ORIGINAL RESEARCH PAPER

Anaesthesiology

THE NATIVE LUNG AS THE OXYGENATOR: ANAESTHETIC MANAGEMENT OF OXYGENATOR-FREE RIGHT HEART BYPASS FOR REDO TRICUSPID VALVE REPLACEMENT

KEY WORDS: Right heart bypass; Cardiac anaesthesia; Tricuspid valve replacement; Pulmonary vascular resistance

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ABSTRACT

When right heart bypass is conducted without an oxygenator, venous return is delivered straight to the pulmonary artery and the patient's own lungs remain the only gas exchanger available. This inverts the usual division of labour on bypass: responsibility for oxygenation stays with the anaesthesiologist instead of passing to the perfusionist. We describe our anaesthetic conduct in a 29-year-old woman undergoing redo tricuspid valve replacement by this technique, one year after repair of the same valve for endocarditis. She carried a high preoperative risk of pulmonary complications and had preserved left ventricular function. Bypass lasted 95 minutes on a beating heart, without aortic cross-clamping or cardioplegia. Ventilation continued without interruption, and every element of management was directed at keeping pulmonary vascular resistance low, since both pulmonary blood flow and systemic oxygenation depended wholly on the native lung. Oxygenation and lactate stayed satisfactory throughout. She was extubated on the first postoperative day and discharged on the sixth. The technique is attractive physiologically, but it obliges the anaesthesiologist to treat ventilation as a haemodynamic intervention and to remain alert to hypoxaemia for the whole bypass period.

INTRODUCTION

Surgery on the tricuspid valve is ordinarily undertaken with full cardiopulmonary bypass (CPB), an aortic cross-clamp and cardioplegic arrest. Within that circuit the membrane oxygenator contributes by far the greatest area of foreign surface, and contact between blood and this material triggers the contact, complement and coagulation pathways that generate much of the inflammatory burden attributed to CPB [1,2].

For procedures restricted to right-sided structures, an alternative exists. Caval blood may be pumped directly into the pulmonary artery, leaving gas exchange to the alveolar capillary bed and dispensing with the oxygenator, the cross-clamp and cardioplegia altogether. What this arrangement demands of the anaesthesiologist has seldom been discussed. We describe our management of such a case and the principles we consider essential to its safe conduct.

Case Report

A 29-year-old woman, 46 kg in weight and 152 cm tall (body mass index 19.9 kg/m^2), reported breathlessness on exertion of three months' duration, limiting her to New York Heart Association class III, along with swelling of both legs and hands and periorbital puffiness. Tricuspid valve repair had been carried out a year earlier for endocarditis of that valve. Her jugular venous pressure was elevated, a right ventricular heave was palpable below the xiphisternum, and a pansystolic murmur of grade 4/6 intensity was audible over the tricuspid area.

Echocardiography showed free regurgitation across the tricuspid valve with dilatation of both right-sided chambers. Tricuspid annular plane systolic excursion measured 14 mm; left ventricular ejection fraction was 60% and pulmonary regurgitation was trace. The cardiac silhouette was enlarged radiographically, and computed tomography showed fibroatelectatic change in both lung fields. An Assess Respiratory Risk in Surgical Patients in Catalonia (ARISCAT) score of 47 placed her at high risk of pulmonary complications postoperatively. She was graded American Society of Anesthesiologists physical status III, with a European System for Cardiac Operative Risk Evaluation (EuroSCORE) II of 2.52%.

No premedication was given. Electrocardiography, pulse oximetry and invasive pressure monitoring via a 20-gauge right radial arterial cannula were established before induction. Fentanyl 3 µg/kg was given for analgesia, followed by propofol 2 mg/kg titrated to effect and rocuronium 0.8 mg/kg. The trachea was intubated with a 7.5 mm cuffed tube and a 7-French triple-lumen catheter was placed in the right internal jugular vein. Cerebral oximetry and nasopharyngeal temperature monitoring were added. Transoesophageal echocardiography performed after induction excluded an intracardiac shunt.

Maintenance used sevoflurane at approximately 1 minimum alveolar concentration, titrated to a bispectral index of 40 to 60, with a fentanyl infusion at 1 µg/kg/h. After redo sternotomy and adhesiolysis, heparin 4 mg/kg was given and cannulation proceeded once an activated clotting time of 480 seconds was confirmed. Both venae cavae were cannulated for drainage and the arterial return was sited in the main pulmonary artery. Bypass ran through a roller pump and venous reservoir with no oxygenator interposed.

Ventilation was never suspended. We used 5 to 7 mL/kg predicted body weight (225 to 315 mL for a predicted body weight of 45 kg), an inspired oxygen fraction of 1.0, and 3 cmH_2O of positive end-expiratory pressure, adjusting rate to hold end-tidal carbon dioxide near 30 to 35 mmHg. Bypass flow was regulated to keep systolic pressure in the 70 to 90 mmHg range, with noradrenaline at up to 0.1 µg/kg/min, and fluids were given sparingly. Normothermia was intended throughout and active temperature management was not employed; warmth was preserved with a forced-air blanket and warmed intravenous fluids, and core temperature fell no lower than 33.1 °C. Blood gases drawn on bypass confirmed satisfactory oxygenation with lactate values that never exceeded 1.2 mmol/L. Baseline cerebral oximetry was 69% and was followed continuously throughout bypass.

A mechanical prosthesis was implanted with the heart

beating. Bypass ran for 95 minutes and the rhythm remained sinus. Weaning was supported by dobutamine 3 µg/kg/min and noradrenaline 0.03 µg/kg/min. Blood loss totalled 500 mL; one unit of packed red cells and six units of cryoprecipitate were transfused. She reached the intensive care unit ventilated and was extubated on the first postoperative day. Drain output was modest and postoperative chest radiography showed no features of pulmonary congestion. Discharge on warfarin followed on the sixth day, and she was well at review a month later.

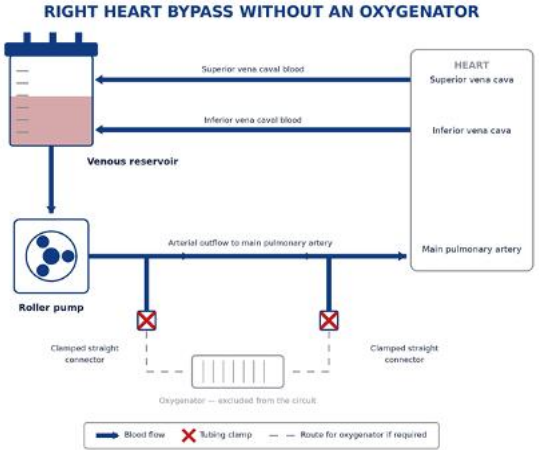

Figure 1. Schematic of the right heart bypass circuit. Blood drains from the superior and inferior venae cavae into the venous reservoir and is delivered by the roller pump directly to the main pulmonary artery. The oxygenator is excluded from the circuit; the two straight connectors are clamped throughout and provide a route for rapid interposition of an oxygenator should conversion to conventional cardiopulmonary bypass become necessary.

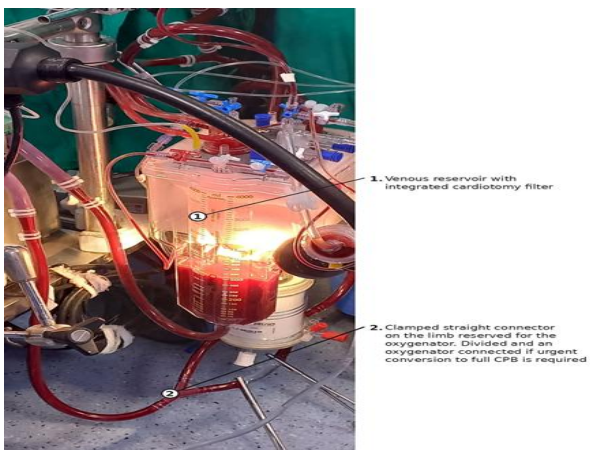

Figure 2. The assembled circuit in theatre. 1, venous reservoir with integrated cardiotomy filter; 2, clamped straight connector on the limb reserved for the oxygenator.

DISCUSSION

What distinguishes this technique for the anaesthesiologist is that the customary handover does not occur. On conventional bypass the lungs stand idle and ventilation may be stopped; here they are the sole gas exchanger, so any deterioration in ventilation-perfusion matching, compliance or pulmonary vascular tone appears at once as arterial desaturation. Ventilation must continue through sternal retraction and every phase of surgical handling.

Ventilator settings consequently become a haemodynamic tool. Carbon dioxide retention constricts pulmonary vascular smooth muscle through acidosis, while alveolar hypoxia does so via hypoxic pulmonary vasoconstriction [3]. That reflex serves a purpose when local, but once widespread it curtails pulmonary blood flow and undermines the circuit. Rising pulmonary vascular resistance (PVR) also drives up arterial line pressure, and since the pulmonary trunk tolerates distension less well than the aorta, injury becomes a real concern. We therefore held carbon dioxide slightly below normal, limited end-expiratory pressure so as not to create West zone I conditions, and kept tidal volumes protective.

Anaesthetic depth deserves more attention than it usually receives. Light planes, insufficient analgesia and the sympathetic surge that follows are established causes of pulmonary vasoconstriction [4], and in this setting they degrade circuit performance rather than merely disturbing the anaesthetic. We maintained depth with a continuous opioid infusion alongside titrated volatile agent and omitted nitrous oxide for its effect on pulmonary vascular tone. Fluids were restricted deliberately, because volume excess in a patient with right-sided disease may flood the very organ on which oxygenation depends [5].

Echocardiography is indispensable. A patent foramen ovale must be excluded before bypass begins, since the pressure relationship across the atrial septum shifts and right-to-left shunting would produce desaturation resistant to any ventilatory manoeuvre [6]. It also permits continuous appraisal of filling, ventricular performance and prosthetic seating on a beating heart.

Anticoagulation differs in one important respect. The prin-cipal thrombogenic surface is absent from this circuit, and reduced heparin requirements have been described with oxygenator-free right heart support [7]. Our patient never-theless received full conventional heparinisation, with an acti-vated clotting time of 480 seconds. Whether a lesser dose is safe where a reservoir, roller head and clamped side limbs remain in circuit is unproven, and those low-flow segments argue for caution. Lastly, redo sternotomy with dense adhesions, hepatic congestion from long-standing right heart failure and previous anticoagulation together make significant bleeding likely; readiness for major transfusion should be assumed, and viscoelastic testing is of value where available.

CONCLUSION

Oxygenator-free right heart bypass permits tricuspid surgery on a beating heart with gas exchange left to the patient's own lungs. The price is that oxygenation rests entirely with the anaesthesiologist for the duration of bypass. Safety depends on ventilation that is never interrupted and always protective, on deliberate control of pulmonary vascular resistance through carbon dioxide, oxygenation, anaesthetic depth and fluid restraint, on echocardiographic exclusion of shunting, and on continuous dialogue with the surgical and perfusion teams.

Declarations

Informed consent: written consent was obtained from the patient for publication of this report and accompanying images.

Conflict of interest: none declared. Funding: none.

REFERENCES

1. Millar, J. E., Fanning, J. P., McDonald, C. I., McAuley, D. F., & Fraser, J. F. (2016). The inflammatory response to extracorporeal membrane oxygenation (ECMO): A review of the pathophysiology. Critical Care, 20, 387.
2. Zakkar, M., Guida, G., Suleiman, M. S., & Angelini, G. D. (2015). Cardiopulmonary bypass and oxidative stress. Oxidative Medicine and Cellular Longevity, 2015, 189863.
3. Sylvester, J. T., Shimoda, L. A., Aaronson, P. I., & Ward, J. P. T. (2012). Hypoxic pulmonary vasoconstriction. Physiological Reviews, 92(1), 367–520.
4. Price, L. C., Wort, S. J., Finney, S. J., Marino, P. S., & Brett, S. J. (2010). Pulmonary vascular and right ventricular dysfunction in adult critical care. Critical Care, 14(5), R169.
5. Mathison, M., Buffolo, E., Jatene, A. D., Jatene, F. B., Reichenspurner, H., & Matheny, R. G. (2000). Right heart circulatory support facilitates coronary artery bypass without cardiopulmonary bypass. The Annals of Thoracic Surgery, 70(3), 1083–1085.
6. Rahmanian, M., Mohammadian, M., Mollazadeh, R., Moayerifar, M., & Gholipour, M. (2025). Right heart bypass without an oxygenator as an alternative technique for surgical management of right-sided heart problems: A case report. Annals of Medicine and Surgery, 87(6), 3858–3861.
7. Suematsu, Y., Ohtsuka, T., Miyaji, K., Murakami, A., Miyairi, T., Eyileten, Z., Kotsuka, Y., & Takamoto, S. (2000). Right heart mini-pump bypass for coronary artery bypass grafting: Experimental study. European Journal of Cardio-Thoracic Surgery, 18(3), 276–281.