Fluid Management & Blood Transfusion

Fabio Guarracino and Rubia Baldassarri

Fluid Management

Fluid management is crucial in cardiac surgery patients. The underlying heart disease and the poor cardiovascular reserve make these patients unable to adapt to the frequent hemodynamic variations occurring during surgery. Because both positive and negative fluid balance harm organs and worsen the clinical outcome, cautious fluid management is pivotal.

Patients undergoing cardiac surgery can present with different types of cardiac dysfunction. The presence of left ventricle (LV) dysfunction, both systolic and diastolic, right ventricle (RV) failure, heart valve disease influence the response to fluid administration depending on both the severity of the illness and the surgical technique.

Although the dysfunctional heart depends on adequate preload to provide stroke volume and systemic perfusion, exceeding fluid administration can lead to pulmonary edema because the heart cannot adapt to the increasing filling pressures.

This is particularly true when RV failure and LV diastolic dysfunction occur.

At the same time, negative fluid balance can affect organ function by either reducing oxygen delivery or inducing arrhythmias, such as atrial fibrillation. For these reasons, the maintenance of stable fluid balance, ensuring proper oxygen delivery to the peripheral tissues throughout the surgical procedure, is the main purpose of intraoperative fluid management in cardiac surgery.

Some specific features of cardiac surgery, including the use of the cardiopulmonary bypass (CPB), are responsible for abnormal vascular permeability and

F. Guarracino (✉) · R. Baldassarri
Department of Anaesthesia and Critical Care Medicine, University Hospital of Pisa, Via Paradisa 2, 56L23 Pisa, Italy

M. Vives and A. Hernandez (eds.), *Cardiac Anesthesia and Postoperative Care in the 21st Century*, https://doi.org/10.1007/978-3-030-79721-8_13

altered microcirculatory function. Haemodilution, hypothermia, intraoperative bleeding, coagulation disorders, as well as surgery and anesthesia may affect the fluid distribution between the intra and extravascular space.

Impaired microcirculatory function and, as recently highlighted, endothelial glycocalyx dysfunction, harm the oxygen supply/demand balance (Fig. 1).

Thanks to the hand-held vital microscopes availability, the microcirculation can be safely investigated. Nevertheless, none of the microcirculation function indexes seem to be useful to improve the clinical outcome in cardiac surgery.

Fluid management in cardiac surgery is still a challenge. Intraoperative fluid management should be focused on the effective patient's response to fluid administration rather than on the conventional hemodynamic monitoring (mean arterial pressure, central venous pressure).

In this context, intraoperative transesophageal echocardiography (TEE) is useful to assess either the filling state or the response to fluid administration in cardiac surgery patients. Additional information about cardiac function is also fundamental to guide fluid management.

Fluid responsiveness is defined as the ability to increase the stroke volume (about 10–15%) after fluid challenge.

As aforementioned, the identification of the patients who are fluid-responder is extremely useful to manage fluid therapy during cardiac surgery. It should be kept into account that, because of the unicity of the hemodynamic pattern of the cardiac surgery patients fluids should be carefully given even in those patients who are thought to benefit from fluid therapy.

In clinical practice, dynamic indexes of fluid responsiveness, such as Stroke Volume Variation (SVV) and Pulse Pressure Variation (PVV), are useful to

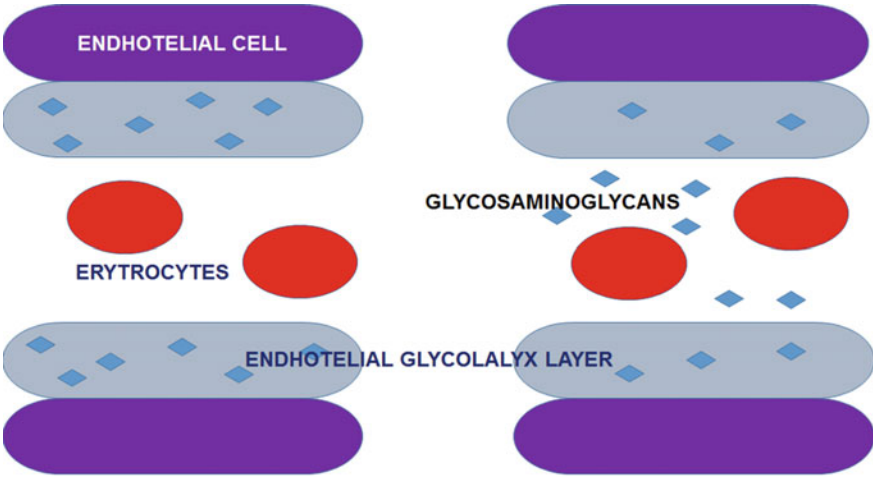


Fig. 1 Endhotelial Glycolalyx Layer. Healhty glycolalyx layer on the left and altered glycolalyx on the right where the glycosaminoglycans are shedding to the plasma

optimize the therapeutic approach in hemodynamically unstable patients. The respiratory variation of the diameters of superior and inferior vena cava are other important indicators of fluid responsiveness.

Advanced hemodynamic monitoring and intraoperative TEE are powerful tools for guiding fluid management in the cardiac surgery setting. The implementation of individualized strategies is helpful to achieve hemodynamic stabilization.

Blood Management

Perioperative bleeding, depending on both patients' predisposing risk factors and surgery-related mechanisms, is a common complication in cardiac surgery (Table 1).

In cardiac surgery, allogenic blood products, such as packed red blood cells, fresh frozen plasma, or platelets transfusion, are the usual therapeutic approach to intraoperative blood loss. Because of the strong association between blood components transfusion and adverse outcomes, any effort to prevent and minimize intraoperative bleeding should be ensured in cardiac surgery patients (Table 2).

Non-surgical intraoperative bleeding mostly depends on coagulation disorders. The cardiac surgery patients, who present with coagulopathy and/or anemia from different causes before surgery, are at high risk for major bleeding.

Several factors, including the use of CPB, systemic heparin, haemodilution, and hypothermia affect intraoperative hemostasis.

During CPB, the clot activation induced by the blood trauma in the extracorporeal circuits, as well as haemodilution and hypothermia alter the coagulation pattern by reducing and impairing the circulating coagulant factors.

The current guidelines recommend to minimize hemodilution, maintenance of normothermia (temperature > 36 °C), and pH within the physiological range (7.35–7.45) to reduce the effects of CPB on intraoperative coagulopathy. In this context, normovolaemic haemodilution, antegrade autologous priming, and retrograde autologous priming have been considered for cardiac surgery.

Table 1 Predisposing risk factors for intraoperative bleeding

Advanced age
Preoperative dual antiplatelet therapy
Poor platelet function
Preoperative anaemia
Small body surface area
Female gender
Non-elective surgery, nonisolated surgery, non-CABG surgery and redo surgery

Table 2 Adverse events associated with allogenic blood transfusion

Transfusion-associated lung injury (TRALI)
Transfusion-associated immunomodulation
Transfusion-related circulatory overload
Cellular hypoxia
Postoperative renal dysfunction
Pneumonia
Wound infections
Sepsis and septic shock
In-hospital mortality

The use of shorter, closed, and biocompatible coating extracorporeal circuits can also be helpful in patients submitted to CPB.

Patient's blood donation and cell save techniques can effectively reduce the amount of transfusion, but both of them have side effects that should be carefully considered in cardiac surgery.

Patient Blood Management

Recent Guidelines have endorsed the implementation of proper algorithms with well-defined interventional triggers to achieve adequate patient blood management (PBM) in adult cardiac surgery.

The Society for the Advancement of Blood Management has recently defined PBM as *"the timely application of evidence-based medical and surgical concepts designed to maintain hemoglobin (Hb) concentration, optimize hemostasis and minimize blood loss in an effort to improve patient outcome."*

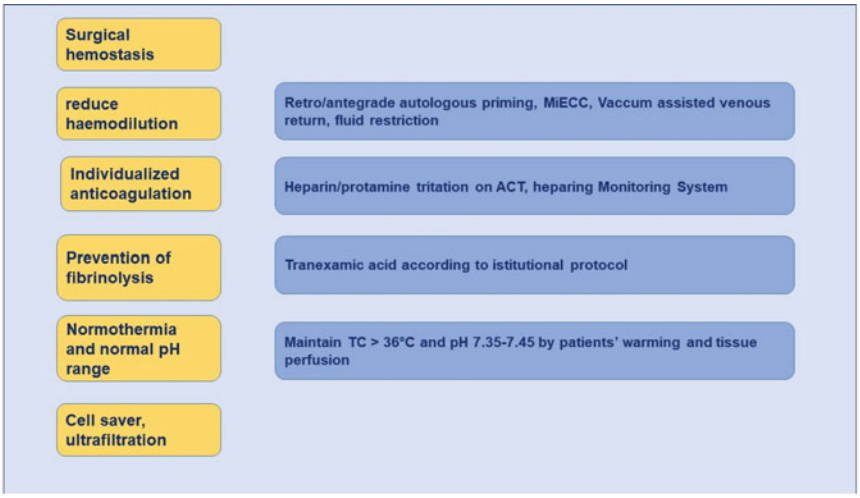
Therefore, PBM is a global strategy for the prevention of major bleeding, including the preoperative assessment of the predisposing risk factors and the management of postoperative complications. Intraoperatively, PBM depends on interventional strategies aimed to prevent and treat blood loss (Table 3).

As recommended by the current Guidelines, the patient's history, preoperative antithrombotic/anticoagulant medicaments, anemia, and eventual congenital coagulopathy, should be therefore carefully investigated. In high-risk patients, strategies to optimize the coagulation pattern and normalize the Hb levels should be performed before surgery to reduce the perioperative risk for bleeding.

During cardiac surgery, the point-of-care (POC) coagulation tests allow the early detection of the pathophysiological mechanisms involved in the clotting formation and stabilization by analyzing the global coagulation process.

In addition to the activated clotting time (ACT), which is is used for monitoring heparin therapy and the adequacy of anticoagulation therapy during cardiac surgery, the viscoelastic coagulation tests including rotation thromboelastometry (ROTEM) and Thromboelastography (TEG) have been recommended in cardiac surgery as

Table 3 Intraoperative blood management algorithm



part of the PBM. The European Society of Anesthesiology (ESA) and the European Association of Cardiothoracic Surgeon/Anesthesiology (EACTS/EACTA) guidelines on patient blood management for adult cardiac surgery, recommend the implementation of interventional algorithms based on predefined triggers. Transfusion strategies cannot be guided by solely clinical judgment; evidence-based decision-making approaches are recommended because safer and more effective in preventing perioperative adverse events.

POC testing-based interventional algorithms are effective in both the prevention and treatment of perioperative bleeding in the cardiac surgery setting. Finally, POC-test-guided algorithms are effective in reducing perioperative allogeneic blood transfusion (Tables 4 and 5).

PBM is an important part of fluid management in cardiac surgery. Intraoperative bleeding is one of the main causes of hypovolemia and major bleeding can lead to severe hemodynamic instability.

Because several causes, including intraoperative bleeding, are responsible for the hemodynamic impairment occurring in cardiac surgery, the proper diagnosis of the underlying pathogenic mechanisms is fundamental to provide adequate treatment. In this context, advanced hemodynamic monitoring is fundamental to guide fluid administration and the routine application of POC-guided interventional algorithms has been shown effective in reducing intraoperative bleeding and the requirement for blood components transfusion.

Table 4 Viscoelastic testing (VET) based perioperative management of active bleeding

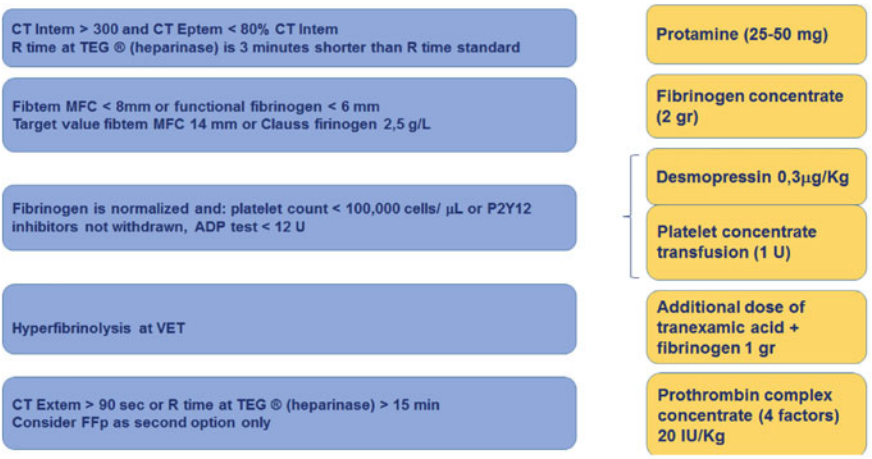
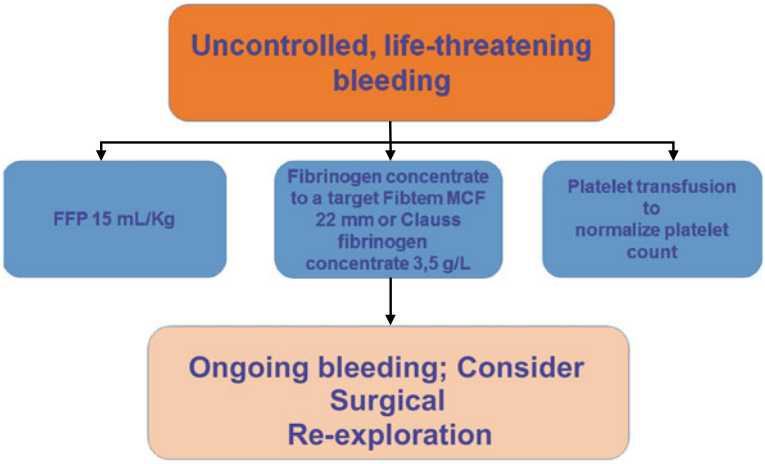


Table 5 Management of ongoing active bleeding



Intraoperative Coagulation

The balance between proper anticoagulation and hemostasis is crucial in cardiac surgery. The coagulation system must adequately work to prevent and stop intraoperative bleeding. Intraoperative hemostasis depends on the complex interaction of surgical and clinical strategies.

An unfavorable balance between procoagulant and anticoagulant factors can lead to hemorrhagic/thrombotic events increasing perioperative morbidity and mortality.

Heparin is commonly administered according to body weight, usually 300 IU/kg heparin with a target ACT $\geq$ 400–450 sec. The occurrence of heparin resistance and heparin rebound can affect the reliability of this tool. The implementation of interventional algorithms based on the clinical response to heparin could be effective in reducing the risk of intraoperative bleeding.

According to current Guidelines, protamine should be used to reverse the heparin-induced effects. To restore the procoagulant activity of the blood the protamine/heparin ratio 1:1 is generally adequate in cardiac surgery. An additional dose of protamine should be carefully considered because of the risk of bleeding.

In case of low blood levels of antithrombin (AT), its administration should be considered to increase heparin sensitivity when heparin resistance is shown.

Transfusion Strategies

In most cardiac surgery centers, blood transfusion is still the current strategy to treat intraoperative blood loss. Although blood transfusion can be lifesaving in some specific circumstances (major bleeding, hemorrhagic shock, ischemic complications, potential organ failure), a liberal approach to allogenic blood components transfusion is not free from risks.

Both anemia and blood transfusion affect the clinical outcome by increasing perioperative morbidity and mortality.

Therefore, the primary challenge is to understand when transfusion is appropriate and the benefits overcome the risks.

Anemia

In the cardiac surgery population, the incidence of perioperative anemia is about 30% (from 23% up to 43%). There is evidence that perioperative anemia affects the clinical outcome by increasing morbidity and mortality. Also, preoperative anemia is an independent risk factor for increased blood transfusion. Preoperative anemia should be adequately treated before surgery.

The safe transfusion threshold is still controversial and restricted versus liberal transfusion strategies have been investigated in the cardiac surgery setting.

Although the Hb value is still the main transfusion trigger, the patient's clinical conditions, as well as his/her ability to compensate for the reduction of the Hb levels, are, or should be, the main decision-making criteria when transfusion seems to be the best therapeutic option. The patient's response to either acute bleeding or the reduction of the Hb values below critical levels depends on several factors including the patient's preoperative status and the intraoperative setting. In

particular, in dealing with cardiac patients the coronary perfusion plays a key role in the response to anemia by increasing the cardiac output. When coronary perfusion is suboptimal, sudden decompensation can occur in presence of low Hb levels.

The evidence of systemic hypoperfusion and reduced tissue oxygenation is pivotal to guide the transfusion strategy.

Conclusion

PBM is part of the more complex issue of fluid management in the cardiac surgery setting. Intraoperative bleeding is one of the main causes of hypovolemia and major bleeding can lead to severe hemodynamic instability.

Because the hemodynamic impairment occurring in cardiac surgery may be due to very different causes, a correct diagnose of the underlying pathogenic mechanisms is fundamental to provide an early adequate treatment. In this context, advanced hemodynamic monitoring is fundamental to guide fluid administration and the routine application of POC-guided interventional algorithms has been shown effective in reducing intraoperative bleeding and the requirement for blood components transfusion.

Recommended Readings

1. Scolletta S, et al. Patient blood management in cardiac surgery: The "Granducato algorithm." Int J Cardiol. 2019;289:37–42.
2. Pagano D, Milojevic M, et al. (2018) EACTS/EACTA Guidelines on patient blood management for adult cardiac surgery. Eur J Cardiothorac Surg. 2018;53(1):79–111. https://doi.org/10.1093/ejcts/ezx325.
3. Kozek-Langenecker SA, Ahmed AB, Afshari A, et al. Management of severe perioperative bleeding: guidelines from the European Society of Anaesthesiology: first update 2016. Eur J Anaesthesiol. 2017;34:332–95.
4. Bignami E, Guarnieri M et al (2017). Fluid management in cardiac surgery patients: pitfalls, challenges and solutions. Minerva Anestesiol. 2017;83(6):638–651. doi: https://doi.org/10.23736/S0375–9393.17.11512–9.
5. Protsyk V, Rasmussen BS, et al. Fluid management in cardiac surgery: results of a survey in European cardiac anesthesia departments. J Cardiothorac Vasc Anesth. 2017;31(5):1624–9. https://doi.org/10.1053/j.jvca.2017.04.017.
6. Raphael J, Mazer CD, et al. Society of cardiovascular anesthesiologists clinical practice improvement advisory for management of perioperative bleeding and hemostasis in cardiac surgery patients. Anesth Analg. 2019;129(5):1209–21. https://doi.org/10.1213/ANE.0000000000004355.
7. Dhir A, Tempe DK. Anemia and patient blood management in cardiac surgery-literature review and current evidence. J Cardiothorac Vasc Anesth. 2018;32(6):2726–42. https://doi.org/10.1053/j.jvca.2017.11.043.