A comparison of renal function between open and endovascular aneurysm repair in patients with baseline chronic renal insufficiency

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Objective: **Endovascular aneurysm repair (EVAR) is rapidly becoming the predominant technique for repair of abdominal aortic aneurysms. Results from current studies, however, are conflicting on the effect of EVAR on renal function compared with standard open repair. Furthermore, data for open repair in patients with baseline renal insufficiency suggests worse outcomes, including renal function. This analysis compared the effects of open repair vs EVAR on renal function in patients with baseline renal insufficiency.**

Methods: **We reviewed our records for patients with preoperative chronic renal insufficiency (serum creatinine, 1.5 mg/dL) who underwent open repair or EVAR between 1999 and 2004. The same group of vascular surgeons at a single institution performed aneurysm repair on 98 patients: 46 open (37 men, 9 women) and 52 EVAR (50 men, 2 women). Preoperative, postoperative, and follow-up serum creatinine and creatinine clearance were compared, as was the development of postoperative renal impairment (increase in serum creatinine >30%).**

Results: **Serum creatinine and creatinine clearance were not statistically different between the open and EVAR groups during any time period studied. Likewise when comparing the magnitude of change in serum creatinine in patients between the postoperative and follow-up times with preoperative values, no significant differences existed between the open and EVAR groups. When the change in serum creatinine over time within each group was compared, however, the open group had a significant increase in serum creatinine postoperatively (2.43 ± 1.20 vs 2.04 ± 0.64, $P = .012$), which returned to baseline during follow-up (1.96 ± 0.94, $P = .504$). Although serum creatinine in the EVAR group increased compared with preoperative values of 2.04 ± 0.55 (postoperative, 2.27 ± 1.04; follow-up, 2.40 ± 1.37), this failed to reach statistical significance for the postoperative ($P = .092$) or follow-up ($P = .081$) periods. A similar pattern was noted in creatinine clearance. Postoperative renal impairment was noted in 13 open (28%) and 15 EVAR patients (29%) and was not statistically different between groups. Overall, two patients (4.3%) from the open group and four (7.7%) from the EVAR group required hemodialysis; one in the EVAR group required permanent hemodialysis. This difference was not statistically significant ($P = .681$).**

Conclusions: **Open and endovascular repair of abdominal aortic aneurysms in patients with pre-existent renal insufficiency can be performed safely with preservation of renal function. In contrast to previous reports, no significant differences existed between open repair and EVAR in postoperative alterations in renal function. Although a significant increase in serum creatinine develops in patients with renal insufficiency postoperatively with open repair, this appears to be transient, and preoperative renal dysfunction alone should not exclude either approach. After EVAR, patients with pre-existing renal insufficiency continue to be at risk for progressive renal dysfunction, and protective measures should be taken to preserve renal function in this patient population. (J Vasc Surg 2006;44:706-11.)**

Since the original description in 1991 by Parodi et al,[1] endovascular aneurysm repair (EVAR) has become the predominant method for treatment of infrarenal abdominal aortic aneurysms. Despite recent prospective studies that have demonstrated better outcomes after EVAR in the perioperative and intermediate time periods,[2,3] concerns remain about the long-term durability and safety of EVAR.[4,5]

One patient population at increased risk for perioperative complications after open or endovascular repair are those with baseline renal insufficiency.[6] The effects of EVAR on renal function in these patients remains uncertain. Although recent studies have shown that progressive renal dysfunction may develop in patients after EVAR, data are conflicting about the effect of EVAR on renal function compared with standard open repair.[7,8] Furthermore, to our knowledge, no study to date has compared the impact of EVAR on renal function in patients with baseline renal insufficiency with those receiving standard open repair. The purpose of this study is to compare the effects of open repair vs EVAR on renal function in patients with pre-existent renal insufficiency.

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METHODS

Between August 1998 and September 2004, 98 patients with preoperative chronic renal insufficiency (serum creatinine, 1.5 mg/dL) underwent open or endovascular infrarenal abdominal aortic aneurysm repair. All patients

Table I. Patient characteristics

	EVAR *n = 52 (%)*	*Open* *n = 46 (%)*	P
Age (years)			.0002
Mean	77.3 ± 6.2	71.3 ± 8.8	
Range	62-90	36-84	
Male gender	96.2	80.4	.022
Hypertension	89.1	81.3	.343
Diabetes mellitus	8.9	9.4	.999
Coronary artery disease	63	80.6	.13
Peripheral vascular disease	42.5	36.7	.806
Tobacco use (%)	80.5	87.5	.532
AAA size (mm)			.522
Mean	57.4 ± 9.9	58.7 ± 9.4	
Range	37-82	41-80	
Operative time (min)	248 ± 82	253 ± 68	.768
Length of follow-up (months)	15.6 ± 14.7	19.8 ± 19.8	.253

EVAR, Endovascular aneurysm repair; *AAA,* abdominal aortic aneurysm. Data are in percentages or mean ± SD and ranges.

were treated by the same group of vascular surgeons working at a single institution. Of these, 46 patients (37 men, 9 women) underwent open repair of an abdominal aortic aneurysm. Five required a suprarenal cross clamp. All patients were treated by the same group of vascular surgeons working at a single institution.

During this same period, 52 patients (50 men and 2 women) underwent aneurysm repair using endovascular techniques. The endografts used were 3 Ancure (Guidant Corp, Indianapolis, Ind), 6 AneuRx (Medtronic, Santa Rosa, Calif), 13 Zenith (Cook Diagnostic, Bloomington, Ind), 2 Lifepath (Edwards Lifesciences LLC, Irvine, Calif), 10 Powerlink (Endologix, Inc, Irvine, Calif), 1 Excluder (W.L. Gore and Assoc, Flagstaff, Ariz), 13 Talent (World Medical Manufacturing Corp, Sunrise, Fla), 1 TriVascular (TriVascular Inc, Santa Rosa, Calif), and 3 with unknown manufacturer. Of these, 19 (13 Zenith, 5 Powerlink, and 1 TriVascular) used suprarenal fixation.

Preoperative contrast-enhanced computed tomography (CT) scans were obtained in all open and EVAR patients using multidetector scanners (General Electric HISPEED CTi or LightSpeed Qxi, GE Medical Systems, Milwaukee, Wis). The three-phase CT angiogram (CTA) consisted of a noncontrast scan through the lower chest and abdomen, followed by a CTA using 120 mL of nonionic contrast. A 2-minute delayed CT scan was then performed again through the lower chest and abdomen. EVAR patients were followed-up with CTA at 1, 6, and 12 months and then annually thereafter. Open patients had annual follow-up duplex scans. All contrast requiring imaging and procedures performed after 2000 were pretreated with acetylcysteine,[9] and those performed after 2004 were pretreated with acetylcysteine and sodium bicarbonate solution.[10]

Patient data were collected in a retrospective manner from hospital and office chart review. Baseline demographic data were recorded, including age, gender, a history of tobacco use, diabetes mellitus, hypertension, coronary artery disease, or peripheral vascular disease. For comparison of the effects of open repair and EVAR on renal function, serum creatinine (SCr) levels were recorded preoperatively, immediate postoperatively, and at the last follow-up. To compensate for weight, age, and gender differences, creatinine clearances (CrCl) were calculated using the Cockcroft-Gault formula, CrCl = (140 – age) × weight/(SCr × 72).[11] The development of postoperative renal impairment and the need for hemodialysis was also recorded.

Baseline renal insufficiency was defined as a preoperative serum creatinine >1.5 mg/dL. Renal impairment was defined as an increase in serum creatinine >30% or the newly acquired need for hemodialysis. Coronary artery disease was defined as angina, myocardial infarction, or a history of cardiac surgery. Peripheral vascular disease was defined as claudication, rest pain, or a history of surgery for arterial occlusive disease.

Data analysis. Data were expressed as mean ± standard deviation where appropriate. Comparison of continuous variables between groups was made using Student's *t* test for independent variables. Student's *t* test was used for comparisons within the open and EVAR groups over time. Categoric variables were compared using the Fisher exact test. Differences were considered significant if the two-tailed *P* value was <.05.

RESULTS

Demographics. The average age was significantly higher in the EVAR group (77.3 ± 6.2 years) than in the open group (71.3 ± 8.8 years) (*P* = .0002). In addition, the percentage of men was significantly higher in the EVAR group (96.2%) vs the open group (80.4%) (*P* = .022). Preoperative aneurysm diameter, operative time, and the prevalence of comorbid conditions were similar between the groups (Table I). Mean intraoperative contrast administration was 134 ± 69 mL during EVAR. In the open group, mean cross-clamp time was 45 ± 12 minutes. Mean follow-up was 15.6 ± 14.7 months for EVAR and 19.8 ± 19.8 months for open (*P* = .253).

Renal function. Baseline serum creatinine was similar between both cohorts (Table II). Although serum creatinine increased in the EVAR group over time (preoperative, 2.04 ± 0.55 mg/dL; postoperative, 2.27 ± 1.04 mg/dL; follow-up, 2.40 ± 1.37 mg/dL) it failed to reach statistical significance when the postoperative (*P* = .091) and follow-up (*P* = .081) levels were compared with preoperative levels (Table III). In the open group, serum creatinine significantly increased in the postoperative period (2.43 ± 1.20 mg/dL) compared with preoperative levels (2.04 ± 0.64 mg/dL, *P* = .012). During subsequent follow-up, however, serum creatinine returned to baseline (preoperative, 2.04 ± 0.64 mg/dL; follow-up, 1.96 ± 94 mg/dL; *P* = .504). There were no statistically significant differences in serum creatinine levels between the EVAR and open patients during the preoperative (*P* = .992), postoperative (*P* = .479), or the follow-up (*P* = .100) periods (Fig, *A*).

A similar trend was noted in creatinine clearance, with no statistically significant difference between EVAR

Table II. Renal outcomes

	EVAR *n = 52 (%)*	*Open* *n = 46 (%)*	P*
Serum creatinine (mg/dL)			
Baseline	2.04 ± 0.55	2.04 ± 0.64	.992
Change			
Pre-op vs post-op	0.25 ± 0.94	0.39 ± 0.99	.416
Pre-op vs follow-up	0.37 ± 1.36	−0.08 ± 0.74	.077
Renal impairment†			
Total	15 (28.8)	13 (28.3)	.999
Post-op	9 (17.3)	11 (23.9)	.46
Follow-up	13 (25.0)	5 (10.9)	.12
Hemodialysis (%)	4 (7.7)	2 (4.3)	.681

EVAR, Endovascular aneurysm repair.
Data presented as numbers (%) or mean ± SD.
*Comparison between open and EVAR groups.
†Defined as elevation in serum creatinine by ≥30%.

Table III. Comparison of change in serum creatinine and creatinine clearance over time

	EVAR *n = 52*	P*	*Open* *n = 46*	P*
Serum creatinine (mg/dL)				
Preoperative	2.04 ± 0.55		2.04 ± 0.64	
Postoperative	2.27 ± 1.04	.092	2.43 ± 1.20	.012
Follow-up	2.40 ± 1.37	.081	1.96 ± 0.94	.504
Creatinine clearance (mL/min)				
Preoperative	39.0 ± 12.9		39.2 ± 16.2	
Postoperative	39.9 ± 17.5	.789	37.1 ± 18.0	.644
Follow-up	37.2 ± 17.1	.599	46.4 ± 22.5	.18

EVAR, Endovascular aneurysm repair.
Data are presented as mean ± SD.
*Paired Student's *t* test compared with preoperative values.

and open groups in the preoperative (P = .950), postoperative (P = .517), or the follow-up (P = .065) periods (Fig, *B*). Likewise, although the preoperative, postoperative, and follow-up creatinine clearance decreased in EVAR patients (39.0 ± 12.9, 39.9 ± 17.5, and 37.2 ± 17.1 mL/min, respectively) and increased in the open group (39.2 ± 16.2, 37.1 ± 18.0, and 46.4 ± 22.5 mL/min, respectively) over time, this too failed to reach statistical significance (Table III).

The absolute change in serum creatinine between the postoperative and preoperative time periods was similar between groups (EVAR, 0.25 ± 0.94 mg/dL; open, 0.39 ± 0.99 mg/dL; P = .479). When the absolute change in serum creatinine between the follow-up and preoperative time periods was compared, there was a notable difference between groups (EVAR, 0.37 ± 1.36 mg/dL; open, −0.08 ± 0.74 mg/dL); however, this difference failed to reach statistical significance (P = .077).

Renal impairment developed in 15 EVAR (28.8%) and 13 open patients (28.3%), which was not statistically different (P = .999) (Table II). To further examine the time frame during which renal impairment developed, those patients whose renal impairment developed in the postoperative period or follow-up periods were compared. In the postoperative period, renal impairment was present in nine EVAR (17.3%) and 11 open patients (23.9%) (P = .460). During the follow-up period, eight of the 11 patients in the open group recovered to baseline, and late renal impairment developed in only two additional patients. In contrast, of the nine EVAR patients who had renal impairment in the postoperative period, only two recovered, and renal impairment developed in six additional patients during follow-up.

Despite this different pattern of renal impairment after aneurysm repair, there were no statistically significant differences in renal impairment during follow-up in the EVAR (25%) and open patients (10.9%) (P = .120). Hemodialysis was required in four EVAR patients (7.7%), one of which was temporary. Two open patients (4.3%) required permanent dialysis. These differences were not statistically significant (P = .681).

DISCUSSION

Endovascular abdominal aortic aneurysm repair has become increasingly more common since its inception and is rapidly becoming the predominant technique for repair of infrarenal abdominal aortic aneurysm. Despite recent studies that have confirmed the decreased perioperative risk after EVAR compared with open repair,[2,3] recent data have suggested that issues remain regarding the durability and long-term safety of EVAR.[4,5]

Of particular concern is the demonstration by several investigators,[7,12,13] and most recently by our group,[8] of the development of progressive renal dysfunction over time after EVAR. Greenberg et al[12] compared their experience in 199 patients who underwent EVAR using the Zenith suprarenal fixation device with 80 patients who had standard open repair. Although renal function did not differ between groups during the perioperative period, the EVAR patients did demonstrate a trend toward worsening renal function over time.

Surowiec et al[13] reviewed their results in 82 patients after EVAR with a mean follow-up of 23 months and compared them with 65 patients with open repair. Patients who underwent EVAR with either suprarenal or infrarenal fixation had similar serum creatinine levels, but both developed progressively worsening renal function over time, which was significantly worse than open controls when compared with patients with infrarenal fixation. Alsac et al[7] published their data after EVAR in 277 patients and demonstrated an approximate 10% decrease in calculated creatinine clearance within the first year after EVAR.

Most recently Parmer and Carpenter[8] demonstrated a similar trend with progressive renal dysfunction after EVAR in 283 patients. In this study comparing the effects of suprarenal or infrarenal fixation on renal function, serum creatinine increased and calculated creatinine clearance significantly decreased in both groups after EVAR. Furthermore, this elevation was persistent in those patients with follow-up >12 months, suggesting either an ongoing effect from EVAR or follow-up contrast CTA on renal func-

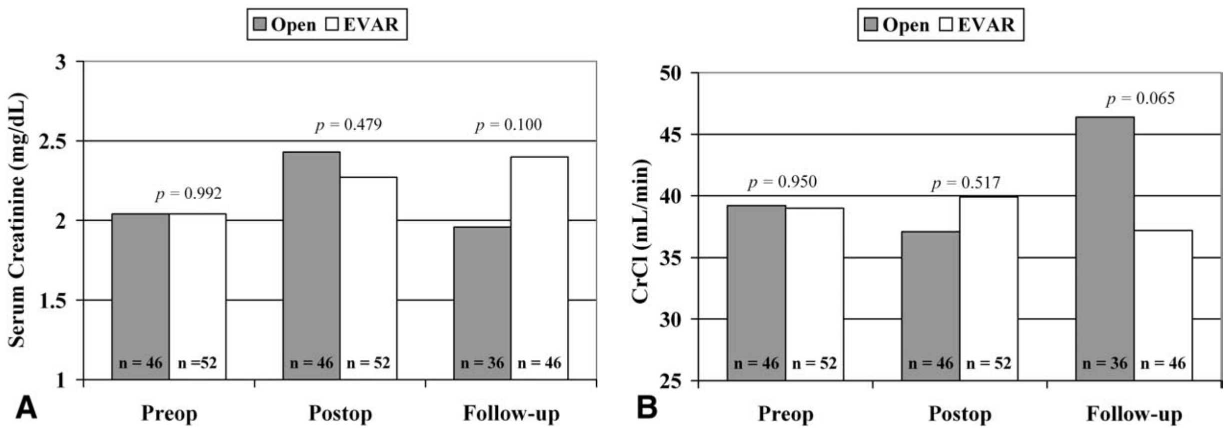

Fig. Bar graphs compare mean serum creatinine **(A)** and creatinine clearance *(CrCl)* **(B)** between patients with open and endovascular aneurysm repair *(EVAR)* during preoperative, postoperative, and follow-up time periods.

tion. Additionally, a subgroup analysis of those with preoperative renal insufficiency failed to demonstrate a statistical difference between suprarenal and infrarenal fixation in the development of renal impairment after EVAR.

In the current study, we compared the effect of EVAR and open repair on renal function in patients with preexistent renal insufficiency, a population particularly prone to complications. Several findings in this analysis that deserve further discussion.

Both patient populations were well matched for comorbid conditions and had similar aneurysm sizes and operative times (Table I), but the EVAR patients were significantly older than those with open repair. Although this may impact the data, because older patients tend to be more sensitive to renal insults, this finding is not surprising. Especially during the early experience, EVAR was typically reserved for the older, higher-risk patients. This trend is becoming less common because younger patients are now being treated with EVAR in increasing numbers.

In addition, the EVAR group included significantly fewer women. This is consistent with previous data that demonstrated that more than half of female patients fail to be candidates for EVAR, whereas approximately 70% of male patients qualify.[14] Although with continued innovation, EVAR devices and introduction sheaths are becoming lower in profile, many women continue to not qualify owing to access constraints from inadequate access vessel size.

Regarding renal function, this study failed to demonstrate any significant difference between EVAR and open patients with respect to changes in serum creatinine levels (Fig, *A*) or creatinine clearance (Fig, *B*) after aneurysm repair. There are, however, several interesting findings. Although these differences failed to reach statistical significance, a clear difference emerged in the pattern of changes in serum creatinine levels between groups.

In the open group, serum creatinine levels significantly increased in the postoperative period, but the average level returned over time to baseline (Table III). In contrast, the EVAR group had a progressive increase in serum creatinine levels in the postoperative and follow-up periods compared with preoperative levels, but these changes were not statistically significant (Table III). A similar trend was noted with respect to creatinine clearance in the open and EVAR groups (Table III). When examining the proportion of patients who developed significant renal impairment, defined as a rise in serum creatinine levels >30%, further insight into these differences can be seen.

During the immediate postoperative period, renal impairment developed in 11 open patients (23.9%), and eight (73%) recovered. Only an additional two patients developed late renal impairment, resulting in a renal impairment rate of 10.9% during long-term follow-up after open repair. From these data, it seems clear that despite the presence of multiple comorbid conditions, most patients undergoing open aneurysm repair are at greatest risk for renal impairment in the immediate postoperative period.

Although all effort was made to minimize perioperative renal insults, this likely represents the cumulative effect of renal insults occurring at the time of surgery, including ischemia during cross-clamping, embolic events, and hypotension. Six (13%) of the 46 open patients had renal artery stenosis; of these, two underwent bypass and three had endarterectomy at the time of the aneurysm repair. In addition, these patients are at higher risk than EVAR patients for developing postoperative hypotension, which could further impact renal function. Interestingly, however, the effects on renal function in most are relatively short lived and appear to be reversible.

In contrast, EVAR patients demonstrated a marked difference in the pattern of changes in renal function. Although renal impairment developed in only nine EVAR patients (17.3%) in the immediate postoperative period, only two (22%) recovered. During subsequent follow-up, significant renal impairment developed in an additional six EVAR patients, resulting in a follow-up rate of 25%, more than twice that seen with open repair, although not statistically significant ($P = .120$).

Because of the typical short hospital stay and much lower incidence of postoperative hypotension, renal impairment during the immediate postoperative period likely represents insults occurring intraoperatively. These causes are likely multifactorial, including a combination of contrast, mechanical, and atheroembolic sources.[15] These patients are routinely exposed to intravenous contrast dye during CT or, less commonly, catheter angiography during preoperative evaluation. Also, one of the 52 EVAR patients had significant bilateral renal artery stenosis requiring stent placement during aneurysm repair. Furthermore, during placement, self-expanding grafts are often partially deployed in the suprarenal position and pulled down the aorta into the final position. This maneuver may potentially dislodge aortic debris, resulting in atheroemboli into the renal vessels, as evidenced by renal infarction rates as high as 19% during EVAR.[16] Finally, many devices use balloon fixation of the proximal graft, which may temporarily occlude the renal vessels potentially resulting in thrombosis, embolus, or dissection.

Perhaps more concerning is that those who develop renal impairment seem to rarely recover after EVAR, and in addition, increased numbers of patients having undergone EVAR seem to be at continued risk for renal impairment during follow-up. This likely represents the cumulative effect of repeated contrast exposure during routine surveillance. This has been also suggested in previous studies.[8,13,17] Efforts to limit this effect include the use of magnetic resonance angiography (MRA) or duplex ultrasonography (DUS) as an alternative to CT angiography and should be considered, especially in those at high risk for developing contrast-induced nephropathy. Furthermore, with further development of pressure sensing devices, contrast-enhanced studies may be reduced or eliminated altogether. In the meantime, acetylcysteine[9] and sodium bicarbonate,[10] alone or in combination, should be used because they have been shown to decrease the incidence of contrast-induced nephropathy.

CONCLUSION

Open and endovascular repair of abdominal aortic aneurysms in patients with pre-existent renal insufficiency can be performed safely with preservation of renal function. Although with limited numbers perhaps making this study prone to a type II statistical error, in contrast to previous reports, there were no significant differences between open repair and EVAR in postoperative alterations in renal function. Perhaps more interesting, however, is the trend of changes in renal function in patients with baseline renal insufficiency that this study brings to light. Patients with renal insufficiency have a significant increase in serum creatinine levels postoperatively with open repair, but this appears to be transient. After EVAR, patients with preexisting renal insufficiency continue to be at risk for progressive renal dysfunction, and protective measures should be taken to preserve renal function in this patient population. In short, preoperative renal dysfunction alone should not exclude either approach.

AUTHOR CONTRIBUTIONS

Conception and design: SP, EW
Analysis and interpretation: SP, RF, JC, JK, OV, EW
Data collection: SP, JK, EW
Writing the article: SP, EW
Critical revision of the article: SP, RF, JC, JK, OV, EW
Final approval of the article: SP, RF, JC, JK, OV, EW
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