# Outcome after abdominal aortic aneurysm repair in Sweden 1994–2005

**A. Wanhainen**[1]**, N. Bylund**[1,2] **and M. Björck**[1]

[1]Department of Surgical Sciences, Section of Vascular Surgery, Uppsala University Hospital, Uppsala, and [2]Department of Surgery, Gävle County Hospital, Gävle, Sweden

*Correspondence to:* Dr A. Wanhainen, Department of Surgical Sciences, Section of Vascular Surgery, Uppsala University Hospital, SE-371 85 Uppsala, Sweden (e-mail: andwan@algonet.se)

**Background:** **The aim was to study the epidemiology of abdominal aortic aneurysm (AAA) repair in Sweden.**

**Methods:** **Primary AAA repairs registered in the Swedish Vascular Registry between 1994 and 2005 were studied. Mortality data were obtained from the national population registry, and age- and sex-specific populations for each calendar year from Statistics Sweden.**

**Results:** **Some 10 691 primary AAA repairs were identified. In the population aged 60 years or over the incidence of intact AAA repair increased from 27·0 per 100 000 in 1994–1999 to 28·8 per 100 000 in 2000–2005 ($P = 0{\cdot}006$), while the incidence of surgery for ruptured AAA (rAAA) remained stable (13·8 *versus* 14·1 per 100 000; $P = 0{\cdot}595$). Open repair with a bifurcated graft decreased, whereas endovascular repair (EVAR) increased to 35·0 per cent of intact AAA and 10·3 per cent of rAAA procedures in 2005. Patients who had EVAR were older than those undergoing open repair (74·1 *versus* 71·9 years; $P < 0{\cdot}001$). The 30-day mortality rate decreased over time for intact and ruptured aneurysm operations ($P = 0{\cdot}001$). Age, female sex and open repair (compared with EVAR) were independently associated with a higher 30-day mortality rate in a logistic regression model.**

**Conclusion:** **The introduction of EVAR was associated with an increasing incidence of intact AAA repair, whereas the rate of rAAA was stable. Perioperative mortality rates decreased over time.**

Paper accepted 30 January 2008
Published online 25 February 2008 in Wiley InterScience (www.bjs.co.uk). **DOI:** 10.1002/bjs.6109

## Introduction

During the past two decades the management of abdominal aortic aneurysm (AAA) has undergone important changes, including the introduction of endovascular treatment[1,2], timing of intervention[3,4] and improved postoperative care[5,6]. The effects of these changes on national practice and outcome are not well known as few contemporary nationwide reports exist[7,8]. Large studies from North America are based on different subsamples from non-federal hospitals (Nationwide Inpatient Sample)[9–11], from Medicare databases (Centers for Medicare and Medicaid Services)[12,13] or from non-federal, acute care hospitals with an average length of stay of less than 30 days (National Hospital Discharge Survey)[14,15], which may not represent nationwide data.

The Swedish Vascular Registry (Swedvasc) started in 1987 and since 1994 the registry has had nationwide coverage. More than 90 per cent of open and endovascular arterial procedures performed in Sweden are reported to the registry, compared with the National Inpatient Registry used for reimbursement[16]. Patient characteristics, preoperative risk factors, indication for surgery[17], type of operation (open or endovascular), anatomy (inflow and outflow), and outcome after 30 days and 1 year (including complications) are registered prospectively. Cross-check with the national population registry is performed every week, resulting in accurate survival data.

The aim of this study was to review the epidemiology of AAA repair in Sweden from 1994 to 2005, in particular to determine changes in national practice and outcome.

## Methods

All AAA repairs registered in Swedvasc between 1994 and 2005 were identified. Operations on patients under 50 years

**Table 1** Prevalence of preoperative risk factors in patients undergoing elective, urgent or emergency aortic aneurysm repair

| | All patients ($n$ = 10 691) | Sex | | | Surgical technique | | | Time interval | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Men ($n$ = 8952) | Women ($n$ = 1739) | $P$* | Open repair ($n$ = 9627) | EVAR ($n$ = 1064) | $P$* | 1994–1999 ($n$ = 5101) | 2000–2005 ($n$ = 5590) | $P$* |
| Mean age (years) | 72·1 | 71·8 | 73·8 | < 0·001† | 71·9 | 74·1 | < 0·001† | 71·7 | 72·5 | < 0·001† |
| Diabetes (%) | 7·7 | 7·9 | 7·0 | 0·215 | 7·2 | 12·6 | < 0·001 | 6·6 | 8·7 | < 0·001 |
| Heart disease (%) | 53·5 | 54·9 | 46·3 | < 0·001 | 53·0 | 57·7 | 0·005 | 53·3 | 53·7 | 0·652 |
| Pulmonary disease (%) | 17·9 | 20·2 | 17·4 | 0·010 | 17·7 | 19·4 | 0·198 | 17·3 | 18·4 | 0·199 |
| Renal impairment (%) | 10·9 | 11·0 | 10·5 | 0·510 | 10·6 | 13·7 | 0·003 | 10·6 | 11·3 | 0·270 |

EVAR, endovascular repair. *$\chi^2$ test unless indicated otherwise; †independent samples $t$ test.

of age or on non-Swedish citizens, redo procedures and duplicate entries were excluded. In January 2007 data were cross-checked against the national population registry, permitting 1-year follow-up regarding survival on all patients. Information on age- and sex-specific population sizes for each calendar year was obtained from Statistics Sweden. The study was approved ethically by the registry review board, which according to Swedish law has the authority concerning registry data.

Preoperative risk factors recorded included diabetes (treated by diet, medically or with insulin), heart disease (history of myocardial infarction, angina pectoris, atrial fibrillation, heart failure, coronary bypass surgery or heart valve surgery), pulmonary disease (any diagnosed pulmonary disease), and renal impairment (serum creatinine at least 150 mmol/l).

## Statistical analysis

Independent samples $t$ test was used for comparison of normally distributed data and uncorrected $\chi^2$ test for comparison of two proportions. One-way ANOVA was used to study time trends. Multivariable logistic regression models were used to estimate the odds ratios for various factors in relation to 30-day mortality. $P < 0·050$ was considered statistically significant. Statistical evaluation of the data was carried out using SPSS® PC version 14.0 for Windows® (SPSS, Chicago, Illinois, USA).

# Results

Of 114 255 vascular procedures registered in Swedvasc between 1994 and 2005 (12 complete calendar years), 10 691 primary AAA repairs (7175 intact AAAs and 3516 ruptured AAAs (rAAAs)) were identified, 9·4 per cent of all procedures. Some 17·2 per cent of all intact AAA repairs and 14·3 per cent of all rAAA repairs were done in women ($P < 0·001$). Comparing the first with the second 6-year interval, the total crude number of operations performed for intact AAA increased by 11·4 (95 per cent confidence interval (c.i.) 10·4 to 12·5) per cent, whereas operations for rAAA increased by 6·0 (4·9 to 7·2) per cent. The prevalence of preoperative risk factors in different subgroups is shown in *Table 1*.

## Incidence of abdominal aortic aneurysm repair

The incidence of AAA repair was 10·0 per 100 000 person years, 16·6 per 100 000 in men and 3·3 per 100 000 in women. Some 93·4 (95 per cent c.i. 92·9 to 93·9) per cent of all men and 95·9 (94·9 to 96·8) per cent of all women who had intervention for AAA were aged 60 years or more. In this age group a significant increase in the rate of AAA repair was observed between the first and second 6-year intervals (40·8 *versus* 42·9 per 100 000; $P = 0·011$). Subgroup analysis revealed a significant increase in the incidence of intact AAA repair between the two time intervals (27·0 *versus* 28·8 per 100 000; $P = 0·006$), whereas

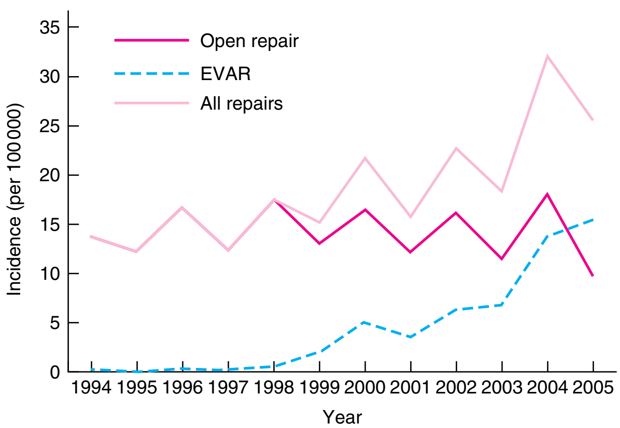


**Fig. 1** Repair of intact abdominal aortic aneurysms among octogenarians over time, by procedure. EVAR, endovascular aneurysm repair

the incidence of rAAA remained stable (13·8 *versus* 14·1 per 100 000; $P = 0·595$).

## Age distribution

Mean ages of the different subgroups are displayed in *Table 1*. The mean age in patients with an intact AAA increased over time ($P < 0·001$), whereas no significant age trend was observed in those with rAAA ($P = 0·080$). The proportion of patients aged 80 years or more increased significantly from 12·2 (95 per cent c.i. 10·1 to 14·6) per cent in 1994 to 19·3 (16·8 to 22·0) per cent in 2005 ($P < 0·001$). Among octogenarians the rate of intact AAA repair increased between the first and the second 6 years, from 14·6 to 22·7 per 100 000 ($P < 0·001$) (*Fig. 1*).

## Surgical technique

The use of bifurcated grafts (aortoiliac and aortofemoral) for open repair decreased, while endovascular repair (EVAR) increased over time (*Fig. 2*). In 1994 three patients (0·5 per cent) had EVAR for an intact AAA; this increased over time and 230 procedures were reported in 2005 (35·0 (95 per cent c.i. 31·3 to 38·7) per cent of all intact AAA repairs) ($P < 0·001$). The first patient who had EVAR for rAAA was reported in 2000; this too increased in frequency

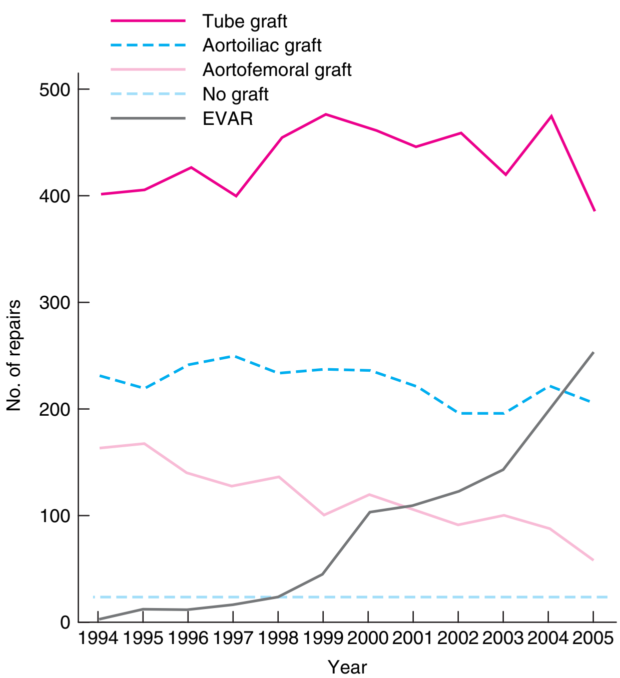


**Fig. 2** Annual number of abdominal aortic aneurysm repairs according to graft type. EVAR, endovascular aneurysm repair

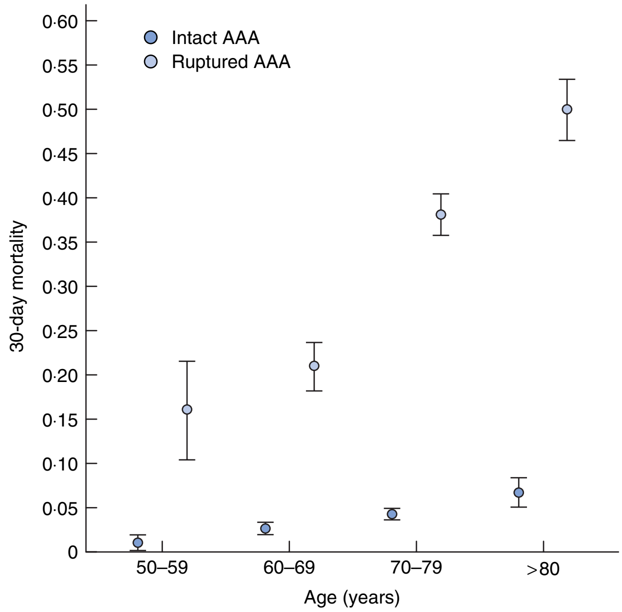


**Fig. 3** Thirty-day mortality rates, with 95 per cent confidence intervals, after repair of intact and ruptured abdominal aortic aneurysm (AAA), by age group

and 28 procedures were reported in 2005 (10·3 (95 per cent c.i. 7·3 to 15·3) per cent of all rAAAs) ($P < 0·001$). In 2005 10·9 (95 per cent c.i. 7·3 to 15·3) per cent of all EVARs were for rAAA. There was a significant difference in the use of EVAR for intact AAA between men and women (14·0 (95 per cent c.i. 13·1 to 14·9) *versus* 11·4 (9·6 to 13·2) per cent; $P = 0·016$), whereas no difference was seen for rAAA (2·4 (1·0 to 3·7) *versus* 2·7 (2·1 to 3·2) per cent; $P = 0·720$).

## Mortality

Mortality rates after aneurysm surgery are displayed in *Table 2*. The 30-day mortality rate was higher in women than in men after intact AAA repair (5·3 *versus* 3·6 per cent; $P = 0·004$), as well as after surgery for rAAA (43·3 *versus* 34·3 per cent; $P < 0·001$). Age was associated with increasing 30-day mortality in patients who had surgery for an intact AAA (odds ratio 1·07 per year; $P < 0·001$) or rAAA (odds ratio 1·07 per year; $P < 0·001$) (*Fig. 3*). The 30-day mortality rate after EVAR for intact AAA was 2·5 (95 per cent c.i. 1·5 to 3·4) per cent compared with 4·1 (3·6 to 4·6) per cent after open repair ($P = 0·015$). The 30-day mortality rate after EVAR for rAAA was 15·2 (7·7 to 22·7) per cent compared with 36·1 (34·5 to 37·7 per cent) after open repair ($P < 0·001$).

The mortality rate after intact AAA repair decreased between the two time intervals (4·7 *versus* 3·2 per cent;

**Table 2** Thirty-day mortality rates for patients with different indications for aneurysm repair

| Mortality rate (%) | | | | |
|---|---|---|---|---|
| Elective asymptomatic ($n$ = 5381) | Elective symptomatic ($n$ = 877) | Urgent non-ruptured ($n$ = 917) | Emergency ruptured ($n$ = 1167) | Emergency ruptured, shock ($n$ = 2349) |
| 3·2 (2·7, 3·6) | 4·8 (3·4, 6·2) | 7·2 (5·5, 8·9) | 20·0 (17·7, 22·3) | 43·3 (41·3, 45·3) |
| Non-ruptured 3·9 (3·4, 4·3) | | | Ruptured 35·6 (34·0, 37·1) | |
| Elective 3·3 (2·9, 3·8) | | Non-elective 29·7 (28·3, 31·0) | | |

Values in parentheses are 95 per cent confidence intervals.

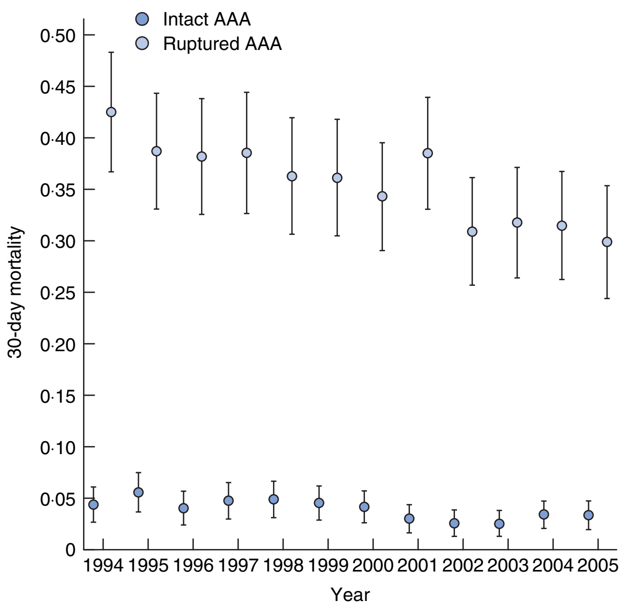


**Fig. 4** Thirty-day mortality rates, with 95 per cent confidence intervals, after repair of intact and ruptured abdominal aortic aneurysm (AAA), over time

$P$ = 0·001), as did that after rAAA surgery (38·4 *versus* 32·9 per cent; $P$ = 0·001) (*Fig. 4*). The mortality rate after open repair for intact AAA (4·7 *versus* 3·4 per cent; $P$ = 0·008) and rAAA (38·4 *versus* 33·9 per cent; $P$ = 0·007) also decreased over time.

Results of multivariable analysis of factors associated with 30-day mortality are summarized in *Table 3*. Open repair retained an association with increased mortality after rAAA surgery when the presence of shock was included in the model (odds ratio 2·2 (95 per cent c.i. 1·2 to 4·2)).

## Discussion

A nationwide registry, such as Swedvasc, offers a unique opportunity to study the possible impact of recent advances in the management of AAA. The Swedvasc registry was extensively validated both internally and externally, showing that core surgery, such as AAA repair[18,19], carotid artery thrombendarterectomy[20] and lower extremity artery surgery[21], are reported after more than 90 per cent of procedures and with great validity of data. Furthermore, the fact that every Swedish citizen has a unique identity code makes it possible to obtain accurate survival data for those registered, after a delay of only 3 weeks. Mortality analysis in this paper was not based on the surgical reports, but on data from the National Population Registry. An important limitation of the Swedvasc registry is the lack of information on subjects who did not undergo surgery. Differences in selection criteria between countries may to some extent explain differences in operative mortality. Moreover, changes in selection criteria over time may have an effect on time trends studied.

**Table 3** Adjusted odds ratios for factors associated with 30-day mortality after surgery for intact and ruptured abdominal aortic aneurysms

| | Intact AAA | | Ruptured AAA | |
|---|---|---|---|---|
| Risk factor | Odds ratio | $P$ | Odds ratio | $P$ |
| Age (per year) | 1·07 (1·04, 1·09) | < 0·001 | 1·07 (1·06, 1·09) | < 0·001 |
| Female sex | 1·5 (1·1, 2·1) | 0·010 | 1·0 (0·8, 1·3) | 0·892 |
| Repair (per year) | 0·96 (0·92, 1·00) | 0·042 | 0·95 (0·92, 0·97) | < 0·001 |
| Open repair | 2·2 (1·3, 3·7) | 0·002 | 2·9 (1·5, 5·4) | 0·001 |
| Diabetes | 1·4 (0·9, 2·2) | 0·154 | 1·7 (1·2, 2·3) | 0·001 |
| Heart disease | 1·7 (1·3, 2·3) | < 0·001 | 1·3 (1·1, 1·6) | 0·001 |
| Pulmonary disease | 1·3 (0·9, 1·8) | 0·103 | 1·3 (1·1, 1·6) | 0·015 |
| Renal impairment | 2·4 (1·7, 3·4) | < 0·001 | 2·2 (1·7, 2·8) | < 0·001 |

Values in parentheses are 95 per cent confidence intervals. Odds ratios adjusted for all factors in a logistic regression model. AAA, abdominal aortic aneurysm.

A major finding is the increased rate of intact AAA repair in the population aged 60 years or more. An increased workload of AAA repair, owing to the introduction of EVAR, has been anticipated but not yet verified. Recent North American reports found a stable[10] or even decreasing[12] incidence of intact AAA repair. The stable incidence of rAAA repair is in accordance with some previous reports[10,14], whereas others found a decreased incidence[11,12]. In Sweden twice as many patients had surgery for intact AAA than for rAAA. This was similar to the Netherlands[22], but different from nationwide reports from North America, where four to 12 times more intact AAAs than rAAAs were treated[10–12,14].

Among recent improvements in the management of AAA, the introduction of EVAR is perhaps the most important. In the present study the introduction of EVAR was associated with an increased rate of intact AAA repair. In *Fig. 1* it can be observed that the number of open repairs was stable over time, whereas the number of EVAR procedures increased rapidly; among octogenarians EVAR is now the preferred technique. Although other factors may have had an influence on this trend, such as increased diagnostic activity, it seems to be mainly the result of changing the indication for intervention. Patients treated with EVAR were older and had more co-morbidities. The proportion of intact AAAs treated by EVAR was, however, lower than in two recent North American reports; in 2003 EVAR was used for 41 per cent[10] and 43 per cent[12] of intact AAA repairs, compared with 22·6 per cent in 2003 and 35·0 per cent in 2005 in Sweden. In contrast to the findings in Sweden, these two studies concluded that EVAR is replacing open repair without an increase in overall case volume[10,12].

Even though patients who had EVAR were older with a higher prevalence of diabetes, heart disease and renal impairment, the short-term outcome following both intact AAA repair and rAAA surgery was significantly better than after open repair. The favourable outcome after EVAR for rAAA was not affected substantially by the lower rate of EVAR among patients in shock. The degree of shock was, however, not assessed in the present study. The anatomical complexity of the aneurysm is another potentially important confounding factor that could not be assessed in this study. It is notable, however, that, even though patients with ever more anatomically complex procedures (such as juxtarenal aneurysms) are concentrated in the open repair group, there was no trend towards increasing mortality rates over time among these patients. The observed favourable outcome after EVAR is consistent with previous nationwide reports[8,10,13] and randomized trials[23,24].

Most previous national studies have reported decreasing mortality over time after intact AAA repair[10,11,13]. This was also the case in Sweden despite a low mortality rate at baseline. A significantly decreasing mortality rate was also noted after open repair, and so the improved survival after intact AAA repair was only partly explained by the introduction of EVAR.

The reduction in mortality over time after rAAA surgery was in accordance with the findings from a large meta-analysis[25], as well as from a study based on a subsample of non-federal hospitals in North America between 1993 and 2000[10]. Others have found a more stable mortality rate after rAAA surgery[7,11,12,14]. This reduction was not explained by the introduction of EVAR, which was used in only a small fraction of all rAAA procedures. Other possible explanations are improvements in patient selection, surgical or anaesthetic technique and postoperative care. Unfortunately, there are no data on these variables in Sweden.

The higher age among women who had surgery may be explained by the later development of AAA among them[26], and does to some extent explain their higher postoperative mortality rates. Female sex was independently associated with a higher 30-day mortality rate after intact AAA repair, but not after rAAA surgery, on logistic regression analysis. This observation is consistent with several previous large population-based or nationwide studies[12,27–31], whereas others found no sex difference in mortality rates[7,14,32–34].

Age, open repair (compared with EVAR), heart disease and renal impairment were independently associated with higher mortality after intact AAA and rAAA repair, whereas female sex was associated with increased mortality after intact AAA repair only, and pulmonary disease and diabetes after rAAA repair only.

The introduction of EVAR has resulted in an increased rate of intact AAA repair in Sweden as well as an increase in the age of among those treated; the rate of rAAA repair was stable. Over time the mortality rate after both intact AAA and rAAA repairs has decreased. Although outcomes are worse after open repair, most of the observed decrease in mortality has causes other than the increased use of EVAR.

## Acknowledgements

Swedvasc steering committee: M. Björck, K. Eliasson, C. Forssell, I. Jansson, A. Lundell, L. Karlström and J. Malmström. Senior advisors: D. Bergqvist, L. Norgren and T. Troëng.

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