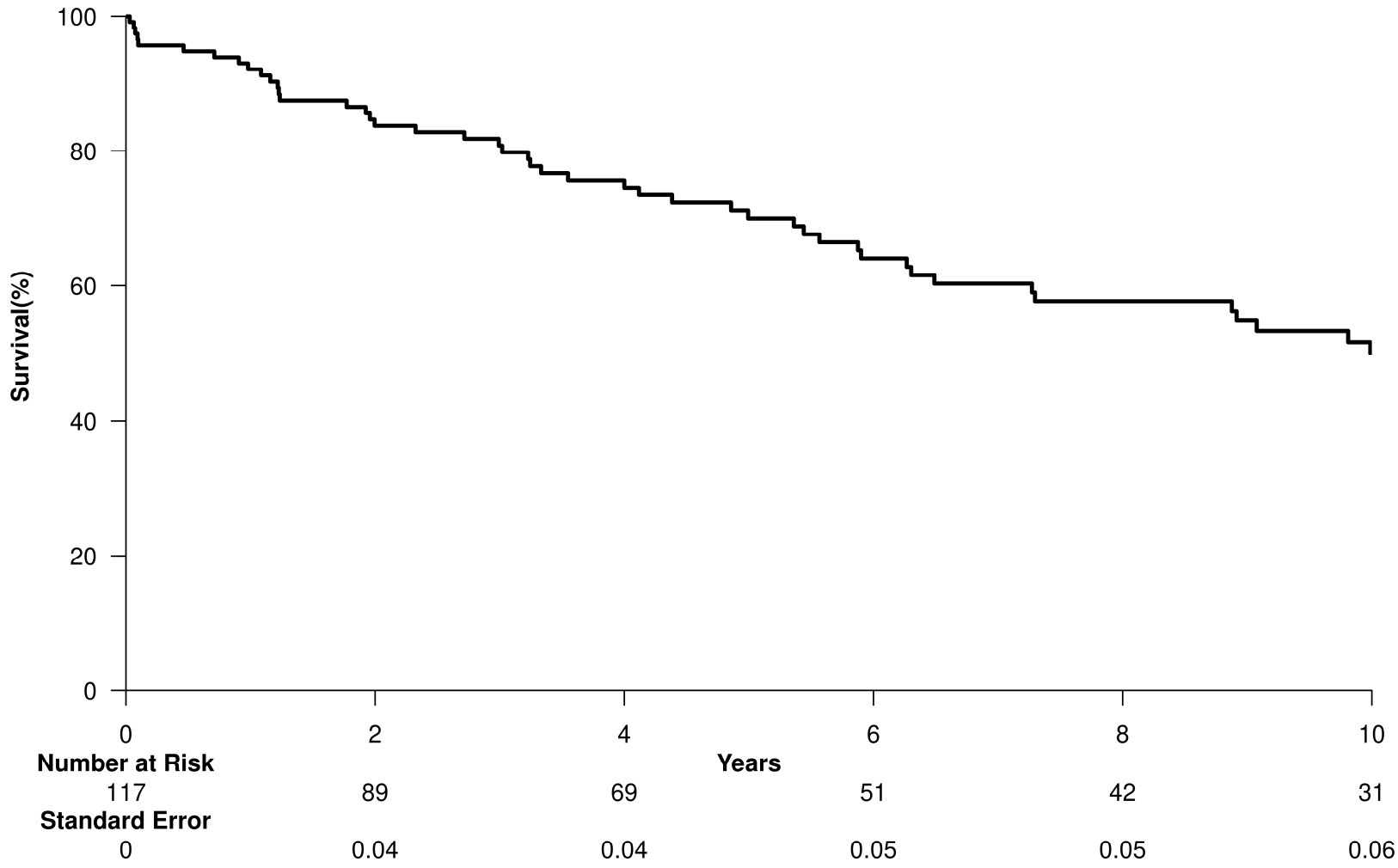
0.05
0.05
0.04
0.04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Survival(%)
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2
4
6
8
10
Years
Number at Risk
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69
51
42
31
Standard Error
0
0.04
0.04
0.05
0.05
0.06