European Journal of Cardio-Thoracic Surgery 50 (2016) 1111–1117
doi:10.1093/ejcts/ezw235 Advance Access publication 22 June 2016

ORIGINAL ARTICLE

Cite this article as: Melvinsdottir IH, Lund SH, Agnarsson BA, Sigvaldason K, Gudbjartsson T, Geirsson A. The incidence and mortality of acute thoracic aortic dissection: results from a whole nation study. Eur J Cardiothorac Surg 2016;50:1111–7.

# The incidence and mortality of acute thoracic aortic dissection: results from a whole nation study

**Inga H. Melvinsdottir[a], Sigrun H. Lund[b], Bjarni A. Agnarsson[b,c], Kristinn Sigvaldason[d], Tomas Gudbjartsson[a,b] and Arnar Geirsson[a,e,f,*]**

[a] Department of Cardiothoracic Surgery, Landspitali University Hospital, Reykjavik, Iceland
[b] Faculty of Medicine, University of Iceland, Reykjavik, Iceland
[c] Department of Pathology, Landspitali University Hospital, Reykjavik, Iceland
[d] Department of Anesthesiology, Landspitali University Hospital, Reykjavik, Iceland
[e] Section of Cardiac Surgery, Yale University School of Medicine, New Haven, CT, USA
[f] Department of Surgery, Veterans Affairs Connecticut Healthcare System, West Haven, CT, USA

* Corresponding author. Department of Cardiothoracic Surgery, Landspitali, Hringbraut, 101 Reykjavik, Iceland. Tel: +354-5431000; fax: +354-5437346; e-mail: arnarge@landspitali.is (A. Geirsson).

Received 29 March 2016; received in revised form 24 May 2016; accepted 6 June 2016

## Abstract

**OBJECTIVES**: Acute thoracic aortic dissection (ATAD) is a devastating condition associated with a high mortality rate. Recent reports suggest that its incidence is rising. Utilizing nationwide data comprising the whole Icelandic population, we aimed to determine the incidence, mortality rate and time-dependent mortality risk of ATAD.

**METHODS**: Data were retrospectively collected using centralized hospital discharge registries, autopsy records and Cause of Death Registry in Iceland from 1992 to 2013.

**RESULTS**: Age- and gender-adjusted incidence of ATAD was 2.53/100 000/year, and no significant change in incidence was observed during the study period. The mean age was 66.9 ± 13.6 years and 66.0% (101/153) were Stanford type A. Of the whole group, 17.6% (27/153) died prior to hospital arrival, whereas the risk of death for patients who arrived alive to a hospital was 21.4% (27/126) within 24 h and 45.2% (57/126) at 30 days. During the course of the study, patients with type A dissection were more likely to undergo an operation and the management of type B dissection changed from open to endovascular repair. The 30-day mortality rate declined every year and the 5-year survival rate improved in the last third of the study.

**CONCLUSIONS**: The incidence of ATAD was 2.53/100 000/year and remained constant throughout the study, contradicting recent perceptions of a rising incidence. ATAD, type A in particular, remains a highly lethal condition: Over half of all patients die within 30 days of the index event. A reduced 30-day mortality rate and an increased long-term survival rate indicate improved overall outcomes in patients with this complex condition.

**Keywords:** Aortic dissection • Aortic surgery • Epidemiology • Population studies

## INTRODUCTION

Acute thoracic aortic dissection (ATAD) is a complex disease generally associated with high morbidity and mortality rates [1, 2]. Its pathogenesis is reasonably well defined and patients die of aortic rupture, tamponade, acute aortic insufficiency and malperfusion syndromes [3]. Existing studies describing the incidence of ATAD have predominantly looked at incidence in geographically limited areas or included primarily hospital admissions and thus may not reflect the true incidence of ATAD. These studies differ in design but suggest that for the past decades, the incidence of ATAD has increased from 2–3.5/100 000/year to more than 6/100 000/year for a general cohort and up to 15/100 000/year in older individuals [4–9].

Defining the true incidence of aortic dissection is hampered by its high early mortality rate and the challenge of diagnosing the disease. Death outside of a hospital is reported to be between 21 and 49%, whereas the early (<24 h) mortality rate can reach 50%, at times associated with delay in diagnosis or missed diagnosis [4, 7]. The national healthcare system in Iceland is a modernized single-payer system, allowing easy access to healthcare. Comprehensive hospital databases as well as reasonably high autopsy rates, therefore, allow for a near-complete capture of all cases of ATAD. This makes Iceland a particularly appealing place to study such a relatively uncommon and morbid disease.

Accordingly, in this study, we aimed primarily to assess the contemporary incidence and outcome of ATAD but also to analyse time-dependent mortality risk and the effects of treatment strategies on outcomes. To do so, we utilized nationwide data from the whole Icelandic population from 1992 to 2013.

## MATERIALS AND METHODS

### Data sources

Data were retrospectively collected utilizing databases from the Landspitali University Hospital and all (four) regional hospitals in Iceland, the separate intensive care unit database at Landspitali as well as hospital and forensic autopsy databases of the Department of Pathology at Landspitali (where all autopsies in Iceland are performed) between 1 January 1992 and 31 December 2013. The Cause of Death Registry at The Directorate of Health, for the same period, was queried and concurred with clinical and autopsy databases. To capture all cases, extended search criteria for ATAD were used that are given in Supplementary Table 1. These criteria included diagnostic codes, procedure codes and pathology codes comprising aneurysm, dissection and aortic operations involving the chest cavity. ATAD was defined as disruption of the media layer of the aorta with bleeding within and along the wall of the aorta resulting in separation of the layers of the aorta [10]. The index event of acute dissection was defined as a dissection less than 2 weeks old confirmed by autopsy, imaging or an operative report. Intramural haematoma or penetrating aortic ulcers were not defined separately since the designation and ICD coding for these conditions are not well described. In cases where chronic aortic dissection was identified, the original acute index event was backtracked to the approximate month and year of the initial diagnosis.

Initial queries of databases retrieved 3637 returns for 1910 individual patients. Medical records of 3 patients were not available for review or were missing, resulting in 1907 electronic medical records and paper charts that were manually reviewed. A computerized autopsy database was available only from 1995 onwards; thus, 1161 autopsy records from 1992 to 1994 were manually reviewed. Two members of the research team (I.H.M. and A.G.) manually reviewed the charts to exclude or confirm the diagnosis of ATAD. One individual was diagnosed with two separate dissections, initially with type B and 2 years later with type A dissection. Each was counted as an index event, but the first event was censored for survival once the second event occurred.

Demographics, medical history, risk factors and clinical symptoms, totalling 92 variables, were retrospectively collected for all patients and are shown in Supplementary Methods.

### Primary outcomes

The primary outcomes were short-term mortality and long-term overall survival. Short-term mortality was defined as death prior to hospital, death within 6 or 24 h of hospital arrival and death within 30 days of admission. Long-term survival was defined as survival from the day of the index event until death or end of follow-up. Individuals who died prior to arrival to hospital were excluded from survival calculations. Information on survival was available for all patients with Icelandic ID numbers from Registers Iceland, queried on 1 March 2015, and was 100% complete. Survival for foreign visitors (7 cases) was censored on the day of discharge or last encounter. Median survival of all patients who arrived alive to hospital was 2.88 years [95% confidence interval (CI): 0.04–4.82] with a total 469 years of follow-up.

### Statistical analysis

Incidence was calculated and standardized according to the age and gender distribution of the population in the year 2013, derived from the National Statistics Iceland. Foreign visitors were not counted in incidence calculation but were included in short-term outcome data. Differences in incidence by age, gender, the type of dissection or calendar period were estimated with Poisson regression, using population data as offset. Continuous variables were expressed as mean ± SD and categorical variables as percentages. Student's $t$-test was used for continuous variables and $\chi^2$ and Fisher's exact test were used for categorical variables. Odds ratios (ORs) for predictors of short-term mortality (<24 h or 30-day mortality rate) were estimated with logistic regression. Cases of death prior to hospital arrival were excluded from risk analysis. Hazard ratios for predictors of long-term survival were estimated with Cox proportional hazards regression. Independent predictors of short-term mortality and long-term survival were determined with a stepwise-selected multivariate logistic regression model and a stepwise-selected Cox proportional hazards regression model, respectively; we chose the model that minimized the Akaike information criterion. Possible predictors of outcomes used in models determining the 24-h mortality rate included age, sex, whether operation was performed, hypotension and the presence of malperfusion syndrome; the 30-day mortality rate: age, sex, chronic renal insufficiency, whether an operation was performed, family history of dissection and malperfusion; and the long-term survival rate: age, chronic renal insufficiency, coronary artery disease, family history of dissection, whether an operation was performed, hypotension and malperfusion. Kaplan–Meier curves were drawn to estimate the overall survival rate, as well as survival by gender, type of dissection and calendar period.

The study was approved by the Icelandic National Bioethics Committee and the Icelandic Data Protection Commission. As individual patients were not identified, obtaining individual consent for the study was waived.

## RESULTS

### Patient characteristics

During the study period, 153 index events of ATAD were identified in 152 patients of which 101 (66.0%) patients were diagnosed with Stanford type A and 52 (34.0%) with Stanford type B dissection. Demographics and clinical characteristics of the patients are presented in Table 1. The mean age at the index event was 66.9 ± 13.6 years, with the women being significantly older than the men (71.9 ± 10.9 vs 63.8 ± 14.3 years, $P$ < 0.001). There were more men than women (1:59). Hypertension was present in 57.5% of patients and 62.0% had a history of smoking. Patients diagnosed with type A dissection more often had a positive family history of dissection and presented with signs signifying greater severity of the illness, such as hypotension and syncope. Chest pain was the prevailing symptom at presentation in all groups of patients.

**Table 1:** Demographics, risk factors, clinical presentation and imaging methods for diagnosis by type of dissection

| | All ($n$ = 153) | Type A ($n$ = 101) | Type B ($n$ = 52) | $P$-value |
|---|---|---|---|---|
| Mean (SD) age, years | 66.9 (13.6) | 65.6 (15.0) | 69.6 (10.1) | 0.052 |
| Male | 94 (61.4) | 60 (59.4) | 34 (65.4) | 0.586 |
| Hypertension ($n$ = 146) | 84 (57.5) | 53 (55.8) | 31 (60.8) | 0.684 |
| Diabetes ($n$ = 148) | 3 (2.0) | 3 (3.0) | 0 (0.0) | 0.552 |
| Dyslipidaemia ($n$ = 105) | 26 (24.7) | 12 (19.0) | 14 (33.3) | 0.153 |
| CRI ($n$ = 131) | 11 (8) | 6 (7.4) | 5 (10.0) | 0.748 |
| Coronary artery disease | 40 (26.7) | 25 (25.5) | 15 (28.9) | 0.153 |
| Peripheral vascular disease | 22 (14.5) | 14 (14.0) | 8 (15.4) | >0.999 |
| Prior TIA | 5 (3.3) | 3 (3.0) | 2 (3.9) | >0.999 |
| Prior stroke | 7 (4.7) | 5 (5.0) | 2 (3.9) | >0.999 |
| COPD | 13 (8.7) | 7 (6.9) | 6 (11.8) | 0.367 |
| Smoking history ($n$ = 121) | | | | |
| Active smoker | 41 (33.9) | 23 (30.0) | 18 (40.9) | 0.111 |
| Prior smoker | 34 (28.1) | 22 (28.6) | 12 (27.3) | |
| Known thoracic aneurysm | 15 (11.5) | 10 (9.9) | 5 (9.6) | >0.999 |
| Connective tissue disease | 3 (2.0) | 2 (2.0) | 1 (1.9) | >0.999 |
| Bicuspid aortic valve ($n$ = 122) | 6 (4.9) | 6 (6.7) | 0 (0.0) | 0.339 |
| Family history of dissection | 7 (4.6) | 6 (5.9) | 1 (1.9) | 0.023 |
| Chest pain ($n$ = 128) | 109 (85.1) | 69 (89.6) | 40 (78.4) | 0.137 |
| Heart failure ($n$ = 120) | 9 (7.5) | 8 (11.0) | 1 (2.1) | 0.088 |
| Syncope ($n$ = 140) | 57 (40.7) | 50 (55.6) | 7 (14.0) | <0.001 |
| Hypotension ($n$ = 119) | 43 (36.1) | 41 (56.9) | 2 (4.3) | <0.001 |
| Malperfusion syndrome ($n$ = 106) | 31 (29.2) | 19 (31.7) | 12 (26.1) | 0.682 |

Categorical data expressed as $n$ (%).
SD: standard deviation; CRI: chronic renal insufficiency; TIA: transient ischaemic attack; COPD: chronic obstructive pulmonary disease.



AORTIC SURGERY

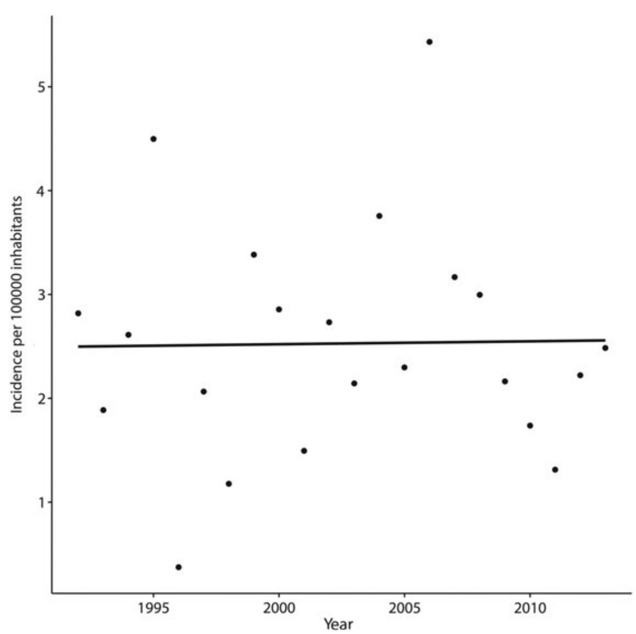


**Figure 1:** Incidence of acute thoracic aortic dissection in Iceland 1992–2013, adjusted to the age and gender distribution of the population in the year 2013.

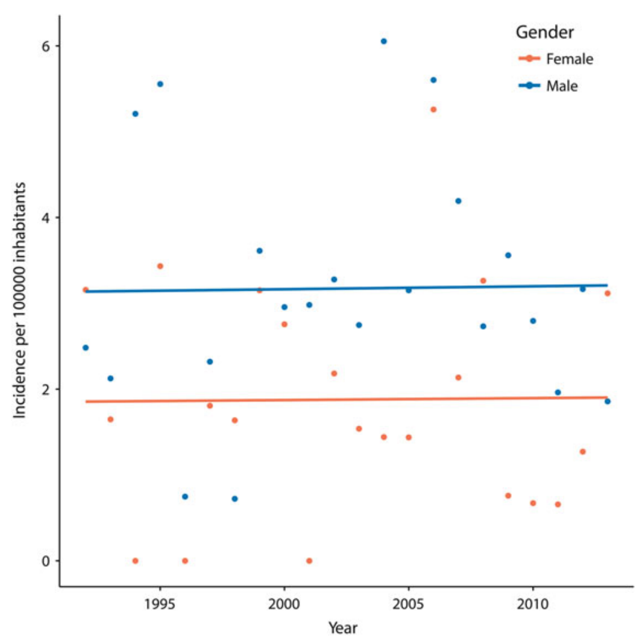


**Figure 2:** Incidence of acute thoracic aortic dissection in men and women, adjusted to the age distribution of each gender of the population in the year 2013.

## Incidence of acute thoracic aortic dissection

The population of Iceland was 259 727 in 1992 and increased to 321 857 in 2013 with an average of 290 072 for the study period [11]. Using a numerator of 153 index events, the age- and gender-adjusted incidence of ATAD was estimated to be 2.53/100 000/year (95% CI: 2.13–3.00). No significant change was observed in the incidence rate during the course of the study, where annual percent change (APC) was 0.68% ($P$ = 0.606) (Fig. 1). For men, the incidence was 3.17/100 000/year (95% CI: 2.54–3.94), which was significantly higher than that for women, 1.88/100 000/year (95% CI: 1.41–2.50) with an incidence rate ratio (IRR) of 0.61 ($P$ = 0.004).

No change was noted in the incidence rates for either men (APC: 0.57%) or women (APC: 0.83%, $P = 0.923$) over the course of the study (Fig. 2). In patients aged less than 65 years, the incidence was 1.10/100 000/year (95% CI: 0.82–1.45), whereas in patients aged ≥65 years, it was 12.12/100 000/year (95% CI: 9.75–15.13) with an IRR of 12.53 ($P < 0.001$). The incidence in patients less than 65 years of age did increase (APC: 4.17%), whereas it decreased in the age group ≥65 years (APC: −1.85%, $P = 0.030$) during the study period (Fig. 3). The incidence for different types of dissections was 1.71/100 000/year for type A and 1.04/100 000/year for type B, and no significant change was noted in incidence rates of either type (Supplementary Figure 1).

## Early outcomes

Early time-dependent mortality rates for patients with ATAD are presented in Table 2. There were 27 (17.6%) cases of death prior to hospital arrival, of which 92.6% (25/27) had a type A dissection ($P = 0.003$). For patients who arrived alive to a hospital, the mortality rate was 10.3% in the first 6 h, 21.4% within 24 h and 45.2% within 30 days. Including all cases, the 30-day mortality rate from the index event was 54.9%, regardless of treatment modality. The 24-h and 30-day mortality rates were significantly higher for patients diagnosed with a type A than for patients with a type B dissection. During the course of the study, the proportion of patients who died prior to hospital arrival did not change nor did the 24-h mortality rate (OR: 1.02, 95% CI: 0.95–1.09, excluding dead on arrival cases). However, the 30-day mortality rate decreased significantly for each calendar year of the study period (OR: 0.94, 95% CI: 0.88–0.99).

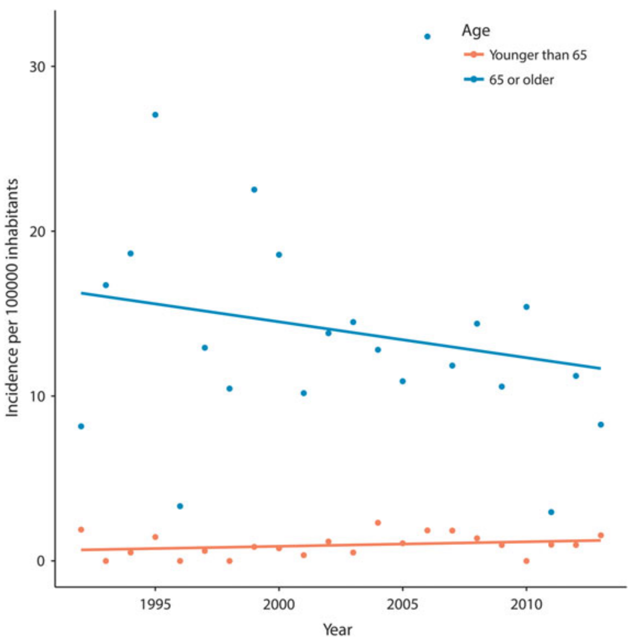


**Figure 3:** Incidence of acute thoracic aortic dissection stratified to individuals over the age of 65 and individuals 65 years and younger, adjusted to the gender distribution of the population in 2013.

The analysis of the 101 patients diagnosed with type A dissection revealed that 24.8% (25/101) died prior to arrival at a hospital and of the remaining 76 patients, 55.3% (42/76) underwent an operation to repair the dissection. Of the 34 patients who arrived alive to a hospital, but did not undergo an operation, 17.6% (6/34) died before reaching the operating room after a decision had been made for an operation; 26.5% (9/34) were not operated on because they were considered to be of extreme operative risk; 1 refused an operation; in 11.8% (4/34), the reason for not operating was unknown; and in 41.2% (14/34), the diagnosis was not established until autopsy. The 30-day mortality rate for patients operated for type A dissection was 28.6% and did not change significantly throughout the study period. Of the 34 non-operated patients with type A dissection, only 2 patients (5.9%) survived to discharge and there were no survivors beyond 1 year from the index event. The proportion of patients undergoing an operation for type A dissection increased significantly over the study period: 75.8% (25/33) patients underwent surgery in the years 2007–2013 compared with 38.1% (8/21) in 1992–1999 and 40.9% (9/22) in 2000–2006 ($P = 0.007$).

Of the 52 patients with type B dissection, only 2 died prior to hospital arrival. Of the patients admitted to hospital, 26.0% (13/50) underwent an operation for the treatment of the dissection. The overall 30-day mortality rate decreased from 50% (8/16) in 1992–1999 to 0% (0/13) in 2006–2013 ($P = 0.011$). In the first third of the study, the primary operative method was open thoracotomy aortic repair, whereas endovascular methods were used in the last third.

Univariate logistic regression analysis of risk factors associated with early mortality is given in Supplementary Table 2. Using multivariate analysis, independent predictors of death within 24 h were determined to be female sex and hypotension for 30-day

**Table 2:** Short-term outcome by type of dissection

| | All ($n$ = 126) | Type A ($n$ = 76) | Type B ($n$ = 50) | $P$-value |
|---|---|---|---|---|
| Death prior to hospital ($n$ = 153) | 27 (17.6) | 25 (24.8) | 2 (3.8) | 0.003 |
| Death <6 h of hospital arrival | 13 (10.3) | 11 (14.5) | 2 (4.0) | 0.112 |
| Death <24 h of hospital arrival | 27 (21.4) | 22 (28.9) | 5 (10.0) | 0.021 |
| Death <30 days of hospital arrival | 57 (45.2) | 43 (56.6) | 14 (28.0) | 0.003 |
| Operation performed | 55 (43.7) | 42 (55.3) | 13 (26.0) | <0.001 |
| Mean (SD) ICU stay, days | 6.5 (10.0) | 6.7 (9.6) | 6.1 (10.6) | 0.772 |
| Mean (SD) hospital stay, days | 18.7 (23.2) | 19.0 (23.1) | 18.3 (23.7) | 0.883 |

Categorical data expressed as $n$ (%).
SD: standard deviation; ICU: intensive care unit.

**Table 3:** Multivariate predictors of mortality

| | OR | 95% CI |
|---|---|---|
| Death <24 h | | |
| Female sex | 4.26 | 1.09–20.14 |
| Operation performed | 0.34 | 0.08–1.32 |
| Hypotension | 4.87 | 1.28–20.88 |
| Malperfusion syndrome | 3.91 | 0.98–16.96 |
| 30-Day mortality rate | | |
| Female sex | 4.10 | 1.47–12.20 |
| Chronic renal insufficiency | 11.94 | 1.87–110.36 |
| Operation performed | 0.46 | 0.15–1.31 |
| Family history of dissection | 2.95 | 1.02–9.32 |
| Hypotension | 3.90 | 1.32–12.52 |
| Malperfusion syndrome | 3.68 | 1.22–12.07 |
| | HR | 95% CI |
| Long-term mortality rate | | |
| Age | 1.04 | 1.01–1.08 |
| Family history of dissection | 1.55 | 0.86–2.79 |
| Operation performed | 0.48 | 0.25–0.94 |
| Hypotension | 2.53 | 1.32–4.85 |
| Malperfusion syndrome | 1.80 | 0.97–3.35 |

Independent predictors of short-term mortality rate (<24 h or 30-day mortality rate) were determined with the stepwise-selected multivariate logistic regression model. Independent predictors of long-term survival rate were determined with the stepwise-selected Cox regression model. OR and HR from the final model.
OR: odds ratio; HR: hazard ratio; CI: confidence interval.

mortality rate: female sex, chronic renal insufficiency, family history of aortic dissection, hypotension and malperfusion syndrome, while performing an operation predicted lower mortality (Table 3).

## Late outcomes

The long-term survival rate of all patients diagnosed with dissection was 52.9 ± 4.5% at 1 year, 39.6 ± 4.6% at 5 years, 33.6 ± 4.8% at 10 years and 21.5 ± 6.7% at 20 years (Supplementary Figure 2). The long-term survival rate was not different between genders ($P = 0.103$) or between type A and B dissections ($P = 0.086$) (Supplementary Figures 3 and 4). The 5-year survival rate improved during the course of the study from 31.8 ± 7.8% in 1992–1999 to 51.6 ± 8.6% in 2007–2013 (hazard ratio: 0.52, 95% CI: 0.29–0.94, $P = 0.030$) (Fig. 4). Results of univariate Cox proportional hazards regression on risk factors associated with higher long-term mortality are given in Supplementary Table 2. On multivariate analysis, using the stepwise-selected Cox proportional hazards regression model, the identified independent predictors of late mortality were age and hypotension on arrival to hospital, whereas undergoing an operation was associated with a decreased hazard ratio for time-dependent mortality (Table 3).

## DISCUSSION

The main objective of this study was to define the true incidence of ATAD using across-the-board nationwide data from a well-defined population. Great efforts were made to include all cases

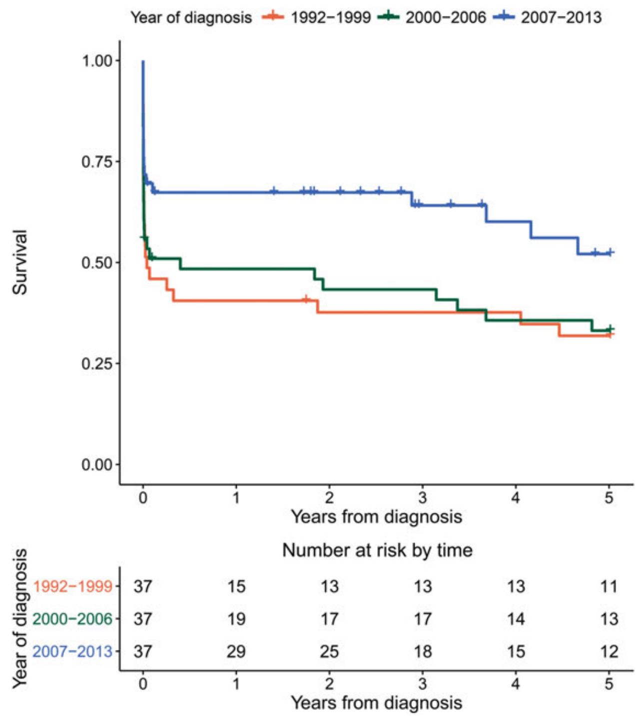


**Figure 4:** Kaplan–Meier estimates of survival of patients with acute thoracic aortic dissection in different periods. Hazard ratio (HR) by Cox regression, calendar period 1992–1999 as baseline, for 1999–2006: 0.92, 95% CI: 0.55–1.54, $P = 0.761$; 2007–2013: 0.52, 95% CI: 0.29–0.94, $P = 0.03$.

by querying many different hospitals and registry databases in Iceland and using broad definitions to avoid overlooking miscoded cases. We report the incidence of ATAD to be 2.53/100 000/year, and it remained stable throughout the study period. Our findings contradict recent reports suggesting that the incidence of ATAD is rising. The Oxford Vascular Study, which is the only prospective study looking specifically at vascular diseases, reported the incidence of ATAD as 6/100 000/year. However, it included only patients registered to general physician practices in a geographically limited area with a population of 92 728 [7]. The Malmö Diet and Cancer study reported an even higher incidence of 15/100 000/year, using a retrospective cohort designed to investigate the association of diet and cancer in middle-aged individuals born between 1923 and 1950. Although different age groups were not categorized in the Malmö Diet and Cancer study, their incidence is comparable with the incidence that we observed in persons ≥65 years in the present study, indicating that the population incidence was overestimated due to underrepresentation of younger individuals in their cohort [9]. A large nationwide population-based study described a rising incidence of thoracic aortic aneurysm and dissection in Sweden from 1987 to 2002; however, the data included the incidence of both aneurysms and dissections, making it impossible to draw a specific conclusion regarding ATAD [6]. The incidence we report in the present study is, however, in line with contemporary data from the Medicare admission database where the rates of hospitalization for ATAD remained stable at 10/100 000/year in patients >65 years of age from 2000 to 2011 [12]. It also agrees with long-term data from Olmsted County, Minnesota, where the incidence of ATAD has remained between 2.6 and 3.5/100 000/year for the last decades, and from a study from Sumeg, Hungary that showed an incidence of 2.9/100 000/year [3–5]. These studies suffer from

AORTIC SURGERY

relatively small populations or cohorts containing fewer than 100 000 individuals, whereas the mean size of the Icelandic population during the study period was ∼290 000 inhabitants [11]. The only larger population-based study on ATAD incidence comes from the National Health Insurance Database in Taiwan where incidence was reported as 4.3/100 000/year; however, that study included only hospital admissions and was limited by possible miscoding [8].

We feel confident that we included practically all admissions and hospital deaths due to ATAD. Whether we captured all deaths due to dissection that occurred outside of hospital settings, however, is more difficult to determine. According to Icelandic law, it is mandatory to perform an autopsy on individuals who die without an obvious cause of death. In an attempt to minimize missed index cases of out-of-hospital deaths, we queried all forensic and hospital autopsies performed in Iceland during the study period. Similar to that of many other Western countries, the total autopsy rate in Iceland steadily declined during the study period, or from 24.0% in 1992 to 9.2% in 2013 (averaging 15.4%) [13]. This was primarily due to a decline in autopsies performed in hospital where the rate dropped from 16.5% in 1992 to 2.5% in 2013, whereas the rate of forensic autopsies remained stable at ∼8.5 ± 1.6%. The current autopsy rate in Iceland is similar to that in the United States (8.5%), whereas rates in Western European countries range from 3 to 34% [14–18].

Hypertension was present in 57.5% of patients and is the primary established treatable risk factor for ATAD [7, 9]. Smoking has not been defined as a strong risk factor like hypertension, but smoking rates are consistently higher in ATAD patients than in controls [9]. History of smoking was 62.0%, whereas in the Icelandic population, it was 52.7% during the study period [19]. Over the last decades, Iceland has observed significant improvement in blood pressure control and smoking cessation. In men aged 45–65 years, blood pressure decreased from mean systolic blood pressures of 140 mmHg in 1967 to 127 mmHg in 2007 [20]. Similarly, rates of active smoking in Iceland have decreased from 33.2% in 1994 to 16.8% in 2013 [19]. Modulation of these and other risk factors such as cholesterol levels and physical inactivity is believed to explain most of the decline in coronary artery disease mortality observed in Iceland over the last three decades [21]. Risk profiles for patients with coronary artery disease are not dissimilar to those of patients with ATAD. Improved blood pressure control and smoking cessation could explain the observed reduction in incidence of ATAD in the group aged 65 and over; however, we did not see a reduction in ATAD rates in the younger or in the overall group. It is possible that other uncontrolled or unknown cumulative factors could have counteracted the beneficial effects of improved blood pressure control and smoking cessation in the younger group or that a certain lag time is required to observe positive effects.

Time interval data for admission and mortality provide interesting information on mortality rates before patients reach the hospital as well as mortality rates in the first few hours after arriving to the hospital. Of the patients who arrived alive to a hospital, 10.3% died within 6 h and 21.4% within 24 h. This is similar to what was observed by Anagnopoulos *et al.* [1] over four decades ago, where the mortality rate for type A dissection was estimated to be 1% per hour. Contrary to what one might expect, death prior to hospital arrival or within 6 and 24 h of admission did not change over the course of the study, indicating that advancement in diagnostic technology and urgent medical care has had minimal effects on the mortality rates of patients with ATAD in the first 24 h [22]. This was especially true for type A dissection where combined death prior to hospital and <24-h mortality reached nearly 50%. The urgent medical care system in Reykjavik, where two-thirds of the Icelandic population resides, has an average ambulance response time of 6.3 min and Landspitali University Hospital, where all surgery for ATAD in Iceland is performed, can be reached expeditiously [23]. Most patients therefore arrive early in the disease process, some seriously ill, as reflected in 56.9% rates of patients with hypotension on arrival and fairly high portion of type A patients who died en route to the operating room. These unique conditions in Reykjavik give insight into the early ATAD disease process but might not be applicable to other countries where distance and transport time to a specialized hospital could be longer. Referral to a hospital with extensive experience in treating ATAD should not be underestimated since both higher volume and surgeon experience are strongly associated with improved surgical outcomes, but these factors will obviously not capture the very early deaths due to ATAD [24].

Both short- and long-term outcomes improved over the course of the study, especially for the period 2007–2013. The reason probably resides in more aggressive treatment of type A dissection but also in changes in the management strategies for type B dissection. In the first and second thirds of the study, only 40% of patients with type A dissection underwent an operation. This proportion increased significantly in the last third, where 76% of type A patients underwent surgery. The 30-day mortality rate for type A dissection was high, which correlates with the very unstable preoperative condition of the patients. This is at least partially due to the low yearly volume of operations for ATAD at Landspitali University Hospital, but mortality rate was comparable with that of both the International Registry of Acute Aortic Dissection (IRAD) and Medicare [12, 25, 26]. The 30-day mortality rate did not change significantly during the study period, but since more patients underwent an operation, the overall number of patients who survived increased. Operations for type B dissection were performed in 26% of cases, which also is in line with the IRAD registry [27]. The overall outcome for type B dissection improved significantly during the study period, probably due to the change in operative methods from open to endovascular repair. This finding supports the impression that outcomes of type B dissections are improving, changing from 20 to 40% mortality risk for open operations, to much lower mortality rates of 4–20% associated with endovascular repair [27–29].

The main strengths of this study include a well-defined study population of a whole nation that has a modern single-payer nationalized healthcare system. We had access to centralized hospital and autopsy databases from the whole country, together with detailed patient records and complete survival follow-up information. The primary limitation of the study resides in its small number of index cases of ATAD in a relatively small population. Still this is the second largest population-based study reported in the literature. The Icelandic population is quite homogeneous, and the relatively low incidence of ATAD observed in our study might be a reflection of unidentified genetic and/or environmental factors.

In conclusion, ATAD is an uncommon condition with an incidence of 2.53/100 000/year. The incidence of ATAD remained constant for over two decades in Iceland, contradicting recent reports indicating that the incidence of ATAD is rising. The proportion of patients undergoing operation for ATAD has, however, increased. One out of every five patients died prior to hospital arrival, one in three within 24 h from the index event and over half of all patients died within 30 days of ATAD. Patients with type A dissection were treated more aggressively, and the therapeutic strategy for type B dissection changed from open to endovascular therapy. This change was associated with a reduction in the 30-day mortality rate and improvement in the long-term survival rate, demonstrating that the overall outcome of this complex condition is improving.

## SUPPLEMENTARY MATERIAL

Supplementary Material is available at *EJCTS* online.


## ACKNOWLEDGEMENT

Gunnhildur Johannsdottir provided essential assistance with data query and medical chart collection.

## Funding

This work was supported by the grant from Landspitali University Hospital Scientific Fund and the University of Iceland Research Fund.

**Conflict of interest:** none declared.


## REFERENCES


[1] Anagnopoulos C, Prabhakar M, Kittle C. Aortic dissections and dissecting aneurysm. Am J Cardiol 1972;30:263–73.
[2] Golledge J, Eagle KA. Acute aortic dissection. Lancet 2008;372:55–66.
[3] Bickerstaff LK, Pairolero PC, Hollier LH, Melton LJ, Peenen HJV, Cherry KJ *et al*. Thoracic aortic aneurysm: a population-based study. Surgery 1982; 92:1103–8.
[4] Meszaros I, Morocz J, Szlavi J, Schmidt J, Tornoci L, Nagi L *et al*. Epidemiology and clinicopathology of aortic dissection. A population-based longitudinal study over 27 years. Chest 2000;117:1271–8.
[5] Clouse WD, Hallett JW, Schaff HV, Spittell PC, Rowland CM, Ilstrup DM *et al*. Acute aortic dissection: population-based incidence compared with degenerative aortic aneurysm rupture. Mayo Clin Proc 2004;79:176–80.
[6] Olsson C, Thelin S, Stahle E, Ekbom A, Granath F. Thoracic aortic aneurysm and dissection. Increasing prevalence and improved outcomes reported in a nationwide population-based study of more than 14000 cases from 1987-2002. Circulation 2006;114:2611–8.
[7] Howard DP, Banerjee A, Fairhead JF, Perkins J, Silver LE, Rothwell PM. Population-based study of incidence and outcome of acute aortic dissection and premorbid risk factor control. Circulation 2013;127:2031–7.
[8] Yu H-Y, Chen Y-S, Huang S-C, Wang S-S, Lin F-Y. Late outcome of patients with aortic dissection: study of a national database. Eur J Cardiothorac Surg 2004;25:683–90.
[9] Landenhed M, Engstrom G, Gottsater A, Caulfield MP, Hedblad B, Newton-Cheh C *et al*. Risk profiles for aortic dissection and ruptured or surgically treated aneurysm: a prospective cohort study. J Am Heart Assoc 2015;4:e001513.
[10] Hiratzka LF, Bakris GL, Beckman JA, Bersin RM, Carr VF, Casey DE *et al*. ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM Guidelines for the diagnosis and management of patients with thoracic aortic disease. Circulation 2010;121:e266–369.
[11] Statistic Iceland. Population of Iceland 1992–2013. http://statice.is/Statistics/Population/Overview (24 September 2015, date last accessed).
[12] Mody PS, Wang Y, Geirsson A, Kim N, Desai MM, Gupta A *et al*. Trends in aortic dissection hospitalization, interventions, and outcomes among Medicare beneficiaries in the United States, 2000-2011. Circ Cardiovasc Qual Outcomes 2014;7:920–8.
[13] Statistic Iceland. Birth and Deaths in Iceland 1992-2013. http://www.statice.is/Statistics/Population/Births-and-deaths (24 September 2015, date last accessed).
[14] Hoyert DL. The changing profile of autopsied deaths in the United States, 1972-2007. NCHS Data Brief 2011;1–8.
[15] Frost J, Slordal L, Vege A, Nordrum IS. Forensic autopsies in a naturalistic setting in Norway: autopsy rates and toxicological findings. Forensic Sci Int 2013;223:353–8.
[16] Burton JL, Underwood J. Clinical, educational, and epidemiological value of autopsy. Lancet 2007;369:1471–80.
[17] Turnbull A, Osborn M, Nicholas N. Hospital autopsy: endangered or extinct? J Clin Pathol 2015;68:601–4.
[18] Lindstrom P, Janzon L, Sernby N. Declining autopsy rate in Sweden: a study of causes and consequences in Malmo, Sweden. J Intern Med 1997; 242:157–65.
[19] Statistic Iceland. Smoking Habits 15-79 Years 1987-2013. http://www.statice.is/Statistics/Health,-social-affairs-and-justi/Lifestyle-and-health (24 September 2015, date last accessed).
[20] The Icelandic Heart Association Statistical Handbook—Cardiovascular Disease in Iceland and Risk Factors, 2008.
[21] Aspelund T, Gudnason V, Magnusdottir BT, Andersen K, Sigurdsson G, Thorsson B *et al*. Analysing the large decline in coronary heart disease mortality in the Icelandic population aged 25-74 between the years 1981 and 2006. PLoS One 2010;5:e13957.
[22] Kocher KE, Meuer WJ, Fazel R, Scott PA, Krumholz HM, Nallamothu BK. National trends in use of computed tomography in the emergency department. Ann Emerg Med 2011;58:452–62.
[23] Mogensen BA, Bjornsson HM, Thorgeirsson G, Haraldsson GE, Mogensen B. Results of pre-hospital cardiac resuscitation in the Reykjavik area 2004-2007. Laeknabladid 2015;101:137–41.
[24] Chikwe J, Cavallaro P, Itagaki S, Seigerman M, DiLuozzo G, Adams DH. National outcomes in acute aortic dissection: influence of surgeon and institutional volume on operative mortality. Ann Thorac Surg 2013;95: 1563–9.
[25] Mehta RH, Suzuki T, Hagan PG, Bossone E, Gilon D, Llovet A *et al*. Predicting death in patients with acute type A aortic dissection. Circulation 2002;105:200–6.
[26] Geirsson A, Melvinsdottir IH, Arnorsson T, Myrdal G, Gudbjartsson T. Outcomes of acute type A aortic dissection repairs in Iceland. Laeknabladid 2016;102:71–6.
[27] Fattori R, Tsai TT, Myrmel T, Evangelista A, Cooper JV, Trimarchi S *et al*. Complicated acute type B dissection: is surgery still the best option? J Am Coll Cardiol Intv 2008;1:395–402.
[28] Bozinovski J, Coselli JS. Outcomes and survival in surgical treatment of descending thoracic aorta with acute dissection. Ann Thorac Surg 2008; 85:965–71.
[29] Zeeshan A, Woo EY, Bavaria JE, Fairman RM, Desai ND, Pochettino A *et al*. Thoracic endovascular aortic repair for acute complicated type B aortic dissection: superiority relative to conventional open surgical and medical therapy. J Thorac Cardiovasc Surg 2010;140:S109–15.