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# Renal Outcomes Following Fenestrated and Branched Endografting

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**WHAT THIS PAPER ADDS**

This study adds new markers of renal function and renal volume, which can easily be assessed during follow up to demonstrate renal impairment. The results from this study confirm that FEVAR and BEVAR are durable options for the treatment of complex aortic aneurysms and are associated with a low renal morbidity rate, without any differences between these devices.

**Objective:** The purpose of this study was to analyze immediate and long-term renal outcomes (renal function and renal events) after fenestrated (FEVAR) and branched endovascular aortic aneurysm repair (BEVAR).
**Methods:** All FEVAR and BEVAR performed between October 2004 and October 2012 were included in this study. Post-operative acute renal failure (ARF) was defined according to the RIFLE criteria. Renal volume (calculated with a 3D workstation) and estimated glomerular filtration rate (GFR) (estimated with the Modification of Diet in Renal Disease [MDRD] formula) were evaluated before the procedure, before discharge, 12 months after, and yearly thereafter. Renal stent occlusion, dissection, fracture, stenosis, kink, renal stent related endoleak, and renal stent secondary intervention were all considered "renal composite events" and analyzed. A time to event analysis was performed for renal events and secondary renal interventions.
**Results:** 225 patients were treated with FEVAR and BEVAR. Renal target vessels ($n = 427$) were perfused by fenestrations ($n = 374$), or branches ($n = 53$). Median follow up was 3.1 years (2.9—3.3 years). Technical success was achieved in 95.5% of patients. Post-operative ARF was seen in 64 patients (29%). Mean total renal volume and eGFR at 1 year, 2 year, and 3 year follow up were significantly lower when compared with pre-operative levels (after BEVAR and FEVAR); the decrease at 3 years was 14.8% (6.7%; 22.2%) ($p = .0006$) for total renal volume and 14.3% (3.1%; 24.3%) ($p = .02$) for eGFR. The 30 day and 5 year freedom from renal composite event was 98.6% (95.8—99.6%) and 84.5% (76.5—89.9%) after FEVAR and BEVAR (NS). The 30 day and 5 year freedom from renal occlusion was 99.5% (96.7—99.9%) and 94.4% (89.3—97.1%) after FEVAR and BEVAR (NS).
**Conclusion:** FEVAR and BEVAR are durable options for the treatment of complex aortic aneurysms and are associated with low renal morbidity, without differences between devices types. The clinical impact of decreasing renal volume over time in these patients is yet to be fully understood.

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## INTRODUCTION

The first reports of endovascular treatment of complex juxtarenal/pararenal aortic aneurysms (JR-PRAA) and thoraco-abdominal aortic aneurysms (TAAA) were published by Faruqui et al. in 1999[1] and Chuter et al. in 2001.[2] Since that time, the technology has come into mainstream clinical use, and a recent review comparing endovascular and open repair[3] of complex aneurysms reported a 2.4% 30 day mortality rate after fenestrated endovascular repair (FEVAR) versus 3.4% after open repair and 5.3% following chimney repair.

Post-operative renal impairment is one of the most frequent major complications associated with complex aneurysm treatment using any modality. Nordon et al.[4] described in their systematic review an incidence of early transient renal failure of 15% following FEVAR compared with 20% after open repair. Mid- and long-term renal outcomes after complex endovascular repair are associated with "branch instability" as defined by Mastracci et al[5]: branch occlusion, device migration affecting a branch, branch related growth, or the need for any secondary

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intervention. However, because several definitions of renal impairment are used in the literature describing outcomes for fenestrated repair, it is difficult to perform an effective comparison across all reports. The purpose of this study was to analyze immediate and long-term renal outcomes after complex endovascular repair performed in a high volume center.

## MATERIAL AND METHODS

### *Study population*

All complex endovascular repairs (including both FEVAR [fenestrated endovascular aortic aneurysm repair] and BEVAR [branched endovascular repair]) performed in a single institution between October 2004 and October 2012 were included in this study. Ruptured aneurysms and acute aortic dissections were excluded.

All patients were treated by the same group of vascular surgeons at a single high volume academic center. In order to have a follow up $\geq$ 12 months, patients treated after October 2012 were not included. All endovascular procedures were performed with fenestrated or branched endografts manufactured by Cook Medical (Bloomington, IN, USA). The FEVAR and BEVAR procedures were performed with a mobile C-arm. In accordance with the literature,[6,7] iso-osmolar iodixanol contrast media (Visipaque, 320 mg I/mL, GE Healthcare, Dublin, Ireland) was used when the estimated glomerular filtration rate (eGFR) was $<$ 60 mL/min/1.73 $m^2$, and low osmolar iohexol contrast media (Omnipaque, 300 mg I/mL, GE Healthcare) in the remaining patients.

Patient data were prospectively collected in an electronic database and electronic or paper medical records were also reviewed retrospectively for the purpose of this study. Baseline demographics and risk factors, including medications with renal impact and intra-operative contrast volume, were collected.

### *Renal function*

eGFR was determined using the abbreviated MDRD study equation (eGFR mL/min/1.73 $m^2$ = 186 $\times$ [serum creatinine]$^{-1.154}$ $\times$ [age]$^{-0.203}$ $\times$ [0.704 if female] $\times$ [1.210 if African American]).[8] The eGFR was calculated and collected pre-operatively, on the first post-operative day, on the day of discharge, and yearly thereafter. Chronic kidney disease (CKD) was defined as eGFR $<$ 60 mL/min/1.73 $m^2$ based on the National Kidney Foundation/Kidney Disease Outcome Quality Initiative (NKF/KDOQI).[8] The RIFLE classification,[9] based on eGFR evaluated 48—72 hours after the procedure, was used for the post-operative diagnosis of acute renal failure (ARF), defined as an increase in eGFR of at least 25%.

### *Imaging analysis*

Pre-operative multi-detector computed tomography (MDCT) scans were obtained in all patients. A CT scan was also performed at discharge, 12 months, and yearly thereafter. All CT scans analyzed in this study were performed during the standard follow up protocol after FEVAR/BEVAR. Renal duplex imaging was also performed to supplement data.

MDCT scans were loaded into a workstation (AquariusNET software, TeraRecon Inc., San Mateo, CA, USA) for imaging analysis by one of the authors (T.M.G.). A standardized protocol for assessment was developed. The longest cranio-caudal renal length was selected from the three dimensional volume rendered reconstruction and measured on both sides. Combined kidney length measurements (mean renal length) were calculated for each pair of kidneys. The volume of each kidney was calculated by the following method: a semi-automated post-processing treatment extracted the renal contour. The pelvicalyceal systems, fat and vessels in the renal sinus, and renal cysts were excluded by manual correction on multiplanar views in case they had been automatically included. Then, the renal volume was automatically measured (in $cm^3$). Combined kidney volumes (sum of right and left volumes) were also calculated for each pair of kidneys. Intra- and inter-observer differences were analyzed using the intraclass correlation coefficient (ICC). Ten patients included in a previous study with similar analysis were analyzed three times by two physicians. No significant intra- or inter-observer variation were observed (volume: ICC = 0.999 [CI 95%, 0.998—1.000] [$p < .000$]; length: ICC = 0.991 [CI 95%, 0.980—0.996] [$p < .000$]).

The renal artery angles were measured by the method described by Conway et al.[10]: a semi-automated centerline was generated from the aortic bifurcation to the level of the diaphragm. The centerline was assessed with multiplanar reconstruction views perpendicular to the centerline of flow. A positive renal artery implantation angle (RAIA) was defined as an angle above the horizontal plane perpendicular to the aortic centerline of flow at the mid level of the renal ostia. A quantitative angular measurement for the RAIA was taken using the angular measurement tool provided in the AquariusNET software. The process was repeated for each renal artery, stented or involved in the graft including accessory renal arteries, pre-operatively and at each follow up. Accessory renal arteries were measured and recorded only if they were included in the device.

Renal outcome events were assessed using the MDCT scan and were complemented with duplex ultrasound. Duplex ultrasound criteria applied were defined by Mohabbat et al.[11] and MDCT scan interpretation was based on the methods described by Dowdall et al.[12] Imaging outcomes were defined according to reporting standards[13] and to modifications assessed by Mastracci et al.[5] Renal composite outcome included branch occlusion, in-stent stenosis, stent kinking, stent fracture, and renal related endoleak.

### *Statistical analysis*

Analyses were conducted using SAS software (SAS version 9.2, SAS Institute Inc., Cary, NC, USA).