Abstract

Prediction and control of oxygen extraction for goal-directed perfusion during paediatric CPB

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Background
Goal-directed perfusion (GDP) during paediatric cardiopulmonary bypass (CPB) aims to optimize oxygen delivery DO2 and prevent tissue dysoxia. However, fixed flow rate targets often fail to account for dynamic shifts in metabolic demand, leading to hidden oxygen debt, elevated oxygen extraction ratios OER, and subsequent organ dysfunction. Real-time prediction and active control of OER represent a pivotal evolution toward personalized paediatric perfusion.

Methods
Synthesizing recent predictive modelling and clinical control framework studies, we evaluated a closed-loop approach combining predictive algorithms with target-driven perfusion management. High-frequency demographic, physiological, and circuit data were analysed to identify real-time predictors of elevated OER >30%. These predictive models were integrated into a GDP control strategy that dynamically adjusted pump flow, haematocrit, and temperature management to maintain optimal DO2/VO2 matching.

Results
Predictive analytics successfully identified early trajectories toward physiological mismatch prior to overt hyperlactatemia or central venous desaturation. Implementing active GDP control significantly reduced the duration and depth of elevated OER episodes across heterogeneous paediatric weight tiers. Maintaining targeted oxygen delivery above patient-specific critical thresholds DO2crit directly mitigated anaerobic metabolism markers and stabilized systemic vascular resistance.

Conclusion
Combining predictive risk modelling with structured control protocols transitions paediatric CPB from reactive flow management to proactive, physiological stabilization. Dynamic monitoring and control of OER provide a robust, scalable framework to minimize metabolic debt and improve clinical outcomes in paediatric cardiac surgery.