Cardiopulmonary Bypass

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Case Vignette
A 75-year-old lady with a height of 157 cm and a weight of 65 kg is referred to your team for coronary surgery. Her hemoglobin is 11.7 g/dl (7.3 mmol/l). You are concerned about blood transfusion and your team wonders how her risk of transfusion can be minimized during CPB.

Why Is It Important?

The extracorporeal circuit supposedly reinforces the systemic inflammatory response due to contact activation and initiation of the coagulation system. Moreover, the contact of blood with ambient air in the reservoir contributes to blood activation. Blood activation and reduced concentration of coagulation factors due to hemodilution result in an increase of the risk of blood transfusion, particularly in patients with a small body surface area [1]. A number of amendments to the extracorporeal system have been discussed and investigated to ameliorate blood activation and reduce hemodilution. The aim of these improvements is to reduce blood loss by limiting blood activation and hemodilution.

In an effort to optimize cardiopulmonary bypass (CPB), several measures have been combined to reduce the invasiveness of the extracorporeal circuit. These minimized systems are commonly summarized under the acronym of minimally invasive extracorporeal circulation (MiECC) systems, and this system is described in a separate chapter. Relevant measures to improve patient blood management during cardiopulmonary bypass are the use of closed systems, autologous priming, and

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bioactive coating of the tubing. The purpose of this chapter is to provide insight in improvements of the biocompatibility of the extracorporeal circuit during cardiac surgery.

Closed Extracorporeal Circuit

Most closed extracorporeal systems include collapsible bags with integrated screen filters. Despite advantages, closed reservoirs also have the disadvantage of resulting in more complicated perfusion, since the removal of air has to be performed in an active fashion. Moreover, the use of cardiotomy suction requires a separate reservoir and vacuum-assisted venous drainage cannot be applied to the collapsible reservoir bag.

A large number of trials combined several components of a blood conservation strategy during CPB. Therefore, it is difficult to separate the isolated effect of a closed reservoir compared to a standard open reservoir. For instance, some trials combined the elimination of cardiotomy suction with the use of a closed system or investigated the combined effect of surface coating, closed system, and different pumps [2, 3]. It was shown that closed systems reduced thrombin generation and fibrinolysis during coronary artery bypass grafting [2] and reduced levels of a number of markers of blood activation [3] compared to open systems. In a follow-up randomized trial, Nakahira and coworkers isolated the effects of closed systems and found no difference between open and closed systems on markers of coagulation activation, fibrinolysis, and inflammation, including the thrombin–antithrombin complex, D-dimers, and interleukin-6 [4].

Only a few studies focused on the isolated effect of a closed system. Casalino et al. found significantly reduced transfusion requirements in a small single-center randomized trial [5]. A more recent trial investigated the transmission of microbubbles in different reservoirs and showed that a closed soft-shell reservoir led to less microbubble transmission [6]. However, the effect of this on blood loss or transfusion requirements was not investigated, and most available studies are not powered to show effects on clinical outcomes. In contrast, others found no advantage of closed systems in tests focusing on coagulation activation and inflammation [7, 8]. Adequately sized randomized trials on closed versus open systems are lacking, so that clear recommendations for clinical practice cannot be drawn yet.

Biocompatible Coating

Biocompatible coating aims to improve the hemocompatibility and hydrophilicity of the extracorporeal system by emulating the natural endothelial lining. There are different types of biocompatible coatings available. The first ones used ionic or covalent heparin bonding. However, due to the complexity of manufacturing heparin-based biocompatible coatings, alternative coatings have been introduced, including poly2-methoxy-ethylacrylate (PMEA) and phosphorylcholine.

The isolated impact of biocompatible coating in patient blood management programs may be limited and is still under debate. A systematic review and meta-analysis that was published in 2009 included 36 randomized trials issued between 1992 and 2006, showing that the use of any biocompatible coating reduced the odds for packed red blood cell transfusion when compared to the use of a non-coated circuit [9]. A more recent systematic review of 14 randomized trials confirmed the superiority of second and third generation heparin-coated circuits with respect to perioperative blood loss in about 50% of the included studies and when compared to non-coated circuits only [10]. In a third systematic review it was shown that 6 out of 14 included randomized trials showed better clinical outcome in patients subjected to a biocompatible-coated circuit [11].

In more recent publications it was shown that also the use of phosphorylcholine-coated circuits [12, 13] might contribute to less perioperative blood loss and transfusion requirements when compared to the use of non-coated circuits. However, perioperative hemostasis was not the primary endpoint in any of these studies [12, 13], and the results were biased by comparison of different CPB designs [12]. In a small, randomized trial with perioperative blood loss as study endpoint, the use of a phosphorylcholine-coated circuit was associated with less 6-h blood loss, but without differences in transfusion needs when compared to a non-coated circuit [14].

In addition to placebo-controlled investigations, two smaller studies compared the effect of PMEA, phosphorylcholine, and heparin-coated circuits on postoperative blood loss and transfusion requirements [15, 16]. Only one study showed that PMEA coating was associated with less platelet transfusions when compared to heparin coating [16]. Additionally, biocompatible coatings of oxygenators have been shown to reduce the risk of abnormal pressure gradients and prevent oxygenator failure [17].

Retrograde and Antegrade Autologous Priming

Several methods have been devised to reduce hemodilution in extracorporeal circulation, such as small volume extracorporeal circuits. Antegrade and retrograde autologous priming (RAP) are simple, inexpensive, and efficient ways to address the issue of hemodilution. This is achieved by allowing the blood to displace the fluid in the circuit into an external reservoir in an antegrade or retrograde manner. Antegrade displacement is mediated by the blood pressure of the patient, and retrograde displacement is achieved by pumping the fluid actively into the external reservoir. Retrograde priming is used more commonly, and with this technique usually 200–600 mL of priming fluid can be discarded after retrogradely replacing it with arterial blood before initiation of cardiopulmonary bypass.

The largest meta-analysis on this topic was published by Sun et al. in 2013 [18]. It was concluded that RAP reduced transfusion requirements, but did not influence other clinical parameters such as length of stay [4]. A total of six RCTs that were conducted specifically to investigate RAP are summarized in a meta-analysis including 557 patients [19]. The meta-analysis showed that RAP

significantly reduced the number of patients receiving intraoperative packed red cell transfusions and red cell transfusions during total hospital stay. Furthermore, the number of units of packed red blood cells transfused over the total hospital stay was significantly reduced, whereas the number of transfused packed red cells during surgery was not [19]. These findings were confirmed in a randomized trial on 120 patients with a small body surface area (<1.5 m^2) [1] and a more recent study that included 753 patients [20]. All studies point towards a favorable recommendation regarding the use of retrograde and antegrade autologous priming as part of a blood conservation strategy to reduce transfusion during cardiopulmonary bypass.

Implications for Daily Practice

As part of a blood conservation strategy, the above-discussed measures should be considered. A combination of several measures increases the likelihood of success with respect to a decrease in bleeding and blood product transfusions (Fig. 13.1).

Biocompatible coating, especially coating of oxygenators, is widely implemented in today's systems. However, this comes with an increased cost. The use of closed systems and autologous priming, possibly in combination with blood collection in a cell saver system, needs to be practiced by a perfusion team in order to ensure satisfactory realization. In particular, autologous priming has been shown to be simple and effective to reduce crystalloid load with the priming volume of the CPB circuit. It should be emphasized that blood management during bypass needs to be part of a concerted effort, including the preoperative and postoperative treatment. Liberal fluid therapy on the postoperative unit (for example, intensive care unit) will easily setback intraoperative achievements.

Returning to the case presented at the beginning of this chapter, a combination of measures would be most suitable to reduce the need for transfusion in this patient. As a first step autologous priming is recommended. It is likely that using a closed coated circuit and omission of cardiotomy suction further improves biocompatibility of perfusion.

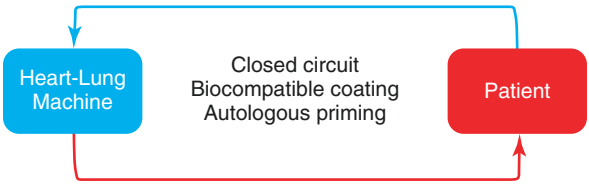

Fig. 13.1 Different technical interventions during cardiopulmonary bypass can be combined as part of a patient blood management program in order to reduce perioperative transfusion requirements

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