Ann Thorac Cardiovasc Surg 2022; 28: 278–285
Online April 7, 2022
doi: 10.5761/atcs.oa.21-00258

Original Article

Effects of Suprarenal Aortic Cross-Clamping and Adjunctive Renal Reconstruction on Outcomes of Open Abdominal Aortic Aneurysm Repair

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Purpose: To analyze our contemporary experience in open abdominal aortic aneurysm (AAA) repair. We focused on the effects of suprarenal (SR) aortic cross-clamping and adjunctive renal reconstruction (RR) on postoperative outcomes.
Methods: We retrospectively reviewed our institutional data of 141 consecutive patients who received elective open AAA repair between January 2014 and December 2020.
Results: Seventy-five procedures were performed with SR aortic cross-clamping, 20 of which required an adjunctive RR. Patients in the SR group had a higher incidence of postoperative acute kidney injury (AKI) (18.7% vs. 7.6%, P = 0.045). There were no significant between-group differences in other major complications. The 30-day mortality rate in the infrarenal (IR) and SR groups was 0% and 1.3%, respectively. After a median follow-up of 33 months, the rates of chronic renal decline in the IR (18.2%) and SR (21.3%) groups were similar. All reconstructed renal arteries were patent without reintervention. The 5-year overall survival rate in the IR and SR groups was 88.8% and 83.2%, respectively.
Conclusions: SR aortic cross-clamping was associated with postoperative AKI but neither SR aortic cross-clamping nor RR affected the long-term renal function or mortality. Open repair remains an essential option for patients with AAA, especially those with complex anatomy.

Keywords: abdominal aortic aneurysm, juxtarenal abdominal aortic aneurysm, suprarenal aortic cross clamping, renal artery reconstruction, renal function

Introduction

Over the last 30 years, endovascular aneurysm repair (EVAR) has developed and become the treatment of choice for the majority of patients with infrarenal (IR) abdominal aortic aneurysms (AAAs).

Several studies have reported that the application of EVAR resulted in a proportionate decrease in the overall volume of open AAA repairs, with a concomitant increase in the ratio of complex open AAA repairs that require suprarenal (SR) aortic cross-clamping with or without additional renal reconstruction (RR).[1,2] In order to provide appropriate treatment for complex AAAs in the endovascular era, a clear understanding of the contemporary results of open surgery must be established.

In this report, we describe our contemporary experience and the results of open AAA repair, focusing on the effects of SR aortic cross-clamping and adjunctive RR on postoperative outcomes.

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Materials and Methods

This was a single-center, retrospective study. The clinical data of consecutive patients who underwent AAA repair at Tsuchiura Kyodo General Hospital between January 2014 and December 2020 were collected. Type IV thoracoabdominal aneurysms were excluded from this study. Patients with preoperative end-stage renal disease and patients who underwent emergency surgery were also excluded. During the study period, 286 patients underwent elective AAA repair (endovascular repair, n = 145; open repair, n = 141).

At our institution, open repair was the first-line choice for elective AAA treatment. EVAR was performed for patients of >75 years of age with a high degree of surgical risk, unless the patient had unsuitable anatomy. EVAR was used with emphasis on adherence to the instruction for use of endografts pertaining to the proximal aortic neck.

Patients who underwent open AAA repair were divided into the IR and SR groups according to the location at which aortic cross-clamping was performed. The SR group also included patients who received inter-renal clamping. The SR group patients were further subcategorized according to whether they had adjunctive RR (SR + RR) or not (SR − RR). The patient demographics, comorbidities, intraoperative parameters, and relevant clinical and imaging outcomes were collected from their electronic medical records. This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. The ethics committee of Tsuchiura Kyodo General Hospital approved this study (reference number: 965).

All operations were performed through a midline transperitoneal approach under general anesthesia. SR aortic cross-clamping was performed for aneurysms with no (or a short) IR neck, which did not allow IR aortic cross-clamping (i.e., juxtarenal/pararenal AAA). The decision to perform adjunctive RR was based on the patient's arterial anatomy and the surgeon's preference. Adjunctive RR techniques included direct re-implantation of the renal artery or aortorenal bypass. In all cases, 50 U/kg of heparin was administered before cross-clamping of the aorta. For the patients who required SR aortic cross-clamping, we routinely administered mannitol (0.5 g/kg) before SR aortic cross-clamping. In selected cases in whom a prolonged renal artery clamp time was anticipated, the kidney was infused with 60 mL of 4°C heparinized saline.

Postoperative follow-up with laboratory tests and imaging by duplex ultrasound or computed tomography was performed at 3 months, 6 months, and 1 year after surgery, and then yearly thereafter.

The main outcome of the present study was procedure-related morbidity, all-cause mortality, and the change in the postoperative renal function. The preoperative renal function was estimated using the chronic kidney disease (CKD) staging system. The estimated glomerular filtration rate (eGFR) was calculated using the following formula: $eGFR\,(mL/min/1.73\,m^2) = 194 \times \text{serum creatinine}^{-1.094} \times age^{-0.287} \times 0.739$ (if female).[3]

The postoperative renal function during the hospital stay was evaluated using the risk, injury, failure, loss of function, and end-stage renal disease (RIFLE) criteria.[4] Patients who met the RIFLE criteria for the categories of risk, injury, and failure were defined as having acute kidney injury (AKI). Chronic renal decline (CRD) was defined as a sustained decline in eGFR of <60 mL/min/1.73 m^2 in patients without preoperative CKD (CKD stages 1 and 2) or an eGFR reduction of >20% in patients with preoperative CKD (stages 3 and 4).[5]

Statistical analyses

Continuous variables were expressed as the median value (interquartile range). The postoperative outcomes of the two groups were compared using the χ^2 test or Fisher's exact test for categorical data and the Mann–Whitney U test for continuous or original data. A survival analysis was performed with the Kaplan–Meier method. A Cox regression analysis was used to identify risk factors for CRD and long-term mortality.

All statistical analyses were performed using BellCurve for Excel (Social Survey Research Information Co., Ltd. Tokyo, Japan).

Results

From January 2014 to December 2020, 141 elective open AAA repairs were performed. A total of 66 (46.8%) elective open AAA repairs were performed with IR aortic cross-clamping and 75 (53.2%) were performed with SR aortic cross-clamping, 20 (26.7%) of which required an adjunctive RR. The SR group included 24 patients who received inter-renal clamping. Two patients in the RR group with stage 3 CKD underwent RR in order to treat renal artery stenosis. The patients' demographic factors and preoperative comorbidities are shown in **Table 1**. One hundred twenty-nine patients (91.5%)

were men, and the median age was 69 (64–75) years. The most prevalent comorbidity was hypertension (70.9%), followed by dyslipidemia (60.3%). There were 48 (34.0%) CKD patients. Patients in the SR group were older than those in the IR group (72 [65–76.5] vs. 67 [62–71], P = 0.009). The prevalence of coronary artery disease was higher in the SR group (37.3% vs. 16.7%, P = 0.006).

The operative details are shown in **Table 2**. The SR group had a longer operative time and greater blood loss in comparison to the IR group. The median renal ischemia time was 26.5 (23–31) minutes in the SR − RR group and 47 (37–66) minutes in the SR + RR group (P <0.001). The infusion of 4°C heparinized saline into the renal artery was used in six (4.3%) patients. Adjunctive RR procedures included renal artery reimplantation (n = 4) and aortorenal bypass (n = 16). Bilateral RRs were performed in five patients. All the grafts used for aortorenal bypass were 6 mm heparin-bonded expanded polytetrafluoroethylene (ePTFE) grafts (Gore Propaten; W. L. Gore & Associates, Flagstaff, AZ, USA).

Table 3 shows the early postoperative outcomes. Postoperative complications within 30 days were observed in 27.7% of all patients. In the IR and SR groups, major postoperative complications occurred in 18.2% and 36.0% of patients, respectively (P = 0.018). Overall, 19 (13.5%) patients had postoperative AKI.

Table 1 Demographics and preoperative comorbidities of the study population

	All subjects (n = 141)	IR group (n = 66)	SR group (n = 75)	P value	SR − RR (n = 55)	SR + RR (n = 20)	P value
Age, years	69 (64–75)	67 (62–71)	72 (65–76.5)	0.009	72 (65–76.5)	70.5 (65–75)	0.509
Male	129 (91.5)	59 (89.4)	70 (93.3)	0.548	51 (92.7)	19 (95.0)	0.597
Hypertension	100 (70.9)	51 (77.3)	49 (65.3)	0.119	31 (56.4)	18 (90.0)	0.005
Dyslipidemia	85 (60.3)	42 (63.6)	43 (57.3)	0.445	35 (63.6)	8 (40.0)	0.067
Diabetes mellitus	33 (23.4)	13 (19.7)	20 (26.7)	0.329	14 (25.5)	6 (30.0)	0.694
Coronary artery disease	39 (27.7)	11 (16.7)	28 (37.3)	0.006	21 (38.2)	7 (35.0)	0.801
Managed medically	18 (12.8)	7 (10.6)	11 (14.7)		7 (12.7)	4 (20.0)	
Treated with PCI/ CABG	21 (14.9)	4 (6.1)	17 (22.7)		14 (25.5)	3 (15.0)	
Cerebrovascular disease	24 (17.0)	9 (13.6)	15 (20.0)	0.316	13 (23.6)	2 (10.0)	0.164
COPD	38 (27.0)	13 (19.7)	25 (33.3)	0.069	19 (34.5)	6 (30.0)	0.675
CKD total	48 (34.0)	20 (30.3)	28 (37.3)	0.395	20 (36.4)	8 (40.0)	0.773
Stage 3	42 (29.8)	17 (25.8)	25 (33.3)		17 (30.9)	8 (40.0)	
Stage 4	4 (2.8)	2 (3.0)	2 (2.6)		2 (3.6)		
Stage 5	2 (1.4)	1 (1.5)	1 (1.3)		1 (1.8)		
Ever smoked	116 (82.3)	53 (80.3)	63 (84.0)	0.566	48 (87.3)	15 (75.0)	0.176
eGFR, mL/min/1.73 m^2	64.9 (52.7–76.3)	66.2 (56.6–77.0)	63.5 (49–74.8)	0.105	63.2 (51.3–72.7)	67.1 (46.2–80.7)	0.248

Data are expressed as number (percentage) or median value (interquartile range).

IR: infrarenal; SR: suprarenal; RR: renal reconstruction; PCI: percutaneous coronary intervention; CABG: coronary artery bypass grafting; COPD: chronic obstructive pulmonary disease; CKD: chronic kidney disease; eGFR: estimated glomerular filtration rate

Table 2 Operative details

	All subjects (n = 141)	IR group (n = 66)	SR group (n = 75)	P value	SR − RR (n = 55)	SR + RR (n = 20)	P value
Operation time, minutes	270 (226–327)	244 (204–310)	289 (250–339)	0.002	270 (239–301)	345.5 (304–380)	<0.001
Renal ischemia time, minutes	–	–	30 (24–42)		26.5 (23–31)	47 (37–66)	<0.001
Blood loss, mL	1417 (1033–2292)	1200 (790–2100)	1559 (1234–2371)	0.009	1410 (1177–2155)	2269 (1550–3630)	0.009

Data are expressed as median value (interquartile range).

IR: infrarenal; SR: suprarenal; RR: renal reconstruction

Table 3 The early postoperative outcomes

	All subjects (n = 141)	IR group (n = 66)	SR group (n = 75)	P value	SR − RR (n = 55)	SR + RR (n = 20)	P value
Postoperative hospital stay, days	10 (9–13)	9 (8–11)	11 (9–14)	0.017	10 (9–13)	12 (10–14)	0.179
Postoperative complications within 30-days							
Any[a]	39 (27.7)	12 (18.2)	27 (36.0)	0.018	17 (30.9)	10 (50.0)	0.128
AKI (RIFLE category)							
Risk	7 (5.0)	2 (3.0)	5 (6.7)		4 (7.3)	1 (5.0)	
Injury	9 (6.4)	2 (3.0)	7 (9.3)		2 (3.6)	5 (25.0)	
Failure	3 (2.1)	1 (1.5)	2 (2.7)		2 (3.6)		
AKI total	19 (13.5)	5 (7.6)	14 (18.7)	0.045	8 (14.5)	6 (30.0)	0.129
Heart failure	1 (0.7)	0 (0.0)	1 (1.3)	0.532	1 (1.8)	0 (0.0)	0.733
Arrhythmia	4 (2.8)	1 (1.5)	3 (4.0)	0.360	3 (5.5)	0 (0.0)	0.389
Pneumonia	5 (3.5)	2 (3.0)	3 (4.0)	0.561	1 (1.8)	2 (10.0)	0.172
Pulmonary embolism	2 (1.4)	2 (3.0)	0 (0.0)	0.217	0 (0.0)	0 (0.0)	1.00
Stroke	1 (0.7)	0 (0.0)	1 (1.3)	0.532	1 (1.8)	0 (0.0)	0.733
Lower limb ischemia	6 (4.3)	2 (3.0)	4 (5.3)	0.403	2 (3.6)	2 (10.0)	0.288
Type B aortic dissection	1 (0.7)	0 (0.0)	1 (1.3)	0.532	0 (0.0)	1 (5.0)	0.267
Paralytic ileus	4 (2.8)	1 (1.5)	3 (4.0)	0.360	3 (5.5)	0 (0.0)	0.389
Ischemic colitis	1 (0.7)	1 (1.5)	0 (0.0)	0.468	0 (0.0)	0 (0.0)	1.00
Pancreatitis	1 (0.7)	1 (1.5)	0 (0.0)	0.468	0 (0.0)	0 (0.0)	1.00
Wound infection	1 (0.7)	1 (1.5)	0 (0.0)	0.468	0 (0.0)	0 (0.0)	1.00
Postoperative mortality within 30 days	1 (0.7)	0 (0.0)	1 (1.3)	0.532	1 (1.8)	0 (0.0)	0.733

Data are expressed as number (percentage) or median value (interquartile range).

[a]The total number of complications listed exceeds this number because some patients had more than one complication.

IR: infrarenal; SR: suprarenal; RR: renal reconstruction; AKI: acute kidney injury; RIFLE: risk, injury, failure, loss of function, and end-stage renal disease

Patients in the SR group had a higher incidence of AKI than those in the IR group (18.7% vs. 7.6%, P = 0.045). Patients in the SR + RR group had the highest incidence of AKI (30.0%), but there was no significant difference between the SR − RR and SR + RR groups. Other than AKI, there were no significant between-group differences in other major complications. Two patients (1.4%), one each in the IR and SR − RR groups, temporarily required hemodialysis after surgery.

The 30-day postoperative mortality rate was 0.7% (n = 1) for all patients (IR, 0% vs. SR, 1.3%, P = 0.532). Only one patient in the SR − RR group, who was known to have coronary artery disease, which had been managed by medical treatment, died of ventricular arrhythmia soon after being discharged.

Table 4 shows the late postoperative outcomes. The median follow-up period was 33 (19–53) months. During follow-up, CRD occurred in 19.9% of all patients. The last available eGFR was lower in the SR group (IR, 63.8 [50.3–72.7] vs. SR, 55.0 [42.6–67.9], P = 0.022), but the rates of CRD in the IR and SR groups were similar (18.2% vs. 21.3%, P = 0.129). Two patients, one each in the IR and SR − RR groups, required permanent hemodialysis during follow-up. Both patients had baseline stage 5 CKD. One of these patients in the IR group, whose preoperative serum creatinine level was 5.05 mg/dL, required permanent hemodialysis at 12 months after surgery. The other patient required permanent hemodialysis at 6 months after surgery; his preoperative serum creatinine level was 3.37 mg/dL. Neither patient required temporary hemodialysis after surgery. In the follow-up period, all reconstructed renal arteries were patent without reintervention. The two patients who underwent RR in order to treat renal artery stenosis exhibited an unchanged renal function. The 1-year overall survival rates in the IR and SR groups were 98.4% and 93.3%, respectively, while the 5-year overall survival rates were 88.8% and 83.2%, respectively. The most common causes of death were cardiovascular events (33.3%, n = 5), cancer (26.7%, n = 4), and respiratory infection

Table 4 The late postoperative outcomes

	All subjects (n = 141)	IR group (n = 66)	SR group (n = 75)	P value	SR − RR (n = 55)	SR + RR (n = 20)	P value
Follow-up, months	33 (19–53)	36 (19–60)	31 (19–50)	0.399	29 (18–51)	43 (23–50)	0.303
Last available eGFR	61.0 (46.5–69.9)	63.8 (50.3–72.7)	55.0 (42.6–67.9)	0.022	59.2 (42.0–68.8)	53.2 (43.8–62.2)	0.672
Chronic renal decline	28 (19.9)	12 (18.2)	16 (21.3)	0.129	11 (20.0)	5 (25.0)	0.867
Renal failure requiring hemodialysis	2 (1.4)	1 (1.5)	1 (1.3)	0.719	1 (1.8)	0 (0.0)	0.733
Death during follow up	15 (10.6)	5 (7.6)	10 (13.3)	0.291	8 (14.5)	2 (10.0)	0.540

Data are expressed as number (percentage) or median value (interquartile range).
IR: infrarenal; SR: suprarenal; RR: renal reconstruction; eGFR: estimated glomerular filtration rate

Table 5 Perioperative risk factors for chronic renal decline and long-term mortality

Risk factor	Chronic renal decline		Long-term mortality	
	HR (95% CI)	P value	HR (95% CI)	P value
Age	1.07 (1.02–1.12)	0.009	1.07 (0.99–1.14)	0.057
Diabetes mellitus	1.69 (0.76–3.75)	0.195	1.22 (0.39–3.84)	0.731
Coronary artery disease	2.38 (1.13–5.02)	0.022	4.10 (1.46–11.52)	0.007
COPD	1.13 (0.51–2.50)	0.766	0.88 (0.28–2.77)	0.830
CKD	1.83 (0.87–3.85)	0.113	3.93 (1.34–11.51)	0.012
SR aortic cross-clamping	1.44 (0.67–3.08)	0.352	1.79 (0.61–5.24)	0.287
Adjunctive RR	1.44 (0.54–3.83)	0.462	0.84 (0.19–3.72)	0.816
Renal ischemia time >50 minutes (vs. <50 minutes)	1.26 (0.38–4.18)	0.711	0.65 (0.09–4.97)	0.681
Postoperative AKI	7.63 (3.43–16.97)	<0.001	2.44 (0.78–7.67)	0.127

HR: hazard ratio; CI: confidential interval; COPD: chronic obstructive pulmonary disease; CKD: chronic kidney disease; SR: suprarenal; RR: renal reconstruction; AKI: acute kidney injury

(26.7%, n = 4). Age, history of coronary artery disease, and postoperative AKI were significant predictors of CRD. A history of coronary artery disease and preoperative CKD were significant predictors of long-term mortality (**Table 5**). Neither SR aortic cross-clamping nor adjunctive RR was associated with CRD and long-term mortality.

Discussion

This study investigated the contemporary trends in open AAA repair and also highlighted the effects of SR aortic cross-clamping and adjunctive RR on postoperative outcomes. At our institution, more than half of open AAA repairs were performed with SR aortic cross-clamping during the study period and 14.2% of all patients, namely 26.7% of patients in the SR group, required adjunctive RR. These rates were much higher in comparison to the rates reported in the relevant literature. The high SR aortic cross-clamping and RR rates may be a reflection of the increased anatomical complexity of the AAAs encountered in a regional referral center, and may also reflect our open-first treatment strategy for juxtarenal/pararenal AAAs.

Early studies demonstrated that, in comparison to IR AAAs, open repair of juxtarenal/pararenal AAAs was associated with an increased risk of operative morbidity and mortality.

A large series of patients undergoing juxtarenal AAA repair was first reported in 1986 by Crawford et al.[6] They reported an operative mortality rate of 7.9% with new-onset hemodialysis in 7.9% of patients.

Since the late 2000s, improved outcomes have been reported. In 2009, Chong et al.[7] reported that the patients

who required SR cross-clamping during open AAA repair had an operative mortality rate of 1.8%, which was similar to the rate of 1.1% that they observed after IR AAA repairs. More recently, Chaufour et al.[8] reported that the operative mortality rate following open juxtarenal AAA repair in French high-volume centers was 0.9%.

In the present study, the operative mortality rate of the SR group was 1.3%, and there was no significant difference between the IR and SR groups. Our results support the recent findings that open juxtarenal/pararenal AAA repair can be performed with low mortality, similar to standard IR open AAA repair.

Regarding postoperative complications, AKI is reported to be the most frequent complication after open repair for juxtarenal/pararenal AAAs.[1,6,8,9] Also, cardiac and pulmonary complications are common and can be life-threatening.[9] In the present study, AKI was the most common early postoperative complication and—as would be expected—patients requiring SR aortic cross-clamping had a significantly greater postoperative AKI rate. The prevalence of AKI in the SR group observed in the present study (18.7%) was similar to recently published data for patients who underwent open juxtarenal AAA repair.[8] The effect of SR aortic cross-clamping on postoperative AKI was not negligible; however, recovery or partial recovery was observed by the time of hospital discharge, except for one patient who required temporary hemodialysis in association with multiple complications. It is important to note that, in our series, SR aortic cross-clamping was not associated with an increased need for postoperative hemodialysis or increased rates of other postoperative complications.

The safe renal ischemia time during open AAA repair is commonly accepted to be 45–50 minutes.[10,11] Wahlberg et al.[11] reported that the risk of transient renal dysfunction in patients with a renal ischemia time of >50 minutes is 10 times higher than that in patients with a renal ischemia time of <25 minutes; however, there was no significant difference in the development of transient renal dysfunction between patients with a renal ischemia time of 26–50 minutes and those with a renal ischemia time of >50 minutes. In the present study, although the renal ischemia time was longer in the SR + RR group (47 [37–66] minutes) in comparison to that in the SR – RR group (26.5 [23–31] minutes), the rates of AKI did not differ to a statistically significant extent. This suggests that there was little clinically significant difference in the effect—in terms of the postoperative renal function—of a renal ischemia time of approximately 30 minutes and that of a maximum acceptable duration of 50 minutes. Another possible reason for our results is that infusion of 4°C saline into the renal artery performed in selected cases was effective for preventing postoperative renal dysfunction in patients with a long renal ischemia time.

To achieve durable outcomes of juxtarenal/pararenal AAA repair, the techniques involved in RR are important. Some studies indicated that performing adjunctive RR during open AAA repair was associated with an increased risk of operative morbidity and mortality.[12] In contrast, others reported the feasibility of simultaneous renal and aortic reconstruction because they found similar outcomes to IR aortic repair.[13]

In the present study, zero operative mortality and the long-term preservation of the renal function—or a mildly decreased but stable renal function—were achieved in patients who received adjunctive RR, suggesting the safety of adjunctive RR during open AAA repair. At our institution, bypass with a heparin-bonded ePTFE graft is now the first choice of RR procedure[14] and a 100% primary patency was achieved during a median follow-up period of 43 months, which may help improve the outcomes and long-term durability of complex AAA repairs.

EVAR with the use of aortic branch preservation techniques, represented by fenestrated EVAR and chimney EVAR, is now a widely recognized alternative for the treatment of complex AAAs and can offer fewer postoperative complications.[15] However, despite the clear advantages as a minimally invasive procedure, they are not entirely devoid of risks and potential complications. Reports regarding fenestrated EVAR and chimney EVAR have shown 30-day mortality rates of 1%–4%,[16,17] branch loss rates of 3%–10%,[16,18] and 5-year reintervention-free survival rates of 50%–84%.[17,19] In addition, these options can be limited by device availability.

Our results and the results from recent studies on open repair compare favorably with those of complex EVAR in terms of operative morality and long-term durability. However, at a very fundamental level, studies on EVAR have included a certain proportion of patients who were not candidates for open repair because of medical comorbidity, and it is therefore difficult to directly compare outcomes across studies.

The present study demonstrated that the 5-year survival rate after open AAA repair requiring SR aortic

cross-clamping was 83.2%. Even though 37.3% patients in the SR group had coronary artery disease and 33.3% had chronic obstructive pulmonary disease, a satisfactory result was achieved.

The decision on how to treat a complex AAA may not always be clear cutoff and should be tailored to each patient. In the authors' opinion, open repair is a preferable option for patients without severe comorbidities, especially those with long life expectancy. Our results indicated that coronary artery disease adversely affected the postoperative survival outcomes. To optimize the benefits of open AAA repair, strict surveillance and optimal medical therapy, especially in patients with known coronary artery disease, are important. Therefore, follow-up not only with a vascular surgeon but also with a primary care physician or a cardiologist should be considered. We also found a relatively high prevalence of CRD (19.9%), regardless of the use of SR aortic cross-clamping. This emphasizes the importance of postoperative regular follow-up and cardiovascular risk management.

The present study was associated with some limitations, including its retrospective single-center design. Other factors, such as our indications for open repair and progress in perioperative management, may have influenced the better treatment outcomes in comparison to earlier studies. Nevertheless, the results of the present study provide insights into the current status and clinical benefit of open AAA repair in the era of endovascular repair.

Conclusions

This study showed that SR aortic cross-clamping during open AAA repair was associated with postoperative AKI but did not increase other complications or mortality. Adjunctive RR was safe and durable over a long period of time. Open repair remains an essential option for patients with AAA, especially those with complex anatomy in contemporary practice.

Disclosure Statement

All authors have no conflicts of interest.

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