

Bloodless cardiopulmonary bypass for neonates and infants: an ultimate teamwork achievement

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In open heart surgery for neonates and small children, the cardiopulmonary bypass (CPB) circuit surface and the priming volume are relatively large in relation to patient size and blood volume. Therefore, use of allogeneic blood is inevitable to maintain the optimal haematocrit level during the bypass.

The deleterious effects of allogeneic blood transfusion are well documented in adult patients. Studies in adults demonstrated that low haematocrit was associated with postoperative renal dysfunction, but transfusion of red blood cells concentrate (RBCs) to compensate for haemodilution significantly increased the risk of renal impairment and failure [1,2,3]. This suggests that severe haemodilution during CPB may diminish systemic oxygen delivery and that allogeneic blood transfusion may worsen ischaemic organ injury. Silliman and associates have shown that blood transfusion is a major factor for post injury multi-organ failure and that the transfusion related morbidity positively correlated with the duration of blood storage [4]. Potassium level and free haemoglobin level from erythrocyte lysis increase with duration of blood storage as well as activated complement fragments and inflammatory cytokine levels (IL-8 and TNF- α) [5]. The importance of the elevated lactate levels measured in the stored blood in relation to the clinical outcome has not been established [6].

Recently, total avoidance of allogeneic blood during paediatric open heart surgery became strongly advocated. Commercially available minimized elements, an adjusted set up of the systems and paediatric dedicated heart-lung machines allow reduction of the amount of allogeneic blood in the prime and during

the bypass. Consequently, in selected paediatric patients bloodless open heart surgery could be safely and successfully performed [7-10].

Still, there are additional measures needed to obtain asanguinous cardiopulmonary bypass for the majority of neonatal and infant patients. Selection of the most relevant requirements contains: the adjustment of acceptable haemodilution level during CPB, enhancement of patient preoperative haematocrit value and optimization of oxygen demand/supply monitoring during CPB.

Owing to general availability of continuous monitoring of mixed venous oxygen saturation (SVO₂), regional cerebral and systemic oxygenation (rSO₂) and frequent measurement of plasma lactate level during bypass, investigators were able to accept haemodilution levels as low as 20% during CPB for biventricular corrections and 25% for univentricular corrections in neonatal and infant patients.

If there were difficulties to maintain the SVO₂ above 70% and rSO₂ above 50%, despite increasing the pump flow and oxygen concentration during bypass, allogeneic blood transfusion was administered. Similarly, when plasma lactate level was increased above 4.0 mmol/l blood transfusion was performed [11,12].

Directly after the cessation of bypass, patient haematocrit may be enhanced through modified ultrafiltration. Study of Kuratani and associates demonstrated that the advantage of modified ultrafiltration over conventional ultrafiltration consists of significant improvement of clinical conditions in the immediate post bypass period. On the other hand, the

postoperative outcome parameters were not significantly influenced by the type of ultrafiltration [13].

Pre-operative patient haematocrit is an important factor that strongly influences the level of haemodilution during asanguinous CPB. Since recombinant human erythropoietin (EPO) has become available for clinical use, it is successfully administered in adult patients undergoing open-heart surgery to avoid transfusion of allogeneic blood [14]. Shimpo and collaborators proved that EPO is an effective adjuvant therapy for open heart surgery without blood transfusion in children [15].

Peri-operative administration of EPO, with or without predonation protocol, was concluded to be an effective strategy for bloodless heart surgery. On the downside, there are costs involved with EPO administration and predonation strategy (need for prolonged hospitalization) as well as physical and psychological stress for the patient. In addition, some patients, due to their cardiac conditions, cannot wait for this strategy to result in the desired, higher level of haematocrit.

In recent years, commercially available oxygenators, arterial line filters and haemofilters, designed to serve paediatric patient underwent consequent miniaturization. This process of technical refinement is still going on and the latest products are very promising. The newest oxygenators incorporate an arterial line filter thus further limiting priming volume (Terumo Capiox Fx 0.5, Maquet Quadrox - Neonate and Pediatric). Despite the availability of minimized system elements, the rest of the CPB circuit should be drastically reduced in volume. All technical measures to reduce priming volume result in such small neonatal and infant CPB circuits that their haemodilutional effects are markedly diminished. For example, Durandy and co-operators created a system of 120 ml volume for patients up to 10 kg [10], Merkle and associates used a circuit of 190 ml volume for children with a body weight under 6 kg [9], and Charette with associates reduced their CPB system to 172 ml [16].

As there is a general agreement that bloodless CPB for small children could be safely and successfully performed, a specific centre-related programme is required to achieve this objective. Institutional guidelines and multidisciplinary efforts undertaken in the pre- and postoperative period proved to be of great importance concerning bloodless heart surgery and should be seriously pursued by all involved healthcare professionals.

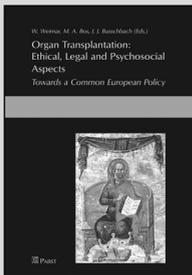
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