comorbidity, the investigators excluded patients with baseline kidney disease, operations requiring circulatory arrest or cooling below 34°C, and patients on extracorporeal membrane oxygenation or intra-aortic counterpulsation devices. Finally, the short-term follow-up limits insight into potential long-term effects of DO₂-directed CPB.

Nevertheless, this RCT presents clear evidence for the efficacy of DO₂-directed CPB in protecting against postoperative AKI. It sets the foundation for subsequent investigation of DO₂-directed CPB in sicker patients undergoing more complex procedures. These would include patients both at higher risk for perioperative kidney injury and whose postoperative course would be most affected by AKI. Further analyses of real-world data across different national contexts (eg, perhaps with patients with higher average body mass index). With the robustness of their design, the authors have presented a promising CPB management paradigm for the reduction of mild AKI in patients undergoing routine cardiac surgery while simultaneously laying the groundwork for a research agenda to generate

important results regarding more severe perioperative AKI after CPB.

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Commentary: Delivering the news about oxygen-delivery on pump

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Acute kidney injury (AKI) increases length of stay (LOS), morbidity, and mortality following cardiac surgery.^{1,2} Pre-operative risk factors such as pre-existing renal dysfunction, recent contrast, diabetes, and advanced age combined with perioperative fluctuations in cardiac output and renal perfusion may lead to impaired kidney function postoperatively. During cardiopulmonary bypass (CPB), hemodilution and

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CENTRAL MESSAGE

Greater oxygen delivery goals during cardiopulmonary bypass may be one part of a bundle to reduce postoperative kidney injury.

systemic vascular resistance alterations may decrease renal oxygen delivery (DO₂) by 20% or more.³

Mukaida and colleagues⁴ present a single-center, randomized control trial (RCT) including 300 patients undergoing normothermic CPB for routine cardiac procedures and compare a strategy of optimizing DO₂

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(>300 mL/min/m²) with conventional perfusion. The authors report a 2-fold reduction in early postoperative AKI with the DO₂ strategy compared with conventional perfusion (14.6% vs 30.4%, $P = .002$), and conclude that a DO₂ strategy minimizes the development of AKI postoperatively. Patients with smaller body surface area and greater hemodilution were most likely to benefit from the DO₂ strategy.

This study adds to previous work investigating effect of DO₂ on postoperative AKI. In a contemporary multicenter RCT, Ranucci and colleagues⁵ used a lower DO₂ cutoff for intervention (280 mL/min/m²) and showed comparable effects on rates of mild AKI.

Several components limit the applicability of these results to standard cardiac surgery practices. Moderate- and high-risk surgical cases were excluded. Only early postoperative AKI (first 48 hours) was considered for primary end points, and the efficacy of findings came from differences in stage 1 AKI (defined by modified Kidney Disease: Improving Global Outcomes criteria), without significant differences in later AKI stages. There were also no differences between strategies in secondary outcomes like intubation times, postoperative LOS, mortality, and, importantly, predischARGE kidney function between groups. Multivariate analysis demonstrated that longer pump times (but not the DO₂ strategy) had a significant impact on postoperative AKI. In addition, only normothermic perfusion was included in the study, whereas hypothermic perfusion is commonly used globally and may have an impact on the development of AKI,⁶ particularly later stages. Lastly, although DO₂ variability is impacted by hemoglobin and pump flows (and less significantly by arterial oxygen tension), pump flow was the primary element adjusted to maintain a goal DO₂. This leaves uncertainty as to which component was more renal protective—greater pump flows or DO₂—and requires further investigation.

The strength of this RCT comes not as one single powerful change making a profound impact in patient outcomes but as part of a bundle for the prevention of postoperative AKI. Although this study demonstrated no difference in secondary outcomes, previous work has demonstrated that even mild AKI negatively impacts outcomes (neurologic function, LOS, intubation times, and mortality) following cardiac surgery.¹ New work suggests that specific urinary biomarkers can identify renal stress within 1 hour of initiation of CPB.⁷ Following these trends may allow timely adjustments to perioperative care, such as transition to a greater DO₂ strategy during CPB. Through the application of the theory of marginal gains, strategies to decrease AKI even modestly at every single opportunity may aggregate to a larger impact in the prevention of postoperative AKI.

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