Evaluating abdominal aortic aneurysm and carotid artery surgery in the Netherlands: variations in indication, treatment and outcomes measures

Karthaus, E.G.

CHAPTER 3

Saccular Abdominal Aortic Aneurysms: Patient Characteristics, Clinical Presentation, Treatment and Outcomes in the Netherlands

E.G. Karthaus, T.M.L. Tong, A.C. Vahl, J.F. Hamming

Annals of Surgery 2019

ABSTRACT

Background and objective
Based on the assumption that SaAAAs are more prone to rupture, guidelines suggest early elective treatment. However, little is known about the natural history of SaAAAs and the threshold for intervention is not substantiated. The objective is to analyze differences between saccular (SaAAAs) and fusiform abdominal aortic aneurysms (FuAAAs) regarding patient characteristics, treatment and outcome, to advise a threshold for intervention for SaAAAs.

Methods
Observational study including primary repairs of degenerative AAAs in the Netherlands between 2016-2018 in which the shape was registered, registered in the Dutch Surgical Aneurysm Audit (DSAA). Patients were stratified by urgency of surgery; elective versus acute (symptomatic/ruptured). Patient characteristics, treatment and outcome were compared between SaAAAs and FuAAAs.

Results
7659 primary AAA-patients were included, 6.1% (n=471) SaAAAs and 93.9% (n=7188) FuAAAs. There were 5945 elective patients (6.5% SaAAA) and 1714 acute (4.8% SaAAA). Acute SaAAA-patients were more often female (28.9% vs 17.2%, p=0.007) compared to acute FuAAA-patients. SaAAAs had smaller diameters than FuAAAs, in elective (53.0mm vs 61mm, p=0.000) and acute (68mm vs 75mm, p=0.002) patients, even after adjusting for gender. Additionally, 25.2% of acute SaAAA-patients presented with diameters <55mm and 8.4% <45mm, versus 8.1% and 0.6% of acute FuAAA-patients (p=0.000). Postoperative outcomes did not significantly differ between shapes in both elective and acute patients.

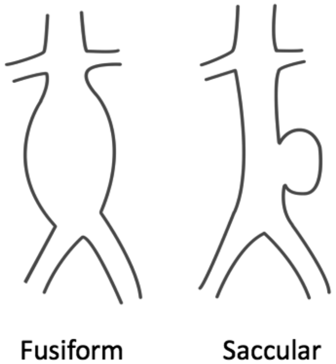
Conclusion
SaAAAs become acute at smaller diameters than FuAAAs in DSAA patients. This study therefore supports the current idea that SaAAAs should be electively treated at smaller diameters than FuAAAs. The exact diameter threshold for elective treatment of SaAAAs is difficult to determine, but a diameter of 45mm seems to be an acceptable threshold.

INTRODUCTION

A saccular shaped abdominal aortic aneurysm (SaAAA), a focally spherical asymmetric dilatation of the aorta, is not common, and is reported to account for about 5% of all abdominal aortic aneurysms (AAAs) (figure 1).[1,2] The vast majority of all AAAs is fusiform shaped (FuAAAs). According to current international guidelines, elective AAA surgery is indicated in aneurysms with a maximum aortic diameter of at least 55mm in men and 50mm in women.[3] However, this only concerns the frequently presenting FuAAAs. The most recent American and European guidelines suggest that elective surgical treatment of SaAAAs is indicated at even smaller diameters, but fail to give an exact threshold for intervention in these patients.[3,4] There is a long-standing belief that SaAAAs should be treated at smaller diameters, as the unique asymmetrical shape might predispose them to rupture.[5-7] Additionally, Kristmundsson et al. showed that small ruptured AAAs (<5.5cm) were more often saccular shaped.[2] However, Shang et al. found no significantly increased risk of rupture in patients with a SaAAA, compared to patients with a FuAAA based on radiologic findings.[8]

Currently no large case series or cohort studies of patients with SaAAAs have been reported. The natural history of patients with SaAAAs is actually unknown and the question remains whether a different treatment diameter threshold should be applied. This study aims to present an overview of the experience with patients with SaAAAs in the Netherlands. Using data from the Dutch Surgical Aneurysm Audit (DSAA) differences are analyzed between SaAAAs and FuAAAs regarding patient characteristics, clinical presentation, treatment and outcome, to substantiate a threshold for operative correction.

Figure 1. Saccular and fusiform shaped abdominal aortic aneurysm



METHODS

Data source

The Dutch Surgical Aneurysm Audit (DSAA) is a nationwide and compulsory quality registry, that registers all patients undergoing aortic surgery in the Netherlands. The DSAA was started in 2013 as an audit for primary AAA surgery and from 2016 all aortic aneurysm/dissection surgical procedures were included. Since 2016 the shape of degenerative aneurysms (fusiform or saccular) is registered in the DSAA. In other pathologies, the shape is not registered. The final responsibility for the registered patient data lies with the vascular surgeon. Verification of the DSAA data was carried out in 2015 by a third trusted party, through a random sample of hospitals and will be continued in the future.[9]

Patient selection

All patients undergoing primary AAA repair in the Netherlands between January 2016 and December 2018 and registered in the DSAA were selected for this study. To consider a patient eligible for analysis the date of birth, date of surgery, type of surgical procedure, urgency of surgical procedure and survival status at time of discharge and 30-days postoperatively had to be known. Furthermore, only patients with a degenerative AAA, in which the aneurysm shape (fusiform/saccular) was specified, were included for analysis.

Definitions and statistical analyzes

A saccular shaped AAA was defined as a focally spherical asymmetric dilatation of the abdominal aorta and fusiform as a coil-shaped dilatation (figure 1). Patients were stratified by the urgency of surgery; elective versus acute presentations. We assume that surgery is indicated in all acute presentations in order to prevent rupture and/or death. As we are interested in a diameter thresholds for elective surgery of SaAAA, all patients with an acute symptomatic or ruptured AAA were grouped and classified as ''acute". Aneurysm shape and diameter registered in the DSAA are extracted from the radiology report and confirmed by a vascular surgeon. In FuAAAs this concerns the largest measured aneurysm diameter, anterior-posterior with ultrasound or computed tomography angiography (CTA) and in SaAAAs the largest diameter measured on axial CTA coupe. Postoperative mortality was defined as mortality within 30-days after surgery or during admission (30-days/in-hospital). Postoperative complication (30-days/in-hospital) were categorized by surgical and non-surgical complications. Descriptive analyses were performed comparing patient characteristics, clinical presentation, treatment and postoperative outcomes between SaAAA and FuAAA patients. Postoperative outcomes were analyzed separately for acute symptomatic and ruptured patients.

Continuous variables were analyzed with a T-test or Mann-Whitney U test when appropriate. Categorical variables were analyzed with a chi-square test. A p-value of <0.05 was considered as significant. To evaluate diameter thresholds for elective repair, the relative risk (RR) for acute presentation between SaAAA and FuAAA was determined per diameter category in acute patients. All statistical analyses were performed using SPSS statistical software (version 24; IBM Corp, Armonk, NY).

RESULTS

Between January 2016 and December 2018, 9089 patients underwent a primary AAA repair in the Netherlands and were registered in the DSAA, of which 9035 (99.4%) were eligible for analysis. The AAA had a degenerative pathology in 7668 (84.9%) of patients. In the remaining 1367 patients, the AAA was caused by infection or inflammation (n=222, 2.5%), dissection (n=62, 0.7%), trauma (n=5, 0.1%), connective tissue diseases (n=86, 1.0%) and unknown pathology (n=992, 11.0%). All 7659 (99.9%) patients with a degenerative AAA, in which the shape was specified, were included in this study: 6.1% (n=471) had a SaAAA and 93.9% (n=7188) a FuAAA. The elective group consisted of 5945 patients and the acute group of 1714 patients. Stratified by the urgency of surgery there were 6.5% (n=388) SaAAAs in elective group and 4.8% (n=83) in the acute (symptomatic/ruptured) group.

Patient characteristics

Patient characteristics, stratified by urgency of surgery and compared between patients with a SaAAA and FuAAA, are presented in table 1. The cohort consisted predominantly of males (84.8% elective, 82.2% acute). In the elective group, distribution of sex was comparable between patients with SaAAA and FuAAA. In the acute group, patients with a SaAAA were more often female, compared to patients with a FuAAA (28.9% vs 17.2%; p=0.007). Baseline characteristics were similar regarding age, cardiac status, pulmonary status, preoperative laboratory results and Glasgow Coma Scale.

Aneurysm and treatment characteristics

In the elective group, patients with SaAAAs were treated at smaller diameters than patients with FuAAAs (mean 53.0 SD 11.4 vs 61.0 SD 9.5; p=0.000) (table 1). Adjusted for gender, the differences in mean diameter between aortic shapes remained (table 2a). Additionally, when dividing maximum aneurysm diameters into categories, patients with SaAAAs were more often undergoing elective surgery at diameters of <45mm, 45-49mm or 50-55mm compared to patients with FuAAAs (<45mm: 20.1% vs 0.7%, 45-49mm: 14.7% vs 1.6% and 50-55mm 19.6%-13.4%; p=0.000). There were no significant differences in type of AAA and type of surgical procedures between the elective SaAAA and FuAAA patients. In the acute setting, patients with SaAAAs had also a smaller mean maximum aneurysm diameter compared to patients with FuAAAs (mean 70.7 SD 23.1 vs 76.5 SD 17.3; p=0.000), also when adjusted for gender (table 2b). When analyzed in categories, a different distribution of maximum diameters between SaAAAs and FuAAAs was seen: acute SaAAA patients more often had a maximum diameter <55mm compared to patients with FuAAAs (25.2%

Table 1. Patient and treatment characteristics

	Elective AAA					**Acute AAA**				
	Fusiform		**Saccular**		***P-value***	**Fusiform**		**Saccular**		***P-value***
	N	%	N	%		N	%	N	%	
Number of patients	5558	93.5%	388	6.5%		1631	95%	83	4.8%	
Age (mean, years)	73.5 SD 7.3		74.0 SD 7.4		*0.175*	74.2 SD 8.0		74.3 SD 8.0		*0.856*
Sex					*0.110*					*0.007*
Male	4722	85%	318	82.0%		1350	83%	59	71%	
Female	835	15%	70	18.0%		281	17%	24	29%	
Cardiac comorbidity					*0.991*					*0.258*
None	2052	37%	142	36.6%		629	39%	29	35%	
Yes	3390	61%	238	61.3%		833	51%	49	59%	
Unknown	115	2.1%	8	2.1%		169	10%	5	6.0%	
Pulmonary comorbidity					*0.406*					*0.679*
None	3961	71%	265	68.3%		988	61%	50	60%	
Yes	1520	27%	116	29.9%		320	20%	19	23%	
Unknown	76	1.4%	7	1.8%		323	20%	14	17%	
Preoperative laboratory results										
Hemoglobin (mean, mmol/L)	8.7 SD 1.0		8.7 SD 1.0		*0.779*	7.7 SD 1.4		7.8 SD 1.4		*0.511*
Creatinine (median, mmol/L)	90 IQR 77-108		90 IQR 77-108		*0.896*	100 IQR 80-125		89 IQR 74.5-107		*0.028*
Glasgow Coma Scale										*0.217*
Normal GCS						1310	80%	72	87%	
Lowered GCS						228	14%	6	7.2%	
GCS unknown						93	5.7%	5	6.0%	
Aneurysm diameter (mean, mm)	61.0 SD 9.5		53.0 SD 11.4		*0.000*	76.5 SD 17.3		70.7 SD 23.1		*0.033*
Aneurysm diameter (median, mm)						75 IQR 62-89		68 IQR 53-82		*0.002*
Min-max (mm)	31-140		31-9			32-150		32-140		
Aneurysm diameter categories					*0.000*					*0.000*
<45mm	37	0.7%	78	20%		9	0.6%	7	8.4%	
45-49mm	88	1.6%	57	15%		38	2.3%	8	9.6%	
50-54mm	742	13%	76	20%		85	5.2%	6	7.2%	
55-64mm	3364	61%	111	29%		302	19%	13	16%	
65-75mm	797	14%	33	8.5%		310	19%	14	17%	
>=75mm	509	9.2%	19	4.9%		824	51%	30	36%	
Missing	20	0.4%	14	3.6%		63	3.9%	5	6.0%	
Type of AAA					*0.309*					*0.438*
Infrarenal	4888	88%	351	91%		1380	85%	74	89%	
Juxtarenal	615	11%	35	9.0%		237	15%	9	11%	
Suprarenal	52	0.9%	2	0.5%		14	0.9%	0	0.0%	
Missing	3	0.1%	0	0.0%		0	0.0%	0	0.0%	
Urgency of surgery										*0.001*
Acute symptomatic						527	34%	42	51%	
Acute rupture						1084	67%	41	49%	
Missing						0	0.0%	0	0.0%	
Treatment					*0.080*					*0.526*
EVAR	4333	78%	313	81%		836	51%	47	57%	
OSR	5	0.1%	1	0.3%		766	47%	35	42%	
Converted to OSR	1188	21%	69	18%		10	0.6%	1	1.2%	
Other	31	0.6%	5	1.3%		19	1.2%	0	0.0%	
Missing	1	0.0%	0	0.0%		0	0.0%	0	0.0%	

Table 2a. Mean abdominal aortic diameter adjusted for gender and shape in elective patients

					95% Confidence Interval for B	
	B	Std. Error	Beta	Sig.	Lower Bound	Upper Bound
(Constant)	73,709	0,675		0,000	72,387	75,032
Sex	-4,236	0,344	-0,155	0,000	-4,909	-3,562
Aneurysm shape	-7,861	0,507	-0,195	0,000	-8,854	-6,868

Table 2b. Mean abdominal aortic diameter adjusted for gender and shape in acute patients

					95% Confidence Interval for B	
	B	Std. Error	Beta	Sig.	Lower Bound	Upper Bound
(Constant)	92,776	2,436		0,000	87,999	97,553
Sex	-9,979	1,114	-0,216	0,000	-12,164	-7,794
Aneurysm shape	-4,639	1,997	-0,056	0,020	-8,556	-0,721

vs. 8.1%; p=0.000), which results in a RR for an acute presentation of 3.1 (95%CI 2.1-4.7) in SaAAA with a diameter <55mm, compared to FuAAAs of the same size (table 3). Additionally, 8.4% (n=7) of SaAAA patients was presented with a diameter <45mm versus 0.6% (n=9) in FuAAA (RR 15.3, 95%CI 5.8-40.0). SaAAAs were presented more often as acute symptomatic (50.6% vs 32.1%) and less frequent as an acute rupture compared to the FuAAAs (49.4% vs 66.5%; p=0.002). Additionally, there were no significant differences in type of surgical procedures performed in the acute setting between the SaAAA and FuAAA.

Surgical outcomes

Regarding perioperative and postoperative complications there were no significant differences between the SaAAA and FuAAA groups (table 4), in elective, acute symptomatic and ruptured patients. In respectively 16.3% (5.7% surgical) and 20.2% (8.8% surgical) of elective SaAAA and FuAAA patients, a postoperative complication occurred. In acute symptomatic patients,

Table 3. Relative risk for acute presentation between saccular and fusiform AAAs

	Fusiform		Saccular		Relative Risk for acute presentation	95% Confidence Interval
	N	%	N	%		
	1631		83			
Aneurysm diameter						
<45mm	9	0.6%	7	8.4%	15.3	5.8–40.0
≥45mm	1622	99.4%	76	91.%		
<50mm	47	2.9%	15	18.0%	6.3	3.7–10.7
≥50mm	1584	97.1%	68	82.0%		
<55mm	132	8.1%	21	25.2%	3.1	2.1–4.7
≥55mm	1499	91.9%	62	74.8%		
<65mm	434	26.6%	34	40.9%	1.5	1.2–2.0
≥65mm	1197	73.4%	49	59.1%		

Table 4. Postoperative outcomes

	Elective					Acute Symptomatic					Ruptured				
	Fusiform		Saccular		P	Fusiform		Saccular		P	Fusiform		Saccular		P
	N	%	N	%		N	%	N	%		N	%	N	%	
Perioperative complication					*0.662*					0.157					0.441
No complication	5247	94.5%	365	94.1%		515	94.1%	41	97.6%		897	82.7%	34	82.9%	
Reanimation/MI	11	0.2%	1	0.3%		0	0.%	0	0%		55	5.1%	1	2.4%	
Occlusion of side branch	46	0.8%	6	1.5%		6	1.1%	0	0%		20	1.8%	0	0%	
Type 1 endoleak	92	1.7%	4	1.0%		11	2.0%	0	0%		11	1.0%	2	4.9%	
Type 3 endoleak	10	0.2%	0	0.0%		1	0.2%	1	2,40%		4	0.4%	0	0%	
Bowel injury	8	0.1%	0	0.0%		1	0.2%	0	0%		9	0.8%	0	0%	
Ureter injury	2	0.0%	0	0.0%		0	0.0%	0	0%		3	0.3%	0	0%	
Other	139	2.5%	12	3.1%		13	2.4%	0	0%		85	7.8%	4	9.8%	
Postoperative complication					*0.172*					0.228					0.096
No complication	4434	79.8%	325	83.8%		390	71.3%	26	61.9%		351	32.4%	20	48.8%	
Surgical complication	314	5.7%	17	4.4%		33	6.0%	1	2.4%		131	12.1%	4	9.8%	
General complication	631	11.4%	41	10.6%		95	17.4%	12	28.6%		383	35.3%	7	17.1%	
Surgical and general complication	170	3.1%	5	1.3%		29	5.3%	3	7.1%		213	19.6%	10	24.4%	
Unknown complication	8	0.1%	0	0.0%		0	0%	0	0%		6	0.6%	0	0%	
Reintervention	261	4.7%	15	3.5%	*0.248*	33	6.0%	3	7.1%	0.772	218	20.1%	10	24.4%	0.721
Length of hospital stay (mean, days)	5.1 SD 13.5		4.3 SD 7.42		*0.247*	8.0 SD 18.6		8.0 SD 12.3		0.985	16.1 SD 21.4		21.8 SD 24.0		0.183
Re-admission	325	5.8%	21	5.4%	*0.723*	41	7.5%	5	11.9%	0.305	65	6.0%	5	12.2%	0.107
Death	99	1.8%	7	1.8%	*0.974*	24	4.4%	1	2.4%	0.534	332	30.6%	7	17.1%	0.063

this was seen in 38.1% (9.5% surgical) of the SaAAA group and 28.7% (11.3% surgical) of the FuAAA group and in 51.2% (34.2% surgical) versus 67.6% (31.7% surgical) in ruptured patients. Postoperative mortality was similar between SaAAA and FuAAA in elective (1.8% vs 1.8%; p=0.974), acute symptomatic (2.4% vs. 4.4%, p=0.534) and ruptured patients (17.3% vs. 30.6%, p=0.063).

DISCUSSION

Of all patients undergoing primary AAA surgery because of degenerative AAA in the Netherlands between 2016 and 2018, 6.1% had a SaAAA (6.5% elective, 4.8% acute). Patient characteristics were comparable between SaAAAs and FuAAAs, except that acute SaAAA patients were more often female compared to acute FuAAA patients. The accepted threshold for surgery is 55mm in FuAAAs (50mm in women).[3,4] As expected, elective patients with a SaAAA were operated at smaller diameters than elective FuAAA patients and the majority of elective SaAAA patients were undergoing surgery with a diameter <55mm. Also, acute SaAAA patients were more often presented with smaller diameters than acute FuAAA patients: 25.2% of the acute SaAAAs had a diameter <55mm and 8.4% <45mm, while this was only 8.1% and 0.6% of the FuAAA group respectively. This resulted in a RR on an acute presentation of >3 in SaAAAs with diameters <55mm compared to FuAAAs of the same size and >15 in SaAAAs <45mm. This suggests a threshold of at least 45mm. Both SaAAAs and FuAAAs had similar treatment ratios with EVAR and OSR in the elective and acute setting, there were no differences in postoperative outcomes.

SaAAAs have been described as a relatively rare condition since early in the 20th century.[10] Since then, mainly case reports and small case series have been published on their clinical presentation and etiology.[11-14] Where FuAAAs often occurs as a result of degeneration of the arterial wall, SaAAAs appear to have a more varied etiology, including trauma, aortic infection, inflammatory diseases, degeneration of a penetrating atherosclerotic ulcer and previous aortic surgery.[15-17] With the development of imaging techniques, larger cohorts of patients with a saccular aortic aneurysm are identified.[1,2,8] Reported incidences of SaAAAs vary from 1.5%-5.0%, which corresponds to our finding 6.1% in the Dutch population.[1,2,8] Shang et al. described the largest cohort so far: 284 patients with a saccular thoracic or abdominal aortic aneurysm.[8] The majority of saccular aneurysms in this cohort were located in the descending thoracic aorta and only 24.2% (n=78) in the abdominal aorta. While case-series suggested a varied etiology of SaAAAs, Shang et al. found that the majority (81.1%) of saccular aortic aneurysms was caused by atherosclerosis (degeneration) and only 3.7% followed after trauma, 1.2% was caused by infection, 1.0% by arteritis and in 13.1% the etiology was unclear. Comparable data about the etiology for specifically SaAAA alone is not available to date.

Despite the fact that little is known about the natural course of SaAAAs, the assumption prevails that SaAAAs are more prone to rupture than those with a fusiform shape. The association between aneurysm shape and risk of rupture is based on the case-control study from Szilagyi et al in 1966 in which aneurysm characteristics were compared between patients with surgical and nonsurgical treatment.[7] It was thought that the asymmetrical shape of a SaAAA predisposes to rupture.[7,18] While there was no hard evidence for the association between shape and rupture, this association is mentioned in many case-series ever since.[1,2,6,8,19] In 1992, the subcommittee of the Joint Council of the Society for Vascular Surgery published a report recommending surgical treatment of saccular aneurysms regardless the size or symptom status.[5] Although this recommendation is only suggested in the current guidelines of the American and European Society for Vascular Surgery, it seems that it is still met by many vascular surgeons.[4,20] Apparently this recommendation is also followed by vascular surgeons in the Netherlands as more than half of elective patients with a SaAAA in our series was operated at a diameter <55mm. Although early surgical treatment is performed in the majority of elective SaAAAs in the Netherlands, still 17.6% of all SaAAAs presented in an

acute setting. Additionally, patients with acute SaAAAs presented with significantly smaller diameters than acute FuAAAs, even when adjusted for gender. These findings are consistent with Kristmundsson et al, who reported that small ruptured AAAs (<5.5cm) were more often saccular shaped, particularly in women.[2] Remarkably enough 8.4% of acute SaAAAs in our cohort had a smaller diameter than 45mm and the smallest diameter even 32mm. Furthermore, when looking at all AAAs <55mm, we found a RR of 3.1 for SaAAA patients to become acute compared to FuAAA patients. When lowering the diameter threshold this RR increased to even 15.3 for SaAAAs <45mm. This supports the current idea that SaAAAs should be electively treated at smaller aortic diameters than FuAAAs.[2]
On the contrary, Shang et al., found similar aneurysm growth rates between saccular and fusiform aneurysms and did not find any relation between shape and risk of rupture. However, this study included all types of aortic aneurysms, not only abdominal, and all pathologies.[8]

As cohorts of patients with a SaAAA are rarely described, little is known about the treatment and its outcomes, therefore we compared the treatment and outcomes of SaAAAs with their fusiform counterparts. In the Netherlands, SaAAAs are treated with EVAR in respectively in 80.7% of elective and 56.6% of acute patients, which is comparable with FuAAA patients. Comparing crude peri- and postoperative outcomes between patients with SaAAAs and FuAAAs, in elective, acute symptomatic and ruptured setting we found no significant differences.

This study has some limitations. The Dutch Surgical Aneurysm Audit only registers patients who underwent surgical repair of an aortic aneurysm. Patients with an AAA who are not (yet) operated or acute patients that died before they reached the hospital or could be operated, are not included in this dataset. Secondly, the DSAA was primarily set up as a quality registry for aortic surgery in the Netherlands and was not specifically designed for scientific purposes. Therefore, more detailed anatomic information or other measurements than maximum aneurysm diameters were not available. Furthermore, the measurement of maximum diameters in ruptured aneurysms can be difficult. In both the SaAAA and FuAAA group we found very small maximum aortic diameters. FuAAAs sometimes involve the iliac arteries, in these cases the indication for surgical repair can be based on the maximum iliac diameter instead of maximum aortic diameter, which may have resulted in unjustified lower diameters in the FuAAA group. This will not occur in the SaAAA group and may have influenced our comparison of diameters between the two shapes. The difference in diameters between SaAAA and FuAAA could actually be greater.

Until now this seems to be the largest cohort of exclusively SaAAAs and comparing the characteristics and results to fusiform counterparts. As our findings support the idea that SaAAAs should be surgically treated at smaller diameters than FuAAAs, it would be important to know what the threshold for elective surgery should be in saccular patients. Ideally, a trial could test the effectivity of a newly proposed threshold. However, considering the low incidence of SaAAAs this is not an easily feasible option. Since only observational data are available, a threshold could be chosen based on the smallest diameters is which acute patients were presented. In our cohort of 83 patients with an acute SaAAA, 25.2% was presented with a diameter < 55mm, 8.4% <45mm and the smallest diameter in an acute patient was 32mm. Associated RR makes it clear that SaAAAs have a considerably greater chance to become acute at smaller diameters than FuAAAs. However, this based on a relative small cohort and does not provide an exact threshold. Pooling of observational data on SaAAAs could help to eventually determine a threshold for intervention.

CONCLUSION

SaAAAs become acute at smaller aortic diameters than FuAAAs in the Dutch Surgical Aneurysm Audit database. This study therefore supports the current idea that SaAAAs should be electively treated at smaller aortic diameters than FuAAAs. The exact diameter thresholds for elective treatment of SaAAAs is difficult to determine, but a minimum of at least 45mm seems to be an acceptable threshold.

REFERENCES

1. Iwai T, Sato S, Muraoka Y, Inoue Y, Sugano N, Endo M. Atherosclerotic abdominal aorta saccular protrusion. *Int Surg.* 1996;81(2):189-194.
2. Kristmundsson T, Dias N, Resch T, Sonesson B. Morphology of Small Abdominal Aortic Aneurysms Should be Considered before Continued Ultrasound Surveillance. *Ann Vasc Surg.* 2016;31:18-22.
3. Wanhainen A, Verzini F, Van Herzeele I, et al. Editor's Choice–European Society for Vascular Surgery (ESVS) 2019 Clinical Practice Guidelines on the Management of Abdominal Aorto-iliac Artery Aneurysms. *Eur J Vasc Endovasc Surg.* 2019;57(1):8-93.
4. Chaikof EL, Dalman RL, Eskandari MK, et al. The Society for Vascular Surgery practice guidelines on the care of patients with an abdominal aortic aneurysm. *J Vasc Surg.* 2018;67(1):2-77 e72.
5. Hollier LH, Taylor LM, Ochsner J. Recommended indications for operative treatment of abdominal aortic aneurysms. Report of a subcommittee of the Joint Council of the Society for Vascular Surgery and the North American Chapter of the International Society for Cardiovascular Surgery. *J Vasc Surg.* 1992;15(6):1046-1056.
6. Taylor BV, Kalman PG. Saccular aortic aneurysms. *Ann Vasc Surg.* 1999;13(6):555-559.
7. Szilagyi DE, Smith RF, DeRusso FJ, Elliott JP, Sherrin FW. Contribution of abdominal aortic aneurysmectomy to prolongation of life. *Ann Surg.* 1966;164(4):678-699.
8. Shang EK, Nathan DP, Boonn WW, et al. A modern experience with saccular aortic aneurysms. *J Vasc Surg.* 2013;57(1):84-88.
9. Dataverification Dutch Surgical Aneurysm Audit 2015. [PDF]. http://dica.nl/media/660/Eindrapport_dataverificatie_DSAA_2016.pdf, 2016.
10. Baird IM. Saccular aneurysms of the abdominal aorta; report of three cases and review. *AMA Arch Intern Med.* 1953;91(5):626-632.
11. Kelemen E, Jr., Balogh J. Saccular aneurysm of the abdominal aorta due to medianecrosis. *Angiology.* 1966;17(4):247-251.
12. Yasuhara H, Muto T. Infected abdominal aortic aneurysm presenting with sudden appearance: diagnostic importance of serial computed tomography. *Ann Vasc Surg.* 2001;15(5):582-585.
13. Owen RP, Chan C. Saccular abdominal aortic aneurysm: clear cause of exquisite back pain. *BMJ Case Rep.* 2012;2012.
14. Minor ME, Menzoian JO, Raffetto JD. Noninfectious saccular abdominal aortic aneurysm—a report of two cases. *Vasc Endovascular Surg.* 2003;37(5):353-358.
15. Brown SL, Busuttil RW, Baker JD, Machleder HI, Moore WS, Barker WF. Bacteriologic and surgical determinants of survival in patients with mycotic aneurysms. *J Vasc Surg.* 1984;1(4):541-547.
16. Coady MA, Rizzo JA, Hammond GL, Pierce JG, Kopf GS, Elefteriades JA. Penetrating ulcer of the thoracic aorta: what is it? How do we recognize it? How do we manage it? *J Vasc Surg.* 1998;27(6):1006-1015; discussion 1015-1006.
17. Benrashid E, McCoy CC, Rice HE, Shortell CK, Cox MW. Mycotic Saccular Abdominal Aortic Aneurysm in an Infant after Cardiac Catheterization: A Case Report. *Ann Vasc Surg.* 2015;29(7):1447 e1445-1447 e1411.
18. Vorp DA, Raghavan ML, Webster MW. Mechanical wall stress in abdominal aortic aneurysm: influence of diameter and asymmetry. *J Vasc Surg.* 1998;27(4):632-639.
19. Pappu S, Dardik A, Tagare H, Gusberg RJ. Beyond fusiform and saccular: a novel quantitative tortuosity index may help classify aneurysm shape and predict aneurysm rupture potential. *Ann Vasc Surg.* 2008;22(1):88-97.
20. Moll FL, Powell JT, Fraedrich G, et al. Management of abdominal aortic aneurysms clinical practice guidelines of the European society for vascular surgery. *Eur J Vasc Endovasc Surg.* 2011;41 Suppl 1:S1-S58.