Revascularization of occluded renal artery stent grafts after complex endovascular aortic repair and its impact on renal function

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ABSTRACT

Background: Acute occlusion of renal bridging stent grafts after fenestrated/branched endovascular aortic repair (F/B-EVAR) is an acknowledged complication with high morbidity that often results in chronic dialysis dependence. The feasibility and effect of timely or late (≥6 hours of ischemia) renal artery revascularization has not been adequately reported.

Methods: We performed a retrospective, multicenter study across 11 tertiary institutions of all consecutive patients who had undergone revascularization of renal artery stent graft occlusions after complex EVAR. The end points were technical success, association between ischemia time and renal function salvage, interventional complications, mortality, and mid-term outcomes.

Results: From 2009 to 2019, 38 patients with 46 target vessels (TVs; eight bilateral occlusions) were treated for renal artery occlusions after complex EVAR (mean age, 63.5 ± 10 years; 63.2% male). Six patients had a solitary kidney (15.8%). Of the 38 patients, 16 (42.1%) had undergone FEVAR and 22 (57.9%) had undergone BEVAR. The technical success rate was 95.7% (44 of 46 TVs). The recanalization technique used was sole aspiration thrombectomy in 5.3%, aspiration thrombectomy and stent graft relining in 52.6%, and sole stent graft relining in 36.8%. The median renal ischemia time was 27.5 hours (range, 4-720 hours; interquartile range, 4-36 hours). Most patients (94.4%) had been treated after ≥6 hours of renal ischemia time, and 55.6% had been treated after 24 hours. In 14 patients (36.8%), renal function had improved after intervention (mean glomerular filtration rate improvement, 14.2 ± 9 mL/min/1.73 m^2). However, 24 patients (63.2%) showed no improvement. Improvement of renal function did not correlate with the length of renal ischemia time. Of the 14 patients with bilateral renal artery occlusion or a solitary kidney, 9 experienced partial recovery of renal function and no longer required hemodialysis. In-hospital mortality was 2.6%. The cause of renal stent graft occlusion could not be identified in 50% of the TVs (23 of 46). However, in 19 (41.3%), significant stenosis or a kink of the renal stent graft was found. The median follow-up was 11 months (interquartile range, 0-28 months). The estimated 1-year patient survival and patency rate of the renal stent grafts was 97.4% and 83.8%, respectively.

Conclusions: Revascularization of occluded renal bridging stent grafts after F/B-EVAR is a safe and feasible technique and can lead to significant improvement of renal function, even after long ischemia times (>24 hours) of the renal parenchyma or bilateral occlusion, as long as residual perfusion of the renal parenchyma has been preserved. Also, the long-term patency rates justify aggressive management of renal artery occlusion after F/B-EVAR. (J Vasc Surg 2021;73:1566-72.)

Keywords: Complex aortic repair; Fenestrated/branched EVAR; Renal artery occlusion; Renal function salvage

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Renal artery occlusion (RAO) is an infrequent clinical condition that can cause significant morbidity, including difficult to control hypertension and a decrease in renal function or can lead to hemodialysis in the case of bilateral occlusion or occlusion of a solitary kidney artery. Clinical presentation can vary among patients, most of whom will present with flank pain in the first hours after the event. However, patients can also present with fever, nausea and/or vomiting, or diarrhea.[1,2] The varied clinical presentation, combined with the low clinical suspicion owing to the rarity of the condition, can lead to a significant delay in treatment, which can, in turn, negatively affect the outcome.

The occlusion of the renal arteries has become more relevant than ever in the era of complex endovascular aortic surgery, with the calculated risk of occlusion of the renal bridging stent grafts reaching as high as 9% in the first 4 years after fenestrated and/or branched (F/B)-endovascular aortic repair (EVAR).[3] Although medical and surgical treatment of symptomatic chronic renal artery stenosis or occlusion has been adequately studied, to the best of our knowledge, no therapeutic protocol or optimal period has been established for the revascularization of acute RAO. Since the first successful intervention of an acute renal artery embolism in 1937,[4] only case reports and small case series have been reported. These reports have shown that even late revascularization of acute RAOs can lead to symptom improvement and salvage of the function of previously normal renal parenchyma,[5,6] in contrast to the previously commonly accepted dogma that kidney ischemia >6 hours will lead to irreversible damage.

In the present multicenter study, we recruited cases of acute renal stent graft occlusion after complex EVAR from experienced centers to study the feasibility of revascularization and its effects on renal function.

ARTICLE HIGHLIGHTS

- **Type of Research:** An international, multicenter, retrospective, cohort study
- **Key Findings:** A total of 38 patients with occlusion of the renal artery stent graft after complex endovascular aortic repair underwent endovascular recanalization after a median of 27.5 hours of renal ischemia time. The technical success rate was 95.7%. Of 14 patients with bilateral occlusions or a solitary kidney, 9 no longer required hemodialysis, despite the prolonged ischemia time.
- **Take Home Message:** Revascularization of occluded renal bridging stent grafts after fenestrated/branched endovascular aortic repair can lead to significant improvement of renal function even after long ischemia times of >24 hours.

METHODS

We performed a multicenter, retrospective study of the data collected in the RENUVAR (renal function salvage after fenestrated and branched EVAR) registry. The study complied with the Declaration of Helsinki, with the data collection and analysis approved by the local ethic committee. The institutional review board waived the requirement for written patient consent for the present retrospective study. A total of 11 medical centers participated in the present study, 10 European and one North American (Table I). The participating centers were chosen because of their high volume of complex aortic repair and previous participation in multicenter complex aortic studies. All patient data, including demographics, intraoperative and postoperative values, and outcome data, were collected from the individual institutes separately using a standardized datasheet with clearly predefined variables.

Indications and patient selection. Patients with complex aortic pathologies that had been treated with F/B-EVAR and had experienced occlusion of one or both renal bridging stent grafts were included in the present study. Patients with isolated, spontaneous renal artery occlusion without previous EVAR and patients who had been conservatively treated for the stent graft occlusion were excluded. Patients treated with chimney/snorkel EVAR were also excluded. The renal stent graft occlusion, defined as the total loss of bridging stent or stent graft lumen patency, was confirmed using either computed tomography angiography (CTA) or duplex ultrasonography. Although the precise decision and indication of the treatment algorithm differed slightly among the participating centers, revascularization of the occluded renal bridging stent grafts was attempted when the renal parenchyma showed remaining perfusion in the late/venous phase of the CTA or on the ultrasound scan, regardless of the ischemia time.

Definitions. Occlusion was defined as the total loss of lumen patency of the bridging stent graft after complex EVAR, with or without a reduction in kidney function. Complex EVAR was defined as the endovascular treatment of aortic pathologies with F/B-EVAR extending to or above the level of the renal arteries, including the pararenal, suprarenal, thoracoabdominal, and post-dissection aortic aneurysms. Technical success was defined as successful endovascular recanalization of the renal stent graft without remaining high-grade stenosis (>70%) or a type III endoleak on the final angiogram. Successful recanalization with minimal or no flow to the renal parenchyma on the final angiogram was still considered technical success as long as the relevant hilum branches of the renal artery had been preserved.

Clinical success was defined as termination of hemodialysis therapy or improvement in renal function in patients who had not previously required hemodialysis. As a measure of clinical success, we defined the change in glomerular filtration rate (ΔGFR) as the difference

Table I. Participating medical centers

Participating centers	Patients contributed, No.
Paracelsus University Hospital, Nuremberg, Germany	4
Mayo Clinic, Rochester, Minnesota, USA	2
University Heart Center, Hamburg, Germany	9
University Hospital of Bologna, Bologna, Italy	3
Sapienza University Rome, Rome, Italy	2
Skåne University Hospital, Malmö, Sweden	4
Hôpital Marie Lannelongue, Paris, France	2
Torino University Hospital, Torino, Italy	1
University Hospital LMU Munich, Munich, Germany	4
Uppsala University Hospital, Uppsala, Sweden	4
University Hospital Regensburg, Regensburg, Germany	3

between the last known GFR after renal recanalization and the GFR before renal artery occlusion (ΔGFR equal to GFR postoperatively minus GFR before the occlusion event). The estimated time of renal ischemia was calculated as the interval between the appearance of the first symptoms or the first detection of elevated serum creatinine levels in the blood sample and renal stent graft intervention.

End point definitions. The primary end points of the present study were the technical success of the revascularization as defined and the degree of renal function improvement or deterioration after intervention and during the course of follow-up. Mortality and morbidity (including major stroke and vascular complications) during the early postoperative period (first 30 days) and during follow-up and the investigation and determination of causal factors for renal endograft occlusion were defined as the secondary end points of the present study.

Measurements of renal function and degree of function impairment. Impairment in renal function is reported in terms of acute kidney injury (AKI) for all patients in the present cohort and was classified according to the 2012 clinical practice guidelines proposed by the Kidney Disease Improving Global Outcomes (KDIGO).[7] Using the KDIGO criteria, AKI was defined as an increase in serum creatinine by ≥0.3 mg/dL within 48 hours or an increase in serum creatinine to ≥1.5 times the baseline value within the previous 7 days. Stage 1 AKI corresponds to an increase in serum creatinine to 1.5 to 1.9 times the baseline value, stage 2 as 2 to 2.9 times the baseline values, and stage 3 as an increase in serum creatinine to three times the baseline value, a serum creatinine value of >4 mg/dL, or the initiation of renal replacement therapy (hemodialysis).

Several patients had presented with chronic kidney disease (CKD) before the renal artery occlusion event. CKD was defined as either kidney damage or a decreased GFR of <90 mL/min/1.73 m^2 and was classified using the widely accepted KDIGO criteria.[8] Thus, stage 1 CKD was defined as kidney damage with a normal GFR (>90 mL/min/1.73 m^2). Stage 2 was defined as a mild reduction in the GFR (60-89 mL/min/1.73 m^2). Stage 3a and 3b were defined as a moderate reduction in the GFR (45-59 and 30-44 mL/min/1.73 m^2, respectively). Stage 4 CKD was defined as a severe reduction in the GFR (15-29 mL/min/1.73 m^2) and stage 5 as kidney failure (GFR <15 mL/min/1.73 m^2 or dialysis).

Statistical analysis. Categorical data are presented as absolute numbers and percentages. Normally distributed continuous variables are presented as the mean ± standard deviation and non-normally distributed continuous variables as the median and interquartile range (IQR). Independent two-sample *t*-tests were used for the normally distributed continuous variables. Spearman's rho nonparametric correlation test was used to evaluate the possible correlation between the ischemia time and renal function outcomes. Missing values were disregarded in the variables if <2% of the values were missing. The *P* value was considered statistically significant at $P < .05$. Statistical analysis was performed using SPSS, version 25.0, for Windows (IBM Corp, Armonk, NY).

RESULTS

A total of 38 patients had undergone treatment from 2009 to 2019 at the 11 participating institutions for occlusion of the renal bridging stent graft after F/B-EVAR. Their mean age was 63.5 ± 10 years, and 63.2% of the patients were men. The median time between the aortic repair and the diagnosis of renal occlusion was 7 months (IQR, 0-14 months). The patient demographics and comorbidities are presented in Table II. The underlying aortic pathology previously treated with F/B-EVAR was a degenerative aneurysm in 33 patients (86.8%), dissection in 4 (10.6%), and a mycotic aneurysm in 1 (2.6%). Of the 38 patients, 16 (42.1%) had undergone FEVAR and 22 (57.9%) had undergone BEVAR. Six patients (15.8%) had a solitary kidney. Eight patients (21.1%) had presented with bilateral renal graft occlusion; in all eight cases, recanalization of both arteries was attempted. The total number of target vessels (TVs) was 46, of which 21 (45.7%) had undergone FEVAR and 25 (54.3%), BEVAR.

Causes of renal stent graft occlusion. The cause of the renal stent graft occlusion could not be identified for 23 of the 46 TVs (50%). However, for 19 (41.3%), a significant

Table II. Demographic characteristics (N = 38 patients)

Characteristic	Patients, No. (%)
Male sex	24 (63.2)
Coronary artery disease	12 (36.4)
Atrial fibrillation	2 (6.1)
Congestive heart failure	4 (12.1)
Hypertension	30 (90.9)
Hyperlipidemia	17 (51.5)
Smoking	20 (60.6)
COPD	12 (36.4)
Diabetes mellitus	2 (6.1)
Creatinine at admission, mg/dL	
Median	3.1
Range	0.59-14.7
Stage 3 AKI (dialysis/predialysis)	17 (45)
Cerebrovascular disease	1 (3)
Peripheral arterial disease	7 (21.2)
Coagulopathy	8 (3.5)
Connective tissue disorder	3 (9.1)
Type of aortic pathology	
Aneurysm	33 (86.8)
Dissection/postdissection aneurysm	4 (10.6)
Other	1 (2.6)
Type of endovascular aneurysm repair	
Fenestrated EVAR	16 (42.1)
Branched EVAR	22 (57.9)
Only left renal stent graft occluded	13 (34.2)
Only right renal stent graft occluded	17 (44.7)
Bilateral occlusion	8 (21.1)
Solitary kidney	6 (15.8)

AKI, Acute kidney injury; *EVAR*, endovascular aortic repair.

kink or stenosis of the stent graft was determined to be the causal factor. For the remaining cases, the causal agent was presumed to be perioperative coagulopathy (heparin-induced thrombopenia) in 2 TVs (4.3%), possible mechanical destruction or embolism after relining of the contralateral renal stent graft a few days earlier in 1 TV (2.1%), and dehydration combined with planned discontinuation of the antiplatelet therapy in 1 TV in a patient receiving novel oral anticoagulant therapy (2.1%).

Operative characteristics. For endovascular recanalization of the renal arteries, transfemoral access was used for 10 patients (26.3%), transbrachial or transaxillary access in 26 patients (68.4%), and both upper and lower extremity access in 2 patients (5.2%). The technical success rate for the recanalization procedure was 95.7% (44 of 46 TVs). Catheterization of two TVs was unsuccessful. The treatment strategy used was sole aspiration thrombectomy in 2 patients (5.3%), aspiration thrombectomy and relining of the renal stent grafts in 20 (52.6%), and sole stent graft relining in 14 patients (36.8%). Selective thrombolysis of the TV was used adjunctively in 20 of the 28 patients (52.6%). Of the 38 patients for whom aspiration thrombectomy was used, manual thromboembolic aspiration was used in 15 (39.5%), the Penumbra Indigo thrombectomy device (Penumbra Inc, Alameda, Calif) was implemented in 3 (7.9%), and the AngioJet thrombectomy system (Boston Scientific, Marlborough, Mass) was used in 4 (10.5%). The mean procedure time was 140 ± 66 minutes. The mean volume of contrast agent used was 62 ± 28 mL, and the mean fluoroscopy time was 41.6 ± 28 minutes. The perioperative and early postoperative data are presented in Table III.

Early outcomes. Early mortality (first 30 days postoperatively) was 2.6%. One patient had died after cardiac arrest of unknown cause on the 10th postoperative day. No major strokes occurred. Four patients (10.5%) had presented with access-related vascular complications, of whom one (2.6%) had undergone surgical treatment of a brachial artery occlusion immediately postoperatively.

Early renal function outcomes. On admission, 11 patients had presented with no renal function impairment (29%) and 17 (44.7%) had presented with stage 3 AKI, according to the KDIGO criteria. Ten patients (26.3%) had presented with CKD stage 3 to 5 using the KDIGO criteria for CKD. The estimated median renal ischemia time was 27.5 hours (range, 4-720 hours; IQR, 4-36 hours). Of the 38 patients, 94.4% had been treated after a minimum of 6 hours of renal ischemia time and 55.6% after 24 hours. The 17 patients with stage 3 AKI had all required hemodialysis perioperatively, at least intermittently. At 30 days, 10 of these patients (26.3%) required permanent hemodialysis therapy. The clinical success of recanalization treatment (ie, improvement of renal function) did not correlate with the renal ischemia time (Spearman's rho correlation between estimated renal ischemia time and ΔGFR, $P = .354$). Of the 14 patients with bilateral renal artery occlusion or a solitary kidney, nine had experienced improvement in their renal function and no longer required hemodialysis, although four had continued to require hemodialysis. The course of the creatinine value before, during, and after treatment is shown in Fig 1.

Late outcomes. The median follow-up time was 11 months (IQR, 0-28 months). Of the 38 patients, five (13.2%) were lost to follow-up, none of whom had required hemodialysis dependent at discharge. Of the remaining 33 patients, 9 had required permanent hemodialysis (23.7%) and 1 patient who had previously required hemodialysis had undergone kidney transplantation. Five patients had required procedural-related reinterventions during follow-up (2.6% each). Of these five patients, one had required renal stent graft relining because of stenosis on the second postoperative month

Table III. Operative data and early (30-day) outcomes[a]

Variable	Patients (n = 38) or target vessels (n = 46), No. (%)
Cause of occlusion	
Unidentified	23/46 (50)
Stenosis/kinking of stent graft	19/46 (41.4)
Coagulopathy	2/46 (4.3)
Other	2/46 (4.3)
Estimated mean ischemia time, hours	
Median	27.5
Range	4-720
IQR	4-36
Type of procedure	
Only aspiration thrombectomy	2 (5.3)
Aspiration thrombectomy and relining of bridging stent graft	20 (52.6)
Only relining	14 (36.8)
Type of thrombectomy	
Manual aspiration	15 (39.5)
Penumbra	3 (7.9)
AngioJet	4 (10.5)
Procedure access	
Transfemoral	10 (26.3)
Transbrachial/transaxillary	26 (68.4)
Both	2 (5.2)
Technical success	44/46 (95.7)
Death	1 (2.6)
Access vessel complication	4 (10.5)
Type of bridging stent graft used	
Advanta V12[b]	19/46 (41.3)
Viabahn[c]	17/46 (37)
Fluency[d]	16/46 (34.8)
BeGraft[e]	10/46 (21.7)
Protegé[f]	9/46 (19.6)
Everflex[f]	6/46 (13)
Genesis[g]	8/46 (17.4)
Visipro[f]	4/46 (8.7)
Covera[d]	1/46 (2.2)
SMART[g]	1/46 (2.2)
Lifestream[d]	1/46 (2.2)
Zilver[h]	2/46 (4.4)

IQR, interquartile range.
[a]The cause of occlusion, technical success, and type of bridging stent graft used refer to the target vessels with a denominator of 46; the remaining values refer to the patient cohort (n = 38).
[b]Getinge AB, Gothenburg, Sweden.
[c]W.L. Gore and Associates, Inc, Flagstaff, Ariz.
[d]Bard Peripheral Vascular Inc, Tempe, Ariz.
[e]Bentley InnoMed GmbH, Hechingen, Germany.
[f]Medtronic, Dublin, Ireland.
[g]Cardinal Health, Dublin, Ireland.
[h]Cook Medical, Bloomington, Ind.

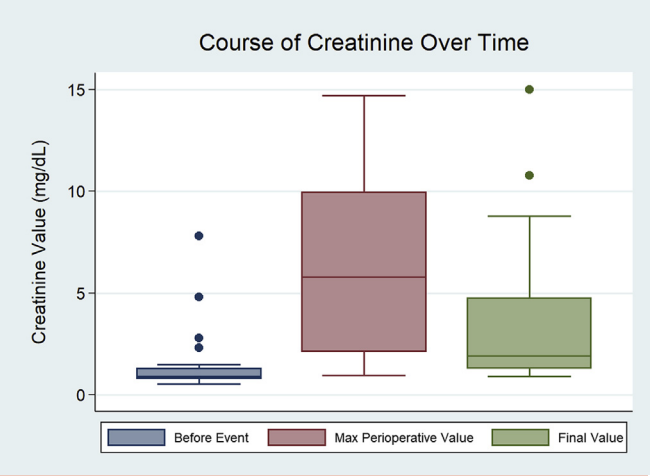


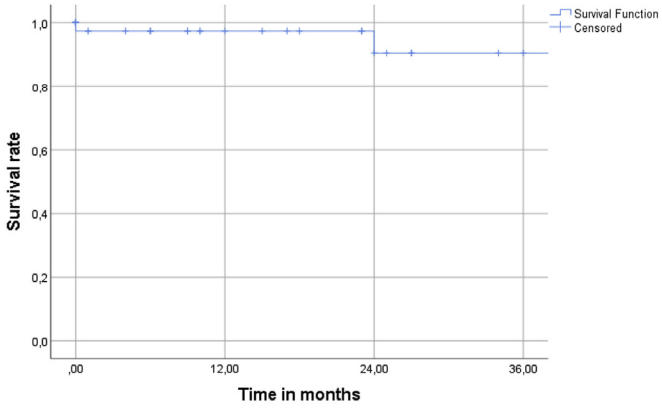
Fig 1. Course of creatinine value before, during, and after treatment.

(POM). One had undergone attempted recanalization of a distal renal artery stent graft for restenosis on the second POM. However, the procedure was aborted because of an intraprocedural transient ischemic attack. One patient had required recanalization of the renal stent graft because of new occlusion in the third POM. One patient had required drug-coated balloon angioplasty to treat distal renal stent graft stenosis in the 24th POM. Finally, one patient had undergone relining of the renal stent graft for stenosis in the 57th POM. No reduction in the GFR value was observed in the patient with reocclusion. The Kaplan-Meier survival analysis and estimation of reintervention and patency after recanalization are presented in Figs 2 and 3.

DISCUSSION

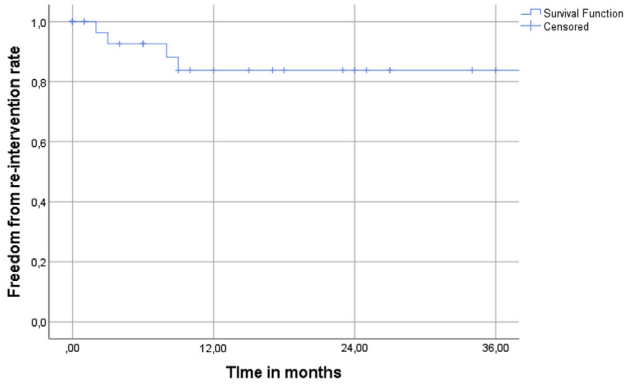
Abdominal aortic aneurysms, including juxtarenal, pararenal, and thoracoabdominal aneurysms, have been increasingly treated by endovascular repair, mainly owing to its lower short- and midterm morbidity and mortality rates.[9-11] Of the different available endovascular options, F/B-EVAR procedures have the largest body of evidence and have been recommended by the guidelines.[11,12] Other endovascular solutions, such as chimneys, periscopes, and snorkels, should be limited to emergency settings or when F/B-EVAR cannot be used because of anatomic limitations or availability.

Visceral vessel patency is one of the most important mid- and long-term aspects after F/B-EVAR. A recent analysis of 354 patients and a total of 1305 target renovisceral vessels reported primary patency rates for the left and right renal arteries of 94% and 92% at 36 months, respectively.[3] Another recent analysis of 523 target renovisceral vessels found an overall visceral vessel loss of 3.8% at 38 months of follow-up, with a greater incidence



	6-month	12-month	24-month
Alive	97.4%	97.4%	90.4%
Patients at risk	26	19	13

Fig 2. Kaplan-Meier survival estimation curve, with all results represented within a standard error of 10%.



	6-month	12-month	24-month
Freedom from re-intervention	92.6%	83.8%	83.8%
Patients at risk	23	17	11

Fig 3. Kaplan-Meier freedom from reintervention estimation curve, with all results represented within a standard error of 10%.

(6.4%) after treatment of thoracoabdominal aneurysms and after BEVAR (compared with FEVAR; 9% vs 2%). They found an overall visceral vessel loss of 4.4% of renal arteries, with 13% after BEVAR compared with 2.5% after FEVAR ($P = .001$).[13] Another recent study specifically of RAO found an incidence of 3.3% at 11 months of follow-up.[14] However, although the incidence and magnitude of the complication has been reported with greater frequency, available, high-quality data regarding the possible treatment options and outcomes are lacking.

At present, only a few case reports and one case series have been reported. Heidemann et al[14] performed a single-center retrospective analysis of seven patients (nine cases of RAO) who had undergone successful treatment by endovascular recanalization from December 2014 to March 2017. They found that renal function can be salvaged, even if the revascularization procedure has been delayed.[14] They reported a 100% secondary patency rate found on follow-up CTA, without any cases of permanent dialysis postoperatively.[14] The mean renal ischemic time to revascularization was 24 hours (range, 7-168 hours). In contrast, in the present study, the median renal ischemia time was 27.5 hours (range, 4-720 hours), slightly longer than that reported by Heidemann et al,[14] with a larger range of values. This might reflect different patterns of patient referral from the primary and secondary institutions to tertiary hospitals with a vascular team associated with each specific country. The findings from the present study second the idea that regardless of whether revascularization has been performed after >6 hours of renal ischemia, renal function and urine output can potentially be salvaged. However, the clinical success did not correlate with the renal ischemia time, possibly owing to the small sample size and the existence of extreme outliers. Although after revascularization, 10 patients were discharged requiring permanent hemodialysis (26.3%), 17 (44.7%) had required temporary hemodialysis at admission, a reduction in the hemodialysis rate of nearly 20%. Even patients who will continue to require dialysis might benefit from recanalization if relevant urine output can be preserved that will allow for better fluid management.

Regarding the technique of reestablishing flow to the renal artery, no concrete suggestions can be provided from our findings, given the heterogeneity of the approaches used, which ranged from simple aspiration thrombectomy to sole stenting of the recanalized renal branch and artery. In the latter, it was presumed that the thrombus had been pushed between the previous and new stent grafts.

An essential topic is the timing of attempting revascularization. Increasing experience has demonstrated that determining which patients will have a good chance of having their renal function significantly improved is not predictable. The length of occlusion time should not be the only parameter used to determine whether to reintervene. Even after prolonged occlusion of weeks, the collateral vascular network can maintain the viability of the renal parenchyma and lead to complete renal function restoration once antegrade perfusion to the kidney has been established. Although revascularization within 24 hours should always be pursued, a good indicator of whether to proceed with late revascularization could

be the presence of renal parenchyma perfusion on color Doppler or contrast-enhanced renal ultrasound scan or in the venous phase of a CTA scan.

Finally, the results from the present study have underlined the significance of adequately informing all patients undergoing F/B-EVAR and their primary care physicians regarding the possible event of renal stent graft occlusion, because timely intervention can possibly prevent the patient from requiring dialysis. This information could prove essential in preventing unnecessary delays in the diagnosis and treatment of renal stent graft occlusion, because most primary care physicians will not be familiar with complex aortic repair and its possible complications and might, therefore, not suspect it. Moreover, a high degree of suspicion is required for a timely diagnosis because renal artery occlusions can present with nonspecific symptoms, including flank pain, nausea or vomiting, and diarrhea.[2]

Study limitations. The present study was designed as a retrospective registry of recanalized renal arteries with a focus on the feasibility and effect of the treatment. The incidence of RAO after F/B-EVAR procedures cannot be calculated from the data available in the present study, given that the centers were asked only to include all cases in which RAO had been diagnosed and treated. Thus, the total number of FEVAR procedures performed in each center for the study period was unknown. Overall, the renal stent occlusion rates per center, incidence of occlusion of different stent types, and technical details concerning the initial F-BEVAR were beyond the scope of the present study. Furthermore, only patients who had received treatment were included; thus, the present study lacked a "control" group in which RAO was detected but left untreated (patients without any contrast in the kidney parenchyma found on the preoperative CTA or duplex ultrasound scan). Moreover, because the clinical presentation of AKI can vary, the estimation of the renal ischemic time was an "as-close-as-possible" approximation to the real value, although the risk of over- or underestimation could not be completely avoided.

Thus, the present study included data from a cohort of patients, which, although retrospective and multicenter in nature (different treatment strategies and protocols, different medications and stent grafts), had good external validity and represents an accurate "real-world" experience.

CONCLUSIONS

Revascularization of occluded renal bridging stent grafts after F/B-EVAR is a safe and feasible technique, which can lead to significant improvement of renal function, even after long ischemia times (>24 hours) of the renal parenchyma or bilateral occlusion. Also, the long-term patency rates justify aggressive management of renal artery occlusion after F/B-EVAR.

AUTHOR CONTRIBUTIONS

Conception and design: NK, NT
Analysis and interpretation: NK, NT
Data collection: NK, TK, ND, EV, AW, MG, KO, FV, FH, BS, AK, KM, CF, EG, KP, MR, ET, FS, SH, GO, NT
Writing the article: NK, CF, NT
Critical revision of the article: NK, TK, ND, EV, AW, MG, KO, FV, FH, BS, AK, KM, CF, EG, KP, MR, ET, FS, SH, GO, NT
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Overall responsibility: NT

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