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Commentary: Optimizing oxygen delivery during cardiopulmonary bypass to minimize morbidity and mortality: Have our goals been achieved?

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Strategies involving goal-directed perfusion during cardiopulmonary bypass (CPB) have been associated with decreased acute kidney injury (AKI) following cardiac surgery.¹ However, it is unclear as to what defines goal-directed perfusion during CPB and whether it can reduce not only AKI, but all morbidity and mortality in all patients undergoing cardiac surgery on CPB.

In this edition of the *Journal*, Magruder and colleagues² report the relationship between oxygen delivery (DO_2) during CPB and morbidity and mortality in 834 cardiac surgery patients on CPB using an electronic perfusion medical record system (Quantum Perfusion Systems, Spectrum Medical, Fort Mill, SC) that provides continuous online data of flow parameters and hemodynamic variables, including DO_2 , blood pressure, cardiac index, pump flow, and hemoglobin (Hgb). The institutional target for DO_2 was at least $260 \text{ mL/O}_2/\text{min/m}^2$, which was achieved by optimizing flow parameters, reinfusing blood sequestered in the operative field, and transfusing blood products. The primary outcome was the occurrence of a composite of Society of Thoracic Surgeons (STS) morbidity/mortality outcomes (mortality, postoperative renal failure, surgical reexploration,

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CENTRAL MESSAGE

Optimizing oxygen delivery during cardiopulmonary bypass may minimize morbidity and mortality.

postoperative prolonged intubation for >24 hours, deep sternal wound infection, and stroke). Although a $\text{DO}_2 < 280$ was associated with an increased incidence of the composite STS outcome, the increase failed to reach statistical significance ($P = .07$). However, in those patients undergoing nonisolated CABG procedures, a $\text{DO}_2 < 280$ was significantly associated with the primary outcome ($P = .02$). This was driven largely by an increased incidence of prolonged ventilation for >24 hours when the DO_2 was < 280 ($P = .04$). STS-defined renal failure was not associated with DO_2 in the entire patient cohort ($P = .07$); however, stage 1 AKI within 72 hours of surgery was independently associated with a $\text{DO}_2 < 280$ ($P = .02$). Overall, patients with a preoperative glomerular filtration rate $\text{GFR} < 65$ and a Hgb level $< 12.5 \text{ mg/dL}$ appeared to be most vulnerable for morbidity and mortality when the DO_2 was < 280 .

This study has several limitations, which the authors have acknowledged. The sample size was relatively small, which limited the ability to determine causality. Data obtained during the period of weaning from CPB was included, which may have altered the outcomes. The interventions used to increase DO_2 when values fell below 260 were not uniform. The database could not determine when patients were actively treated to maintain the target DO_2 ,

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and whether the initiated treatment resulted in improved outcomes. No data were provided on the relationship between low DO_2 and serum lactate, glucose, and cerebral oximetry on CPB, and whether correcting these parameters during CPB would improve postoperative outcomes. Finally, there were no controls, that is, a group of patients undergoing CPB managed without a targeted DO_2 .

Despite these limitations, the authors are to be congratulated for developing an innovative tool to help optimize DO_2 during CPB and to study its effects on reducing morbidity and mortality. Their data suggest that patients with preoperative anemia and reduced GFR may be most susceptible to increased morbidity and mortality when DO_2 is <280 . This also may be reflective of the increased incidence of comorbidities in these patients. It will be important to determine whether optimizing DO_2 in these high-risk patients will be successful in minimizing postoperative complications. DO_2 is dependent on flow and Hgb, but it also may be important to study the effects of perfusion pressure in these more vulnerable patients.

The authors should be encouraged to continue their investigations on the effect of DO_2 during CPB with prospective, randomized studies in patients targeted to achieve a

DO_2 of 280 versus those receiving standard of care perfusion practices without a targeted DO_2 . These studies should be sufficiently powered to achieve statistical significance among the 6 STS performance variables. Data during the weaning period from CPB should not be included, but important variables, such as lactate, serum glucose, inotropic and vasopressor support, and cerebral oximetry, are essential. An algorithm for various interventions to be implemented to achieve a DO_2 of 280 should be in place, and the combination of flow and pressure in addition to flow and Hgb also should be studied. Data derived from these studies will be essential for determining whether optimizing DO_2 during CPB will help achieve the critical goals of minimizing morbidity and mortality in cardiac surgery patients.

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