Temporal Trends and Management of Acute Aortic Occlusion: A 21 Year Experience

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WHAT THIS PAPER ADDS
Acute aortic occlusion is a rare, serious, and yet poorly investigated event. It can be caused by different aetiologies and be treated in many different ways. This investigation includes far more patients than all previous reports and can therefore report on time trends including long term survival with reporting of similar results for patient subgroups.

Objectives: The aim was to study patients with acute aortic occlusion (AAO), a rare and life threatening event, in a population based cohort and the outcome of surgical treatment.
Methods: The Swedish nationwide vascular database (Swedvasc) was used to identify cases, and the population registry to study long term survival. Variables associated with outcome were tested with the chi-square test and analysis of variance.
Results: During the 21 year study period (1994–2014), 693 cases of surgical treatment for AAO were included, with a yearly incidence of 3.6 per million inhabitants. Mean $\pm$ SD age was 69.9 $\pm$ 11.2 years, 352 patients (50.8%) were women, and mean $\pm$ SD length of follow up was 5.2 $\pm$ 5.5 years. Most patients presented with bilateral acute limb ischaemia (596 patients, 86.0%). The aetiology of AAO was native artery thrombosis in 458 patients (66.1%), saddle embolus in 152 (21.9%), and occluded graft/stent/stent grafts in 83 (12.0%). The proportion of occluded grafts/stent/stent grafts increased during the study period ($n = 14$ [6.7%] in 1994–2000 *vs.* $n = 45$ [17.4%] in 2008–2014; $p < .001$) with a simultaneous reduction of arterial thrombosis ($n = 149$ [71.6%] in 1994–2000 *vs.* $n = 158$ [61.2%] in 2008–2014; $p <. 001$). Major amputation above the ankle was performed in 39 patients (8.5%), and 140 patients died within 30 days of surgery (20.2%). Thirty day mortality rate was lower after occluded grafts/stents/stent grafts (eight patients [9.6%]) and higher after saddle embolus (47 patients [30.9%]); $p < .001$. There was a reduction in overall 30 day mortality over time ($n = 53$ [25.5%] in 1994–2000 *vs.* $n = 40$ [15.5%] in 2008–2014; $p = .007$). Long term survival revealed significant differences between the subgroups, although the difference occurred early after the event ($p < .001$).
Conclusions: Mortality after surgical treatment of AAO is improving over time, yet a significant mortality rate was observed throughout the study period. The proportion of AAO secondary to occluded grafts/stents/stent grafts increased over time.

INTRODUCTION

Acute aortic occlusion (AAO) is a rare and potentially life threatening event that initiates lower limb ischaemia. The current understanding of AAO is largely based on case reports and case series of modest size, most of them published several decades ago.[1–4] The events of AAO start a chain reaction that often leads to serious local and systemic manifestations. The condition often presents suddenly with lower extremity pain and leg paralysis that may lead clinicians down the wrong path, with extensive neurological work up, even in patients with absent femoral pulses.[5]

Revascularisation by itself does not ensure a successful outcome in these patients, in whom the condition may represent either end stage cardiovascular disease or poorly understood derangement of coagulation homeostasis.[6–8] Two contemporary case series report that mortality and morbidity continue to be high and unchanged in this vulnerable patient group, despite advances in diagnostic and surgical techniques in the last few decades.[9,10]

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The most common aetiologies causing AAOs are large saddle embolus to the aortic bifurcation or native artery thrombosis of an atherosclerotic aorta. Previous surgical reconstructions on the aorta may also occlude and cause AAO. Increasingly, abdominal aortic aneurysms (AAA) are being treated by endovascular aneurysm repair (EVAR).[11–14] Although EVAR rarely leads to acute ischaemic complications,[15,16] with the increasing volume of this surgery a substantial number of patients presenting with acute limb ischaemia secondary to endograft occlusion/collapse and subsequent aortic occlusion is expected.

The Swedish Vascular Registry (Swedvasc) was started in 1987 and since 1994 more than 95% of vascular surgery procedures performed in Sweden have been registered prospectively.[17–21] This offers a unique opportunity to study a large population based cohort of patients treated for AAO. The aim was to study patients with AAO and the outcomes of surgical treatment, as well as to study time trends and long term survival.

METHODS

Study population

The Swedvasc database was assessed in June 2015. All patients registered in the Swedvasc for AAO between 1 January 1994 and 31 December 2014 were identified. This study period was chosen to obtain complete survival follow up of at least three years. Only patients who receive open or endovascular surgical treatment are included in the Swedvasc, not those treated medically or by palliation alone. During the target period, the database had been updated when variables were adjusted, resulting in three separate databases, but with only minor differences in recorded variables. The registry focuses on case mix, treatment, and results; there are no variables describing the diagnostic methods for AAO. These databases were merged into a single database. The Swedvasc registry has enjoyed nationwide coverage since 1994 and is based on prospectively collected data. The register has been extensively validated, both internally and externally, confirming high data validity.[17–21] The fact that every Swedish citizen or permanent resident has a unique personal identification number (PIN) makes it possible to obtain accurate outcome data of those registered. All deaths in Sweden are recorded in the Population registry, not including those who emigrated. Accurate survival data were obtained by cross linking the PINs with the national population registry in January 2018.

The study population was defined with the following inclusion criteria: an emergency admission; level of occlusion was the infrarenal aorta; and indication for surgery was acute ischaemia (recording surgeon had the options of recording acute or chronic ischaemia). Patients treated for AAO secondary to trauma, dissection, or graft infections were excluded.

A similar study population has also been included and analysed in a research letter published in *Circulation*.[22] In that publication patients treated for acute occlusion of axillobifemoral grafts were also included.

Definitions

The following comorbidities and risk factors were registered prospectively: hypertension (>140/90 mmHg); diabetes mellitus (treated by diet, oral medication, or insulin); heart disease (history of acute myocardial infarction [AMI], angina pectoris, atrial fibrillation [AF], heart failure, coronary artery bypass grafting or heart valve surgery); cerebrovascular event (stroke or transient ischaemic attack); renal impairment (serum creatinine $\geq$ 150 μmol/L or renal replacement therapy); and pulmonary disease (any diagnosed pulmonary disease). Tobacco use was defined as never regularly smoked, prior history of smoking, or current smoker.

Further subgroup analyses were based on the aetiology of the occlusion (saddle embolus, native artery thrombosis, or occluded graft/stent/stent graft) as documented by the responsible and most experienced surgeon. The classification of aetiology was based on an overall assessment of the patient, including radiological imaging of the aorta, intraoperative findings, and patient history. Information about the original surgery was retrieved and analysed for patients with occluded grafts/stent/stent grafts. The treatment strategy was decided by the responsible vascular surgeons; no predetermined protocol was used. To study time trends the whole material was divided into three time periods: 1994–2000; 2001–2007; and 2008–2014. All vascular surgical procedures registered for the included patients were retrieved from the Swedvasc database in order to enable study of all procedures before the AAO event, as well as all re-operations after the acute episode. To analyse whether the surgical volume at the treating centre affected outcome, the hospitals were separated into two groups depending on whether they had more or fewer than 20 cases of AAO during the study period.

Outcomes

The primary endpoint of this study was mortality, defined as post-operative death from any cause within the first 30 days of surgery. Secondary outcomes included major morbidity within 30 days of follow up, as well as long term survival. Major morbidity included AMI, cerebrovascular complications, and lower extremity amputation. All information on amputation in this study refers to major amputation, classified as above the ankle.

Statistics

Primary and secondary outcomes were stratified and compared according to aetiology. Variables associated with outcome were tested in univariable analysis, cross tabulation with the chi-square test for dichotomous variables, and one way analysis of variance for continuous variables. Kendall's Tau-b analysis was used to analyse rank correlation between non-parametric variables. Survival was studied with Cox regression analysis.

Statistical significance was expressed as both *p* values and 99% confidence intervals (CIs). A *p* value < .01 was considered statistically significant, adjusting for multiple comparisons. All statistical analysis was performed using

Table 1. Pre-operative characteristics and comorbidities				
	Total	Native artery thrombosis	Saddle embolus	Occluded graft/stent /stent graft	p value
Number of cases	693	458	152	83	
Age, y	69.9 (68.8−71.0)	68.6 (67.2−69.9)	74.3 (72.4−77.2)*	67.3 (64.1−70.6)	<.001
Female sex	50.8 (45.6−54.7)	50.2 (44.4−55.6)	62.1 (52.6−72.6)*	33.4 (22.6−46.2)*	<.001
Time period					
1994−2000	30.0 (26.0−35.8)	31.2 (26.1−37.3)	30.0 (20.5−41.0)	16.9 (6.7−28.1)	.14
2001−2007	32.8 (28.0−37.0)	33.3 (28.2−39.4)	33.3 (24.1−44.5)	29.1 (16.0−40.2)	.45
2001−2007	37.2 (32.1−42.2)	35.4 (29.3−42.5)	36.7 (26.5−47.9)	54.0 (40.2−69.8)*	.003
Smoking					
Current	62.6 (57.1−68.3)	69.1 (62.0−75.3)	42.3 (28.1−48.5)*	58.3 (44.0−76.6)	<.001
Previous	2.2 (0.9−5.9)	2.2 (0.5−5.7)	2.6 (0.4−8.0)	8.3 (0.8−18.6)	.13
Never	34.2 (29.2−41.4)	28.8 (22.7−36.9)	55.1 (40.0−70.3)*	33.3 (14.1−46.6)	<.001
Previous vascular surgery	50.1 (44.0−56.3)	49.5 (42.3−57.8)	30.0 (18.8−43.2)*	100 *	<.001
Comorbidities					
Hypertension	57.0 (50.9−63.0)	55.4 (48.2−63.6)	52.2 (38.1−66.3)	74.6 (57.8−93.4)	.03
Diabetes mellitus	16.5 (12.0−21.2)	17.0 (12.0−22.0)	13.3 (4.1−23.5)	20.8 (5.9−37.7)	.60
Heart disease	60.0 (54.0−66.4)	53.8 (47.6−62.0)	78.9 (68.8−88.0)*	62.2 (43.4−82.0)	<.001
Cerebrovascular event	19.5 (14.9−24.0)	17.7 (12.5−24.9)	27.2 (16.1−40.3)	15.2 (1.8−30.4)	.14
Renal impairment	11.2 (7.1−15.3)	10.2 (6.0−15.4)	11.4 (3.3−20.5)	17.4 (2.0−33.0)	.35
Pulmonary disease	19.8 (15.0−24.8)	18.5 (12.3−25.7)	17.0 (7.0−29.0)	30.4 (12.8−49.0)*	.01

Data are presented as percentage (99% confidence intervals [CIs]) of the total number in the column, or mean (99% CIs). The right column with
p values is based on analysis of variance of all three groups.
*p < .01 when comparing this group with the other two groups.

SPSS version 22.0 (IBM, Armonk, NY, USA). The Regional Ethical Review Board of the Uppsala region approved the study (Dnr 2014/325).

RESULTS

Patients

A total of 693 AAO cases in 662 patients were identified in Sweden between 1994 and 2014. This corresponds to a yearly incidence of 3.6 cases of AAO per million inhabitants, counting only those receiving surgical treatment. Three hundred and fifty-two patients were women (50.8%). Age ranged from 38 to 96 years (median 70.0 years). AAO was due to native artery thrombosis in 458 patients (66.1%), saddle embolus in 152 patients (21.9%), and occluded graft/stent/stent graft in 83 patients (12.0%). Patients were followed for a mean ± SD time of 5.2 ± 5.5 years after the acute episode.

In the group with occluded grafts/stent/stent grafts, 34 patients (41.0%) had occluded grafts after previous open surgical repair for AAA, 19 (22.9%) had occluded stent grafts after previous EVAR, 19 (22.9%) had an occluded aortobi-iliac bypass and 11 patients (13.3%) had occluded aortic stents. The graft/stent/stent grafts occluded a median of 18.3 months (range 0.3−197) after the original surgery.

At presentation, most patients had severe bilateral ischaemia (86.0%) with a mean ± SD ankle brachial index of 0.08 ± 0.18 of the affected limbs (available information in 73.9%). Patients with bilateral ischaemia were more often treated by open surgery and had inferior survival compared with those with unilateral acute ischaemia.

Comorbidity information in Swedvasc was not complete; the frequency of missing data varied between 5% and 40%

for different comorbidities (40% missing data regarding smoking history, in most of the other variables < 10% was missing). Available information of status at presentation and comorbidities are presented in Table 1. A Kendall's Tau-b analysis was performed to further study the correlation between type of occlusion and smoking habits, revealing a positive correlation between active smoking and graft/stent/stent graft occlusions ($\tau_b = 0.162$, $p < .001$).

Patients with AAO due to saddle embolus were older than those in the other groups, they were more often women, few had a history of smoking, few had previous vascular surgery, and a majority had a known heart disease (Table 1). Patients with occluded graft/stent/stent grafts were more often men, it was more common during the last study period, and they had pulmonary disease more often (Table 1). The proportion of patients with saddle embolus did not change during the study period (21.6% in 1994−2000; 22.9% in 2001−2007; 21.3% in 2008−2014 [$p = .89$]). Graft/stent/stent graft occlusions increased (6.7% in 1994−2000; 10.6% in 2001−2007; 17.4% in 2008−2014 [$p < .001$]) with a simultaneous reduction in the proportion of native artery thrombosis (71.6% in 1994−2000; 66.5% in 2001−2007; 61.2% in 2008−2014 [$p < .001$]). The total incidence of AAO did not change during the study period (range 2.5−4.9 cases/million person years).

Management

All patients in the Swedvasc have received some type of revascularisation, or they would not have been entered in the registry. The most used methods for revascularisation were thrombo-embolectomy (31.9%), thrombolysis (22.7%), aortobi-iliac/bifemoral bypass (20.1%) and axillo-bifemoral bypass (19.0%). Less frequently used revascularisation

techniques are presented in Table 2. There were differences in chosen revascularisation techniques depending on the aetiology of the occlusion (Table 2). Endovascular revascularisation became more frequent over time. It was used as the first line treatment during the study periods of 1994–2000 (15.1%), 2001–2007 (23.5%), and 2008–2014 (45.1%) ($p < .001$).

Short term outcome

In 67.1% of the cases, the revascularisation procedure was performed without any complication during the hospital stay. The most frequent complications were re-occlusion (12.2%) and infection (8.5%); of the latter, 6.2% were superficial and 2.3% were deep infections with systemic manifestations. Other complications are described in Table 3. There were no differences in the frequencies of early complications, either when comparing the three subgroups or when comparing open with endovascular surgery. Compartment syndrome and subsequent fasciotomy were, however, more common after open surgery than after endovascular surgery (9.0% *vs.* 0.0%; $p = .004$).

Thirty days after surgery, 140 patients (20.2%) had died and among the survivors 75.6% had their follow up recorded in Swedvasc. Survival data were complete during all follow ups, a result of the cross linkage with the Population registry. Within 30 days of surgery, 6.5% of the patients suffered an AMI, 1.1% had a major stroke, and 8.5% a major amputation. Thirty day mortality was lower after occluded grafts/stents/stent grafts (9.6%) and higher after embolus (30.9%; $p < .001$) (Table 3). This difference remained after adjustment for baseline differences in a Cox regression model and when aggregating patients with embolus and thrombosis into one group (21.6%; $p = .009$). No differences in mortality or amputation rates were found when comparing low and high volume centres ($p = .92$ and $p = .25$, respectively).

There was a reduction in the 30 day mortality rate over time. In the first study period (1994–2000) the mortality was 25.5%, in the second (2001–2007) it was 20.7%, and in the last (2008–2014) it was 15.5% ($p = .007$, comparing the first and last periods).

Long term outcome

During follow up (mean 5.2 years), 45 patients (6.5%) had an aortic or bypass graft re-operation. The re-operations were performed a median of 12.6 months from the index operation (range 0.3–133 months). The most common types of re-operations were thrombo-embolectomy in 16 patients (35.6%), aortobi-iliac/femoral bypass in 11 patients (24.4%), and placement of stents in the aorta or bypass grafts in seven patients (15.6%). There was no difference in the need for re-intervention between the aetiological groups ($p = .16$). Re-operations were performed more frequently if the index operation was thrombolysis ($p = .004$): 11.5% of the patients needed additional surgery after a median time of 8.2 months (range 0.3–104 months) after thrombolysis. Patients who underwent re-operations had a lower mortality rate than other patients, both at 30 days (4.4% *vs.* 20.9%; $p = .007$) and five years after surgery (17.8% *vs.* 61.2%; $p < .001$). Patients that did not have a 30 day follow up recorded in the Swedvasc had a lower one year mortality (16.6% *vs.* 38.4%; $p < .001$), whereas the five year mortality was similar to patients with 30 day of follow up (54.4% *vs.* 59.7%; $p = .23$).

Long term survival also differed between the aetiological groups (Table 3). Fig. 1 shows Cox regression survival curves adjusted for differences in age and sex between the subgroups ($p < .001$). The survival curves include up to eight years of follow up and show a difference between the groups in the early post-operative period. Thereafter, the group with saddle embolic occlusions continued to have an inferior survival throughout follow up. No difference in long term survival was found comparing low and high volume centres in Kaplan–Meier analysis (log rank, $p = .59$).

DISCUSSION

This study is the largest published on AAOs; indeed, most of the previous studies were published more than 20 years ago. AAO continues to be a rare but serious condition.

The most common reason for AAO in this study was native artery thrombosis of a pre-existing atherosclerotic aorto-iliac segment. This condition is thought to be caused by intraplaque haemorrhage with lifting of an intimal flap, low flow due to low cardiac output or hypercoagulable states (in line with Virchow's famous triad: the wall, the flow, and the blood).[23] Acute thrombosis of aortic aneurysms is probably due to similar causes.[3]

The next most common cause for AAO was aortic saddle embolus. In an earlier era the major source for cardiac emboli was rheumatic heart disease.[24] AMI, often large

Table 2. Methods of revascularisation					
	Total	Native artery thrombosis	Saddle embolus	Occluded graft/stent /stent graft	*p* value
Number of cases	693	458	152	83	
Aortobi-ilic/femoral bypass	139 (20.1)	118 (25.8)*	13 (8.6)	8 (9.6)	<.001
Axillobifemoral bypass	132 (19.0)	101 (22.1)	9 (5.9)*	22 (26.5)	<.001
Thrombo-embolectomy	221 (31.9)	102 (22.3)	96 (63.2)*	23 (27.7)	<.001
Stent/stent graft	44 (6.3)	32 (7.0)	11 (7.2)	1 (1.2)	.12
Thrombolysis	157 (22.7)	105 (22.9)	23 (15.1)*	29 (34.9)*	.002

Data are presented as *n* (%). *$p < .010$ when comparing this group with the other two groups.

Table 3. Outcome after revascularisation

|	Total	Native artery thrombosis	Saddle embolus	Occluded graft/stent/stent graft	p value
Number of cases	693	458	152	83	
Complications					
Re-occlusion	12.2 (8.0−16.2)	12.3 (7.2−17.4)	10.8 (4.6−19.8)	15.0 (0.1−30.0)	.78
Infection	8.5 (5.5−12.5)	7.6 (4.2−12.4)	9.7 (2.5−18.9)	12.5 (−0.2 to 27.0)	.53
Bleeding	6.2 (3.0−8.8)	5.3 (2.2−9.4)	8.6 (2.4−18.0)	7.5 (−0.4 to 19.1)	.49
Distal embolisation	3.5 (1.2−6.5)	3.7 (1.0−6.9)	3.2 (0.0−8.8)	2.5 (−0.4 to 9.1)	.92
Local nerve injury	1.8 (0.0−4.6)	2.3 (1.2−5.4)	1.1 (0.0−5.8)	0.0 (0.0−0.0)	.49
Intestinal ischaemia	1.6 (0.0−3.2)	1.0 (0.0−3.3)	2.2 (0.0−7.1)	5.0 (−0.4 to 14.6)	.15
Fasciotomy	7.6 (4.4−11.8)	7.9 (4.1−12.0)	6.5 (1.4−14.6)	7.0 (−0.4 to 17.8)	.89
30 day follow up					
Myocardial infarction	6.5 (3.3−9.7)	6.4 (3.1−10.7)	7.4 (1.2−15.6)	4.4 (−0.4 to 14.2)	.84
Major stroke	1.1 (0.0−2.3)	0.6 (0.0−2.7)	2.1 (0.0−7.1)	2.4 (−0.4 to 9.9)	.35
Amputation	8.5 (5.1−11.9)	9.4 (5.2−14.5)	6.2 (1.0−13.4)	6.8 (−0.4 to 17.4)	.55
Death	20.2 (16.0−23.8)	18.6 (14.4−23.8)	30.9 (22.6−41.0)*	9.6 (1.3−17.6)*	<.001
Amputation free survival	20.2 (16.0−23.8)	74.4 (68.0−80.8)	67.0 (54.8−79.0)	85.7 (70.1−1.0)	.07
Five year follow up					
Death	58.4 (53.6−63.3)	56.1 (50.1−62.1)	69.7 (60.0−79.5)*	50.6 (36.0−65.2)	.004

Data are presented as percentage (99% confidence intervals [CIs]) of the total number in the column, or mean (99% confidence intervals). *$p <$ .01 *vs.* other groups.

with intramural thrombus in the left ventricle, is now the major source of large emboli that occlude the distal aorta. Although the incidence of embolism following AMI is <1%,[25] the frequency of coronary artery disease makes this a common cause. AF and other cardiac arrhythmias are other sources of large emboli, and have been reported in 40%−100% of patients with saddle emboli.[2,25]

A study on aortic saddle embolus published in 1983[2] postulated that the incidence of saddle embolus would increase over time secondary to increasing population age,[2]

Figure 1. Cox regression survival curves adjusted for differences in age and sex between the aetiological subgroups.

use of prosthetic heart valves, and improved care of cardiac patients. During the present 21 year study period no such increase in the incidence of saddle embolus was observed. On the contrary, the incidence was stable over time. Instead, the study shows a shift toward native artery thrombosis rather than embolism becoming the most common aetiology of AAO. Dossa et al.[4] reported that 65% of 46 cases of AAO between 1953 and 1993 were embolic, but that the frequency of thrombotic AAO increased with each decade. Surowiec et al.[1] reported that between 1985 and 1997, 48% of the 33 cases were embolic. In the present study, only 21.3% of the cases with AAO were caused by an embolus. This finding is consistent with the findings from two recent case series,[9,10] which reported embolic occlusions in 8.3% and 28%. This shift in aetiology may reflect a growing population of elderly with advanced aorto-iliac atherosclerosis. It may also be a result of improved secondary prevention of cardio-embolic events with anti-coagulation for patients with AMI, AF, and/or valvular heart disease.

Another interesting finding in the present study is the observed increase over time in graft/stent/stent graft occlusions leading to AAO and subsequent bilateral limb ischaemia. Acute limb ischaemia is a serious complication after AAA repair and remains a challenging emergency in vascular surgery. Occlusions and limb ischaemia after AAA repair are, fortunately, a rare complication with reported frequencies of <2%, but are associated with worse overall outcome.[16] The increased use of EVAR has led to a decrease in post-operative morbidity and shorter hospital stay. Nevertheless, EVAR is burdened with lower limb ischaemic complications, also seen after open aortic surgery.[26] The EVAR trial reported a 3−4 times higher rate of graft related complications or re-interventions in the EVAR group compared with open aortic surgery.[27] However, ischaemic
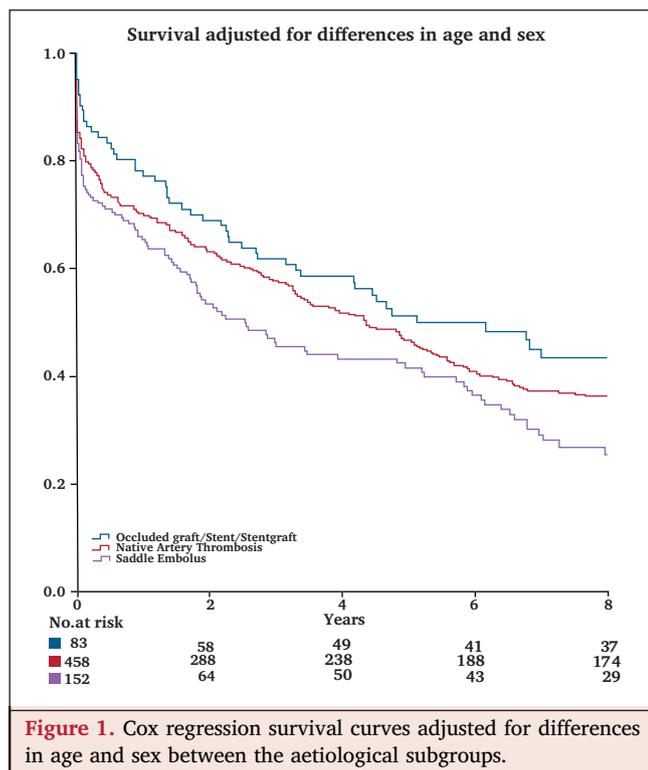
complications related to EVAR have decreased significantly over time as the issue of limb occlusions was acknowledged, and new generation stent grafts are typically manufactured with flexible and more kink resistant limbs.[16] In the UK IMPROVE trial, which randomised patients with ruptured AAA between open repair and EVAR, occlusion of the reconstructions were more common after EVAR.[28]

Another contributing factor to the observed increase in graft/stent/stent graft occlusions might be the overall increase in the frequency aortic interventions, leaving more patients with aortic reconstructions that can possibly occlude.

Previous studies have concluded that the procedure of choice to treat AAO should be bilateral transfemoral thrombo-embolectomy.[1–3] A major advantage of balloon catheter thrombo-embolectomy is that laparotomy can be avoided in most cases, which is a great advantage, especially for frail patients who have embolic occlusions secondary to AMI. It is also possible to perform thrombo-embolectomy under local anaesthesia.[1–3] In the present study, thrombo-embolectomy was the most commonly used method of revascularisation but represented only 31.9% of all procedures. If thrombo-embolectomy fails to re-establish the circulation, the patient is in need of some other emergency treatment. Some authors advocate that aortobi-ilic/bifemoral bypass then is the operation of choice, provided that the patient is otherwise healthy and the ischaemia time has been minimal.[1,3] In high risk patients, extra-anatomical bypass such as an axillobifemoral bypass is indicated because of the increased mortality associated with laparotomy.[3] The proportions of aortobi-iliac/bifemoral bypasses and axillobifemoral bypasses were almost identical in the present study (20.1% vs. 19.0%).

This study also shows that endovascular therapy in AAO is becoming more prevalent over time. Thrombolytic therapy, often in combination with percutaneous transluminal angioplasty and/or stenting, represented 22.7% and stenting alone 6.3% of the procedures. Previous reports have provided both safety and efficacy results for thrombolytic therapy.[10,27] Thrombolysis seems to be particularly efficient in occluded graft/stent/stent grafts and represents a good alternative if the ischaemic state permits a more gradual reperfusion.[29] This may also be the preferred therapy in patients with hypercoagulable states, because this subset of patients responds poorly to surgical intervention, despite normal arteries and good cardiac function.[8] Re-operations were more common if the patient had been treated with thrombolysis: the frequency was 11.5% after thrombolysis vs. an overall re-operations frequency of 6.5%. Some of these re-operations may have been planned, however, as thrombolysis can transform an emergency operation into an elective one, repairing the underlying cause of the AAO in a semi-planned fashion.

The overall 30 day mortality during the entire 21 year study period was 20.2%. Previous studies have reported an in hospital or 30 day mortality rate of 21%—52%.[2–4,6] The two more contemporary studies reported mortality rates of 24% and 31%, respectively.[9,10] The conclusion of these studies was that mortality continues to be high for patients with AAO, which could be verified in this population based study including not only large centres of excellence, but all hospitals of different types performing vascular surgery in an entire country. A gradual reduction in the mortality rate was observed over time, and was only 15.5% during the last seven year period.

As expected, cardiac disease was the most common comorbidity (60.0%), and may partly be responsible for the high mortality observed. Patients with AAO often have extensive comorbidities; and co-existing conditions should be aggressively investigated and treated in order to prevent recurrent events.[6] Advances in cardiology, anaesthesia, and critical care during the last decades are likely to have contributed to the improved results, but the shift towards less invasive endovascular techniques may also have contributed. To minimise recurrent events, aggressive anti-platelet or anticoagulation therapy has been adopted during the study period in Sweden.[30] The change in aetiology of the occlusions also may have contributed to the observed decrease in mortality.

Treatment of AAO is often complicated by reperfusion injury with both local and systemic manifestations. Experimental studies have shown promising results for "controlled reperfusion" after acute ischaemia with reduced manifestations of reperfusion injury.[31,32] To further reduce the mortality associated with AAO, future research efforts should be directed towards the ability to modulate the resultant ischaemia reperfusion injury, and cascades of physiological insults.

Several studies have highlighted the importance of the early detection of AAO in order to reduce morbidity and mortality for these patients, as both tissue damage and reperfusion injury correlate with the duration of ischaemia.[3,6,10] One of the limitations of this study is that detailed data on the time from AAO to revascularisation are lacking. Only cases where the patients received surgical treatment were included and data on comorbidities were not complete in all cases. However, the nature and low incidence of AAO make other types of study designs difficult to pursue. Another limitation is that sometimes the distinction between embolus and thrombosis can be difficult. Embolus/thrombosis is defined by the responsible vascular surgeon, and is based on the overall clinical assessment, imaging, and intra-operative findings. It is sometimes difficult to distinguish the two, particularly if there is an acute on chronic presentation, resulting in a risk of classification bias. The variable was registered prospectively.

CONCLUSIONS

The results from this study suggest a flexible approach to treating AAO, when it comes to the choice of treatment. A great variety of techniques (open aortic surgery, extra-anatomical bypass, and endovascular procedures) were used. The decision regarding treatment strategy should be based upon the type of occlusion, the patient's anatomy,

physiological state, and comorbidities, and tradition and experience at the centre.

Mortality after treatment of AAO is high but has improved over time. Endovascular therapy is used more often in selected patients with AAO, and with similar results to open surgery. The proportion of AAO secondary to occluded graft/stent/stent grafts increased over time, a result of the shift in treating aortic diseases, and, simultaneously, the proportion secondary to native artery thrombosis decreased.

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