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Published in:
European Journal of Vascular and Endovascular Surgery

DOI:
10.1016/j.ejvs.2023.11.006

Publication date:
2024

Document version:
Final published version

Eur J Vasc Endovasc Surg (2024) 68, 110—118

ORIGINAL ARTICLE

Danish Nationwide Study on Surgical Treatment of Infective Native Abdominal Aortic Aneurysms

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WHAT THIS PAPER ADDS

This nationwide study provides a two decade description of patients treated for infective native abdominal aortic aneurysms in Denmark. This retrospective study found that patients were increasingly often being offered repair during the study period; this was being driven by endovascular aortic repair. Endovascular aortic repair demonstrated a better survival in the short term but was comparable with open surgical repair in the long term. The incidence of infection related complications was low.

Objective: This study aimed to describe surgical trends, survival, and infection related complications (IRC) in a Danish cohort of patients with infective native aortic aneurysms (INAAs).

Methods: A retrospective nationwide cohort study including all patients in Denmark who were surgically treated for abdominal INAA between 2000 and 2020 was conducted. Patients were identified through the Danish vascular registry, Karbase, which is a database registering all patients treated with vascular surgery in Denmark. Subsequent data on clinical presentation, treatment, all cause mortality, and complications were obtained from the electronic patient charts.

Results: Seventy-five patients were included in the study, of whom 60 (80%) were male, with a median age of 69 (IQR 64, 75) years. Open surgical repair (OSR) was performed in 54 (72%) patients and endovascular aortic repair (EVAR) in 21 (28%). Median follow up was 52 (IQR 32, 103) months. Open repair was consistently the most frequent treatment modality throughout the study period, but EVAR became more frequent over time. The 30 day survival of the total cohort was 97% (94 — 100%). Kaplan—Meier survival estimates for the cohort were 92% (95% CI 85 — 98%), 80% (95% CI 71 — 91%), 63% (95% CI 52 — 78%), and 48% (95% CI 35 — 66%) at one, three, five and 10 years, respectively. Patients treated by EVAR had comparable long term survival to patients treated by OSR, with a hazard ratio of 0.35 (95% CI 0.10 — 1.22), but was associated with better short term survival up to five years. The most common cause of death was sepsis. Five (9%) OSR patients had IRC compared with one (5%) EVAR patient.

Conclusion: In this nationwide study of patients treated for abdominal INAA, an increasing number of patients were surgically treated during the study period. Patients treated by EVAR demonstrated long term survival comparable to OSR. The incidence of post-operative IRC was low. These results should be interpreted with caution and prospective registries are needed.

Keywords: Infective native aortic aneurysm, Survival, Complications, Endovascular repair, Open repair, Mycotic aneurysm
Article history: Received 8 June 2023, Accepted 3 November 2023, Available online 7 November 2023

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https://doi.org/10.1016/j.ejvs.2023.11.006

INTRODUCTION

Infective native aortic aneurysm (INAA) is a complex disease with an incidence of 0.6 − 2% of all treated abdominal aortic aneurysms (AAA), with an extremely high mortality without prompt diagnosis and treatment.[1,2] Infective native aortic aneurysm is defined as an aortic aneurysm caused by microbial infection.[3] Consensus on definition, diagnostic criteria,[4] and algorithm has recently been established.[5] Treatment of INAAs consists of surgical repair and antibiotic treatment; they may be treated surgically by open surgical repair (OSR)[6,7] or endovascular aortic repair (EVAR).[8−12] Surgical treatment should be coupled with antibiotic treatment as soon as microbiological cultures have been secured.[5,13,14]

The European Society for Vascular Surgery clinical practice guidelines state that the surgical techniques used in INAA repair should be considered based on patient status, local routines, and team experience, with endovascular repair being an acceptable alternative to open repair.[13] There is controversy in the literature and clinical practice as to whether repair should be performed by OSR or EVAR. Typically, OSR is reserved for fit patients, while EVAR is a surgical solution in the frail patient. In retrospective analyses, EVAR has demonstrated better survival compared with OSR, but with a possible increased risk of infection related complications (IRC), as the stent graft is placed in an infected field without surgical debridement.[3,14−16] Open surgical repair with biological grafts have, in selected cases, demonstrated excellent results regarding low IRC rates.[17]

There are no randomised controlled trials on treatment of INAA, due to the rarity and heterogeneous presentations of the disease, and its challenging management.[14] There are three published nationwide population based studies on the management of surgical repair of abdominal INAAs, to date, from Japan, the Netherlands, and Sweden. These have all demonstrated an increased use of EVAR over time, improved survival compared with series published 20 years ago, and a non-negligible post-operative risk of IRC regardless of treatment approach.[16,18,19]

To increase the volume of published data on INAA for future meta-analyses, this study aimed to describe trends in the surgical treatment of abdominal INAAs in Denmark, including outcomes regarding survival and post-operative development of IRC for both OSR and EVAR.

METHODS

Study design

Retrospective, nationwide cohort study.

Patients

Patients treated surgically for INAA between 2000 and 2020 were identified through the national Danish vascular registry, Karbase.[20] This is a mandatory database for the seven Danish vascular surgical centres, where all vascular procedures performed in Denmark are registered and linked to vital status through the Danish Central Population registry.[21,22] Patients with the International Classification of Diseases (ICD-10) coding for AAA and ruptured AAA (DI713 + DI714) together with *Karbase indication for surgery classification 8': Mycotic or infected aneurysm* were identified. Data were then extracted from the electronic patient charts.

Infective native aortic aneurysm was defined as an aortic aneurysm caused by microbial infection of the aortic wall.[5] The diagnostic work up comprised a combination of three criteria: 1) clinical presentation such as fever, pain, or sepsis; 2) laboratory findings such as elevated inflammatory markers or positive cultures; and 3) radiological findings on computed tomography (CT) such as morphology, peri-aortic gas or mass, rupture, and or expansion. The following diagnostic algorithm for an INAA was used: definite diagnosis: three of three clinical criteria and no differential diagnosis being more likely; probable diagnosis: two of three clinical criteria and no differential diagnosis being more likely; not probable diagnosis: one of three clinical criteria. Only patients with two or three of three diagnostic criteria and abdominal location of INAA were included. Exclusion criteria were: aortic vascular graft and endograft infections, aorto−enteric and aorto−ureteral fistulas, inflammatory aneurysms, and penetrating aortic ulcers.

Data, outcomes, and definitions

All cases were reviewed retrospectively, and the following data were obtained according to the study protocol. Further details on these data have previously been described in detail:[5]

1) Demographic data (age, sex, comorbidities).
2) Clinical presentation at the pre-operative consultation (pain, fever [temperature $>$ 38 °C], blood pressure).
3) Laboratory findings (C reactive protein, white blood cell count, cultures).
4) Aneurysm characteristics and radiological features.
5) Type of treatment (OSR including graft types, EVAR, and hybrid procedures [classified as EVAR]).
6) Duration of antibiotic treatment, both pre- and post-operatively.
7) Outcome (early death [30 days], survival, IRC, and operation related complications).

The primary outcome was treatment modality trends, defined as development of choice of treatment, including regional differences. The secondary outcomes were all cause mortality for the total cohort, stratified by surgical approach (OSR and EVAR), IRC, and operation related complications. The OSR group was further stratified into patients treated with biological or synthetic prostheses. Biological grafts were defined as arterial allografts or vein grafts (neo-aorto−iliac system from autologous deep vein grafts [NAIS]). Synthetic grafts were defined as prosthetic grafts, silver prosthesis, or antibiotic coated grafts. Infection

Table 1. Baseline characteristics of 75 patients treated for infective native aortic aneurysm with open surgical repair (OSR) or endovascular aortic repair (EVAR)

	All (n = 75)	OSR (n = 54)	EVAR (n = 21)	p value	Biological graft (n = 23)	Synthetic graft (n = 24)	p value
Patient characteristics at presentation							
Median age − years	69 (64, 75)	69 (63, 73)	70 (67, 79)	.64	68 (59, 70)	70 (67, 74)	.59
Sex − male	60 (80)	44 (82)	16 (76)	.29	21 (91)	18 (75)	.27
Hypertension	34 (45)	24 (44)	10 (48)	.90	10 (44)	12 (50)	.88
Ischaemic heart disease	9 (12)	7 (13)	2 (10)	.092	1 (4)	6 (25)	.12
Cerebrovascular disease	9 (12)	7 (13)	2 (10)	.65	2 (9)	4 (17)	.70
COPD	6 (8)	5 (9)	1 (5)	.49	1 (4)	3 (13)	.63
Any immunosuppressive state	11 (15)	8 (15)	3 (14)	.81	4 (17)	4 (17)	.57
Renal insufficiency	5 (7)	4 (7)	1 (5)	.86	2 (9)	2 (8)	1.0
Diabetes	6 (8)	3 (6)	3 (14)	.51	1 (4)	2 (8)	1.0
Pain − yes	51 (68)	38 (70)	13 (62)	.23	13 (57)	19 (79)	.18
C reactive protein level − mg/L	205±123	213±129	187±107	.11	184±140	257±116	.083
WBC count − x100/L	19±35	21±42	15±5	.22	13±5	32±64	.19
Pre-op BP < 90 mmHg	3 (4)	3 (6)	0 (0)	.41	0 (0)	1 (4)	1.0
Fever > 38 °C pre-op	43 (61)	31 (61)	12 (60)	.57	13 (57)	15 (71)	.48
Positive blood culture	37 (49)	29 (54)	8 (38)	.34	15 (65)	7 (29)	.032
Radiologic findings							
Aneurysm size − mm	52±18	54±19	47±16	.15	49±21	57±16	.16
Rupture	24 (32)	19 (36)	5 (24)	.43	5 (22)	9 (38)	.39
Location				.003			.25
Infrarenal aneurysm	50 (69)	41 (76)	9 (45)		16 (76)	20 (87)	
Juxtarenal aneurysm	3 (4)	3 (6)	0 (0)		2 (10)	0 (0)	
Suprarenal aneurysm	18 (25)	7 (14)	11 (55)		3 (14)	3 (13)	
Follow up − months	52 (32, 103)	59 (35, 103)	48 (31, 92)	.65	50 (36, 95)	68 (46, 112)	.28
30 day survival − %	97 (94, 100)	96 (91, 100)	100 (100, 100)	–	100 (100, 100)	96 (88, 100)	–

Data are presented as n (%), mean ± standard deviation, or median (interquartile range). COPD = chronic obstructive pulmonary disease; WBC = white blood cell; Pre-op BP = pre-operative blood pressure.

related complication was defined as persistent or recurrent sepsis, development of aortic graft or endograft infection, recurrent INAA, or development of an aorto—enteric fistula.[5] Operation related complications were defined as complications as a direct consequence of the surgical treatment, such as bleeding, endoleaks, anastomotic failure, and limb occlusion.

Data analysis and statistics

Data were collected using REDCap (Vanderbilt University, Nashville, TN, USA).[23,24] Data were presented as mean ± standard deviations or median values with interquartile range. Categorical data were presented as number with percentage. Data were grouped according to treatment type, OSR or EVAR, and compared with ANOVA or Fisher's exact test. Survival analyses were performed with the Kaplan—Meier method and plots, and described as 30 and 90 days, and one, three, five, and 10 year survival estimates, and compared with the log rank test. A Cox proportional hazard model analysis was performed to adjust for age, treatment year, and rupture; hazard ratio was calculated for EVAR treatment. Three variables were included in this analysis due to the low number of events. The follow up index was calculated, which is a measure of follow up completeness at the study endpoint.[25] All statistical analysis was performed in RStudio, version 2022.12.0.353 (Posit Software, PBC, Boston, MA, USA).

Ethics

Ethical approval was granted by the regional ethical committee (Journal no: R-20071003).

RESULTS

Patient characteristics

During the study period, 15 054 patients were treated for abdominal aortic aneurysms in Denmark. Seventy-five patients were identified through Karbase as being surgically treated for INAA, resulting in an incidence of 0.5% of all treated AAAs. The patients were included from four centres. Of the total cohort, three of three diagnostic criteria were found in 50 (67%) patients, and two of three diagnostic criteria in 25 (33%) patients. The median age was 69 (64 — 75) years and 60 (80%) were male. Most demographic parameters were comparable; however, more patients treated with OSR had an infrarenal location of the aneurysm compared with EVAR patients (p = .003). Pre-operative CT scans demonstrated rupture in 24 (32%) patients. Circulatory or septic shock was present in three (4%) patients. The 30 day survival of the total cohort was 97% (94 — 100%). For details on clinical, laboratory and imaging data, see Table 1.

Surgical treatment

Open surgical repair was performed in 54 (72%) cases, and EVAR in 21 (28%) cases, of which one was a hybrid

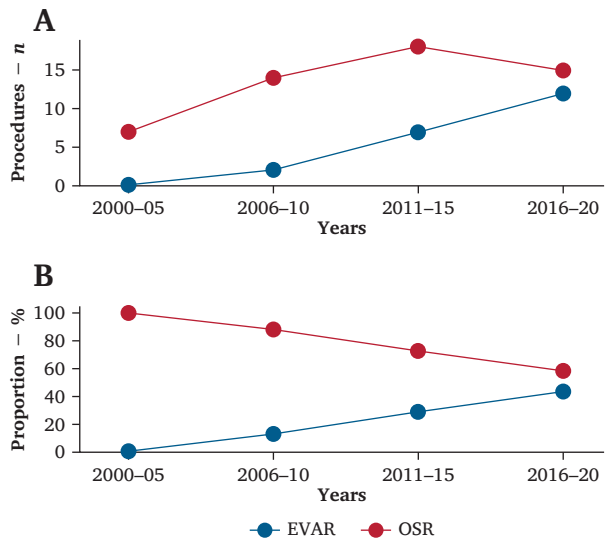


Figure 1. Trends in open surgical repair (OSR) and endovascular aortic repair (EVAR) procedures for infective native aortic aneurysms. (A) Number of open surgical repair and endovascular aortic repair procedures for infective native aortic aneurysms; (B) proportion of open surgical repair and endovascular aortic repair procedures for infective native aortic aneurysms over time.

procedure. No EVAR procedures were performed as bridge prior to OSR. Of patients treated by OSR, biological grafts were used in 23 (43%) cases, (three arterial allografts [13%], 20 NAIS [87%]), Synthetic grafts were used in 24 (44%) cases (nine prosthetic grafts [38%], nine silver impregnated PFT [38%], and three antibiotic coated grafts [13%]). In the remaining seven OSR patients, the graft type was not registered. Of the 24 patients presenting with rupture 19 (75%) were treated by OSR and five (25%) were treated by EVAR.

During the study period, increasing numbers of INAA procedures were carried out: seven during 2000 — 2005, 16 during 2006 — 2010, 25 during 2011 — 2015, and 27 during 2016 — 2020 (Fig. 1A). Figure 1B shows that the percentage of EVAR procedures likewise increased during the study period: 0% of procedures being EVAR during 2000 — 2005 increasing to 45% of procedures during 2016 — 2020. Over the entire study period the proportion of EVAR procedures performed at the four different centres were 0%, 23%, 31%, and 39% ($p = .26$).

Microbiology

Seventy-five patients (100%) had a positive culture result. Of the total cohort, 37 (49%) patients had a positive blood culture, whereas the remaining positive cultures were of various origins. The specific bacterial aetiology was only identified and or registered in the medical record for 50 (67%) patients. The most common pathogens were *Salmonella* spp., *Streptococcus* spp., *Escherichia coli,* and *Staphylococcus aureus,* which represented 84% of all specified microbiological pathogens. Other concurrent infections were found in 40 (53%) patients, see Table 2.

Table 2. Culture results and antibiotic treatment of 75 patients treated surgically for infective native aortic aneurysms

Variable	All ($n = 75$)	OSR ($n = 54$)	EVAR ($n = 21$)
Any positive culture result	75 (100)	54 (100)	21 (100)
Positive blood culture	37 (49)	29 (54)	8 (38)
Species found on cultures			
Salmonella	15 (20)	10 (19)	5 (24)
Streptococcus	12 (16)	8 (15)	4 (19)
Escherichia coli	8 (11)	5 (9)	3 (14)
Staphylococcus aureus	7 (9)	5 (9)	2 (10)
Other species	8 (11)	6 (11)	2 (10)
Not registered	25 (33)	20 (37)	5 (24)
Other current infections			
Urinary tract	5 (7)	4 (7)	1 (5)
Gastrointestinal tract	6 (8)	3 (6)	3 (14)
Respiratory tract	6 (8)	5 (9)	1 (5)
Skin or soft tissue	2 (3)	0 (0)	2 (10)
Bone	1 (1)	0 (0)	1 (5)
Endocarditis	3 (4)	2 (4)	1 (5)
Septic arthritis	4 (5)	2 (4)	2 (10)
Oral	13 (17)	10 (19)	3 (14)
Antibiotic treatment			
Pre-operative antibiotics	63 (84)	44 (89)	19 (90)
Duration of pre-operative antibiotics — weeks	2 (1, 6)	2 (1, 6)	3.5 (2, 8)
Post-operative antibiotics	69 (92)	49 (91)	20 (95)
Lifelong antibiotics	5 (6)	2 (4)	3 (15)
Duration of post-operative antibiotics — weeks	8 (6, 14)	8 (6, 12)	12 (7, 19)

Data are presented as *n* (%), or median (interquartile range). OSR = open surgical repair; EVAR = endovascular aortic repair.

Antibiotic treatment

There were 63 (84%) patients who received pre-operative antibiotics with a median duration of two weeks (1 — 6). There were 69 (92%) patients who received post-operative antibiotics with a median duration of eight weeks (6 — 14). Lifelong antibiotic treatment was prescribed to five (7%) patients (Table 2).

Outcome, survival, and complications of surgery

The overall median follow up was 52 (32 — 103) months. The median follow up was 59 (35 — 103) months for OSR and 48 (31 — 92) months for EVAR. The follow up index was 1 ± 0. Survival estimates for the total cohort were 97% at 90 days (95% CI 94 — 100%), 92% at one year (95% CI 85 — 98%), 80% at three years (95% CI 71 — 91%), 63% at five years (95% CI 52 — 78%), and 48% at 10 years (95% CI 35 — 66%) (Fig. 2).

Patients treated by EVAR were associated with a better short term survival compared with those treated by OSR (Fig. 3), but there were non-significant differences in long term survival ($p = .074$). On Cox regression analysis, the following HR were found: 0.35 (95% CI 0.10 — 1.22) for EVAR, 1.05 (95% CI 0.95 — 1.11) for age, 0.97 (95% CI 0.89 — 1.06) for treatment year, and 1.80 (95% CI 0.81 — 3.99) for rupture

on presentation. Survival stratified by graft type demonstrated better survival in patients treated by EVAR rather than those treated by OSR with synthetic grafts ($p = .046$) (Fig. 4).

Twenty-nine patients died within the study period. The cause of death was unknown in 12 (41%) cases. The most common cause of death was sepsis, registered in four (14%) patients. Post-operative complications are detailed in Table 3. In the OSR group, there were two limb occlusions, one treated with a biological graft and one with a synthetic graft. An OSR patient with anastomotic insufficiency did not have the graft type registered, and this patient later developed an aorto—enteric fistula.

Infection related complications

Post-operative IRC developed in six patients (8%). There were three vascular graft or endograft infections (4%) and one recurrent infected aortic aneurysm (1%); these four patients were also diagnosed with sepsis and two (3%) developed an aorto—enteric fistula. Due to severe comorbidities, all IRCs were treated non-surgically with antibiotics. Five (83%) of these patients died within the study period: the cause of death was infection related in four cases, whereas the fifth patient died of other comorbidities.

Infection related complications were seen in five (9%) patients treated by OSR and in one (5%) patient treated by EVAR, as described in Table 3. The diagnosis of IRC was made after a median of 125 (range 15 — 1 230) days after surgery, and most (67%) developed within the first post-operative year. Of the patients treated by OSR and developing IRC, three were treated with a silver prothesis (synthetic graft), one was treated with an NAIS (biological graft), and one did not have the graft type registered. Of the six patients with IRC, five had pre-operative antibiotics for a median of one (range 0 — 4) week, and all received post-operative antibiotics for a median of eight (range 2 — lifelong) weeks.

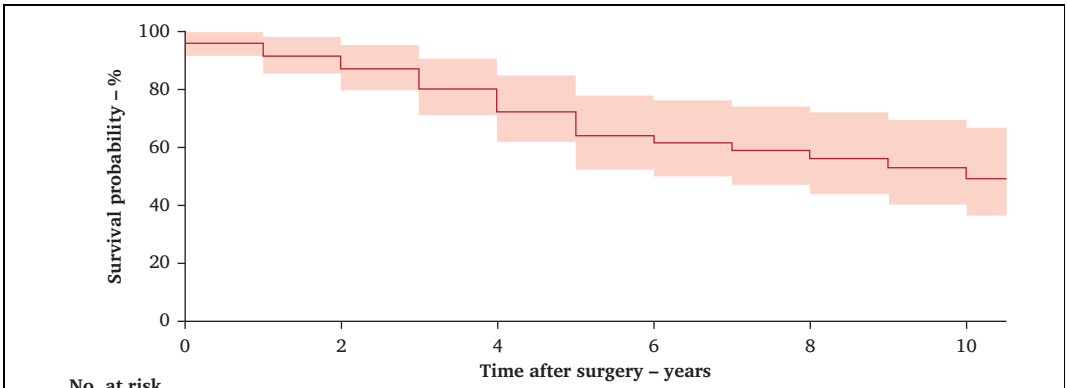
DISCUSSION

Seventy-five patients diagnosed with INAA receiving surgical treatment were identified in this Danish national retrospective study. Open surgical repair was the most frequently used surgical approach throughout the study period, but the proportion of patients treated by EVAR increased over time, as well as the total number of patients treated for INAA. Patients treated by EVAR showed comparable long term survival to those treated by OSR and better short term survival. Six patients were diagnosed with an IRC during follow up.

There was an increase in surgical treatments of INAA during the study period, primarily driven by an increased use of EVAR. However, OSR was consistently the most commonly used treatment modality. This contrasts with trends reported in a systematic review on the management of INAA,[2] where EVAR became the dominant surgical approach after 2010. In a Swedish nationwide cohort, EVAR had already become the most frequent treatment modality in 2001.[16]

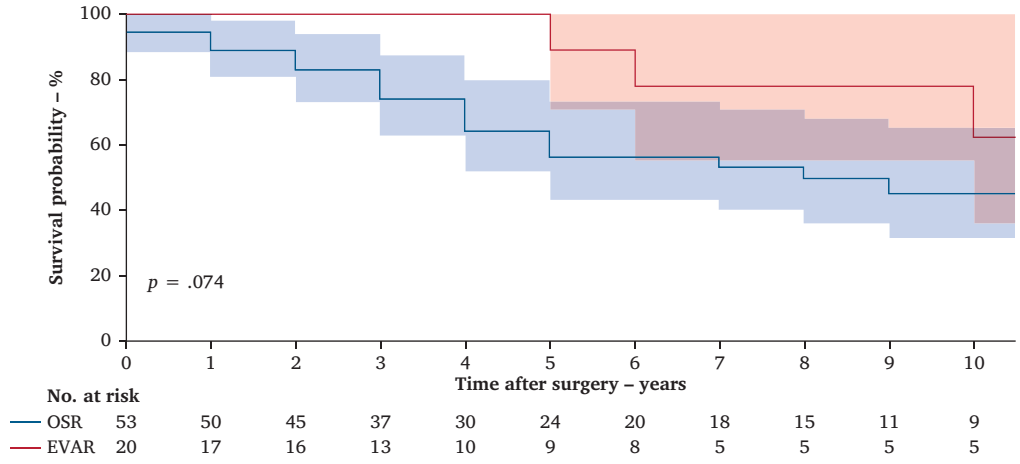
The overall one year survival estimate of 92% in this study is comparable with the three previous nationwide studies from the Netherlands, Japan, and Sweden, where the respective one year survival was estimated at 96%,[18] 83%,[19] and 79%, respectively.[16] The estimated five year survival of 63% in this cohort is in line with the cohorts with longer follow up from Japan and Sweden of 69% and 59%, respectively.[16,19]

The patients treated by EVAR showed a tendency towards better short term survival than patients treated by OSR for the first five years, after which survival was more comparable. These results are similar to the Swedish cohort,[16] which also reported better short term survival among EVAR patients. In the cohort from Japan, comparable survival was reported between EVAR and OSR patients throughout the follow up period.[18] There have been three



	90 days (95% CI)	1 year (95% CI)	3 year (95% CI)	5 year (95% CI)	10 year (95% CI)
Survival estimate	97% (94 – 100%)	92% (85 – 98%)	80% (71 – 91%)	63% (52 – 78%)	48% (35 – 66%)

Figure 2. Cumulative Kaplan—Meier estimate of patient survival with 95% confidence interval (CI) of the entire infective native aortic aneurysm cohort over 10 years.



Survival estimate	90 days (95% CI)	1 year (95% CI)	3 year (95% CI)	5 year (95% CI)	10 year (95% CI)
OSR	96% (91 – 100%)	89% (81 – 98%)	74% (62 – 87%)	56% (43 – 73%)	45% (31 – 65%)
EVAR	100% (100 – 100%)	100% (100 – 100%)	100% (100 – 100%)	89% (71 – 100%)	62% (36 – 100%)
p value	.09	.014	<.001	.004	.38

Figure 3. Cumulative Kaplan–Meier estimates of patient survival with 95% confidence interval (CI) over 10 years for patients with infective native aortic aneurysms treated by open surgical repair (OSR) or endovascular aortic repair (EVAR).

systematic literature reviews on treatment for INAA to date.[2,3,26] The general finding is a better short and midterm survival after EVAR, and comparable long term survival between OSR and EVAR.[3,14]

The number of IRCs in the present cohort was low (8%), but with a high mortality rate of 67%. Several studies have emphasised the major concern of using EVAR in patients with INAA entailing an increased risk of IRC, as the stent graft is placed in an infected bed without resection or drainage of the infected nidus.[13,26] This was reported in the Japanese cohort with an odds ratio of 2.76 for IRC after EVAR,[19] and in a recent meta-analysis where patients treated by EVAR had a relative risk of 2.42 of developing IRC compared with patients treated by OSR.[26] However, criticism has been raised regarding the inclusion criteria, and the infection related endpoints used in both the Japanese nationwide study and the aforementioned systematic literature review.[14,27] No significant difference in IRC was found between EVAR and OSR in the Swedish cohort.[16] Infection related complications were not reported in the cohort from

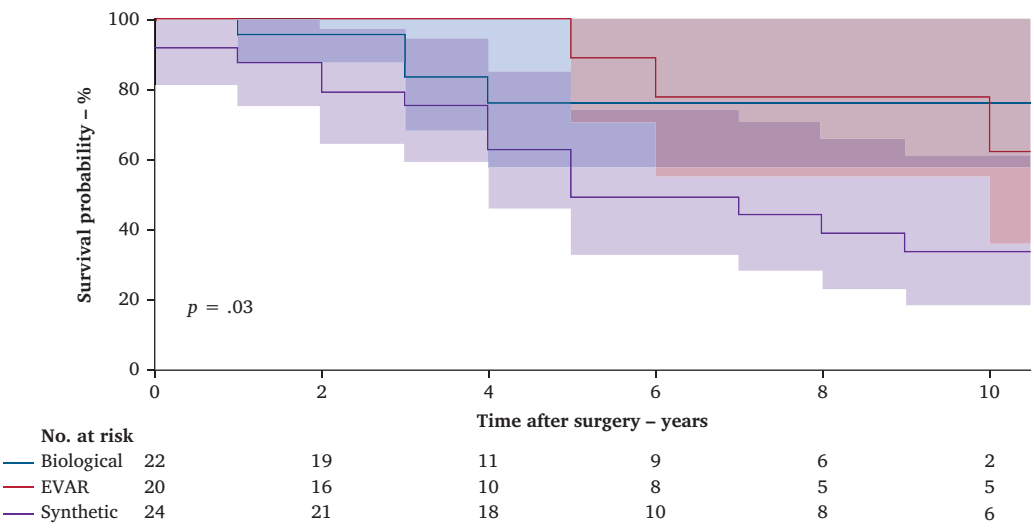


Figure 4. Cumulative Kaplan–Meier estimates of patient survival with 95% confidence interval over 10 years for patients with infective native aortic aneurysms treated with biological grafts, synthetic grafts, or endovascular aortic repair (EVAR). Log-rank *p* values were .46 for EVAR *vs.* synthetic; .79 for EVAR *vs.* biological and .059 for biological *vs.* synthetic.

Table 3. Post-operative complications in 75 patients treated for infective native aortic aneurysm with open surgical repair (OSR) or endovascular aortic repair (EVAR)

	All (n = 75)	OSR (n = 54)	EVAR (n = 21)	Days after surgery
Infection related complication	6 (8)	5 (9)	1 (5)	–
Sepsis	4 (5)	4 (7)	0 (0)	26, 120, 130, 985
Graft infection	3 (4)	3 (6)	0 (0)	26, 130, 985
Recurrent infected aneurysm	1 (1)	1 (2)	0 (0)	101
Aorto–enteric fistula	2 (3)	1 (2)	1 (5)	15, 1 230
Operation related complications	7 (9)	5 (9)	2 (10)	–
Occlusion of graft	3 (4)	2 (4)*	1 (5)†	12, 302, 312
Anastomosis insufficiency	1 (1)	1 (2)‡	–	7
Endoleak	1 (1)	–	1 (5)§	16

Data are presented as n (%).
* One was treated with aortobifemoral bypass, one had a lower limb amputation.
† Treated by re-lining.
‡ Treated by re-suturing the anastomosis.
§ Type 1A, treated with stent graft extension.

the Netherlands; however, re-intervention and re-admission rates were comparable after 30 days and one year between EVAR and OSR.[18]

Bacteria were identified and registered in 67% of the included patients. The most common aetiology was *Salmonella* spp., followed by *Streptococcus* spp., *Escherichia coli*, and *Staphylococcus aureus*. This finding is in line with the literature, particularly in western countries.[2,28,29]

To ensure accurate antibiotic treatment and reduce the risk of IRC, early identification of the causative microorganism is key.[13] Consensus recommendations have recently been published on how to secure and interpret microbiological cultures, in order to be able to direct antibiotic treatment and possibly reduce the incidence of IRCs after surgery.[5] The possibility of intra-operative procurement of microbiological specimens during EVAR is complex, but perioperative biopsies of the aneurysm wall are possible after aneurysm exclusion.[30]

It is believed that no previous studies on INAA have compared survival of patients receiving a biological graft *vs.* a synthetic graft in a population based study. There was a tendency towards improved survival in those who received a biological graft. Hopefully, future studies will report in detail on the differences in graft type and complication rates. Biological grafts are believed to be more resistant to IRCs, although the stress of a longer and more invasive operative procedure (e.g., NAIS procedure) could have a negative impact on this group of frail patients,[31] which might be avoided with fabricated biological grafts.

As this study was retrospective, only associative findings can be made. However, as this is a rare disease, it remains unlikely that a randomised controlled trial will be conducted. It would improve the quality of studies if prospective studies were initiated.

Another limitation was the small sample size of 75 patients, and the numbers at risk in the Kaplan–Meier analyses significantly reduced with time. However, the incidence of treated abdominal INAA per AAA was in line with the literature.[16,18] Due to the Danish central population registry, leading to zero lost to follow up, the follow up index was 1. The three previous nationwide studies were able to include 26, 132, and 832 patients, respectively,[16,18,19] placing this study in the middle of the two European studies in sample size. Since the Danish vascular registry only fully captures the patients who have undergone surgical treatment, conservatively treated patients could not be identified and included.

This study spanned 20 years, which probably affected the results of surgical management, as well as progress in intensive care management and antibiotic treatment. This was corrected for in the Cox regression analysis; however, year of surgery had an insignificant hazard ratio, which should be interpreted with caution and could be explained by the low number of events increasing the risk of type 2 error. The low number of events also limited the number of variables that could be corrected for in the Cox analysis. For this reason, different tendencies in survival could be due to differences in morbidity and not surgical approach.

It was difficult to summarise and further analyse the antibiotic treatment administered, since it was heterogeneous and changed numerous times post-operatively for many patients, with different durations of intravenous and oral regimens, coupled with limited specific details.

Another limitation of this study was the missing data on cause of death, limiting analysis on death being related to treatment type or underlying morbidity. Another major limitation to this study was the lack of information on bacterial aetiology in 33% of the patients. Data on bacterial specimen were not registered for these patients, and it was not possible to obtain this information when reviewing the patients' case notes.

CONCLUSION

In this nationwide study on patients treated for abdominal INAAs, an increasing number of patients were treated surgically during the study period. Endovascular aortic repair is driving this increase in repair, and EVAR demonstrated

comparable long term survival after surgery compared with OSR, with a low incidence of IRC and better short term survival. These results should be interpreted with caution and prospective registries are suggested.

CONFLICTS OF INTEREST

RS received an unrestricted research grant from Medtronic. TR is a consultant for COOK, Bentley. Grants from COOK, GORE, Bentley. Advisory board Artivion. NE, ML and KS report no conflict of interests.

FUNDING

None.

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APPENDIX A. SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejvs.2023.11.006.

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COUP D'OEIL

Be Aware of Routine Punctures

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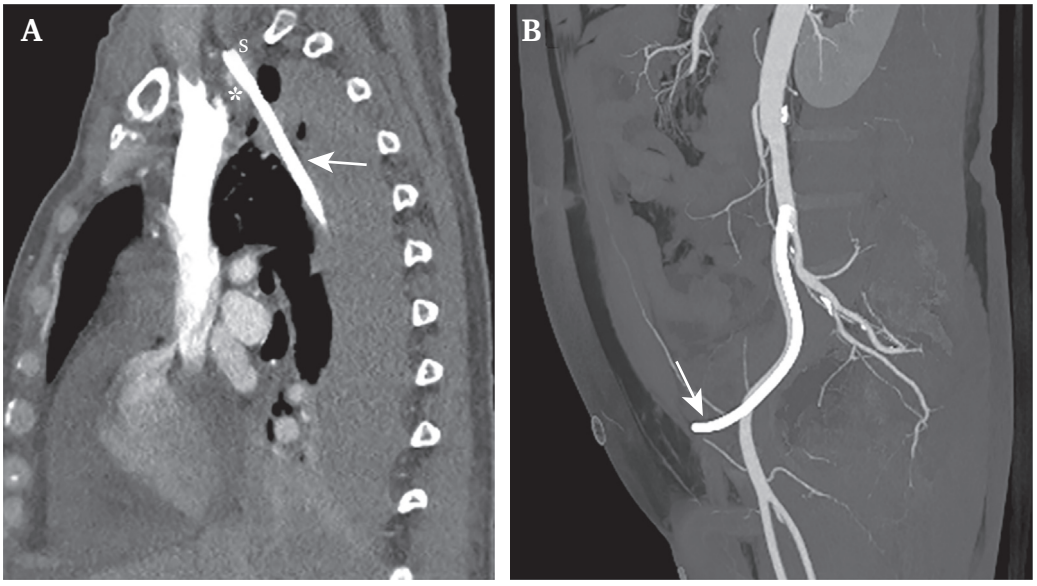

Two patients were referred following routine punctures. One patient had undergone a right internal jugular vein puncture for dialysis without imaging guidance. The vein catheter had pierced the right subclavian artery and reached the lung parenchyma (A, white arrow). The second patient had undergone a pelvic puncture for draining a pelvic haematoma due to a liver problem. Despite the ultrasound guided puncture, the catheter ended up in the iliac artery (B, white arrow). Both patients had these catheters removed after placement of covered self expandable stents (Viabahn; W.L. Gore & Associates, Flagstaff, AZ, USA).

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https://doi.org/10.1016/j.ejvs.2024.03.013