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REVIEW
AORTIC DISEASE

EDITOR'S CHOICE

Renal perfusion in complex abdominal aortic aneurysm open repair: a scoping review

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ABSTRACT

Introduction: To perform a scoping review analyzing the current evidence reporting on acute kidney injury (AKI) after elective open surgery (OS) of complex abdominal aortic aneurysms (c-AAAs) and evaluate the impact of renal perfusion, and the different types of solutions on renal morbidity.

Evidence acquisition: Research questions were defined, and a literature search was performed following the PRISMA guidelines for scoping reviews. Multicenter, single-center observational studies were considered eligible. No abstracts only and unpublished literature were included.

Evidence synthesis: Two hundred and fifty studies were screened, 20 studies met screening criteria and were included, reporting 1552 patients treated for c-AAAs. The majority did not receive renal perfusion and the others received different types of renal perfusions. Acute kidney injury is a common complication after c-AAAs OS, with an incidence up to 32.5%. Heterogeneity in AKI classifications reduce the ability to compare outcomes after perfusion and nonperfusion strategies. Pre-existing CKD, ischemic injury due to suprarenal aortic clamping are major determinants of AKI after aortic surgery. Most papers reported chronic kidney disease (CKD) at admission. Another debated topic is the indication for renal perfusion during c-AAAs OS. Controversial results for cold renal perfusion have been found.

Conclusions: In the context of c-AAAs, this review identified the need to standardize the definition of AKI to reduce reporting bias. Besides this, it showed the need to assess the indication for renal perfusion and the type of perfusion solution to be used.

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Key words: Aortic aneurysm; Surgical procedures, operative; Acute kidney injury; Renal insufficiency, chronic.

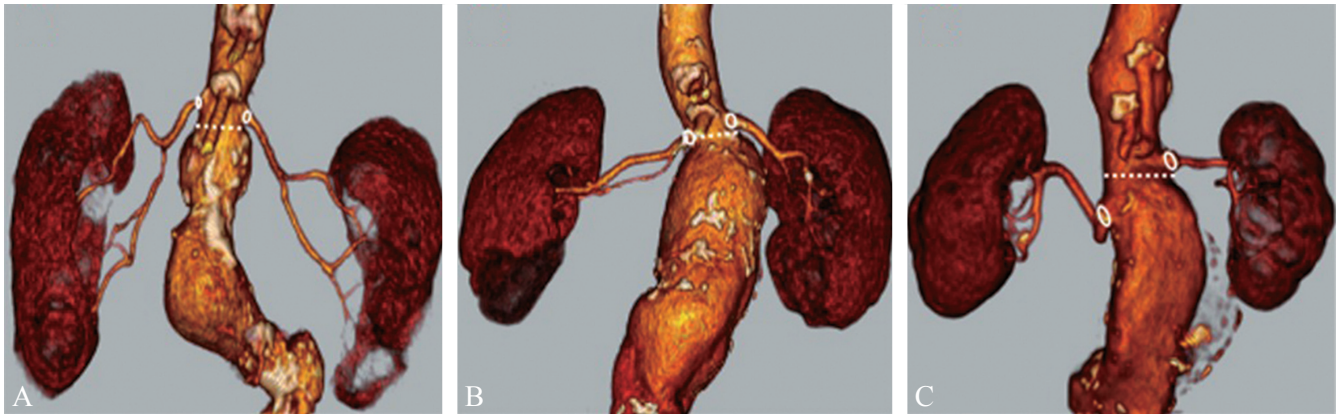

Figure 1.—Classification of complex abdominal aortic aneurysm.
Classification of cAAA. Dotted line marks the proximal extension of the aneurysm sac in relation with renal ostiums (marked with circles). A) Juxtarenal aneurysm: AAA extended to renal ostiums without involvement of these vessels; B) pararenal aneurysm: AAA involves the aorta at the level of one or both renal ostiums; C) suprarenal aneurysm: AAA extended aboce renal ostiums.

Introduction

Complex abdominal aortic aneurysms (c-AAAs) are defined as aneurysms that involve the renal or mesenteric arteries and extend up to the level of the celiac axis or diaphragmatic hiatus but do not extend into the thoracic aorta, and are classified into those involving renal and mesenteric arteries (suprarenal aneurysm, SRAA), one or both renal arteries (pararenal aneurysm), or encroaching one or both renal arteries without an aneurysmatic dilatation of these vessels (juxtarenal aneurysm, JAA) (Figure 1).[1]

In patients with c-AAAs, suprarenal or supravisceral aortic cross-clamping may be required, causing temporary renal flow impairment that may lead to an increased risk of postoperative AKI. Acute kidney injury is defined very heterogeneously in the literature. One important question is whether it will be possible to use a homogeneous definition for AKI, to obtain better defined and comparable results, also specifying the needed for hemodialysis and its duration (temporary or permanent).[2] A crucial question is whether, among the various strategies to prevent AKI after suprarenal aortic clamping, including the perioperative systemic drug administration (diuretics, corticosteroids, etc.), renal perfusion should be considered the method of choice.

The aim of this scoping review is to evaluate the impact of renal perfusion on postoperative AKI, and to evaluate any differences between different types of renal perfusion on postoperative AKI and 30-day mortality after c-AAAs OS.

Evidence acquisition

A scoping review was performed according to PRISMA Protocols Extension for Scoping Reviews.[3] A systematic search strategy was used. A literature search of studies in the PubMed and EMBASE databases was performed up to October 2021 in the English Literature reporting on outcomes of JAA, SRAA and extent IV thoraco-abdominal aortic aneurysm (TAAA) OS.

Main concerns

The present scoping review was conducted following the purposes to:

- identify the types of available evidence in the field of use of renal perfusion during c-AAA OS;
- clarify key concepts/definitions in Literature (*i.e.* AKI, preoperative CKD);
- examine how research is conducted in this specific topic;
- identify and analyze knowledge gap.

Identifying the research questions

This scoping review seeks to answer the following question: "To date, what evidence exists on incidence of AKI after c-AAAs OS?"

The sub-questions for this review included the following:

1. Is there a specific pathophysiology of AKI in patient treated for c-AAAs?

2. Are there any indications that the incidence of postoperative AKI is correlated with the use of renal perfusion?

3. Is the definition of CKD and AKI homogeneous in the literature?

4. Open surgical treatment

• In terms of preoperative CKD are there any differences between perfused and non-perfused patients?

• Do the clamping time and clamping zone influence the onset of AKI?

• Is there any evidence that perfusion prevents the onset of AKI

• Are there any differences in terms of AKI among different perfusion solutions type?

The systematic search was conducted using the following combination of MeSH terms and key words: ((("juxtarenal aneurysm"[All Fields] OR "pararenal aneurysm"[All Fields]) AND ("aorta"[All Fields] AND ("juxtarenal"[All Fields] OR "pararenal" OR "infrarenal")) OR ("juxtarenal aneurysm" [All Fields]) OR ("aneurysm" [All Fields] AND "pararenal" [All Fields]) OR ("IV type" AND aneurysm" [All Fields]) OR ("IV type" [All Fields] AND "thoracoabdominal" [All Fields]) OR (("renal" [All Fields] AND "perfusion" [All Fields]) OR ("renal" [All Fields] AND "protection" [All Fields]) OR ("kidney" [All Fields] AND "protection" [All Fields]) OR (("perfusion" [All Fields] OR "protection" [All Fields]) AND ("cold" [All Fields]) OR (("perfusion" [All Fields] OR "protection" [All Fields]) AND "Ringer's solution" [All Fields]) OR (("perfusion" [All Fields] OR "protection" [All Fields]) AND "Custodiol solution")))) NOT endograft NOT fenestrated NOT branched. The electronic search was supplemented and expanded using the "related articles" function of the search engine and a manual search of the relevant articles. In addition, the reference lists of all included studies were examined for further relevant studies identification. The final search was run in October 2022. We have considered eligibility criteria: observational study design reporting on outcomes after elective c-AAAs OS.

Exclusion criteria included studies with relevant missing data such as patient characteristics, treatment modalities and major outcomes (AKI, 30-day mortality). Studies reporting on ruptured c-AAAs were excluded. If duplicate series of patients were identified, only the latest article was included. Articles in languages other than English were excluded. Full texts of the remaining studies were obtained.

Evidence synthesis

Among 240 papers initially identified through the literature search, 8 duplicates were removed, while 18 papers were added after identification through other sources (reference lists of included studies). Totally, 250 papers were screened and assessed for eligibility, 230 were excluded because of their study design. Twenty studies were included in the present analysis (Figure 2). No previous reported systematic review and meta-analysis were found covering this topic; only one randomized clinical trial (RCT) including extent IV TAAAs was found on this topic.[4]

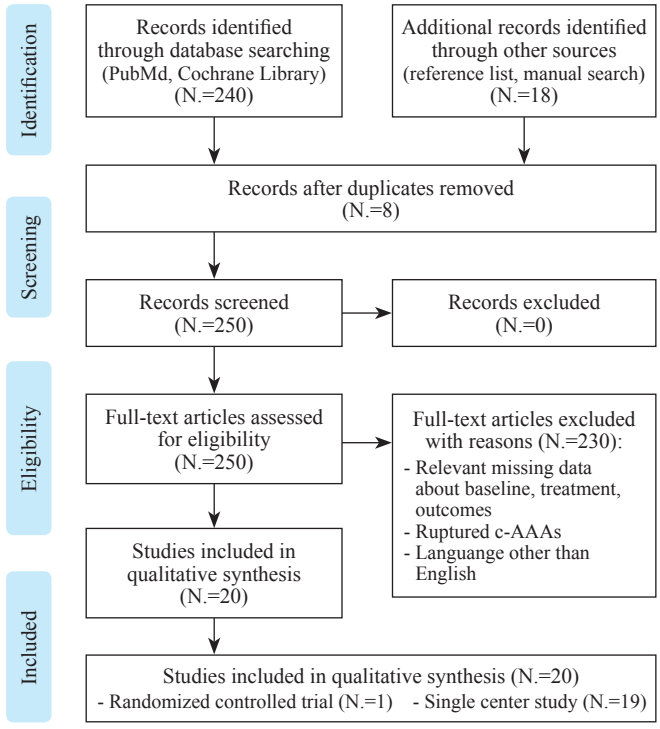

Figure 2.—Flow chart of studies identified and included regarding cAAAs with and without perfusion of the renal arteries.

Pathophysiology of AKI

Ischemic injury due to suprarenal aortic clamping often required during c-AAAs is a major determinant of AKI after aortic surgery.[2] When interruption of blood flow to the kidney is required, less Na+ is transported to the extracellular environment, thus decreasing the activity of the Na+/K+-ATPase pump, ATP consumption and subsequently prolonging tolerance time to ischemia. Several articles suggest that renal ischemia lasting more than 23-30 minutes is associated with a higher risk of postoperative renal dysfunction,[5-10] especially with pre-existing CKD.[11-13]

Several intraoperative mechanisms may affect the integrity of renal tubular cells: hemodynamic instability, anemia, embolism, vasospasm, increased myoglobin resulting from ischemia of the limbs muscles lower, drugs administered and hypoxia.

TABLE I.—*Comparison between the RIFLE, AKIN, KDIGO classification for acute kidney injury (adapted from Belletti* et al.*).*[16]

RIFLE Classification		AKIN Classification		KDIGO Classification		All three
	Cr/GFR		Cr/GFR		Cr/GFR	UO
R	Cr ≥1.5x baseline or GFR reduction >25% *vs.* baseline	1	Cr ≥1.5x baseline; or increased by ≥0.3 mg/dL	1	Cr ≥1.5x baseline within 7 days; or increased by ≥0.3 mg/dL within 48 hours	<0.5 mL/kg/h for >6 h
I	Cr ≥2x baseline or GFR reduction >50% *vs.* baseline	2	Cr ≥2x baseline	2	Cr ≥2x baseline	<0.5 mL/kg/h for >12 h
F	Cr ≥3x baseline; or GFR reduction >75% *vs.* baseline; or Cr≥4 mg/dL and +0.5 mg/dL *vs.* baseline	3	Cr ≥3x baseline; or Cr≥4 mg/dL and +0.5 mg/dL *vs.* baseline; or need for dialysis	3	Cr ≥3x baseline; or Cr≥4 mg/dL; or need for dialysis; or In patients <18 years old, GFR<35 mL/min/1.73 m^2	<0.3 mL/kg/h for >24 h; or anuria for 12 h
L	Dialysis for >28 days	/		/		
E	Dialysis for >3 months	/		/		

UO: urine output: Cr: serum creatinine; GRF: glomerular filtration rate.

Renal perfusion and postoperative AKI

Another question to focus on, is the efficacy of renal perfusion in preventing AKI and if there is any correlation between renal perfusion use and post-operative AKI: it should be noted that in our literature search AKI incidence was higher in patients receiving renal perfusion, but its use was performed mainly in patients with preoperative CKD, which may cause a selection bias, making difficult to assess the protective effect of renal perfusion.

"Chronic kidney disease" and "acute kidney injury" definition

The high variability in AKI definitions in different studies can explain the heterogeneity in reported incidences and associated outcomes. The RIFLE classification (risk, injury, failure, loss, end-stage kidney disease), tried to standardize such definitions based on serum creatinine and urine output[11] and was subsequently modified into the AKIN (Acute Kidney Injury Network) criteria, to include even small (0.3 mg/dL) increments in serum creatinine concentrations in the definition of AKI (class AKIN 1).[14] In 2012, the "Kidney Disease Improving Global Outcome" (KDIGO) guidelines introduced a new AKI definition to account for both previous classifications.[4, 15] (Table I).[16]

Various definitions for preoperative CKD and post-operative AKI were used. The definition of preoperative CKD varied among the studies from serum creatinine level 1.25 mg/dL to 2.0 mg/dL. All studies defined post-operative CKD based upon GFR, urine output criteria and serum creatinine levels. The mildest stage of acute renal dysfunction is defined as an acute increase in serum creatinine level 1.5 mg/dL or a 25% decrease in the glomerular filtration rate (GFR) or reduced urine output 0.5 mL/kg/h during 6 hours.

Open surgical treatment

A debated topic is the indication for renal perfusion during c-AAAs procedure. Uniform data regarding specific protocols for renal perfusion during c-AAAs are lacking in the literature; several considerations can be extrapolated from literature data on renal protection during open TAAA surgery. In most studies, renal perfusion was performed only when prolonged renal ischemia was anticipated, according to procedure complexity or it was the preferred method in other studies, in case of patients presenting with CKD.[17-25]

TABLE II.—*Detailed composition of different type of fluids used for renal perfusion.*[17-25]

Type of fluid	Composition	References
Enriched Ringer's solution"	Ringer's lactate solution enriched with 125 mg per liter of methylprednisolone and 12.5 g per liter of mannitol	17, 18, 20, 23, 25
Custodiol	Istidine-tryptophan-ketoglutarate or Custodiol HTKsolution	18, 20, 25
Other cold (4 °C) solutions	Several combinations of 4 °C isotonic heparinized balanced salt solution containing mannitol, sodium bicarbonate, methylprednisolone	19, 21, 22
Warm solutions	Blood	24

The role of clamping site on the incidence of AKI remains a controversial point, some studies[19] report that the site of aortic clamping affects serum creatinine levels in the postoperative period, other studies suggest that the clamp position was not an independent risk factor for postoperative AKI or operative death.[5, 17, 26]

Several strategies for selective renal artery perfusion have been developed such as blood perfusion, although the renal arteries perfusion with warm blood requires a complex setting in extracorporeal blood circuits and offers only a limited renal protection. Cold blood perfusion did not provide any statistically significant advantage over warm blood perfusion.[19, 21, 22] Cold crystalloid perfusion is a widely employed perfusion solution, the most common one is "Enriched" Ringer's solution, which have been demonstrated to be not inferior compared with cold blood perfusion, but easier to administrate.[17, 18, 20, 23] Custodiol® (Dr Franz-Kohler Chemie GmbH, Bensheim, Germany) has been used for renal protection during TAAA open repair over the last decade. In TAAA open repair significantly lower rates of postoperative AKI have been reported in patients treated with Custodiol compared with patients treated with Ringer's solution.[18, 20, 26] All detailed composition of different type of fluids used for renal perfusion are listed in Table II.[17-25]

Discussion

This is, to our knowledge, the first attempt to perform a review of the literature on renal perfusion in c-AAAs OS. Acute kidney injury (AKI) is a common complication after c-AAAs OS, associated with higher rates of 30-day and long-term mortality.[8] Heterogeneity in AKI classifications reduces the ability to compare outcomes after perfusion and nonperfusion strategies. In 2012, the Kidney Disease Improving Global Outcome (KDIGO) guidelines introduced a new definition of AKI, but despite this, today there is no uniformity in the definition of AKI and thus in the reported outcomes. In the most recent studies screened, however, more structured criteria such as RIFLE classification or AKIN have been used.[27]

Controversial results for cold renal perfusion have been found, positive data have been reported by O'Donnel *et al.*, in a wide range of patients, that cold renal perfusion was associated with lower risk of AKI if clamp time exceeded 25 minutes (OR 0.4 [0.2-0.97]; P=0.041).[28] Yeung *et al*. reports routinely use of cold saline renal perfusion among their 23 consecutive patients with renal revascularization and no case of postoperative elevation of serum creatinine level was found.[21] Few studies demonstrated higher rates of renal dysfunction with cold renal perfusion and other studies with routine use of perfusion showed no benefit.[19, 22, 23] No statistically significant data were reported by Hirose *et al.* reporting no difference in incidence of postoperative AKI and 30-day mortality between the groups, one groups requiring infrarenal aortic clamping and another group requiring a renal artery clamping and renal perfusion with cold Ringer's solution for juxtarenal aneurysm.[23] In this confusing scenario where the role of perfusion is unclear one can draw on the literature of TAAA where an RCT (CURITIBA trial) that reported better results in AKI prevention of Custodiol compared to Ringer's solution during TAAA OS. Perfused patients presented more frequently with preoperative CKD when compared to non-perfused patients (50.5% *vs.* 25.5), resulting in a higher incidence of AKI, but not a higher incidence of temporary or permanent dialysis.[18]

Conclusions

This review identified the need to standardize the definition of AKI and pre-operative CKD to reduce reporting biases. Besides this, it showed the need to assess the indication for renal perfusion, the potential added value or preferential use of renal perfusion, and the type of perfusion solution to be used, the potential added value of one type of renal perfusion over another type of perfusion.

References

1. Oderich GS, Forbes TL, Chaer R, Davies MG, Lindsay TF, Mastracci T, *et al.*; Writing Committee Group. Reporting standards for endovascular aortic repair of aneurysms involving the renal-mesenteric arteries. J Vasc Surg 2021;73(1S):4S–52S.

2. Saratzis A, Joshi S, Benson RA, Bosanquet D, Dattani N, Batchelder A, *et al.*; VERN collaborators. Editor's Choice - Acute Kidney Injury (AKI) in Aortic Intervention: Findings From the Midlands Aortic Renal Injury (MARI) Cohort Study. Eur J Vasc Endovasc Surg 2020;59:899–909.

3. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, *et al.* PRISMA Extension for Scoping Reviews (PRISMA-ScR): checklist and Explanation. Ann Intern Med 2018;169:467–73.

4. Kellum JA, Lameire N, Aspelin P, Barsoum RS, Burdmann EA, Goldstein SL, *et al.*; KDIGO AKI Guideline Work Group. Diagnosis, evaluation, and management of acute kidney injury: a KDIGO summary (Part 1). Crit Care 2013;17:204.

5. Sugimoto M, Takahashi N, Niimi K, Kodama A, Banno H, Komori K. Long-term fate of renal function after open surgery for juxtarenal and pararenal aortic aneurysm. J Vasc Surg 2018;67:1042–50.

6. Crawford ES, Beckett WC, Greer MS. Juxtarenal infrarenal abdominal aortic aneurysm. Special diagnostic and therapeutic considerations. Ann Surg 1986;203:661–70.

7. Jean-Claude JM, Reilly LM, Stoney RJ, Messina LM. Pararenal aortic aneurysms: the future of open aortic aneurysm repair. J Vasc Surg 1999;29:902–12.

8. Dubois L, Durant C, Harrington DM, Forbes TL, Derose G, Harris JR. Technical factors are strongest predictors of postoperative renal dys-

function after open transperitoneal juxtarenal abdominal aortic aneurysm repair. J Vasc Surg 2013;57:648–54.

9. Kasahara H, Shimizu H, Yozu R. Postoperative renal function after juxtarenal aortic aneurysm repair with simple cross-clamping. Ann Vasc Surg 2013;27:291–8.

10. Kudo FA, Nishibe T, Miyazaki K, Murashita T, Yasuda K, Ando M, *et al.* Postoperative renal function after elective abdominal aortic aneurysm repair requiring suprarenal aortic cross-clamping. Surg Today 2004;34:1010–3.

11. Bellomo R, Ronco C, Kellum JA, Mehta RL, Palevsky P; Acute Dialysis Quality Initiative workgroup. Acute renal failure - definition, outcome measures, animal models, fluid therapy and information technology needs: the Second International Consensus Conference of the Acute Dialysis Quality Initiative (ADQI) Group. Crit Care 2004;8:R204–12.

12. Coselli JS, Amarasekara HS, Zhang Q, Preventza O, de la Cruz KI, Chatterjee S, *et al.* The impact of preoperative chronic kidney disease on outcomes after Crawford extent II thoracoabdominal aortic aneurysm repairs. J Thorac Cardiovasc Surg 2018;156:2053–2064.e1.

13. Girardi LN, Ohmes LB, Lau C, Di Franco A, Gambardella I, Elsayed M, *et al.* Open repair of descending thoracic and thoracoabdominal aortic aneurysms in patients with preoperative renal failure. Eur J Cardiothorac Surg 2017;51:971–7.

14. Mehta RL, Kellum JA, Shah SV, Molitoris BA, Ronco C, Warnock DG, *et al.*; Acute Kidney Injury Network. Acute Kidney Injury Network: report of an initiative to improve outcomes in acute kidney injury. Crit Care 2007;11:R31.

15. Kellum JA, Lameire N, Aspelin P, Barsoum RS, Burdmann EA, Goldstein SL, *et al.* Kidney disease: improving global outcomes (KDIGO) acute kidney injury work group. KDIGO clinical practice guideline for acute kidney injury. Kidney Int Suppl 2012;2:1–138.

16. Belletti A, Licheri M, Bove T. Perioperative Renal Pharmacological Protection During Cardiovascular Surgery. In: Tshomba Y, Baccellieri D, Chiesa R, editors. Visceral vessels and aortic repair: challenges and difficult cases. Springer Science and Business Media; 2019.

17. Chiesa R, Marone EM, Brioschi C, Frigerio S, Tshomba Y, Melissano G. Open repair of pararenal aortic aneurysms: operative management, early results, and risk factor analysis. Ann Vasc Surg 2006;20:739–46.

18. Kahlberg A, Tshomba Y, Baccellieri D, Bertoglio L, Rinaldi E, Ardita V, *et al.*; CURITIBA Investigators. Renal perfusion with histidine-tryptophan-ketoglutarate compared with Ringer's solution in patients undergoing thoracoabdominal aortic open repair. J Thorac Cardiovasc Surg 2023;165:569–579.e5.

19. Zarkowsky DS, Inman JT, Sorrentino TA, Hiramoto JS, Vartanian SM, Eichler CM, *et al.* Contemporary Experience with Paravisceral Aortic Aneurysm (PVAAA) Repair in a Tertiary Center. Ann Vasc Surg 2021;75:368–79.

20. Tshomba Y, Kahlberg A, Melissano G, Coppi G, Marone E, Ferrari D, *et al.* Comparison of renal perfusion solutions during thoracoabdominal aortic aneurysm repair. J Vasc Surg 2014;59:623–33.

21. Yeung KK, Jongkind V, Coveliers HM, Tangelder GJ, Wisselink W. Routine continuous cold perfusion of the kidneys during elective juxtarenal aortic aneurysm repair. Eur J Vasc Endovasc Surg 2008;35:446–51.

22. Kabbani LS, West CA, Viau D, Nypaver TJ, Weaver MR, Barth C, *et al.* Survival after repair of pararenal and paravisceral abdominal aortic aneurysms. J Vasc Surg 2014;59:1488–94.

23. Hirose T, Sawabata N, Abe T, Hayata Y, Hiraga S, Nishikawa H, *et al.* Protective effects of cold ringer's solution perfusion in abdominal aortic surgery requiring renal artery clamp. In Vivo 2020;34:739–44.

24. Pichlmaier M, Hoy L, Wilhelmi M, Khaladj N, Haverich A, Teebken OE. Renal perfusion with venous blood extends the permissible suprarenal clamp time in abdominal aortic surgery. J Vasc Surg 2008;47:1134–40.

25. Mascia D, Grandi A, Bertoglio L, Kahlberg A, Saracino C, Melissano G, *et al.* The revascularization technique does not impact renal function after proximal abdominal aortic aneurysm open repair. J Cardiovasc Surg (Torino) 2021;62:42–50.

26. Mascia D, Bertoglio L, Kahlberg AL, Grandi A, Melissano G, Chiesa R. Open Repair of Proximal Abdominal Aneurysms Analyzed According to the Anatomy, Clamping Site, and Theoretical Fenestrated Endovascular Design. Ann Vasc Surg 2020;63:83–91.

27. Lopes JA, Jorge S. The RIFLE and AKIN classifications for acute kidney injury: a critical and comprehensive review. Clin Kidney J 2013;6:8–14.

28. O'Donnell TF, Boitano LT, Deery SE, Clouse WD, Siracuse JJ, Schermerhorn ML, *et al.* Factors associated with postoperative renal dysfunction and the subsequent impact on survival after open juxtarenal abdominal aortic aneurysm repair. J Vasc Surg 2019;69:1421–8.

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