Original article

Population-based study of ruptured abdominal aortic aneurysm

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Background: **The incidence of abdominal aortic aneurysms (AAAs) and their rupture has been reported to be decreasing. The aim was to evaluate trends in ruptured AAA (rAAA) incidence in the hospital district of Helsinki and Uusimaa (HUS) in southern Finland. This was a population-based retrospective review of all patients with rAAA in this well defined geographical area during 2003–2013.**
Methods: **Data for all patients treated for rAAA at Helsinki University Hospital, the only vascular surgery centre in an area of 1·5 million inhabitants, were collected from local vascular registry. All deaths attributed to rAAA were obtained from the cause of death registry of Statistics Finland.**
Results: **The mean(s.d.) age of the 712 patients with rAAA was 76·5(9·6) years; 76·7 per cent of them were men. Only 330 patients (46·3 per cent of those with rAAA) arrived alive at Helsinki University Hospital. The turn-down rate for surgical treatment was 10·3 per cent. Of the 296 patients operated on, 199 (67·2 per cent) were alive at 30 days. Only 27·9 per cent of all patients were alive 30 days after rupture of the AAA. The incidence of rAAA was 4·3 per 100 000 inhabitants and the mortality rate was 3·2 per 100 000 inhabitants. A decreasing trend was seen in incidence and mortality during the 11-year study interval.**
Conclusion: **The incidence of rAAA is decreasing in the HUS district. Mortality from rAAA remains very high, because half of the patients die before reaching the hospital.**

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Introduction

The incidence of ruptured abdominal aortic aneurysm (rAAA) and resulting mortality seem to be decreasing in many parts of the world, although an increase has also been reported in some areas[1,2]. The AAA screening programmes implemented in many countries consistently discover fewer aneurysms than predicted[3–5]. AAA-related mortality also seems to be shifting towards older populations[6,7]. The reasons for these changes are unclear; the increased use of statins and antihypertensive medication may have a role, but perhaps the most important factor is likely to be the decreased prevalence of smoking[8]. Large variations in rAAA mortality, treatment results and turn-down rate for operative treatment exist between different reports and countries[9].

Reporting only operative mortality for patients with rAAA is problematic, because many die before reaching the hospital and major differences exist in the proportion of patients who are turned down for operative treatment once they reach hospital. The indicator for quality of treatment for rAAA should thus not be operative mortality, but population-based mortality, which considers all patients with rAAA, including those who die before reaching hospital and those turned down for operative treatment.

The aim of this study was to evaluate rAAA incidence and mortality trends in a well defined geographical area in southern Finland between 2003 and 2013, including the outcomes of aneurysm repair and turn-down rates.

Methods

Helsinki University Hospital is the only hospital that provides vascular surgery services in the Hospital District of Helsinki and Uusimaa (HUS) in southern Finland, and all patients with rAAA undergo surgery in this hospital. Data for 2003–2013 on all patients who had surgical treatment of rAAA, as well as those deemed moribund and turned down for operative treatment and those who declined operative treatment, were retrieved from patient records and the local vascular registry. Statistics Finland provided

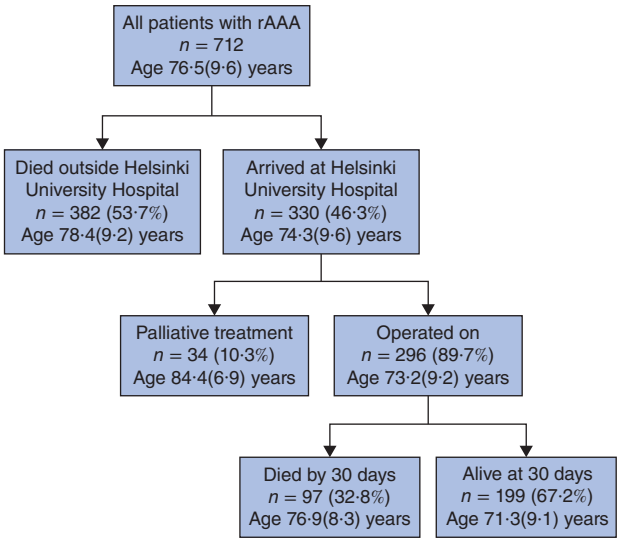

Fig. 1 Outcome of ruptured abdominal aortic aneurysm (rAAA) in Helsinki and Uusimaa district, 2003–2013. Only 27·9 per cent of patients were alive 30 days after rAAA. Age is shown as mean(s.d.)

cause-of-death data for the inhabitants of the hospital district to identify those who died from rAAA before reaching hospital. All patients referred from hospitals outside the HUS district were excluded as well as those with thoracoabdominal aneurysms or isolated iliac aneurysms and patients previously operated on for AAA (such as anastomotic rupture of previous repair).

The autopsy rate was calculated using the number of deaths each year and the number of autopsies during the same year. These statistics were also obtained from Statistics Finland. The autopsy rate was calculated for the whole of Finland because data were not available for the hospital district alone.

Statistical analysis

Yearly trends were analysed using logistic regression, and differences between groups were examined using Student's *t* test or χ^2 test. Statistical analysis was performed with SPSS® version 22 (IBM, Armonk, New York, USA).

Results

Overall, 712 patients with rAAA were identified between 2003 and 2013 (yearly range 46–77). Their mean(s.d.) age was 76·5(9·6) (range 48·7–99·2) years (*Fig. 1*). There were 546 men (76·7 per cent) with a mean age of 74·7(9·4) (48·7–97·8) years, and 166 women (23·3 per cent) of mean age 82·6(7·4) (61·7–99·2) years. The women were

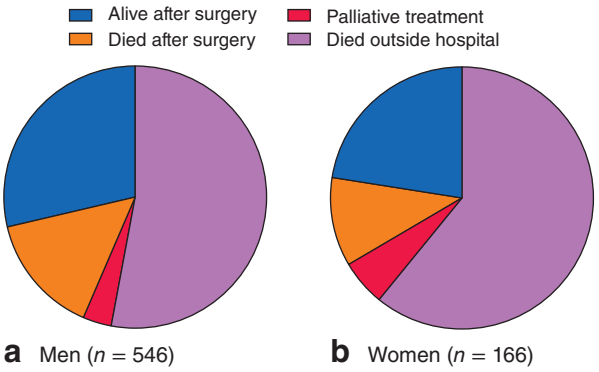

Fig. 2 Outcome of ruptured abdominal aortic aneurysm (rAAA) for men and women. The analysis was adjusted for age as women with rAAA were older

significantly older ($P < 0·001$). A total of 330 patients (46·3 per cent) were alive on arrival at Helsinki University Hospital and 382 (53·7 per cent) died before reaching the hospital. According to the cause-of-death data, 178 (46·6 per cent) of the 382 patients who died outside Helsinki University Hospital were at another healthcare facility and 162 (42·4 per cent) died at home. The remaining patients died elsewhere, for example at a nursing home or abroad. The patients who died at another healthcare facility were older than those who died at home (81·1 *versus* 76·0 years; $P < 0·001$). Women were more likely to die outside the hospital than men; only 62 (37·3 per cent) of all 166 women with rAAA reached the hospital alive as opposed to 268 (49·1 per cent) of 546 men ($P = 0·008$). The patients who reached hospital were younger than those who died before reaching the hospital (74·3 *versus* 78·4 years; $P < 0·001$). After adjustment for age, however, the difference in the proportion of men (257·0 patients, 47·1 per cent) and women (64·9 patients, 39·1 per cent) reaching hospital alive was not statistically significant ($P = 0·070$) (*Fig. 2*).

The turn-down rate for operative treatment was 10·3 per cent for the 11-year interval (yearly range 0–27 per cent). The patients turned down for operative treatment were significantly older (84·4 *versus* 73·2 years; $P < 0·001$). Women were more likely to be turned down for operative repair (25·8 *versus* 6·7 per cent; $P < 0·001$). However, after adjusting for age this difference was not statistically significant. Most patients who did not have surgery died within a day of arriving at the hospital (median day of death after rAAA was 0 (i.q.r. 0–1) day), although one patient lived for 19 days after AAA rupture.

Patients treated surgically with open repair or endovascular aneurysm repair (EVAR) had 30- and 90-day mortality rates of 32·8 and 35·5 per cent respectively. There were seven late AAA-related deaths (after 90 days) owing to

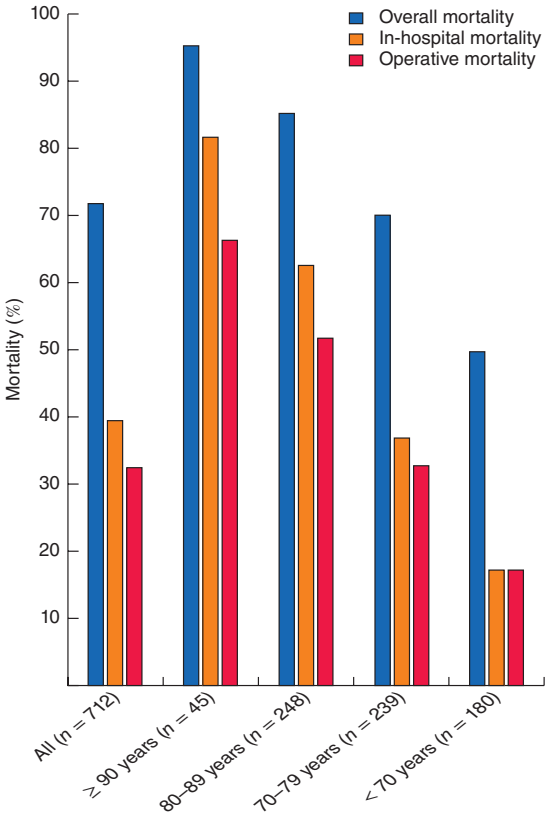

Fig. 3 Overall, in-hospital and operative mortality at 30 days from ruptured abdominal aortic aneurysm in relation to age

Table 1 Mean age of patients with ruptured abdominal aortic aneurysm (rAAA), and yearly incidence and mortality of rAAA among inhabitants of Helsinki and Uusimaa district, 2003–2013

	n	Age (years)*	rAAA incidence (per 100 000 per year)	rAAA mortality (per 100 000 per year)
All	712	76·5(9·6)	4·3 (2·9–5·4)	3·2 (2·4–4·0)
Men	546	74·7(9·4)	6·9 (4·0–8·8)	4·9 (3·1–5·9)
Women	166	82·6(7·4)	1·9 (1·1–2·9)	1·6 (0·6–2·8)
All patients aged ≥ 65 years	621	79·0(4·0)	27·6 (15·2–35·5)	20·9 (13·2–28·7)
Men aged ≥ 65 years	458	77·6(7·1)	50·3 (23·0–68·6)	36·6 (18·2–49·0)
Women aged ≥ 65 years	163	82·9(7·0)	12·0 (7·0–18·2)	10 (3·8–17·3)

Values in parentheses are ranges unless indicated otherwise; *values are mean(s.d.). rAAA, ruptured abdominal aortic aneurysm.

infection (5) or other operation-related causes (2) up to 83 (median 4·6, i.q.r. 3·6–55·1) months after the primary procedure. The overall 30-day rAAA mortality rate was 72·1 per cent, 39·7 per cent for those who reached the hospital alive and 32·8 per cent for those operated on.

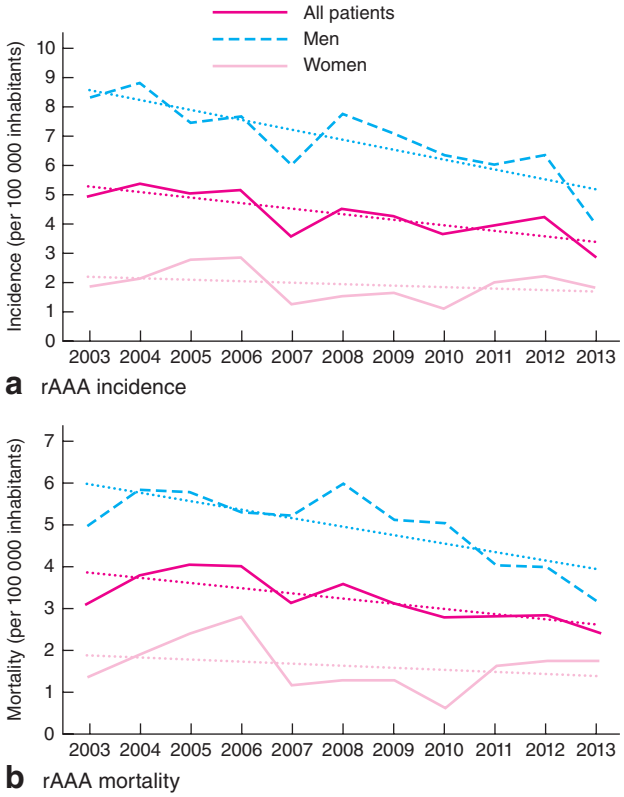

Fig. 4 Yearly **a** incidence of and **b** mortality from ruptured abdominal aortic aneurysm (rAAA) in Helsinki and Uusimaa district for all patients, men and women. Trend lines are shown (dotted). **a** All patients: $F_{1,9} = 16{\cdot}2$, $P = 0{\cdot}003$, $R^2 = 0{\cdot}64$; men: $F_{1,9} = 22{\cdot}0$, $P = 0{\cdot}001$, $R^2 = 0{\cdot}71$; women: $F_{1,9} = 0{\cdot}86$, $P = 0{\cdot}377$, $R^2 = 0{\cdot}09$. **b** All patients: $F_{1,9} = 11{\cdot}6$, $P = 0{\cdot}008$, $R^2 = 0{\cdot}56$; men: $F_{1,9} = 12{\cdot}9$, $P = 0{\cdot}006$, $R^2 = 0{\cdot}59$; women: $F_{1,9} = 0{\cdot}68$, $P = 0{\cdot}430$, $R^2 = 0{\cdot}07$ (linear regression analysis)

Mortality for RAAA increased with age. For 180 patients aged less than 70 years the overall mortality rate was 50·0 per cent (90 patients) and the operative mortality rate 17·4 per cent (19 of 109 patients; all patients in this age category who arrived at the hospital were operated on). Among the 532 patients aged over 70 years the overall mortality rate was 79·5 per cent (423 patients) and the operative mortality rate 41·7 per cent (78 of 187 patients; 34 patients were turned down for surgery). Of the 45 patients aged 90 years and over, 43 died within 30 days of AAA rupture and four of six surgically treated patients died within 30 days (6 of 11 patients who arrived at hospital underwent surgery) (*Fig. 3*).

The population of the HUS district increased from 1 425 878 in 2003 to 1 581 450 in 2013. The proportion of inhabitants aged over 65 years also increased, from 12·1 to 16·2 per cent (Statistics Finland). The mean yearly rAAA incidence during the interval was 4·3 per 100 000

inhabitants (yearly range 2·9–5·4 per 100 000), with a sex difference. The incidence of rAAA was higher among those aged 65 years or older (*Table 1*). There was a decreasing trend in incidence of rAAA during the 11-year interval for all patients and men, but not for women (*Fig. 4a*). The mean population-based annual mortality rate from rAAA during 2003–2013 was 3·2 per 100 000 inhabitants (annual range 2·4–4·0 per 100 000), with a sex difference and higher mortality in the population aged 65 years and over (*Table 1*). The decrease in overall mortality and mortality in men was statistically significant during the 11 years (*Fig. 4b*).

Discussion

A decreasing trend in the incidence of rAAA was found in southern Finland. The incidence in Finland (across the entire country) during the 1990s was 6·1 per 100 000 inhabitants[10], 6·3 per 100 000 for Pirkanmaa region in Central Finland[11] and 5·4 per 100 000 in the HUS district during 1996–2004[12]. In this study the incidence of 4·3 per 100 000 was lower still, with a decreasing rate through the study period. This trend was observed despite an ageing population with an increasing proportion of inhabitants aged over 65 years during the same interval. Over half of the patients died without reaching Helsinki University Hospital, which emphasizes the fact that total mortality from rAAA is extremely high. This underscores the importance of the detection of aneurysms before they rupture, or requirement for improved methods to stabilize patients with rAAA to permit transfer to the vascular unit.

The increasing number of elective operations might partly explain the decrease in rAAA incidence. The number of elective AAA operations increased from 249 during the first 5 years of the study (2003–2007) to 359 during the last 5 years (2009–2013) (unpublished data from vascular registry). This represents on average of 3·4 elective AAA operations per 100 000 inhabitants during the first 5 years and 4·6 per 100 000 during the last 5 years. An increasing proportion of elective operations performed using EVAR (17·5 per cent in 2003 *versus* 71·4 per cent in 2013) might also explain the decrease in incidence and mortality as patients with more co-morbidities can be treated with lower operative mortality. The increase in elective operations is also likely to be due to increased use of imaging, resulting in the incidental detection of AAA.

The decreasing prevalence of smoking is probably a major reason for the apparent decreasing incidence of rAAA. In Finland the proportion of daily smokers has decreased from 27 per cent in 1979 to 16 per cent in 2014, the decrease being especially apparent in men (from 36 to 17 per cent). The number of daily smokers among men aged over 65 years is lower than in the general population, but has decreased as well, from 17 per cent in 1987 to 8 per cent in 2013. The changes among women are less clear[13].

The number of ruptured aneurysms treated with EVAR was low during the study period, being only 8·5 per cent during 2010–2013 and even lower before that. However, offering EVAR primarily to a population with rAAA does not necessarily improve short-term survival[14,15].

In Malmö, Sweden, the incidence of rAAA was reported to be 11 per 100 000 in 2000–2004[16], and was increased compared with that in 1971–1986 when it was 6 per 100 000[17]. Their rate of elective repair, of 7 per 100 000, was higher than in the present authors' area. Since that time, however, a national screening programme for AAA has been started in Sweden and the current situation is likely to be different. In Stavanger, Norway, the reported incidence for the population aged over 30 years was 9·5 per 100 000 and mortality was 6·4 per 100 000 from 2000 to 2012, without a significant change in incidence during this time[18]. Interestingly, a decreasing trend in incidence similar to that described in the present study was not evident in all parts of Finland. In the region of Pirkanmaa and Joensuu, the rAAA incidence from 2001 to 2011 was 6·5 per 100 000, similar to that in the 1990s[11,19].

In Malmö and Stavanger deaths outside hospital represented only 17 and 9 per cent of all deaths respectively, which is considerably lower than the proportion in the present study. Only 43 per cent of patients who arrived at hospital in Malmö, however, had surgery compared with 89·7 per cent in Helsinki. The autopsy rate was 25 per cent in Malmö and less than 1 per cent in Stavanger, compared with 30 per cent in Finland.

Determining the population-based mortality for rAAA is difficult as many patients die outside hospital, without a known AAA. Many of these patients have considerable co-morbidities and the true cause of death often remains unclear as autopsy rates have decreased in many countries. The proportion of patients dying outside a hospital setting is prone to error owing to misdiagnosis of the cause of death if no autopsy is performed and no previous diagnosis of AAA exists. Many rAAA deaths are likely to be listed as cardiac deaths, but cardiac deaths may well be classified as rAAA deaths if the patient has a diagnosis of AAA and no autopsy is carried out after a sudden death. In this regard, the present data should be reliable compared with those from other contemporary studies because autopsy rates in Finland are still fairly high, although declining. The general autopsy rate, including medical and medicolegal autopsies, was 29·8 per cent during the study interval

and 25·3 per cent among those aged 65 years or older. The rate was quite steady (29·8–32·3 per cent yearly) until 2010, after which there was a clear decrease, with an autopsy rate of 23·9 per cent in 2013. Among the patients included in this analysis, the cause of death was based on autopsy data in 60·8 per cent, and in 74·1 per cent for patients who died without arriving at Helsinki University Hospital.

The results of operative treatment for rAAA are comparable to those of other published studies, and the turn-down rate is low in the HUS district, similar to that reported previously[12]. Despite this, overall mortality from rAAA is very high because most patients die without reaching the hospital that provides emergency vascular surgery services. Significantly reducing rAAA mortality would require the identification and surgical treatment of more asymptomatic patients before AAA rupture. This would necessitate a screening programme for rAAA, which currently does not exist in Finland. A report on the feasibility and cost-effectiveness of AAA screening in Finland was published in 2011, which concluded that RAAA mortality could be decreased by screening and screening would be cost-effective compared with no screening[20]. Despite this, a countrywide screening programme was not initiated. The decreasing incidence of AAA could mean that screening might be less cost-effective than previously estimated. In the model used in the analysis, however, the incidence of rAAA had very little impact on cost-effectiveness[20,21]. In spite of the falling incidence in southern Finland, rAAA in men aged 65 years and over is still quite common with 36·6 per 100 000 deaths annually.

Disclosure

The authors declare no conflict of interest.

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