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Results from a nationwide prospective registry on open surgical or endovascular repair of juxtarenal abdominal aortic aneurysms

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ABSTRACT

Background: Juxtarenal abdominal aortic aneurysms (JRAAAs) can be treated either with open surgical repair (OSR) including suprarenal clamping or by complex endovascular aneurysm repair (cEVAR). In this study, we present the comparison between the short-term mortality and complications of the elective JRAAA treatment modalities from a national database reflecting daily practice in The Netherlands.

Methods: All patients undergoing elective JRAAA open repair or cEVAR (fenestrated EVAR or chimney EVAR) between January 2016 and December 2018 registered in the Dutch Surgical Aneurysm Audit (DSAA) were eligible for inclusion. Descriptive perioperative variables and outcomes were compared between patients treated with open surgery or endovascularly. Adjusted odds ratios for short-term outcomes were calculated by logistic regression analysis.

Results: In all, 455 primary treated patients with JRAAAs could be included (258 OSR, 197 cEVAR). Younger patients and female patients were treated more often with OSR vs cEVAR (72 ± 6.1 vs 76 ± 6.0; $P < .001$ and 22% vs 15%; $P = .047$, respectively). Patients treated with OSR had significantly more major and minor complications as well as a higher chance of early mortality (OSR vs cEVAR, 45% vs 21%; $P < .001$; 34% vs 23%; $P = .011$; and 6.6% vs 2.5%; $P = .046$, respectively). After logistic regression with adjustment for confounders, patients who were treated with OSR showed an odds ratio of 3.64 (95% confidence interval [CI], 2.25-5.89; $P < .001$) for major complications compared with patients treated with cEVAR, and for minor complications, the odds ratios were 2.17 (95% CI, 1.34-3.53; $P = .002$) higher. For early mortality, the odds ratios were 3.79 (95% CI, 1.26-11.34; $P = .017$) higher after OSR compared with cEVAR.

Conclusions: In this study, after primary elective OSR for JRAAA, the odds for major complications, minor complications, and short-term mortality were significantly higher compared with cEVAR. (J Vasc Surg 2022;75:81-9.)

Keywords: Aortic aneurysm; Abdominal aortic aneurysm; Endovascular repair; Operative surgical procedures; Mortality

Due to the lower mortality and its minimal invasive character, endovascular aneurysm repair (EVAR) has been widely implemented in daily practice and is the preferred method of treatment of abdominal aortic aneurysms (AAAs) in most practices.[1] Since the introduction of EVAR almost three decades ago, an increasing amount of research has focused on the differences between open surgery and EVAR to treat AAAs.[2-5] Several trials on elective infrarenal aneurysms showed a survival advantage for EVAR in the short term.[6] This advantage was, however, lost after 3 years of follow-up.

The Dutch Surgical Aneurysm Audit (DSAA) is a mandatory nationwide audit for all patients treated for an aortic aneurysm in The Netherlands and was introduced in 2013.[7] Previous research from this database between 2013 and 2015 showed a combined mortality for open surgery and EVAR of 1.9% for infrarenal and juxtarenal aortic aneurysms (JRAAAs) combined. So far, little specific data is published on outcomes of JRAAA repair when JRAAAs account for roughly 15% of all AAAs.[8] As JRAAAs demand a different, more complex approach in open surgery (suprarenal clamping) and in complex endovascular repair (cEVAR; chimney EVAR [CHEVAR] or fenestrated EVAR [FEVAR]), outcomes after JRAAA treatment are most likely different from treatment of infrarenal aneurysms. Therefore, JRAAAs should be

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evaluated separately in observational research as well as in a randomized trial. Consequently, this study evaluates the most recent short-term outcomes after elective juxtarenal aortic repair in a consecutive cohort from a nationwide database reflecting daily practice in The Netherlands.

METHODS

This is a retrospective study performed on a prospectively collected registry. We followed the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) guidelines reporting this study.

Data source. The dataset was derived from the DSAA. The DSAA is a compulsory nationwide audit that was initiated in 2013 and prospectively registers all patients treated for an aortic aneurysm (infrarenal, juxtarenal, suprarenal aneurysms) either with OSR or cEVAR. The purpose of the DSAA is to monitor quality and improve outcomes after aortic aneurysm treatment. Surgeons register their data via a web-based survey or deliver the data as a data file. Our research group was granted permission by the DSAA scientific and ethical committee after submitting a research proposal to evaluate all patients with JRAAAs treated in The Netherlands between January 2016 and December 2018. Patient consent was not necessary according to the ethical committee, as the DSAA database we received was anonymized data. The study complied with the Declaration of Helsinki.

Study population. Between 2016 and 2018, 12,194 patients were registered in the DSAA with an aortic aneurysm. In this dataset, 1243 patients were registered as having a JRAAA. Elective, primary, and atherosclerotic JRAAAs were included. The exact flow diagram of patient inclusion and exclusion is shown in the Fig. The final database consisted of 455 electively and primarily treated patients with JRAAAs in 44 Dutch hospitals; 258 patients treated with OSR and 197 with cEVAR.

Definitions. A JRAAA is generally defined as an aortic aneurysm extending up to but not involving the renal arteries (ie, a short infrarenal aortic neck <10 mm), necessitating inter-renal, suprarenal below the superior mesentery artery, or infra- or supracoeliac clamping.[9,10] The DSAA database included all patients who were marked as segment C AAAs and JRAAAs by the registering clinicians. Segment C aneurysm was defined as an aortic aneurysm distally from the superior mesenteric artery. Suprarenal clamping was defined as clamping above one or both renal arteries. As the DSAA database did not provide us with anatomical features to check if all included patients met the formal definition of a juxtarenal aneurysm, we used operation characteristics to approximate the formal anatomical definition. We excluded all patients with infrarenal clamping in the OSR treatment group, because when infrarenal clamping is used, it is more likely to be an infrarenal aneurysm, and therefore, misclassification is likely. If patients were endovascularly treated, they had to have undergone some type of branch inclusion in the reconstruction (ie, CHEVAR or FEVAR), and therefore at least one targeted vessel. Patients treated with FEVAR with four fenestrations and branched EVAR (BEVAR) were excluded, because in most cases BEVAR was used for suprarenal aneurysms, and therefore, misclassification is most likely. The DSAA database does not specify which arteries were targeted per patient. Study variables included all preoperative and perioperative variables, which are compulsory to submit for every patient with aneurysm in the DSAA registration. Some study variables included the option ‘unknown.’

Preoperative cardiac status was recorded in the DSAA registry as the presence of: (1) no cardiac history; (2) medication for hypertension, angina pectoris, diuretics, or digoxin; (3) presence of peripheral edema or use of vitamin K antagonists or borderline cardiomyopathy; (4) presence of an elevated central venous pressure or cardiomegaly; and (5) unknown. Preoperative pulmonary status was recorded in the registry as the presence of: (1) no pulmonary history; (2) presence of dyspnea during exercise; (3) presence of severe dyspnea, including invalidating dyspnea, dyspnea at rest, consolidation and lung fibrosis; and (4) unknown. Electrocardiogram (ECG) abnormalities consisted of atrial fibrillation, ischemia, or any other abnormalities on ECG.

ARTICLE HIGHLIGHTS

- **Type of research:** Multicenter retrospective analysis of prospectively collected data of the Dutch Surgical Aneurysm Audit
- **Key Findings:** Our study of 455 patients gives a reflection on the current practice of juxtarenal aneurysm treatment in The Netherlands and shows that patients treated with open surgery have an over 3.5-fold higher odds for major complications, over 2-fold higher odds for minor complications, and almost 4-fold higher odds of early mortality, compared with after complex endovascular treatment.
- **Take Home Message:** In the study, after primary elective open surgical repair for juxtarenal abdominal aortic aneurysms, the odds for major complications, minor complications, and short-term mortality were all significantly higher compared with complex endovascular repair. Although this study reflects daily practice in The Netherlands, selection bias and number of included patients should be taken into account when interpreting the generalizability of this study.

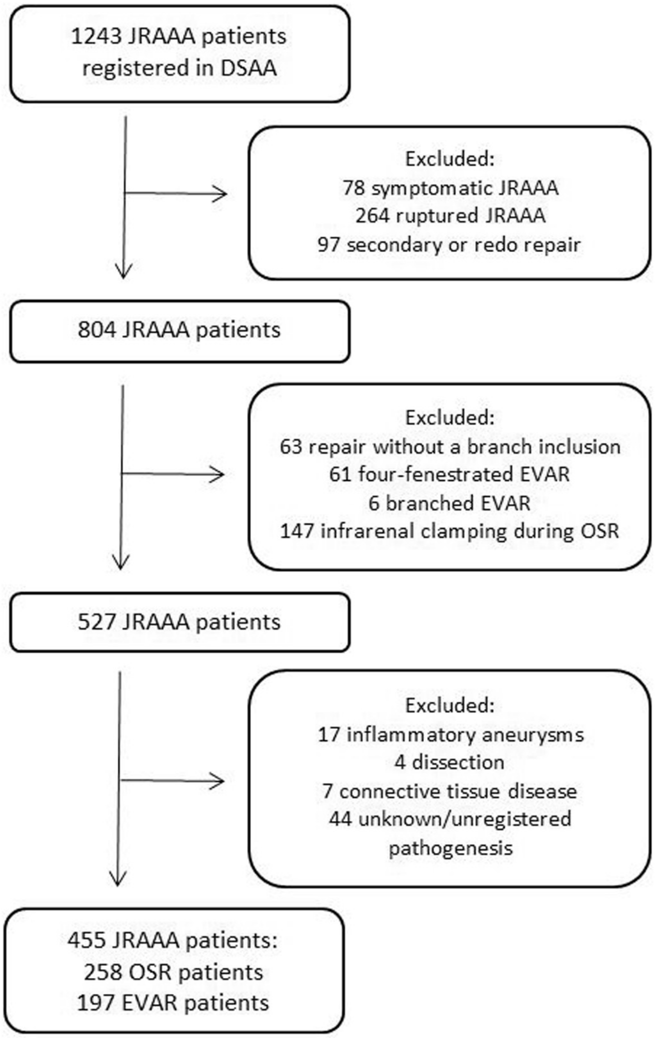

Fig. Patient selection. *DSAA,* Dutch Surgical Aneurysm Audit; *EVAR,* endovascular aneurysm repair; *JRAAA,* juxtarenal abdominal aortic aneurysm; *OSR,* open surgical repair.

A cardiac complication is recorded as yes if myocardial infarction, decompensated heart failure, cardiac arrhythmias, or other cardiac complications occurred. Pulmonary complications are recorded as yes if pneumonia, pulmonary embolism, pneumothorax, or other pulmonary complications occurred. Renal complications are recorded as yes if renal insufficiency not requiring hemodialysis or renal insufficiency requiring hemodialysis occurred. Neurologic complications are recorded as yes if cerebrovascular accident, paraplegia, delirium, or other neurologic complications occurred. Abdominal complications are recorded as yes if abdominal abscess, abdominal sepsis, ileus, spleen injury, bowel ischemia, bowel injury, stoma placement, or other abdominal complications occurred. Arterial occlusions are recorded as yes if (major) amputation, renal artery arterial occlusion, or other arterial occlusion (including trash foot) occurred. Reconstruction and prosthesis-related complications are recorded as yes if prothesis infection, prothesis migration, or other reconstruction and prosthesis-related complications occurred. Wound complications are recorded as yes if deep wound infection, fascia dehiscence, or other wound complications occurred. Postoperative bleeding was marked as yes if a postoperative bleeding occurred. Infection (nonsurgical) was marked as yes when an infection occurred that was not a surgical or pulmonary infection. The category 'other' complications is any other complication that occurred within 30 days or within hospital admission and did not fit any of the other categories.

The primary endpoint was early mortality, and secondary endpoints were major and minor complications within 30 days, reintervention/reoperations within 30 days, and unplanned readmission within 30 days after discharge. Early mortality was defined as death within 30 days after treatment or within initial hospital admission. A major complication was defined as any postoperative adverse event causing a prolonged hospital stay, reintervention, or early mortality, with a maximum of one major complication.[11] A minor complication was defined as any postoperative adverse event that did not lead to a prolonged hospital stay, reintervention, permanent injury, or early mortality. The definition of major or minor complication is therefore not based on the specific complication but on the consequence the complication had. A prolonged hospital stay was defined as the length of hospital stay beyond the 75th percentile of length of stay per treatment group. Complications that occurred within 30 days after treatment or within initial hospital admission causing permanent injury, like permanent dialysis after kidney failure, were marked as complications <30 days causing permanent injury. Patients who underwent a reoperation or reintervention within 30 days after initial treatment or within hospital admission were marked as reoperation or reintervention <30 days. Unplanned readmissions were admissions within 30 days after discharge of the initial admission that did not involve a planned admission.

Statistical analysis. Categorical variables were described by frequency distribution and compared across patient groups treated with OSR or cEVAR. Continuous variables were tested for normality and linearity by one-sample Kolmogorov-Smirnov testing and then compared across treatment groups using one-way analysis of variance. This was done for preoperative variables as well as intraoperative variables and outcomes. Adjusted odds ratios were estimated by a multivariable logistic regression model adjusting for age, sex, cardiac status, result of last ECG, pulmonary status, preoperative hemoglobin level, preoperative creatinine level, and largest diameter of the aneurysm (Appendix, online only). If variables contained missing data, this is acknowledged in the Tables. All *P*-values are two-tailed, with values <.05

Table I. Preoperative characteristics of elective primary JRAAA repairs

	Total (N = 455)	OSR (n = 258; 57%)	cEVAR (n = 197; 43%)	*P*
Age, years	74 ± 6.2	72 ± 6.1	76 ± 6.0	**< .001**
Sex				**.047**
Male	369 (81)	201 (78)	168 (85)	
Female	86 (19)	57 (22)	29 (15)	
Year of treatment				.431
2016	163 (36)	95 (37)	68 (35)	
2017	147 (32)	77 (30)	70 (35)	
2018	145 (32)	86 (33)	59 (30)	
Cardiac status				.850
No abnormalities	151 (33)	90 (35)	61 (31)	
Antihypertensive medication	254 (56)	139 (54)	115 (58)	
Peripheral edema	33 (7)	20 (8)	13 (7)	
Raised central venous pressure	5 (1)	3 (1)	2 (1)	
Unknown	12 (3)	6 (2)	6 (3)	
Pulmonary status				.564
No dyspnea	343 (69)	181 (70)	162 (68)	
Dyspnea	123 (25)	66 (26)	57 (24)	
Severe dyspnea	23 (5)	9 (3)	14 (6)	
Unknown	6 (1)	2 (1)	4 (2)	
Last preoperative ECG				**.037**
No abnormalities	200 (44)	123 (48)	77 (39)	
Abnormalities	226 (49)	126 (49)	100 (51)	
No ECG performed/unknown ECG	29 (6)	9 (3)	20 (10)	
Hemoglobin, mmol/L	8.6 ± 0.98	8.6 ± 0.96	8.7 ± 1.01	.228
Creatinine, µmol/L	101 ± 44	101 ± 53	101 ± 28	.926
GFR, mL/min/1.73 m^2	70 ± 22	72 ± 23	68 ± 20	.139
Largest diameter aneurysm when treated, mm	60 [11]	60 [12]	61 [10]	.877

cEVAR, Complex endovascular aneurysm repair (fenestrated EVAR or chimney EVAR); *ECG*, electrocardiogram; *GFR*, glomerular filtration rate; *IQR*, interquartile range; *JRAAA*, juxtarenal abdominal aortic aneurysm; *OSR*, open surgical repair.
Data are presented as n (%), mean ± standard deviation, or median (IQR). Boldface *P* represents statistically significant data.

considered statistically significant. All analysis were performed using STATA 14.1MP statistical software (College Station, Tex).

RESULTS

From the included 455 electively primarily treated patients with JRAAAs from 44 Dutch hospitals, 258 patients were treated with OSR and 197 with cEVAR. In the OSR group, patients were significantly younger compared with the cEVAR group (72 ± 6.1 vs 76 ± 6.0 years, respectively; $P < .001$; Table I). Female patients were more often treated with OSR compared with male patients (OSR: female vs male, 22% vs 78%; cEVAR: female vs male, 14% vs 86%; $P = .047$). No difference was seen between comorbidities or preoperative laboratory values. The number of patients treated over the years remained stable also in the distribution between the treatment groups and sex.

During OSR, a tube prosthesis was used in 139 of 258 cases (54%), and in 45% of cases, a bifurcated prosthesis was used (Table II). In 55% of cases, the aortic clamp was placed above both renal arteries, and in 37% above one of the renal arteries. For cEVAR, fenestrated grafts were mostly used (125/197; 69%); the remaining cEVAR cases were treated with chimney EVAR. Almost 90% of procedures involved two or three target vessels.

OSR showed similar intraoperative complications compared with cEVAR (7% vs 8%; $P = .088$), which was mainly due to the occurrence of a type I endoleak in 5 patients (3%) in the cEVAR group. Blood loss was significantly different in favor of cEVAR, in which most patients had blood loss between 101 and 500 mL compared with mostly more than 1000 mL in the OSR group ($P < .001$).

Postoperative characteristics are described in Table III. Almost one-half of the OSR-treated patients had some

Table II. Intraoperative characteristics of elective primary JRAAA repairs

	Total (N = 455)	OSR (n = 258; 57%)	cEVAR (n = 197; 43%)	*P*
Intraoperative characteristics, OSR	NA		NA	NA
Type of prosthesis[a]				
Tube prosthesis		139 (54)		
Bifurcation prosthesis		117 (45)		
Unknown		2 (1)		
Clamping above renal arteries[a]				
Above 1 renal artery		95 (37)		
Above 2 renal arteries		143 (55)		
Unknown		20 (8)		
Intraoperative characteristics, cEVAR	NA	NA		NA
Endovascular procedure[a]				
Chimney EVAR			54 (27)	
Fenestrated EVAR			143 (73)	
Amount or target vessels				
One target vessel			24 (12)	
Two target vessels			82 (42)	
Three target vessels			91 (46)	
Intraoperative complication				.088
None	421 (93)	241 (93)	180 (92)	
Cardiac arrest or resuscitation	1 (0)	1 (0)	0	
Unintended occlusion branch	5 (1)	2 (1)	3 (1)	
Type I endoleak	5 (1)	NA	5 (3)	
Type III endoleak	0	NA	0	
Iatrogenic bowel damage	3 (1)	3 (1)	NA	
Iatrogenic ureter damage	1 (0)	1 (0)	NA	
Other	19 (4)	10 (5)	9 (4)	
Blood loss, mL				**<.001**
<100	56 (13)	2 (1)	54 (27)	
101-500	106 (23)	23 (9)	83 (42)	
501-999	65 (14)	45 (17)	20 (10)	
1000 or more	200 (44)	173 (67)	27 (14)	
Unknown	28 (6)	15 (6)	13 (7)	
Peritoneal contamination	NA		NA	NA
None		234 (92)		
Minimal fluid		19 (7)		
Abscess		0		
Peritonitis, fecal contamination[a]		2 (1)		
Amount of initial procedures				.826
One procedure	406 (89)	229 (89)	177 (90)	
Two procedures	43 (10)	26 (10)	17 (9)	
More than two procedures	6 (1)	3 (1)	3 (1)	

cEVAR, Complex endovascular aneurysm repair (fenestrated EVAR or chimney EVAR); *JRAAA*, juxtarenal abdominal aortic aneurysm; *NA*, not applicable; *OSR*, open surgical repair.
Data are presented as n (%).
Boldface *P* values represent statistical significance.
[a]Missing data <5%.

type of complication within 30 days compared with one-third of the cEVAR-treated patients (no missing data). After OSR, patients more often underwent a reintervention within 30 days after initial JRAAA treatment due to a relatively high amount of re-laparotomies. Unfortunately, the database does not provide data on the reasons for

Table III. Postoperative characteristics of elective primary JRAAA repairs

	Total (N = 455)	OSR (n = 258; 57%)	cEVAR (n = 197; 43%)	*P*
Intensive care admission, days	1 [0-2]	2 [1-3]	0 [0-1]	**<.001**
Hospital admission, days	7 [4-10]	8 [6-12]	4 [3-7]	**<.001**
Patients with a complication within 30 days[a]	192 (42)	127 (49)	65 (33)	**<.001**
Category complications within 30 days[b]				
Cardiac	39 (13)	31 (15)	8 (9)	.057
Pulmonary	59 (19.)	38 (18)	21 (23)	.683
Renal	35 (11)	30 (14)	5 (5)	**.010**
Neurologic	39 (13)	24 (11)	15 (16)	.382
Abdominal	30 (10)	26 (12)	4 (4)	**.004**
Arterial occlusion	22 (7)	16 (8)	6 (7)	.659
Reconstruction/prosthesis-related	10 (3)	5 (2)	5 (5)	.127
Wound	15 (5)	12 (6)	3 (3)	.277
Postoperative bleeding	9 (3)	5 (2)	4 (4)	.492
Infection (non-surgical)	14 (4)	9 (4)	5 (5)	.879
Other	36 (12)	18 (8)	18 (19)	**.023**
Patients with a reintervention or reoperation within 30 days[a]	50 (11)	34 (13)	16 (8)	**.188**
Category reoperation or reintervention within 30 days[a]				
Endovascular procedure	6 (12)	1 (3)	5 (31)	**.046**
Percutaneous procedure	2 (4)	1 (3)	1 (6)	.848
Endoscopic procedure	2 (4)	1 (3)	1 (6)	.848
Reoperation open procedure	27 (55)	22 (67)	5 (31)	**.007**
Opening wound only	2 (7)	1 (5)	1 (20)	.848
Re-laparotomy	15 (56)	15 (68)	0	
Other open procedure	10 (37)	6 (27)	4 (80)	.832
Other procedure	12 (25)	8 (24)	4 (26)	.480

cEVAR, Complex endovascular aneurysm repair (fenestrated EVAR or chimney EVAR); *IQR*, Interquartile range; *JRAAA*, juxtarenal abdominal aortic aneurysm; OSR, open surgical repair.
Data are presented as n (%) or median (IQR). Boldface *P* values represent statistical significance.
[a]No missing data.
[b]Missing data 50%-60%.

these re-laparotomies. More abdominal and renal complications occurred after OSR compared with after cEVAR, but for the different categories of complications, more than one-half of the data was missing. After treatment with cEVAR, patients had a significantly shorter intensive care unit stay and hospital stay compared with OSR (both $P < .001$).

Looking at the outcomes within 30 days, patients treated with OSR had significantly more complications, both major and minor, as well as a higher risk of early mortality (Table IV). The number of targeted vessels were not associated with the occurrence of major or minor complications ($P = .542$ and $P = .648$, respectively). Also, it was not associated with early mortality ($P = .569$). After adjustment for age, sex, cardiac status, result of the last ECG, pulmonary status, preoperative hemoglobin level, preoperative creatinine level, and largest diameter aneurysm, the odds ratios for major complications within 30 days after treatment were 3.64 (95% confidence interval [CI], 2.25-5.89) higher when treated with OSR. For minor complications, the odds ratios were 2.17 (95% CI, 1.34-3.53) higher after treatment with OSR relative to cEVAR, and for early mortality, the odds ratios were higher with 3.79 (95% CI, 1.26-11.34).

DISCUSSION

This study provides data on real-life daily practice in The Netherlands treating JRAAAs. More major and minor complications occurred after OSR compared with cEVAR, as well as a significantly higher 30-day mortality. After adjustment for confounders, the odds ratios for major complications as well as early mortality were over 3.5-fold higher after OSR compared with cEVAR, and minor complications showed a 2-fold higher odds ratio. The generalizability of this study is influenced by patient selection based on the available data (ie, type of treatment), and the number of patients included, which should be taken into account when interpreting this study.

Table IV. Adjusted early outcomes after primary elective JRAAA repair

	Total (N = 455)	OSR (n = 258; 57%)	cEVAR (n = 197; 43%)	OR[a]	95% CI
Major complications <30 days	157 (34.5)	116 (45.0)	41 (20.8)	**3.64**	**2.25-5.89**
Minor complications <30 days	132 (29.0)	87 (33.7)	45 (22.8)	**2.17**	**1.34-3.53**
Complications <30 days causing permanent injury	34 (7.5)	21 (8.1)	13 (6.6)	1.05	0.91-1.22
Reoperation or reintervention <30 days	50 (10.9)	34 (13.2)	16 (8.1)	1.69	0.85-3.40
Unplanned readmission <30 days after discharge	34 (7.5)	14 (5.4)	20 (10.2)	0.55	0.25-1.20
Early mortality	22 (4.8)	17 (6.6)	5 (2.5)	**3.79**	**1.26-11.34**

cEVAR, Complex endovascular aneurysm repair (fenestrated EVAR or chimney EVAR); *CI,* confidence interval; *JRAAA,* juxtarenal abdominal aortic aneurysm; *OR,* odds ratio; *OSR,* open surgical repair.
Data are presented as n (%).
ORs are given for OSR compared with EVAR.
Boldface values represent statistical significance.
[a]Logistic regression is performed for each outcome measure, adjusting for age, sex, cardiac status, result of last electrocardiogram, pulmonary status, preoperative hemoglobin level, preoperative creatinine level, largest diameter aneurysm, hospital operation volume for juxtarenal aneurysms, and year of operation.

A recent meta-analysis discussing the trials for elective infrarenal abdominal aneurysm treatment showed significantly lower early mortality for patients treated with cEVAR.[12] For more complex aortic aneurysms, such as JRAAAs, two high-quality meta-analyses have been published, both showing no significant differences in early mortality between OSR and FEVAR.[13,14] OSR did show a higher number of postoperative complications compared with FEVAR in both studies. These results were also taken into account by the European Society of Vascular Surgery guideline, which recommends that the preferred treatment option for JRAAAs is an endovascular solution with fenestrated endografts when feasible because the mortality is equal but the morbidity is less.[10] Within this guideline, the use of CHEVAR is only recommended in the acute setting or as an endovascular bailout option and is ideally restricted to a maximum of two chimneys. This is due to the advantage of CHEVAR not being a custom-made device, and therefore, it can be used in an emergency setting. The disadvantage is that postoperative type Ia endoleaks and chimney graft occlusion occur more often compared with FEVAR.[10,15,16] Our registry did include patients treated with CHEVAR in the elective setting between 2016 and 2018, which was before the newest guideline publication.

The lack of significant difference in mortality in the meta-analyses of Roa et al and Jones et al was possibly caused by including patients in the endovascular group with more comorbidities.[13,14] In accordance with the previously published literature, in this study, major complications occurred more often in patients treated with OSR compared with cEVAR, especially renal and abdominal complications. This is probably also the explanation for more reinterventions within 30 days after treatment with OSR and could very well have affected the short-term mortality. Although suprarenal clamping in the OSR group does skew the chances of postoperative renal impairment, previous studies found no effect on the occurrence of permanent dialysis and mortality, and this is therefore probably not a complete explanation for the mortality difference in this study.[17-19] In patients treated for infrarenal aneurysms, it is known that a short neck is associated with higher mortality in patients treated with OSR, whereas EVAR is not possible in this group.[20,21] The generally broader range of anatomical characteristics that are accepted for OSR compared with cEVAR could therefore also be a factor contributing to a higher mortality after OSR in this study.

In this registry, the choice of treatment modality was left to the surgeons' discretion. Therefore, some patients may have undergone OSR because cEVAR was not available in that hospital, whereas other patients may have been offered an endovascular solution only in a hospital with an "endovascular-first" strategy for JRAAA. Even when both treatments are equally enrolled in the concerning hospital and the patient's anatomy is suited for both, it can be difficult to decide which patient to offer which treatment. A methodically well-developed preoperative risk model specifically made for JRAAAs could be of value to give more preoperative guidance. A recent study of the Vascular Quality Initiative data did show that acute kidney injury after JRAAA treatment with OSR was associated with increased comorbidities preoperatively and also was associated with worse short- and long-term mortality.[16] Further risk stratification of preoperative comorbidities and also information on the impact of the different treatment modalities on quality of life could aid in the decision-making process.[10] Unfortunately, no randomized controlled trial has been performed comparing treatment outcomes of OSR vs cEVAR for JRAAA, although that would be the best way to truly compare these treatment modalities.[6] Because the choice of a surgical approach is multifactorial, a randomized trial would be the most appropriate method that corrects by default for confounding by indication.[10]

Limitations. This study must be interpreted in the context of its design. Patient selection was done on operation technique only, as there was no information on anatomical configurations, inevitably causing selection bias. Some pararenal or suprarenal AAAs may have been included in the endovascular group and treated with three-fenestrated EVAR. Also, in the OSR group, selection bias could also be present; patients with anatomically true JRAAAs could have been treated using an infrarenal clamp anyway and were therefore excluded from analysis in this study. Also, the local availability of cEVAR and the preference of the surgeon or patient is an influence on the decision of whether to treat the JRAAA endovascularly or openly, which were unknown parameters in this study.

The retrospective analysis of prospectively collected data was done using data from the DSAA registry. As with all registries, it depends on the registering physician reporting on perioperative characteristics, which may lead to errors in interpretation of the data before reporting, errors during data input, or missing data. The DSAA is a prospective quality registry system and provides us with crucial variables to include patients with JRAAAs as adequately as possible (ie, suprarenal clamping during OSR or the usage of branch inclusion in the reconstruction during cEVAR). Despite this, the registry did not provide us the anatomical configurations of the infrarenal neck lengths or aneurysm involvement of the renal arteries or extension above the renal arteries.

CONCLUSIONS

This study provides the data on current practice of the treatment of JRAAAs in The Netherlands. In this study, after primary elective OSR for JRAAAs, the odds for major complications, minor complications, and short-term mortality were all significantly higher compared with cEVAR. Though this study reflects daily practice in The Netherlands, selection bias and number of included patients should be taken into account when interpreting the generalizability of this study. For future research, development of a preoperative risk model would be a valuable tool to preoperatively identify patients most likely to survive treatment, preferably in a prospective cohort including anatomical configurations to prevent the issue of selection bias.

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AUTHOR CONTRIBUTIONS

Conception and design: GvM, MvdL
Analysis and interpretation: GvM, AA, RB, AV, HV, JB, CZ, MvdL
Data collection: GvM, MvdL
Writing the article: GvM
Critical revision of the article: GvM, AA, RB, AV, HV, JB, CZ, MvdL
Final approval of the article: GvM, AA, RB, AV, HV, JB, CZ, MvdL
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APPENDIX (online only).

Multivariable logistic regression models

. xi: logistic endoopen majorcompl ageator male i.cardstatusmin i.ecg i.pulmstatus i.hemoglobcat i.kreatcat grootte		
i.cardstatusmin	_Icardstatu_0-9	(naturally coded; _Icardstatu_0 omitted)
i.ecg	_Iecg_0-8	(naturally coded; _Iecg_0 omitted)
i.pulmstatus	_Ipulmstatu_0-9	(naturally coded; _Ipulmstatu_0 omitted)
i.hemoglobcat	_Ihemoglobc_0-3	(naturally coded; _Ihemoglobc_0 omitted)
i.kreatcat	_Ikreatcat_0-3	(naturally coded; _Ikreatcat_0 omitted)
Logistic regression		Number of obs = 455
		LR chi2(22) = 96.80
		Prob > chi2 = 0.0000
Log likelihood = -260.91068		Pseudo R2 = 0.1565

endoopen	| Odds Ratio	Std. Err.	z	P>|z|	[95% Conf. Interval]	
majorcompl	| 3.641186	.8943204	5.26	0.000	2.249973	5.892621
ageator	| .8883364	.0175991	-5.98	0.000	.8545039	.9235085
male	| .7226028	.2302597	-1.02	0.308	.3869559	1.349391
_Icardstatu_1	| .8170827	.1964234	-0.84	0.401	.5100826	1.308855
_Icardstatu_2	| 1.535505	.7433239	0.89	0.376	.5945558	3.965611
_Icardstatu_3	| .4224013	.4481665	-0.81	0.417	.0527962	3.379462
_Icardstatu_9	| .7608761	.547285	-0.38	0.704	.1858059	3.115792
_Iecg_1	| .9484098	.4347671	-0.12	0.908	.386181	2.32917
_Iecg_2	| 1.115657	.8835632	0.14	0.890	.2362696	5.268099
_Iecg_3	| .9656626	.2346351	-0.14	0.886	.5997937	1.554708
_Iecg_8	|.207166	.1049377	-3.11	0.002	.076763	.5590947
_Ipulmstatu_1	| .9470894	.2477298	-0.21	0.835	.5672082	1.581392
_Ipulmstatu_2	| .1738991	.1089222	-2.79	0.005	.0509501	.5935395
_Ipulmstatu_3	| .2576226	.2457369	-1.42	0.155	.039724	1.670761
_Ipulmstatu_9	| .1388367	.1760535	-1.56	0.119	.0115645	1.666788
_Ihemoglobc_1	| 1.097569	.3966203	0.26	0.797	.5405545	2.228559
_Ihemoglobc_2	|.979814	.3364868	-0.06	0.953	.4998329	1.920713
_Ihemoglobc_3	| .8517246	.3247137	-0.42	0.674	.4034455	1.798099
_Ikreatcat_1	| .7950516	.2384837	-0.76	0.445	.4416405	1.431271
_Ikreatcat_2	| .7676545	.2660378	-0.76	0.445	.389201	1.514111
_Ikreatcat_3	| .7371258	.2578407	-0.87	0.383	.3713626	1.463137
grootte	| 1.004155	.0114435	0.36	0.716	.9819743	1.026836
_cons	| 9366.122	15239.91	5.62	0.000	385.9608	227288

. xi: logistic endoopen minorcompl ageator male i.cardstatusmin i.ecg i.pulmstatus i.hemoglobcat i.kreatcat grootte		
i.cardstatusmin	_Icardstatu_0-9	(naturally coded; _Icardstatu_0 omitted)
i.ecg	_Iecg_0-8	(naturally coded; _Iecg_0 omitted)
i.pulmstatus	_Ipulmstatu_0-9	(naturally coded; _Ipulmstatu_0 omitted)
i.hemoglobcat	_Ihemoglobc_0-3	(naturally coded; _Ihemoglobc_0 omitted)
i.kreatcat	_Ikreatcat_0-3	(naturally coded; _Ikreatcat_0 omitted)
Logistic regression		Number of obs = 455
		LR chi2(22) = 76.73
		Prob > chi2 = 0.0000
Log likelihood = -270.94449		Pseudo R2 = 0.1240

endoopen	| Odds Ratio	Std. Err.	z	P>|z|	[95% Conf. Interval]	
minorcompl	| 2.169524	.5374109	3.13	0.002	1.335101	3.525452

Continued.

endoopen	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ageator	.8863207	.0173836	-6.15	0.000	.8528959	.9210553
male	.5911382	.1847757	-1.68	0.093	.3203492	1.090823
_Icardstatu_1	.9162101	.2148386	-0.37	0.709	.5786288	1.450742
_Icardstatu_2	1.779587	.8246238	1.24	0.214	.7176128	4.413147
_Icardstatu_3	.4861941	.4959112	-0.71	0.480	.0658561	3.589413
_Icardstatu_9	.7734878	.5384951	-0.37	0.712	.1976309	3.027277
_Iecg_1	.6826934	.3163421	-0.82	0.410	.2752969	1.692973
_Iecg_2	1.428157	1.034938	0.49	0.623	.3450949	5.910352
_Iecg_3	1.027079	.2424808	0.11	0.910	.6466148	1.631406
_Iecg_8	.2300025	.1147045	-2.95	0.003	.0865426	.6112729
_Ipulmstatu_1	.9210451	.2351573	-0.32	0.747	.5584133	1.519169
_Ipulmstatu_2	.225839	.1370198	-2.45	0.014	.0687642	.7417122
_Ipulmstatu_3	.3273647	.3210724	-1.14	0.255	.0478841	2.238063
_Ipulmstatu_9	.2521578	.3264725	-1.06	0.287	.0199347	3.189598
_Ihemoglobc_1	1.109834	.3889446	0.30	0.766	.5584084	2.20579
_Ihemoglobc_2	.9737246	.3247472	-0.08	0.936	.5064676	1.872064
_Ihemoglobc_3	.7239647	.2659202	-0.88	0.379	.352421	1.487213
_Ikreatcat_1	.7432266	.2196696	-1.00	0.315	.4164265	1.32649
_Ikreatcat_2	.7920207	.2693389	-0.69	0.493	.4066982	1.542413
_Ikreatcat_3	.7921296	.2697445	-0.68	0.494	.4063834	1.544033
grootte	1.00868	.01115	0.78	0.434	.987061	1.030772
_cons	11193.69	18058.21	5.78	0.000	473.9942	264346.5

. xi: logistic endoopen complblijv ageator male i.cardstatusmin i.ecg i.pulmstatus i.hemoglobcat i.kreatcat grootte		
i.cardstatusmin	_Icardstatu_0-9	(naturally coded; _Icardstatu_0 omitted)
i.ecg	_Iecg_0-8	(naturally coded; _Iecg_0 omitted)
i.pulmstatus	_Ipulmstatu_0-9	(naturally coded; _Ipulmstatu_0 omitted)
i.hemoglobcat	_Ihemoglobc_0-3	(naturally coded; _Ihemoglobc_0 omitted)
i.kreatcat	_Ikreatcat_0-3	(naturally coded; _Ikreatcat_0 omitted)
Logistic regression		Number of obs = 455
		LR chi2(22) = 27.61
		Prob > chi2 = 0.1890
Log likelihood = -107.17722		Pseudo R2 = 0.1141

endoopen	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
complblijv	1.051714	.0783872	0.68	0.499	.9087723	1.217138
ageator	.9002652	.0306111	-3.09	0.002	.842224	.9623062
male	.7706204	.407625	-0.49	0.622	.2732697	2.173149
_Icardstatu_1	1.186324	.4649935	0.44	0.663	.5502564	2.557653
_Icardstatu_2	1.12853	.8256197	0.17	0.869	.2690195	4.734155
_Icardstatu_3	.2838533	.4468327	-0.80	0.424	.0129766	6.209091
_Icardstatu_9	.5043751	.5845588	-0.59	0.555	.0520273	4.889631
_Iecg_1	1.127867	.7162273	0.19	0.850	.3248782	3.915569
_Iecg_2	.3888508	.5995835	-0.61	0.540	.0189358	7.985136
_Iecg_3	1.001733	.3969714	0.00	0.997	.4607163	2.178061
_Iecg_8	.2330793	.1897691	-1.79	0.074	.0472574	1.149574
_Ipulmstatu_1	.6402692	.256047	-1.11	0.265	.2923901	1.402047
_Ipulmstatu_2	.196525	.1912731	-1.67	0.095	.0291718	1.323951
_Ipulmstatu_3	.2448793	.2487292	-1.39	0.166	.0334479	1.792817
_Ipulmstatu_9	.1969443	.3069328	-1.04	0.297	.0092847	4.177531

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endoopen	**Odds Ratio**	**Std. Err.**	**z**	**P>|z|**	**[95% Conf. Interval]**	
_Ihemoglobc_1	.82696	.4907033	-0.32	0.749	.258462	2.645893
_Ihemoglobc_2	.627209	.3680499	-0.79	0.427	.198574	1.981081
_Ihemoglobc_3	.6537808	.4006731	-0.69	0.488	.1966838	2.17318
_Ikreatcat_1	.4969596	.2657687	-1.31	0.191	.1742238	1.417538
_Ikreatcat_2	.4804428	.2841425	-1.24	0.215	.1507391	1.531291
_Ikreatcat_3	.5866442	.3573257	-0.88	0.381	.1777898	1.935721
grootte	1.017035	.0182615	0.94	0.347	.9818655	1.053464
_cons	6275.742	16600.79	3.31	0.001	35.15928	1120186
. xi: logistic endoopen reintreq ageator male i.cardstatusmin i.ecg i.pulmstatus i.hemoglobcat i.kreatcat grootte						
i.cardstatusmin		_Icardstatu_0-9			(naturally coded; _Icardstatu_0 omitted)	
i.ecg		_Iecg_0-8			(naturally coded; _Iecg_0 omitted)	
i.pulmstatus		_Ipulmstatu_0-9			(naturally coded; _Ipulmstatu_0 omitted)	
i.hemoglobcat		_Ihemoglobc_0-3			(naturally coded; _Ihemoglobc_0 omitted)	
i.kreatcat		_Ikreatcat_0-3			(naturally coded; _Ikreatcat_0 omitted)	
Logistic regression					Number of obs = 455	
					LR chi2(22) = 68.83	
					Prob > chi2 = 0.0000	
Log likelihood = -274.89507					Pseudo R2 = 0.1113	
endoopen	**Odds Ratio**	**Std. Err.**	**z**	**P>|z|**	**[95% Conf. Interval]**	
reintreq	1.695376	.602132	1.49	0.137	.8451856	3.400791
ageator	.891834	.0171558	-5.95	0.000	.8588352	.9261007
male	.6246516	.1935032	-1.52	0.129	.3403725	1.14636
_Icardstatu_1	.8629548	.2002938	-0.64	0.525	.547548	1.360047
_Icardstatu_2	1.528272	.7082175	0.92	0.360	.6162328	3.790151
_Icardstatu_3	.4466689	.46989	-0.77	0.444	.0568241	3.511065
_Icardstatu_9	.7639132	.5295782	-0.39	0.698	.1963151	2.972585
_Iecg_1	.9703445	.4361442	-0.07	0.947	.4020993	2.341631
_Iecg_2	1.417968	1.005487	0.49	0.622	.3532452	5.691895
_Iecg_3	1.053423	.2463643	0.22	0.824	.666089	1.665995
_Iecg_8	.2258842	.1119226	-3.00	0.003	.0855317	.596547
_Ipulmstatu_1	1.00689	.2536009	0.03	0.978	.614602	1.649569
_Ipulmstatu_2	.2101519	.1276372	-2.57	0.010	.0639073	.691061
_Ipulmstatu_3	.4989789	.4824188	-0.72	0.472	.0750119	3.319205
_Ipulmstatu_9	.2478409	.3024975	-1.14	0.253	.0226597	2.71076
_Ihemoglobc_1	1.024163	.3544937	0.07	0.945	.5196876	2.018346
_Ihemoglobc_2	.8918041	.293653	-0.35	0.728	.4677201	1.700407
_Ihemoglobc_3	.760628	.2755247	-0.76	0.450	.3739718	1.547055
_Ikreatcat_1	.7806022	.2276287	-0.85	0.396	.4407719	1.382438
_Ikreatcat_2	.8002972	.2685865	-0.66	0.507	.4145537	1.544976
_Ikreatcat_3	.7933079	.2681712	-0.68	0.493	.4089782	1.538804
grootte	1.00849	.0110601	0.77	0.441	.9870442	1.030402
_cons	8174.311	13013.29	5.66	0.000	360.8777	185157.9
. xi: logistic endoopen heropn ageator male i.cardstatusmin i.ecg i.pulmstatus i.hemoglobcat i.kreatcat grootte						
i.cardstatusmin		_Icardstatu_0-9			(naturally coded; _Icardstatu_0 omitted)	
i.ecg		_Iecg_0-8			(naturally coded; _Iecg_0 omitted)	
i.pulmstatus		_Ipulmstatu_0-9			(naturally coded; _Ipulmstatu_0 omitted)	
i.hemoglobcat		_Ihemoglobc_0-3			(naturally coded; _Ihemoglobc_0 omitted)	
i.kreatcat		_Ikreatcat_0-3			(naturally coded; _Ikreatcat_0 omitted)	

Continued.

Logistic regression		Number of obs = 455				
					LR chi2(22) = 68.81	
					Prob > chi2 = 0.0000	
Log likelihood = -274.90347					Pseudo R2 = 0.1112	
Endoopen	**Odds Ratio**	**Std. Err.**	**z**	**P>|z|**	**[95% Conf. Interval]**	
heropn	.551331	.2194226	-1.50	0.135	.2527232	1.202762
ageator	.8913329	.0171784	-5.97	0.000	.8582919	.9256459
male	.5941919	.1837758	-1.68	0.092	.3240867	1.089412
_Icardstatu_1	.8742488	.2024585	-0.58	0.562	.5552823	1.376437
_Icardstatu_2	1.611345	.7458137	1.03	0.303	.6504422	3.991798
_Icardstatu_3	.4468962	.4645215	-0.77	0.438	.0582685	3.427513
_Icardstatu_9	.724285	.5010304	-0.47	0.641	.1866739	2.810189
_Iecg_1	.9479187	.4253882	-0.12	0.905	.3933559	2.284318
_Iecg_2	1.305299	.9265465	0.38	0.707	.3247112	5.247138
_Iecg_3	1.066418	.248761	0.28	0.783	.6751026	1.684556
_Iecg_8	.236585	.1168564	-2.92	0.004	.0898573	.6229041
_Ipulmstatu_1	1.021881	.2572782	0.09	0.931	.6238697	1.673812
_Ipulmstatu_2	.2173814	.1308586	-2.54	0.011	.0668065	.7073368
_Ipulmstatu_3	.6594557	.6522582	-0.42	0.674	.0949018	4.582441
_Ipulmstatu_9	.3156129	.3767729	-0.97	0.334	.0304092	3.275697
_Ihemoglobc_1	1.028985	.3567996	0.08	0.934	.5215015	2.03031
_Ihemoglobc_2	.9042325	.2981827	-0.31	0.760	.4737891	1.725739
_Ihemoglobc_3	.7597894	.2753991	-0.76	0.449	.3733878	1.54606
_Ikreatcat_1	.798335	.2333846	-0.77	0.441	.4501379	1.415874
_Ikreatcat_2	.8276377	.2778814	-0.56	0.573	.4285951	1.598208
_Ikreatcat_3	.8227582	.2772482	-0.58	0.563	.4250494	1.592594
grootte	1.008215	.0110244	0.75	0.454	.9868379	1.030056
_cons	9479.522	15118.31	5.74	0.000	416.1571	215931.3
. xi: logistic endoopen earlymort ageator male i.cardstatusmin i.ecg i.pulmstatus i.hemoglobcat i.kreatcat grootte						
i.cardstatusmin		_Icardstatu_0-9			(naturally coded; _Icardstatu_0 omitted)	
i.ecg		_Iecg_0-8			(naturally coded; _Iecg_0 omitted)	
i.pulmstatus		_Ipulmstatu_0-9			(naturally coded; _Ipulmstatu_0 omitted)	
i.hemoglobcat		_Ihemoglobc_0-3			(naturally coded; _Ihemoglobc_0 omitted)	
i.kreatcat		_Ikreatcat_0-3			(naturally coded; _Ikreatcat_0 omitted)	
Logistic regression		Number of obs = 455				
					LR chi2(22) = 72.96	
					Prob > chi2 = 0.0000	
Log likelihood = -272.83081					Pseudo R2 = 0.1179	
endoopen	**Odds Ratio**	**Std. Err.**	**z**	**P>|z|**	**[95% Conf. Interval]**	
earlymort	3.7875	2.120679	2.38	0.017	1.264015	11.34889
ageator	.8850035	.0173816	-6.22	0.000	.8515835	.9197351
male	.6234365	.1948491	-1.51	0.131	.337876	1.150342
_Icardstatu_1	.862146	.2003365	-0.64	0.523	.5467484	1.359484
_Icardstatu_2	1.449124	.6758126	0.80	0.426	.5809512	3.614693
_Icardstatu_3	.4718231	.4906538	-0.72	0.470	.0614618	3.622036
_Icardstatu_9	.7009695	.4922497	-0.51	0.613	.1769906	2.776183
_Iecg_1	1.022767	.4618081	0.05	0.960	.4221191	2.478096
_Iecg_2	1.426559	1.018126	0.50	0.619	.3522028	5.778125
_Iecg_3	1.027584	.241416	0.12	0.908	.6483952	1.628527

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endoopen	| Odds Ratio	Std. Err.	z	P>|z|	[95% Conf. Interval]	
_Iecg_8	| .2351457	.117065	-2.91	0.004	.0886288	.6238776
_Ipulmstatu_1	| .9769998	.2475747	-0.09	0.927	.5945625	1.60543
_Ipulmstatu_2	| .2273385	.1374655	-2.45	0.014	.0694983	.7436552
_Ipulmstatu_3	| .4268219	.4223066	-0.86	0.390	.0613832	2.967861
_Ipulmstatu_9	| .2937846	.359405	-1.00	0.317	.0267117	3.231148
_Ihemoglobc_1	| 1.008073	.3486721	0.02	0.981	.5117741	1.985662
_Ihemoglobc_2	| .8494004	.2809146	-0.49	0.622	.4442241	1.624137
_Ihemoglobc_3	| .7398456	.2679907	-0.83	0.405	.3637596	1.504762
_Ikreatcat_1	| .7953038	.2332086	-0.78	0.435	.4476447	1.412969
_Ikreatcat_2	| .7750174	.2619107	-0.75	0.451	.3996271	1.503031
_Ikreatcat_3	| .7817854	.2648363	-0.73	0.467	.4024722	1.518585
grootte	| 1.008043	.0111062	0.73	0.467	.986509	1.030048
_cons	| 15539.25	25321.76	5.92	0.000	637.3338	378872.6