ORIGINAL ARTICLE

Perioperative Renal Function Following Suprarenal Aortic Cross-Clamping Without Renal Perfusion in Open Surgical Repair for Juxtarenal Abdominal Aortic Aneurysm

Titi Saichuea, MD[1], Nuttapon Susaengrat, MD[2], Jarruprot Tuangsirisup, MD[2], Pak Hanaroonsomboon, MD[2]

[1] Division of Vascular Surgery, Department of Surgery, Roi Et Hospital, Roi Et, Thailand; [2] Division of Vascular Surgery, Department of Surgery, Khon Kaen Hospital, Khon Kaen, Thailand

Background: In the surgical treatment of juxtarenal abdominal aortic aneurysm (JAAA) using the open surgical repair (OSR) approach, suprarenal aortic cross-clamping is necessary. However, the utilization of this clamp may affect renal function.

Objective: To evaluate the impact of suprarenal aortic cross-clamping without intraoperative renal artery perfusion on JAAA and its subsequent impact on perioperative renal function by analyzing mean differences in creatinine levels and the estimated glomerular filtration rate (eGFR).

Materials and Methods: Between January 2017 and December 2023, the author included 19 patients diagnosed with JAAA who underwent OSR utilizing a suprarenal aortic cross-clamping without intraoperative renal artery perfusion. The analysis focused on perioperative renal function outcomes.

Results: The average renal ischemic time was 29.6±5.9 minutes. Postoperatively, the mean differences in creatinine between the preoperative period, which was 1.13±0.51 mg/dL and the seventh postoperative day, which was 1.28±1.05 mg/dL, was 0.151 mg/dL (95% CI –0.297 to 0.598, p=0.510), and the mean differences in creatinine between the preoperative period, which was 1.13±0.51 mg/dL, and the thirtieth postoperative day, which was (1.17±0.63 mg/dL) were 0.041 mg/dL (95% CI –0.250 to 0.332, p=0.782). Regarding the average mean differences in eGFR between the preoperative period, which was 72.26±24.63 mL/min/1.73 m^2 and the seventh postoperative day, which was 72.84±26.20 mL/min/1.73 m^2, was 0.579 mL/min/1.73 m^2 (95% CI –9.869 to 11.027, p=0.915). Similarly, the average mean differences in eGFR between the preoperative period, which was 72.26±24.63 mL/min/1.73 m^2 and the thirtieth postoperative day, which was 72.26±24.47 mL/min/1.73 m^2 was 0.00 mL/min/1.73 m^2 (95% CI –9.412 to 9.412, p=1.000).

Conclusion: The suprarenal aortic cross-clamping without intraoperative renal artery perfusion can be utilized in the OSR for JAAA without causing harmful effects on renal function. However, minimizing renal ischemia duration remains crucial to reducing the risk of complications.

Keywords: Juxtarenal abdominal aortic aneurysm; Suprarenal aortic cross-clamping; Intraoperative renal perfusion; Renal ischemic time

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Abdominal aortic aneurysm (AAA) is a common and potentially life-threatening condition. Without repair, ruptured AAA is fatal. Of the 50% of patients with ruptured AAA who reach the hospital for treatment, between 50% and 80% will die in the hospital[1,2]. As of 2019, the global prevalence of AAA among individuals aged 30 to 79 years was approximately 0.92%, corresponding to an estimated 35.12 million cases worldwide. Epidemiological studies reveal a steadily increasing incidence of AAA worldwide, with annual growth rates ranging from 4.2% to 11%[3,4].

The most widely accepted definition of AAA is based on the diameter of the abdominal aorta, defined as a diameter of 3.0 cm or more, which is typically more than two standard deviations above the mean diameter for men, whereas a lower threshold is generally considered for women and patients of Asian ethnicity[5,6]. Repair is recommended for symptomatic, complicated, and asymptomatic fusiform AAAs with a diameter of 5.5 cm in males and 5.0 cm in females. It is also advised for AAAs with rapid expansion of 1 cm per year. Saccular AAAs are typically repaired at smaller diameters. However, specific size guidelines are unavailable

Correspondence to:

Saichuea T.

Division of Vascular Surgery, Department of Surgery, Roi Et Hospital, 111, Ronnachaichanyut Road, Muang Roi Et, Roi Et 45000, Thailand.

Phone & Fax: +66-43-518200

Email: Dr.saichuea@gmail.com

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due to their rarity[7,8]. Currently, AAA repair options include endovascular aneurysm repair (EVAR) and open surgical repair (OSR). EVAR is associated with a significant reduction in perioperative mortality and morbidity compared to OSR in the treatment of AAA. However, this benefit decreases over time due to increased reinterventions and late aneurysm ruptures following endovascular repair[9].

Complex AAAs are estimated to constitute about 15% to 20% of all AAAs. Juxtarenal abdominal aortic aneurysm (JAAA) is one of the complex AAA groups. The gold standard for treating JAAA depends on several factors, including the patient's overall health, the anatomy of the aneurysm, and the risk of rupture. The two main treatment options are OSR and EVAR, with fenestrated or branched endografts being key advancements for JAAA. OSR remains the traditional gold standard for JAAA, especially for anatomically complex aneurysms. It is preferred in healthy patients. OSR may be preferred for long-term durability. EVAR remains the alternative gold standard for JAAA using fenestrated endografts while branched devices are increasingly recognized as the gold standard for high-risk patients or those unsuitable for OSR[10-12].

In OSR for JAAA, aortic cross-clamping above one or both the renal arteries, with selective clamping of the renal arteries below the aortic clamp, may be required. Selective renal perfusion can be performed through an occlusion or perfusion catheter inserted from inside the aorta. The temporary aortic cross-clamping proximal to the renal arteries induces renal ischemia and reperfusion, causing acute kidney injury and deterioration in renal function in up to 40% of patients[13]. However, studies have found that performing suprarenal aortic cross-clamping without renal hypothermia is safe and well-tolerated by patients during elective AAA surgery[14].

In the present study, the author evaluated the impact of a suprarenal aortic cross-clamping without intraoperative renal artery perfusion on JAAA and its subsequent effect on perioperative renal function.

Material and Methods

Ethics approval

The present study was conducted in accordance with the principles of the Declaration of Helsinki and Good Clinical Practice guidelines. The study was approved by Ethics Committee of Khon Kaen Hospital, Khon Kean, Thailand on 24 November 2024 (KEXP67006).

Study design

The present study was a retrospective review of 19 patients diagnosed with JAAA underwent OSR between January 2017 and December 2023 at the Vascular Unit, Department of Surgery, Khon Kaen Hospital, Thailand. All patients underwent a single or bilateral suprarenal aortic cross-clamping procedure without intraoperative renal artery perfusion. The authors excluded patients younger than 18 years, intraoperative or perioperative mortality, chronic kidney disease (CKD) stage 5, and end-stage renal disease (ESRD).

Surgical procedures

OSR was performed under general anesthesia. A transperitoneal approach with a midline incision was applied in all cases. The positions of proximal clamps were decided based on the anatomy of the aneurysmal neck. Preoperative computed tomography images were reviewed carefully to choose the best clamping positions for preventing embolization owing to mural thrombus. The left renal vein (LRV) was divided, if necessary, for approaching the proximal neck, and the divided LRV was not reconstructed.

Following systemic heparinization at 80 to 100 IU/kg, single or bilateral renal arteries were controlled with double vascular loops and vascular clamps, and local heparin solution was flushed into the renal arteries before clamping. A single or bilateral suprarenal aortic cross-clamp was then applied. In cases of ruptured JAAA, systemic heparinization was omitted. The renal artery was not perfused, and no specific renal protective measures, such as selective renal perfusion or cooling, were implemented during the interruption of renal perfusion.

The aneurysm was opened via a longitudinal aortotomy, which transitions to a T-shaped incision at the proximal and distal ends to allow for the graft anastomosis. Thrombus was cleared from the aneurysm sac, and back-bleeding lumbar vessels were identified and ligated with sutures. The proximal anastomotic site was cleared of thrombus and calcium, and an end-to-end anastomosis was performed with a running polypropylene suture. Upon completion of the proximal anastomosis, the aortic clamps were repositioned to the infrarenal arteries, and renal perfusion was restored. The distal reconstruction was performed similarly, using either straight or bifurcated knitted Dacron grafts.

Definitions and variables

Preoperative demographic and clinical variables included gender, body mass index (kg/m²), current smoking status, hypertension, diabetes mellitus, CKD, dyslipidemia, chronic obstructive pulmonary disease (COPD), cerebrovascular disease, American Society of Anesthesiologists (ASA) physical status classification, and ruptured or non-ruptured JAAA. Operative details included operative time (minutes), suprarenal aortic cross-clamping time (minutes), location of suprarenal aortic cross-clamping, LRV ligation, total clamping time (minutes), aortic graft type, distal anastomosis, and estimated blood loss (liters). Perioperative outcomes included creatinine levels (mg/dL) and the estimated glomerular filtration rate (eGFR), calculated using the CKD-EPI (2021) formula. Blood chemistry was obtained on postoperative days 0, 1, 3, 5, 7, and during follow-up on day 30.

Outcome

The primary outcome measure was perioperative renal function after OSR for JRAA. As a secondary outcome, this study evaluated perioperative renal function associated with suprarenal cross-clamping in terms of suprarenal clamp time at less than 30 minutes and more than 30 minutes, the location of the suprarenal cross-clamping with single or bilateral suprarenal clamp, and the effect of LRV ligation with or without LRV ligation.

Statistical analysis

Continuous data with normal distributions were expressed as the means and standard deviation. Medians and interquartile ranges (IQRs) were used for other continuous data. Categorical data were presented as percentages. The statistical analysis compared preoperative and perioperative data, using repeated measures ANOVA followed by post hoc analysis with the least significant difference (LSD) method for normally distributed data, while the Friedman test and the Wilcoxon signed-ranks test were applied for non-normally distributed data. When comparing two groups, an independent t-test was used for normally distributed data, whereas the Mann-Whitney U test was used for non-normally distributed data.

A p-value of less than 0.05 was considered significant for all analysis. All statistical analyses were performed using IBM SPSS Statistics, version 27.0 (IBM Corp., Armonk, NY, USA).

Results

During the study period, 37 consecutive surgical JAAA repairs were performed. Of these, 26 patients underwent OSR, and 11 underwent EVAR, with 19 patients meeting the inclusion criteria. Seven patients were excluded from the study. Among these patients, two with ruptured JAAA died due to severe pneumonia and myocardial infarction. Three patients underwent renal perfusion procedures during OSR, one had ESRD, and one was lost to follow-up at 30 days.

The mean age of 19 patients was 71.2±6.15 years at the time of the operation. Fifteen patients (78.9%) were male, and four (21.1%) were female. The average maximum diameter of JAAA was 60±5 mm. Sixteen patients (84.2%) were diagnosed with non-ruptured JAAA, while three (15.8%) were diagnosed with ruptured JAAA. Patient demographics and clinical characteristics are summarized in Table 1.

The mean operative times were 225.47±40.67 minutes. The average total suprarenal aortic cross-clamping time as renal ischemic time and total clamps times were 29.58±5.93 minutes and 65.84±14.29 minutes, respectively. The single and bilateral suprarenal aortic cross-clamping technique was

Table 1. Baseline characteristics of patients

Characteristics	n=19
Age (years); mean±SD	71.21±6.15
Sex; n (%)	
Male	15 (78.9)
Female	4 (21.1)
BMI (kg/m²); mean±SD	21.95±3.59
Smoking; n (%)	9 (47.4)
Comorbidities; n (%)	
Diabetes mellitus	4 (21.1)
Hypertension	9 (47.4)
Chronic kidney disease (CKD)	
• CKD stage 1, 2	13 (68.4)
• CKD stage 3, 4	6 (31.6)
Dyslipidemia	3 (15.8)
COPD	1 (5.3)
Cerebrovascular disease	1 (5.3)
Maximum JAAA diameter (mm); mean±SD	60±5
Diagnosis; n (%)	
Non-rupture JAAA	16 (84.2)
Ruptured JAAA	3 (15.8)
ASA classification; n (%)	
Class 2-3	12 (63.2)
Class 4-5	7 (16.8)
Length of hospital stay; median (IQR)	13 (12 to 16)

SD=standard deviation; IQR=interquartile range; BMI=body mass index; COPD=chronic obstructive pulmonary disease; JAAA=juxtarenal abdominal aortic aneurysm; ASA=American Society of Anesthesiologists

Table 2. Operative details

Characteristics	n=19
Operative time (minutes); mean±SD	225.47±40.67
Suprarenal aortic cross clamp time (minutes); mean±SD	29.58±5.93
Location; n (%)	
Single suprarenal cross clamp	6 (31.6)
Bilateral suprarenal cross clamp	13 (68.4)
Left renal vein ligation; n (%)	
Yes	9 (43.4)
No	10 (52.6)
Total aortic clamp time (minutes); mean±SD	65.84±14.29
Aortic graft; n (%)	
Bifurcated graft	11 (57.9)
Tube graft	8 (42.1)
Distal anastomosis; n (%)	
Abdominal aorta	8 (42.1)
Common iliac artery	9 (43.4)
External iliac artery	2 (10.5)
Estimated blood loss (liters); mean±SD	1.7±1.0

SD=standard deviation

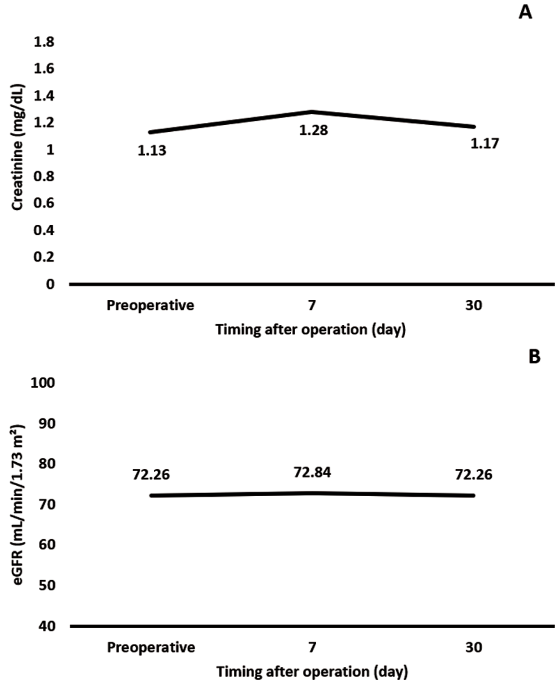

Figure 1. The average mean differences in creatinine (A) and eGFR (B), when compared between preoperative period and postoperative, showed a slight increase at the 7th postoperative day and returned to baseline at the 30th postoperative day, with no statistically significant difference.

applied in six patients (31.6%) and thirteen patients (68.4%), respectively. Ligation and division of the LRV were performed in nine patients (43.4%). The bifurcated aortic graft and tube graft was used to reconstruction eleven patients (57.9%) and eight patients (42.1%), respectively. Operative details are summarized in Table 2.

After surgery, the mean differences in creatinine levels between the preoperative period at 1.13±0.51 mg/dL and the seventh postoperative day at 1.28±1.05 mg/dL was 0.151 mg/dL (95% CI –0.297 to 0.598, p=0.510). The mean differences in creatinine between the preoperative period at 1.13±0.51 mg/dL, and the thirtieth postoperative day at 1.17±0.63 mg/dL, was 0.041 mg/dL (95% CI –0.250 to 0.332, p=0.782). The mean differences in creatinine levels between the preoperative and postoperative measurements showed a slight increase on the seventh postoperative day but returned to baseline by the thirtieth postoperative day, with no statistically significant difference (Table 3, Figure 1A).

Regarding the mean differences in eGFR between the preoperative period, which was 72.26±24.63 mL/min/1.73 m², and the seventh postoperative day, which was 72.84±26.20 mL/min/1.73 m², was 0.579 mL/min/1.73 m² (95% CI –9.869 to 11.027, p=0.915). Similarly, the mean differences in eGFR between the preoperative period, which was 72.26±24.63 mL/min/1.73 m², and the thirtieth postoperative day, which was 72.26±24.47 mL/min/1.73 m², was 0.00 mL/min/1.73 m² (95% CI –9.412 to 9.412, p=1.000). The mean differences in eGFR between the preoperative and postoperative measurements showed a slight increase on the seventh postoperative day but retuned to baseline by the thirtieth postoperative day, with no statistically significant difference (Table 3, Figure 1B).

The secondary outcome was to evaluate perioperative renal function by comparing several factors, including the duration of suprarenal cross-clamping at less than 30 minutes versus more than 30 minutes, the location of the cross-clamp with single or bilateral suprarenal, and the impact of LRV ligation without reconstruction compared to preserving the LRV. The mean differences in creatinine and eGFR between several factors were not statistically significant across all groups (Table 4).

Discussion

JAAA, a subgroup of complex AAAs that account for 15% to 20% of all AAAs, require individualized treatment based on patient health, aneurysm anatomy, and surgical risk. OSR remains the traditional first-line treatment, especially for patients in good health and with low surgical risk,

Table 3. Perioperative renal function outcomes after OAR for JAAA

Outcome (n=19)	Mean±SD	Differences		p-value
		Mean	95% CI	
Creatinine (mg/dL)				
Preoperative	1.13±0.51	Reference		
7th postoperative day	1.28±1.05	0.151	–0.329 to 0.630	0.510
30th postoperative day	1.17±0.63	0.041	–0.271 to 0.353	0.782
eGFR (mL/minute/1.73 m²)				
Preoperative	72.26±24.63	Reference		
7th postoperative day	72.84±26.20	0.579	–10.621 to 11.778	0.915
30th postoperative day	72.26±24.47	<0.001	–10.088 to 10.088	1.000

SD=standard deviation; CI=confidence interval; eGFR=estimated glomerular filtration rate
p-value from repeated measurement ANOVA and post hoc multiple comparisons: LSD, * Significant at p<0.05

Table 4. Secondary outcomes

	Mean±SD	Mean±SD	Differences between group		
			Mean	95% CI	p-value
Suprarenal clamp duration (minutes)	≤30 (n=11)	>30 (n=8)			
Creatinine (mg/dL)					
• Preoperative	1.03±0.36	1.27±0.68	–0.24	–0.746 to 0.269	0.339
• Postoperative 7 days	1.36±1.36	1.17±0.44	0.42	–0.556 to 1.404	0.836
• Postoperative 30 days	1.23±0.77	1.10±0.40	0.36	–0.263 to 0.988	0.967
eGFR (mL/minute/1.73 m²)					
• Preoperative	74.45±19.66	72.00±31.46	5.21	–19.499 to 29.908	0.662
• Postoperative 7 days	73.91±28.55	71.38±24.42	–2.67	–26.071 to 20.730	0.813
• Postoperative 30 days	71.36±25.85	73.50±24.11	–7.34	–28.119 to 13.437	0.710
Suprarenal clamp location	Single (n=6)	Bilateral (n=13)			
Creatinine (mg/dL)					
• Preoperative	1.25±0.81	1.08±0.34	0.17	–0.676 to 1.014	0.640
• Postoperative 7 days	1.85±1.74	1.02±0.41	0.66	–1.188 to 2.512	0.053
• Postoperative 30 days	1.34±1.02	1.10±0.38	0.08	–1.181 to1.338	0.135
eGFR (mL/minute/1.73 m²)					
• Preoperative	72.83±37.23	72.00±18.23	0.83	–38.152 to 39.819	0.960
• Postoperative 7 days	60.83±34.21	78.38±20.89	–18.39	–55.688 to 18.918	0.065
• Postoperative 30 days	71.33±34.05	72.69±20.35	–2.192	–41.232 to 36.847	0.114
Left ranal vein ligation	Yes (n=9)	No (n=10)			
Creatinine (mg/dL)					
• Preoperative	1.06±0.40	1.20±0.61	–0.14	–0.644 to 0.372	0.580
• Postoperative 7 days	1.51±1.47	1.08±0.44	0.57	–0.378 to 1.520	0.540
• Postoperative 30 days	1.26±0.84	1.10±0.39	0.29	–0.334 to 0.921	0.902
eGFR (mL/minute/1.73 m²)					
• Preoperative	72.78±21.84	71.8±28.08	0.98	–23.586 to 25.541	0.934
• Postoperative 7 days	68.11±27.87	77.1±25.29	–9.97	–32.577 to 12.643	0.365
• Postoperative 30 days	70.89±26.73	73.5±23.63	–3.59	–24.387 to 17.209	0.653

SD=standard deviation; CI=confidence interval; eGFR=estimated glomerular filtration rate
p-value from independent t-test or Mann-Whitney U-test, * Significant at p<0.05

due to the aneurysm's proximity to the renal arteries. OSR for JAAAs often involves aortic cross-clamping above one or both renal arteries, with selective clamping of the renal arteries when necessary[12,15]. Insufficient postoperative renal function is a common complication of suprarenal cross-clamping during

OSR, often caused by ischemia-induced acute tubular necrosis. Research suggests that selective renal artery perfusion, performed using a perfusion catheter inserted into the aorta, can reduce the risk of renal insufficiency. However, studies indicate that renal perfusion may not always be necessary[12,14,16].

The present study found that perioperative renal function after suprarenal aortic cross-clamping without renal artery perfusion during OSR for JAAA can be effectively managed, particularly in patients with eGFR of approximately 72 mL/min/1.73 m² or CKD stage 1 or 2 and renal ischemic times of around 30 minutes. In the early postoperative period, acute kidney injury may occur, typically presenting as a slight increase in creatinine levels and a decrease in eGFR during the first or second week. However, these parameters usually return to baseline approximately 30 days after surgery. Additionally, the present study findings suggest that for patients with CKD stages 3 or 4, renal artery perfusion may not be necessary, though further studies in this specific subgroup are warranted.

This finding is consistent with the study by Kudo et al., which demonstrated that suprarenal aortic cross-clamping without renal hypothermia is safe and well-tolerated by patients undergoing elective AAA surgery. However, it emphasizes the importance of carefully limiting the duration of renal ischemia[14]. Additionally, the findings align with those of Rosenfeld et al., who reported that in elective OSR for JAAA, suprarenal clamping does not impact perioperative renal function in patients with normal baseline renal function[16].

In the secondary outcomes, perioperative renal function was compared across different patient groups based on the duration of suprarenal cross-clamping at less than 30 minutes versus more than 30 minutes, the location of the cross-clamp with single versus bilateral suprarenal, and the impact of LRV ligation without reconstruction compared to preserving the LRV.

The study found that the factors compared had no statistically significant impact on changes in perioperative renal function outcomes. A previous study by O'Donnell et al. investigated the duration of suprarenal clamp time and found that a suprarenal clamp time of approximately 25 minutes did not significantly affect perioperative renal function outcomes[17]. In the present study, the suprarenal clamp time was approximately 30 minutes.

Concerning the location of the cross-clamp with single or bilateral suprarenal, the present study also found no significant effect on perioperative renal function, which is consistent with the findings of Varkevisser et al. They concluded that there was no difference between clamping above one versus both renal arteries during OSR for JAAA[18].

Additionally, the impact of LRV ligation without reconstruction showed no effect on perioperative renal function outcomes, consistent with the study by Sugimoto et al., who found no significant impact of LRV division on chronic renal disease in OSR for JAAA[19].

Although the study results showed no significant differences across all CKD stages, most patients were in CKD stages 1 or 2. Therefore, the findings should primarily be applied to patients in CKD stages 1 or 2. Future studies should stratify participants accordingly and explore each specific aspect in greater detail.

Limitation

The present study has limitations, including its retrospective design, the fact that it was conducted at a single hospital, and the small sample size. These factors may affect the validity of the conclusions.

Conclusion

The suprarenal aortic cross-clamping without intraoperative renal artery perfusion can be safely applied in patients with an eGFR of approximately 72 mL/min/1.73 m² or CKD stage 1 or 2, provided the renal ischemic time is approximately 30 minutes. This approach, whether involving a single or bilateral cross-clamping and including LRV ligation without reconstruction, can be used in OSR for JAAA without causing significant harm to perioperative renal function. However, minimizing renal ischemia duration remains crucial to reducing the risk of complications.

What is already known about this topic?

OSR is the preferred treatment for JAAA in healthy, low-risk patients due to the aneurysm's proximity to the renal arteries. The procedure typically requires suprarenal aortic cross-clamping, with selective renal artery clamping as needed to minimize perioperative renal function impairment. Studies have shown that suprarenal cross-clamping for more than 25 minutes can negatively affect renal function[12,17]. Additionally, in JAAA patients, the LRV often obstructs the clamping area, frequently necessitating its resection. However, controversy remains regarding whether the LRV should be reconstructed.

What does this study add?

This study investigates perioperative renal function following suprarenal aortic cross-clamping without renal perfusion during OSR for JAAA. Findings suggest that suprarenal cross-clamping without intraoperative renal artery perfusion can be safely performed in patients with an eGFR of approximately 72 mL/min/1.73 m² or CKD stage 1 or 2, provided the renal ischemic time is limited to around 30 minutes. Additionally, the study assesses whether LRV ligation without reconstruction can be performed without negatively impacting perioperative renal function.

Conflicts of interest

The authors declare no conflict of interest.

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