The effect of suprarenal graft fixation during endovascular aneurysm repair on short- and long-term renal function

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ABSTRACT

Objective: The effect of suprarenal fixation (SR) compared with infrarenal fixation (IR) on renal function during endovascular aneurysm repair (EVAR) remains controversial. This study aims to compare the renal outcomes between fixation types in short- and long-term follow-up.

Methods: Patients undergoing EVAR for infrarenal abdominal aortic aneurysm between 2005 and 2013 were included. The estimated glomerular filtration rate (eGFR) was measured at baseline and during a follow-up of 5 years. A decline in renal function was defined as a 20% or greater decrease in the eGFR. Changes in the eGFR were compared between SR and IR groups at 1 to 7 days, 30 days, and 1 to 5 years postoperatively. Preoperative renal insufficiency was defined as an eGFR of less than 60 mL/min/1.73 m^2, and those patients were included in the subanalyses.

Results: A total of 358 patients were included. Among these, 267 (74.6%) had SR and 91 (25.4%) had IR fixation. A decrease in renal function occurred more commonly after SR than after IR in 1 to 7 days postoperatively ($P = .009$), but no difference was noticed at 30 days and 1 to 5 years. Regardless of the fixation method, renal function steadily decreased steadily over time after EVAR (estimate −3.13 per a year; 95% confidence interval, −3.40 to −2.85; $P < .001$). Patients with preexisting renal insufficiency were included in subgroup analyses, and those with SR were more often found to have a decline in eGFR 5 years postoperatively than their counterparts with IR (59.5% vs 20.0%; $P = .036$).

Conclusions: An immediate postoperative decrease in renal function was seen more often after SR fixation than IR fixation but this difference was transient. SR fixation is a safe method for patients with normal renal function. Long-term results seems to favor IR over SR in patients with preexisting renal insufficiency. (J Vasc Surg 2022;76:96-103.)

Keywords: Abdominal aortic aneurysm; Endovascular aortic repair; Renal function; Suprarenal graft fixation

Endovascular aneurysm repair (EVAR) has become a standard method in the treatment of abdominal aortic aneurysms (AAA) and has demonstrated superior short-term results compared with open surgical treatment.[1-3] However, the long-term results have suggested higher reintervention rates, higher aneurysm-related mortality,[2,3] and a more pronounced decrease in renal function compared with open surgery.[4,5]

The proximal neck morphology is crucial for a stable proximal sealing of the stent graft. Suprarenal fixation (SR) endografts have been developed for preventing stent migration and endoleaks when treating aneurysms with more complex proximal necks. In SR grafts the stent crosses the renal artery ostia, which has led to the assumption that it may have a negative impact on renal function. Moreover, possible reintervention rates and repetitive contrast-enchased computed tomography (CT) scans can also cause adverse effects.[6] Patients with an AAA often have comorbidities and preexisting renal insufficiency, which makes them vulnerable to a further decreases in renal function.[7]

Patients undergoing EVAR may generally have a decrease in renal function over the long term.[4,5,7,8] The effect of the type of stent graft fixation after EVAR on renal function remains uncertain, as reviews of recent research show conflicting results. Some studies have suggested poorer renal function after SR,[9-11] but the majority have demonstrated no differences between the fixation methods, at least in the short term.[6-8,12-14] Thus far, few studies have reported long-term results. The most recent meta-analysis showed poorer renal outcomes after SR in long-term follow-up.[15,16] In addition, it remains uncertain

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whether the possible decline in renal function is more relevant to patients with preexisting renal insufficiency.

The aim of this study was to evaluate the impact of SR compared with infrarenal fixation (IR) on renal function in short- and long-term follow-up.

METHODS

Patients undergoing EVAR for an infrarenal AAA between January 2005 and December 2013 at a single academic institution were identified from a prospectively maintained database and evaluated retrospectively. Patients with end-stage renal disease receiving dialysis therapy at baseline or those with an isolated iliac aneurysm were excluded. Ruptured aneurysm cases were also excluded, but otherwise urgently managed patients with symptomatic or massive aneurysms were included.

Patients were eligible for EVAR if they had an AAA diameter of greater than 5.5 cm (male) or greater than 5.0 cm (female) or an AAA with a rapidly increasing sac (>1 cm per year or >5 mm over a 6-month period). Any symptomatic infrarenal AAA was also eligible. Iopromide was used as the contrast medium, and patients were treated under spinal, local, or general anesthesia.

Baseline demographic data were recorded, including sex, age, and smoking history. Comorbidities were recorded. Diabetes, hypertension, and dyslipidemia were identified when a patient was undergoing active medical treatment or diet modification. Cerebrovascular disease was defined as a history of stroke, transient ischemic attack, or cerebral hemorrhage. Coronary artery disease was identified as a history of myocardial infarction, an abnormal finding in coronary angiography, or angina pectoris symptoms. A history of peripheral artery revascularization was defined as peripheral artery disease. The diagnosis of heart failure and a history of atrial fibrillation were included in the comorbidities. Obstructive pulmonary disease, a history of pulmonary cancer, or another pulmonary disease remarkably affecting pulmonary function studies was recorded. Intraoperative details included device type, operative time, and contrast medium dose. The anatomic measurements were obtained from preoperative CT angiography. The measurements included neck diameter, neck length, sagittal and coronal neck angulation, neck thrombus, neck calcification, neck conicity, and maximum sac diameter. Conical neck shape was defined as a greater than 3-mm increase in the neck diameter for each centimeter of length. Proximal neck thrombus was defined as 50% or greater circumferential thrombus and proximal neck calcification as 50% or greater circumferential calcification. High risk neck was defined as a neck diameter of greater than 30 mm, a neck length of less than 15 mm, or a neck angulation of greater than 60°.

The SR endografts used were the Zenith (Cook, Bloomington, IN) and Endurant (Medtronic, Minneapolis, MN). The Excluder (W. L. Gore & Associates, Flagstaff, AZ) endograft was the only IR device.

ARTICLE HIGHLIGHTS

- **Type of Research:** Single-center retrospective observational study of prospectively collected registry data
- **Key Findings:** Suprarenal fixation was associated more often with a decline in renal function compared with infrarenal fixation (13.7% vs 3.5%) within 7 days postoperatively in 358 patients with abdominal aortic aneurysm but this difference was transient except among those with preexisting renal insufficiency.
- **Take Home Message:** Suprarenal fixation has more often an immediate postoperative decline in renal function but is a safe method in the long term, when treating patients with normal renal function. Long-term results for patients with preexisting renal insufficiency seem to favor infrarenal fixation.

The imaging protocol for radiographic follow-up consisted of a CT scan within 30 days postoperatively, duplex ultrasound examination at 1 year, CT angiography at 2 years, and duplex ultrasound examination yearly thereafter. In addition to duplex ultrasound examination, a CT scan was obtained if there was evidence of an endoleak or sac enlargement.

All creatinine concentration measurements between January 2005 and December 2018 were collected using the local laboratory database. Preoperative creatinine was measured 0 to 7 days preoperatively. The first postoperative measurement was registered, when taken, 1 to 7 days postoperatively. The 30-day (15-40 days postoperatively), 1-year (41-395 days), 2-year (396-761 days), 3-year (762-1126 days), 4-year (1127-1481 days), and 5-year (1482-1856 days) serum creatinine measurements were also collected. The highest measured value for each patient between each time point was used. Owing to the study design, not every patient had measured or available creatinine concentration measurements for every time point. Renal function was assessed with the estimated glomerular filtration rate (eGFR), which was calculated from serum creatinine measurements by using the Chronic Kidney Disease Epidemiology Collaboration equation.

The eGFR was classified into six clinically relevant categories: more than 90 mL/min/1.73 m^2, 60 to 89 mL/min/1.73 m^2, 45 to 59 mL/min/1.73 m^2, 30 to 44 mL/min/1.73 m^2, 15 to 29 mL/min/1.73 m^2, and less than 15 mL/min/1.73 m^2.[16] Preoperative renal insufficiency was defined as an eGFR of less than 60 mL/min/1.73 m^2 at baseline, and these patients were included in the subgroup analysis. Clinically relevant postoperative renal impairment was defined as a decrease of 20% or more from the preoperative eGFR at 1 to 7 days, 30 days,

Table I. Baseline characteristics of all patients and those with preoperative renal insufficiency

	All			eGFR < 60		
	SR (n = 267)	IR (n = 91)	*P* value	SR (n = 86)	IR (n = 25)	*P* value
Age, median, years	77.8	75.5	.169	79.6	83.9	.115
Q1; Q3	72.4; 81.9	69.7; 83.2		75.0; 83.4	74.9; 85.0	
Sex, male	87.6	83.5	.204	79.1	72.0	.587
Urgency, urgent	2.2	12.1	.001	3.5	12.0	.126
Hypertension	58.4	78.0	.001	73.3	80.0	.606
Dyslipidemia	40.4	54.9	.020	44.2	64.0	.111
Coronary artery disease	50.9	44.0	.276	58.1	44.0	.256
Diabetes	15.0	22.0	.143	18.6	20.0	1.00
Cerebrovascular disease	15.0	15.4	1.00	10.5	12.0	.731
Pulmonal disease	22.5	18.7	.555	18.6	24.0	.574
Peripheral artery disease	7.5	8.8	.657	8.1	4.0	.681
Atrial fibrillation	24.7	27.5	.676	22.1	32.0	.304
Heart failure	6.4	8.8	.476	7.0	4.0	1.00
Smoking						
Current	20.6	14.3	.394	15.1	0.0	.031
Ex-smoker	25.1	28.6		30.2	16.0	
Never	10.9	15.4		12.8	24.0	
Missing data	43.4	41.8		41.9	60.0	
Contrast agent, median, mL	200	208	.839	195	190	.881
Q1; Q3	170; 250	160; 250		160; 230	106;140	
Operative time, median, hours	1.80	1.87	.253	1.91	1.83	.631
Q1; Q3	1.53; 2.40	1.54; 2.25		1.40; 2.17	1.56; 2.35	
Endograft						
Zenith	77.5			76.7		
Endurant	22.5			23.3		
Excluder		100			100	

eGFR, Estimated glomerular filtration rate; *IR*, infrarenal fixation; *SR*, suprarenal fixation.
Values are presented as percentages unless stated otherwise.

1 year, 2 years, 3 years, 4 years, or 5 years after EVAR. The need for dialysis therapy within 5 years postoperatively was obtained. The presence of a type Ia endoleak and stent graft migration within 5 years were also included.

Data analysis. Data were expressed as median and quartiles. Categorical variables were compared with the χ^2 test or Fisher's exact test. Comparisons between the two groups were performed with the Mann-Whitney *U* test for continuous variables. Binary logistic regression was applied to assess the effect of parameters that differed between the SR and IR groups. The linear mixed-effects model was used to predict changes in eGFR over time and the difference in the eGFR change between the SR and IR groups. All *P* values were two-sided, with a *P* value of less than .05 regarded as indicative of statistical significance. All statistical analyses were conducted with SPSS software version 26 (SPSS, Armonk, NY).

This study is a retrospective study of prospectively collected registry data and institutional review board approval is not required.

RESULTS

A total of 358 patients who underwent EVAR for infrarenal AAAs during the study period were included. Among these, 267 (74.6%) had SR and 91 (25.4%) had IR fixation. When baseline characteristics were compared, there were no statistical differences between the groups in the percentage of men, mean age, or the incidence of coronary disease, diabetes, cerebrovascular disease, chronic pulmonary disease, peripheral artery disease, atrial fibrillation, congestive heart failure, chronic kidney disease, or smoking. Hypertension (78.0% vs 58.4%; $P = .001$) and dyslipidemia (54.9% vs 40.4%; $P = .020$) were more common in the IR group than in the SR group. In the IR group, there were more urgent operations than in the SR group (12.1% vs 2.2%; $P = .001$). The amount of

Table II. Baseline renal function for all patients and those with preoperative renal insufficiency

	All			eGFR < 60		
	SR (n = 267)	IR (n = 91)	*P* value	SR (n = 86)	IR (n = 25)	*P* value
Creatinine, median	87.0	90.0	.920	118	120	.938
Q1; Q3	74.0; 104.0	74.0; 102.0		105; 133	106; 140	
eGFR, median	72.3	69.5	.824	48,0	45,7	.277
Q1; Q3	55.9; 84.5	57.2; 84.7		41.3; 55.7	38.0; 52.2	
Categorized eGFR, %						
≥90	12.4	16.5	.745			
60-89	55.4	56.0				
45-59	19.9	16.5		64.6	60.0	.621
20-44	8.6	9.9		26.7	36.0	
15-29	3.4	1.1		10.5	4.0	
<15	0.4	0.0		1.2	0.0	

eGFR, Estimated glomerular filtration rate; *IR*, infrarenal fixation; *SR*, suprarenal fixation.

Table III. Proportions of patients with a ≥20% decrease in eGFR at each time point

	All			eGFR < 60		
	SR	IR	*P* value	SR	IR	*P* value
1-7 days	36 (13.7)	3 (3.5)	.009	16 (18.6)	1 (4.2)	.112
30 days	14 (13.0)	8 (11.9)	1.0	8 (21.1)	1 (5,9)	.247
1 years	49 (31.6)	17 (29.3)	.868	22 (40.7)	4 (22.2)	.257
2 years	59 (36.6)	17 (32.1)	.621	29 (54.7)	5 (38.5)	.361
3 years	59 (37.3)	22 (38.6)	.875	24 (52.2)	4 (33.3)	.336
4 years	55 (47.4)	17 (45.9)	1.000	21 (58.3)	4 (44.4)	.482
5 years	58 (52.3)	15 (39.5)	.192	22 (59.5)	2 (20.0)	.036

eGFR, Estimated glomerular filtration rate; *IR*, infrarenal fixation; *SR*, suprarenal fixation.
Values are presented as number (%).

contrast medium used during stent graft deployment and the duration of the procedure did not differ significantly between the groups (Table I).

Aneurysm characteristics were compared. The median neck length was shorter and median neck angulation was greater in SR group than in IR group. Otherwise, no statistical differences between the groups were found (Supplementary Table I, online only).

The median baseline creatinine concentrations and eGFRs were similar between the SR and IR groups (Table II). The numbers of patients with measured eGFRs at each time point are listed in Supplementary Table II (online only).

Within 7 days, 36 patients (13.7%) in the SR group and 3 patients (3.5%) in the IR group had a 20% or greater decrease in the eGFR ($P = .009$; Table III). At 30 days, 1 year, 2 years, 3 years, 4 years, or 5 years, the numbers of patients with a 20% or greater decrease in eGFR did not differ significantly between the groups (Table III). After adjustment for urgency, hypertension, dyslipidemia, neck length and neck sagittal angulation, SR fixation still yielded more 20% or greater reductions in eGFR within 7 days than IR (odds ratio [OR], 4.1; 95% confidence interval [CI], 1.1-14; $P = .016$).

No significant difference in eGFR categories was noticed at baseline between groups (Table II). The eGFR category changes from baseline to 1 to 7 days, 30 days, 1 year, 2 years, 3 years, 4 years, and 5 years were calculated for each patient. Only a shift into a poorer eGFR category was recorded. Within 7 days postoperatively, more patients in the SR group had a change in their eGFR category from the baseline than in the IR group (22.4% vs 11.6%; $P = .029$) (Table IV). Otherwise, the changes in categories were similar between the groups (Table IV). The significant difference in the eGFR category changes at 7 days did not differ after adjustment for urgency, dyslipidemia, hypertension, aneurysm neck length and sagittal neck angulation (OR, 2.5; 95% CI, 1.1-5.8; $P = .037$).

A total of six patients (2.2%) in the SR group but none in the IR group needed dialysis therapy within 5 years postoperatively. This difference was not significant ($P = .344$).

Table IV. Proportions of patients with a change in eGFR category at each time point

	All			eGFR < 60		
	SR	IR	*P* value	SR	IR	*P* value
1-7 days	59 (22.4)	10 (11.6)	.029	22 (25.9)	4 (16.7)	.426
30 days	22 (20.4)	17 (25.4)	.462	11 (28.9)	3 (17.6)	.510
1 years	59 (38.1)	21 (36.2)	.874	24 (44.4)	4 (22.2)	.162
2 years	70 (43.5)	21 (39.6)	.635	30 (56.6)	5 (38.5)	.354
3 years	72 (45.6)	30 (52.6)	.439	24 (52.2)	5 (41.7)	.747
4 years	65 (56.0)	21 (56.8)	1.000	23 (63.9)	4 (44.4)	.449
5 years	72 (64.9)	23.1 (55.3)	.334	25 (67.6)	2 (20.0)	.011

eGFR, Estimated glomerular filtration rate; *IR*, infrarenal fixation; *SR*, suprarenal fixation.
Values are presented as number (%).

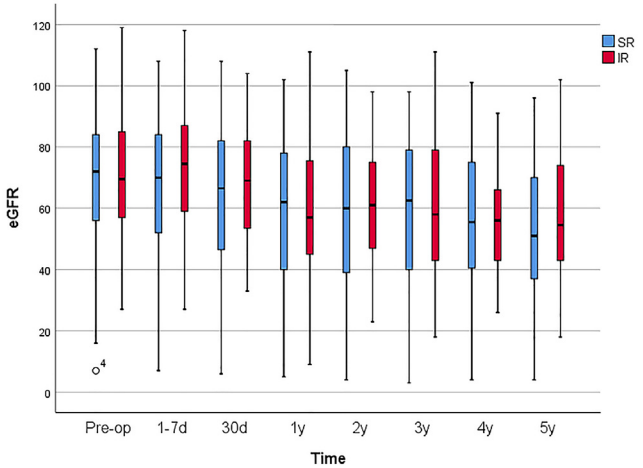

Fig 1. Box and whisker plot of fixation-specific eGFR during follow-up. Boxes represent the inter-quartile range with a median bar. *eGFR*, estimated glomerular filtration rate; *IR*, infrarenal fixation; *SR*, suprarenal fixation.

A significant deterioration in renal function was found during the follow-up in both groups. At the 5-year point, the median eGFR (mL/min/1.73 m^2) had decreased significantly from the baseline in both groups (SR 72.0 vs 51.0 [$P < .001$]; IR 69.0 vs 54.5 [$P = .001$]). Fig 1 shows the change in eGFR during follow-up. A mixed-model analysis for fixed effects demonstrated that eGFR decreases over time after EVAR (by an estimated −3.13 per a year; 95% CI, −3.40 to −2.85; $P < .001$). Fixation level, urgency, hypertension, dyslipidemia, neck length, and neck sagittal angulation were used as fixed effects, with a random intercept for subjects. No difference between SR and IR was found (estimate for SR −1.69; 95% CI, −7.03 to 3.64; $P = .533$), but hypertension was a negative predictor of eGFR change (estimate −5.77; 95% CI, −0.59 to −10.96; $P = .029$).

A total of 39 high-risk necks were found, 30 in the SR group and 9 in the IR group. A decrease in renal function among high-risk neck patients was compared between the groups and no statistical difference was found.

Type Ia endoleaks were found in 17 patients (6.4%) in the SR group and among 3 individuals (3.3%) in the IR group. This difference was not significant ($P = .427$). No proximal migration of the stent graft over the renal ostia was observed during follow-up.

Patients with preoperative renal insufficiency had a decrease in renal function more often at 2 years postoperatively than patients with no preoperative renal insufficiency (51.5% vs 28.4%; $P = .002$). At other time points, no significant difference was found.

Subanalysis. Eighty-six patients (32.2%) in the SR group and 25 patients (27.5%) in the IR group had an eGFR of less than 60 mL/min/1.73 m^2 at baseline and were included in the subanalysis. For these patients, the baseline median creatinine concentrations and eGFRs were similar in the SR and IR groups (Table II). The SR group comprised more smokers than the IR group, but there were no further statistically significant differences between the SR and IR groups in their baseline characteristics, comorbid conditions, or operation details (Table I).

The median neck length was shorter and median neck angulation was greater in the SR group than in the IR group. Otherwise, no statistically significant differences between the groups in their aneurysm characteristics were found (Supplementary Table I, online only).

At 5 years postoperatively, more patients with preoperative renal insufficiency had a 20% or greater decrease in eGFR in the SR group than the IR group (59.5% vs 20.0%; $P = .036$) (Table III). At 5 years, 25 patients (67.6%) in the SR group had a change in their GFR category for the worse, and the same applied to 2 patients (20.0%) in the IR group ($P = .011$) (Table IV). Otherwise, there were no differences between the groups (Tables III and IV). After adjustment for smoking, aneurysm neck length and neck sagittal angulation, more patients in the SR group had a 20% or

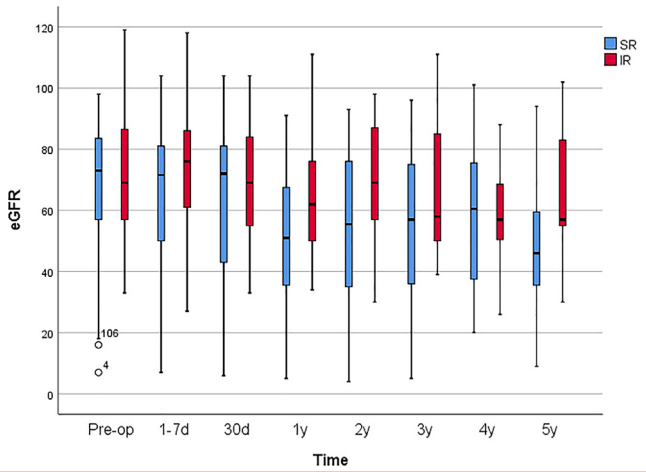

Fig 2. Box and whisker plot of fixation-specific eGFR during follow-up for patients with preoperative renal insufficiency. Boxes represent the inter-quartile range with a median bar. *eGFR*, estimated glomerular filtration rate; *IR*, infrarenal fixation; *SR*, suprarenal fixation.

greater decrease in eGFR at 5 years than in the IR group (OR, 26.4; 95% CI, 2.0-344.6; $P = .012$) and significantly more often a change in the eGFR category at 5 years than in the IR group (OR, 17.3; 95% CI, 1.5-193.5; $P = .021$). Fig 2 shows the eGFR during the follow-up for patients with preoperative renal insufficiency.

DISCUSSION

According to our study, more patients in the SR group experienced a decline in renal function within 7 days postoperatively than in the IR group. However, this difference was transient. The eGFR decreased over time in this study population regardless of the graft fixation method. After 5 years of follow-up, patients with preexisting renal insufficiency who were treated with SR fixation more often had a decrease in renal function.

A deterioration in renal function has been reported to be one of the major contributors to poor long-term outcome after EVAR.[17-19] The effect of the type of stent graft fixation on renal function after EVAR has been controversial. Several nonrandomized studies have reported conflicting results.[6-11] In addition, the number of studies determining the long-term impact has been limited.

In this study, a significant difference between the groups in renal dysfunction based on an eGFR decrease of more than 20% was noticed at 7 days postoperatively, favoring IR fixation over SR fixation. This difference seems to be transient; no difference was observed between the groups at 30 days or 1 to 4 years postoperatively. This temporary difference could be related to the endoluminal manipulations and possible microembolization during suprarenal endograft deployment. In addition, no difference in the presence of postoperative dialysis therapy was found. A review of the currently available meta-analyses suggests that SR fixation is safe in the short and medium term.[12-15,20] The meta-analysis by Sun and Stevenson[20] published in 2006, including 21 studies, compared SR and IR fixation with a mean follow-up ranging from 6 to 37 months. No difference was found with respect to renal dysfunction. Similarly, Walsh et al[14] found no significant difference in renal dysfunction in their meta-analysis of four studies with a median follow-up of 33 months. A meta-analysis published in 2015 by Miller et al[13] pooled data from 21 nonrandomized studies. The median follow-up was 12 months, and this meta-analysis also showed no difference in the risk of postoperative renal complications between SR and IR fixation.

Most recently, two meta-analyses were published on the subject in 2018. Calderbank et al12 analyzed 24 studies and found no significant drop in renal function at 1 year based on eGFR. Stather et al[15] included 25 nonrandomized studies comparing SR and IR fixation. A total of 54,832 patients were included. The decline in renal function was calculated at 30 days, 12 months, and the longest term, defined as the conclusion of the study. No differences were noticed at 30 days or 12 months. However, a small but significant difference in renal function was observed at study conclusion, favoring IR fixation over SR fixation (SR 5.98% vs IR 4.83%: OR, 1.29; 95% CI, 1.18-1.40; $P < .001$).

One study with a follow-up of 5 years reported that SR fixation was significantly more likely to cause an eGFR decrease of greater than 30% at 5 years compared with IR fixation or open aneurysm repair (SR 47% vs IR 32% and open aneurysm repair 33%; $P < .001$).[21] Furthermore, Antonello et al[4] compared the long-term outcomes in patients who did not have renal insufficiency at baseline, with a follow-up ranging from 54 to 124 months (mean, 74 months). They noticed a continuous decrease in renal function after EVAR, but no difference between SR and IR fixation. Our study also found no difference in the number of patients with a 20% or greater decrease in eGFR between SR an IR fixation at the end of follow-up. Moreover, no difference between SR and IR fixation was seen over time in the mixed-model approach in our study. Hypertension was the only significant predictor of an eGFR decrease in the current study (estimate −5.77; 95% CI, −0.59 to −10.96; $P = .029$).

Patients undergoing EVAR are often elderly with comorbidities. Previous studies have shown a decrease in renal function over time after EVAR.[4,5,7,8,21] This trend has also been seen regardless of fixation levels.[4,8] In our study, the findings are consistent with previous reports. A decrease in eGFR was observed during follow-up, and the estimated rate of decline in eGFR was 3.13 per year (95% CI, −3.40 to −2.85; $P < .001$). One reason for the decrease in renal function after EVAR may be the

possible reinterventions and repeated contrast medium exposures during the follow-up.[4,6]

Previous studies have suggested that SR may have a more negative impact on renal function in patients with preexisting chronic kidney disease.[12,15] In our study, patients with renal insufficiency at baseline more often had a decrease in renal function at 5 years after SR fixation than after IR fixation. Unfortunately, there was a lack of available data on creatinine measurements during the follow-up, as only 37 patients (43.0%) with preexisting renal insufficiency in the SR group and 10 patients (40.0%) with preexisting renal insufficiency in the IR group had their creatinine levels measured at 5 years. However, the difference between the groups was still statistically significant. A lower GFR is generally associated with an increased rate of progression of renal insufficiency during time and several factors can influence the likelihood of renal insufficiency progression.[16] This vulnerability can explain why the difference between SR and IR group in long-term renal function was seen only in patients with preoperative renal insufficiency.

This study has some limitations. First, this is a nonrandomized retrospective study using a prospectively maintained database. Therefore, the endograft choices may have been subject to selection bias. SR may be used more often in patients with a more hostile neck anatomy. In this study, the median neck was shorter and the median neck angulation was greater in the SR group than in the IR group, meaning that there were more patients with complex anatomy in the SR group. These measurements were included in the analysis, but may still have an effect on results in the long term. Additionally, the proximal neck anatomic hostility may lead to operating closer to the renal ostia for obtaining more adequate proximal sealing, which may have an impact on renal function. The statistical analysis failed to show any difference in renal function between the SR and IR groups among patients with a high-risk neck, but there were only 39 of these patients, which may have affected results. Despite the possible neck hostility in the SR group, no difference in type Ia endoleaks between the groups was observed during the follow-up. Also, no proximal migration of the stent grafts with a coverage of one or both renal ostia was found. The hostile neck anatomy can also predispose patients to a higher risk of reintervention and, therefore, additional examinations with a contrast medium.[22] Information on contrast medium exposure after the operation was not included in the analyses. The loss to follow-up as regards laboratory testing in the long term was considerable. The number of patients with preexisting renal insufficiency was relatively low, which may have affected the results. In this study, only renal function was included in the results. Suprarenal stent grafts may have benefits in the long term, which outweighs possible renal risks. The suprarenal aorta is supposed to remain more stable in diameter over time than the infrarenal aorta. Anchoring a stent graft suprarenally increases the length of a landing zone, which is supposed to lead to less risk of a type Ia endoleak or migration. However, there is lack of evidence whether SR is more favorable in hostile necks than IR fixation.[23]

The strengths of the present study include the long follow-up and the fact that almost all patients had a serum creatinine measurement within 7 days postoperatively. The study population was relatively large and collected from a single institution. Anatomic factors were included in analyses which should reduce risk for selection bias due to anatomic factors.

In conclusion, our study suggests that SR fixation is more often associated with a decrease in renal function immediately postoperatively than IR but this difference is transient. SR fixation is a safe method for patients with normal renal function at least in the short and medium term. The long-term effect on renal function should be established in the future when treating patients with preexisting renal insufficiency.

AUTHOR CONTRIBUTIONS

Conception and design: TH, IU, SP, VPS
Analysis and interpretation: TH
Data collection: TH, TK, IU, SP, SV
Writing the article: TH
Critical revision of the article: TH, TK, IU, SP, SV, VPS
Final approval of the article: TH, TK, IU, SP, SV, VPS
Statistical analysis: TH
Obtained funding: Not applicable
Overall responsibility: TH

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Supplementary Table I (online only). Baseline aneurysm characteristics for all patients and those with preoperative renal insufficiency

	All			eGFR < 60		
	SR (n = 267)	IR (n = 91)	*P* value	SR (n = 86)	IR (n = 25)	*P* value
Neck diameter, cm	23.9	23.1	.562	24.7	22.8	.592
Neck length, cm	29.7	36.2	.017	29.4	44.4	.001
Neck coronal angulation	15	16	.346	14	18	.325
Neck sagittal angulation	27	24	.019	28	22	.029
Conical neck, %	8.4	9.2	.812	11.9	0.0	.181
Neck calcification ≥50%, %	49.3	15.6	.600	18.6	4.8	.168
Neck thrombus ≥50%, %	1.6	1.3	.868	1.7	0.0	.545
AAA diameter, cm	58.1	58.4	.343	59.0	58.0	.785

eGFR, Estimated glomerular filtration rate; *IR*, infrarenal fixation; *SR*, suprarenal fixation.
Values are presented as medians unless stated otherwise.

Supplementary Table II (online only). The number of patients with available eGFR at each time point

	All		eGFR < 60	
	SR (n = 267)	IR (n = 91)	SR (n = 86)	IR (n = 25)
1-7 days	263	86	85	24
30 days	108	67	38	17
1 year	155	58	54	18
2 years	161	53	53	13
3 years	158	57	46	12
4 years	116	37	36	9
5 years	111	38	37	10

eGFR, Estimated glomerular filtration rate; *IR*, infrarenal fixation; *SR*, suprarenal fixation.