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Renal outcomes analysis after endovascular and open aortic aneurysm repair

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Objective: **The purpose of this study was to compare renal outcomes (glomerular filtration rate [GFR] and renal volume) after endovascular aneurysm repair (EVAR) and open repair (OR) of abdominal aortic aneurysm (AAA).**
Methods: **All AAA repairs performed between November 2009 and July 2011 were included in this retrospective study. Patients requiring suprarenal clamping and renal bypass or reimplantation and patients requiring fenestrated endografting were excluded from the OR and EVAR groups, respectively. All EVARs were performed with transrenal proximal fixation. Renal volume (calculated with a three-dimensional workstation) and GFR (estimated with the Modification of Diet in Renal Disease formula) were evaluated before the procedure, at 12 months after the procedure, and yearly thereafter.**
Results: **The study included 90 patients (41 ORs and 49 EVARs). Both groups were comparable except for age at intervention, body mass index, smoking, peripheral arterial disease, arrhythmia, and vitamin K antagonist treatment. Median follow-up was 2.8 years for OR (2.5-2.9 years) and 3.2 years for EVAR (3.0-3.4 years). In both groups, we found a significant decrease when comparing postoperative estimated GFR with 1-year (14.4% decrease [3.8%-23.8%]; $P = .002$) and 3-year (12.8% decrease [3.8%-20.9%]; $P = .0007$) levels. In both groups, total renal volumes significantly diminished. Median preoperative total renal volume (372 cm^3 [311-349]) significantly decreased (6.7% [2.8%-10.5%]; $P = .008$) between 1 year and 2 years of follow-up.**
Conclusions: **Renal function impairment is similar after open and endovascular AAA repair. It is associated with a decrease in total renal volume, which seems to be an early and constant marker of postoperative renal impairment. (J Vasc Surg 2015;62:569-77.)**

Renal impairment is a frequent complication after both open repair (OR)[1] and endovascular aneurysm repair (EVAR)[2] of infrarenal abdominal aortic aneurysms (AAAs). It is associated with a prolonged hospital stay, morbidity, long-term mortality, and increased health expenses. Reported renal insufficiency rates after OR and EVAR are similar, ranging from 13.9% to 17%[3] and 5% to 20%,[4-6] respectively. Several studies[2,4,5,7-12] have reported that endografts with both suprarenal and infrarenal fixation are associated with a similar incidence of postoperative renal impairment.

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A comparative analysis is difficult to perform because postoperative renal impairment is inconsistently defined; the tests used and the abnormality thresholds vary. Originally, it was identified simply as a rise in serum creatinine concentration. This is now considered nonspecific because various factors can affect serum creatinine levels, including nutritional intake, medications, age, body mass index (BMI), weight, sex, and race. It is also considered a poorly sensitive test because creatinine concentration rises above the normal range only when more than half of the renal function is lost.[13] Recently, several validated formulas have been used for estimated glomerular filtration rate (eGFR),[14] a more reliable measure of renal function.

The purpose of this study was to compare renal outcomes after EVAR and OR using eGFR (evaluated by the Modification of Diet in Renal Disease [MDRD] method) and the criteria commonly accepted to define acute renal failure (ARF) and chronic kidney disease (CKD). We also measured renal volume as a potential early marker of renal impairment.

METHODS

Study population. All infrarenal aneurysm repairs performed in a single high-volume institution between November 2009 and July 2011 were included in this retrospective analysis. Inclusion and exclusion criteria are detailed in Table I.

All endovascular procedures were performed under general anesthesia using the Zenith endograft (Cook Medical, Bloomington, Ind). This device comprises a bare stent for suprarenal fixation. The EVAR procedures were performed with use of a mobile C-arm and low-osmolar iohexol contrast media (Omnipaque, 300 mg I/mL; GE Healthcare, Cork, Ireland) or iso-osmolar iodixanol contrast media (Visipaque, 320 mg I/mL; GE Healthcare) when eGFR was <60 mL × min^{-1} × 1.73 m^{-2}.[15,16]

Clinical data were prospectively collected in an electronic database and retrospectively reviewed for the purpose of this study. Patient demographics and renal risk factors, including potentially nephrotoxic medications and the volume of intraoperative contrast media, were also collected.

The protocol and informed consent were approved by the Institutional Review Board, and all subjects gave informed consent.

Renal function. The eGFR was determined by the abbreviated MDRD study equation (eGFR [mL × min^{-1} × 1.73 m^{-2}] = 186 × [serum creatinine]$^{-1.154}$ × [age]$^{-0.203}$ × [0.704 if female] × [1.210 if African American]).[14] The eGFR was calculated preoperatively, on the day after the procedure, at discharge, and then annually. CKD was defined as eGFR <60 mL × min^{-1} × 1.73 m^{-2} based on the National Kidney Foundation Kidney Disease Outcomes Quality Initiative[14] (Table II). Similar to previous EVAR studies,[3] we have defined CKD as stage 3 or above. Stage 1 and stage 2 patients were considered patients with normal renal function. The RIFLE (Risk, Injury, Failure, Loss of kidney function, End-stage renal disease) classification,[17] based on eGFR measured 48 to 72 hours postoperatively, was applied for the diagnosis of postoperative ARF (Table III).

Renal volume. Preoperative multidetector contrast-enhanced computed tomography (CT) angiography (CTA) was performed in all patients.

Patients who underwent EVAR had CTA performed at discharge, at 12 months, and then annually. We did not perform the CT scan with iodinated contrast material when the eGFR was <60 mL/min/1.73 m^2 except in restricted cases to identify the cause of sac enlargement, under nephroprotection protocol. Patients were also subject to regular duplex ultrasound assessments. Magnetic resonance imaging was not used because the endografts implanted had stainless steel stents. Patients in the OR group had an annual duplex ultrasound examination performed and at least one CTA between the first and third years of follow-up.

CTAs were interrogated using a multiplanar three-dimensional workstation (AquariusNET software; TeraRecon Inc, San Mateo, Calif). The volume of each kidney was calculated with the following method: after selection of an area of interest, a semiautomated postprocessing algorithm extracted the renal contour based on pixels of similar attenuation; the pelvicalyceal system, fat and vessels in the renal sinus, and renal cysts were then excluded by manual correction on multiplanar views (to correct for any confounding automatic inclusion); finally, the renal volume was estimated with an algorithm embedded in the software package (in cubic centimeters; Fig 1). Combined kidney volumes (sum of right and left volumes) were also calculated for each pair of kidneys.

Table I. Inclusion and exclusion criteria

Inclusion criteria	*Exclusion criteria*
>2 years of follow-up	CT scan not available
One or more postoperative CT scans	Aneurysm rupture
	Suprarenal aortic cross-clamping
	Renal bypass
	Renal artery surgery
	Fenestrated endografting

CT, Computed tomography.

Table II. National Kidney Foundation classification stages for chronic kidney disease (*CKD*)[14]

Stage	*Description*	*eGFR (mL/min/1.73 m^2)*
1	Kidney damage with normal or ↑eGFR	≥90 (with CKD risk factors)
2	Kidney damage with mild ↓ eGFR	60-89
3	Moderate ↓ eGFR	59-30
4	Severe ↓ eGFR	29-15
5	Kidney failure	<15 (or dialysis)

eGFR, Estimated glomerular filtration rate.

The robustness of this method was tested: the intraobserver and interobserver differences were estimated by intraclass correlation coefficient, a descriptive statistic to assess the reproducibility of this method. Ten patients included in our study were analyzed three times by two independent physicians. No significant intraobserver or interobserver variations were observed (volume: intraclass correlation coefficient = .999 [95% confidence interval, 0.998-1.000]; $P < .000$).

Statistical analysis. Analysis was performed with SAS version 9.1.3 (SAS Institute, Cary, NC). Categorical variables are described as numbers and proportions; continuous variables are described as mean ± standard deviation or median (25th-75th percentiles) and in cases of non-normal distribution (verified by Shapiro-Wilk tests) as median. OR and EVAR populations were compared with χ^2 tests or Fisher exact tests, as appropriate, for categorical variables and with Student *t*-tests or Mann-Whitney tests, as appropriate, for continuous variables.

Survival curves were estimated by the Kaplan-Meier method and compared with the log-rank test. Confidence bands were built by the method derived by Hall and Wellner. Median follow-up time was estimated with the reverse Kaplan-Meier method.

Renal volumes, differences in renal volume from preoperative level (calculated as a relative decrease, in percentage