Journal of Cardiology and Cardiovascular Research

Butt SP, et al., 2023-J Cardiol Cardiovasc Res
ISSN:2583-259X
Review Article

Exploring Perfusion Safety: A Review of Clinical and Non-Clinical Factors with Emphasis on Quality Improvement

Salman Pervaiz Butt[1*], Nabeel Razzaq[2], Yasir Saleem[3], Bill Cook[4], Fazil Ashiq[5], Arun Kumar[6], Umer Darr[7] and Gopal Bhatnagar[8]

[1]Perfusionist and ECMO Specialist, Cleveland Clinic, Abu Dhabi, UAE

[2]Perfusionist, Cleveland Clinic, Abu Dhabi

[3]Clinical Perfusionist, AIIMS, Rishikesh, India

[4]Perfusionist, Glenfield Hospital, Leicester, UK

[5]MD, Cleveland Clinic, Abu Dhabi

[6]MD, Cleveland Clinic Abu Dhabi

[7]MD, Cleveland Clinic, Abu Dhabi

[8]MD, Cleveland Clinic, Abu Dhabi

[*]**Corresponding Author:** Salman Pervaiz Butt, Perfusionist and ECMO Specialist, Cleveland Clinic, Abu Dhabi, UAE.

Received Date: 09-27-2023
Accepted Date: 10-06-2023
Published Date: 10-16-2023

Abstract

This literature review examines perfusion safety in cardiothoracic surgery, with a primary focus on cardiopulmonary bypass (CPB) and circulatory devices. PRISMA guidelines were followed and various databases, including PubMed, MEDLINE, and Google Scholar, were searched using relevant keywords to identify pertinent studies and literature on the subject. The review traces the historical development of perfusion techniques and underscores the importance of equipment factors, personnel considerations, and perfusion management strategies in ensuring patient safety during CPB and circulatory device usage.

Clinical aspects of perfusion safety, encompassing equipment safety features, temperature management, anticoagulation, and blood conservation, are discussed. Non-clinical aspects, including the implementation of standardized protocols, robust training structures, positive team dynamics, and the fostering of a safety-oriented culture, are also examined.

Quality improvement initiatives for blood conservation, monitoring, and incident reporting are explored, along with an acknowledgment of the significant contributions of major perfusion societies and boards (AmSECT, SCPS, EBCP) in establishing standards and promoting excellence in the field.

Challenges related to device design, patient selection, and perioperative management are addressed, highlighting the need for standardized practices and ongoing research to enhance perfusion safety. This comprehensive review underscores the enduring commitment to advancing perfusion safety and quality through systematic research, education, and collaborative efforts in cardiothoracic surgery.

Citation: Butt SP, Razzaq N, Saleem Y, Cook B, Ashiq F, Kumar A, et al. Exploring Perfusion Safety: A Review of Clinical and Non-Clinical Factors with Emphasis on Quality Improvement. J Cardiol Cardiovasc Res. 2023;4(2):71-85.
DOI: https://doi.org/10.37191/Mapsci-JCCR-4(2)-081

Keywords: Perfusion; Cardiothoracic surgery; Cardiopulmonary bypass; Circulatory devices.

Introduction

Advances in medical technology have transformed cardiothoracic surgery, enabling the successful treatment of complex cardiac conditions. CPB and circulatory devices have revolutionized heart surgery since these devices were introduced, becoming crucial to the management of patients undergoing heart surgery. CPB redirects blood away from the heart and lungs, creating a motionless and bloodless surgical field. It involves a heart-lung machine that temporarily takes over the heart and lung functions. This machine consists of a blood pump, an oxygenator, and monitoring/control systems.

These techniques support vital organs temporarily while enabling surgical interventions on the heart. However, implementing CPB and circulatory devices presents unique challenges and potential risks, necessitating a critical focus on perfusion safety.

For patients with severe cardiac or respiratory dysfunction, circulatory devices including ventricular assist devices (VADs) and extracorporeal membrane oxygenation (ECMO) provide additional mechanical assistance. Which are also used to treat people with advanced heart failure over the long term, serving as a bridge to transplantation.

This review analyzes the historical development of perfusion techniques, highlighting challenges faced and improvements made over time. Understanding this context is essential for appreciating advancements in perfusion safety and identifying areas for further enhancement. The components of perfusion safety encompass equipment/device factors, personnel factors, and perfusion management strategies. Understanding these factors helps healthcare professionals optimize safety and minimize adverse events during CPB and circulatory device use.

Furthermore, the development of strategies and interventions aimed at reducing the occurrence of adverse events and complications associated with perfusion is providing insights into the incidence, impact, and potential preventive measures. Efforts to standardize protocols, enhance collaboration, integrate technological advancements, and address regulatory and ethical considerations are identified. Highlighting current challenges and future directions contributes to ongoing efforts to improve perfusion safety in CPB and circulatory device utilization.

Method

The PRISMA method was employed as the guiding framework for conducting this review. The investigation utilized a qualitative research design to assess the Perfusion Safety aspects. Out of 58 selected journal publications, 39 peer-reviewed and evidence-based research works were shortlisted. The inclusion criteria involved empirical studies, observational research, and comprehensive reviews, resulting in 39 relevant research works.

The review process involved open-source journal publications and the Google Scholar database. Special attention was accorded to the methods of facts collection and the validity of information garnered from secondary sources. The research engagement

employed all the provisions of ethical conduct in research.

Historical perspective on perfusion safety

In the 1940s, cardiac surgery procedures faced severe limitations due to the absence of CPB technology, hindering progress in cardiac surgery and posing challenges for safe complex heart surgeries. The 1950s marked a turning point as hospitals began developing heart-lung machines, significantly expanding the capacity for cardiac surgeries. The Gibbons IBM Heart Lung Machine, introduced in this era, incorporated crucial safety features such as continuous pH measurement, automated venous return adjustment, a backup battery generator, and the use of nitrogen to prevent combustion in the presence of flammable anesthetic agents. These innovations greatly reduced the risk of accidents during cardiac surgeries.

Advancements continued in the 1960s with the implementation of filters and disposable oxygenators with defoaming chambers and heat exchangers, further enhancing safety. Modern perfusion systems now boast features such as audible alarms, blood monitoring devices, and continuous data capture, significantly reducing mortality risks during cardiac surgery.

Despite these substantial advancements, the pursuit of enhanced safety remains ongoing. Today, the focus is shifting towards non-technical skills, emphasizing human factors training, teamwork, and standardized protocols as key factors in improving perfusion safety. Over the years, perfusion techniques have undergone significant evolution, with professional organizations establishing accreditation, certification, and consensus practice guidelines for perfusionists. Contemporary emphasis on a systems approach, quality assurance processes, evidence-based methodologies, and improved communication skills has further advanced perfusion safety, encompassing the entire perioperative care continuum. In conclusion, the historical perspective on perfusion safety reflects an enduring commitment to enhancing it through innovation, education, and a holistic approach to patient care [1,2,3].

Components of perfusion safety

Clinical aspects of perfusion safety

Perfusion equipment, including CPB machines and Extracorporeal Life Support (ECLS) devices, are equipped with an extensive array of safety features. These encompass alarm and limit settings for critical parameters such as temperature, bubble detection, level detection, and pressure thresholds, alongside safeguards for pump operation. Moreover, these systems provide a diverse range of monitoring options, such as Near-Infrared Spectroscopy (NIRS) and continuous blood gas monitoring (CDI), which significantly enhance the safety and functionality.

Ensuring perfusion safety hinges on equipment and device-related factors. Ongoing advancements in the design and functionality of CPB machines have substantially improved patient outcomes. Manufacturers prioritize ergonomic solutions and advanced technology to optimize perfusion delivery during complex surgical procedures. Rigorous quality control measures are implemented to assess the performance and safety of circulatory devices.

Regulatory frameworks and standards impose stringent guidelines on manufacturers, necessitating the reporting of any issues that could compromise patient safety. Monitoring systems play a pivotal role by providing real-time information during perfusion procedures, allowing perfusionists to assess perfusion adequacy, promptly identify complications, and monitor the vital parameter of oxygen delivery (DO_2). The availability and reliability of monitoring systems, especially DO_2 monitoring, are indispensable components of patient safety. Effective temperature management during bypass procedures are critical to prevent ischemic injury and optimize patient outcomes. Precise temperature control minimizes the risk of hypothermia or hyperthermia. Adequate flow ensures tissue perfusion while mitigating complications such as embolism or vascular injury. Techniques for hemodilution and blood conservation are employed to optimize oxygen delivery, reduce clotting risks, and minimize blood loss during surgery. These encompass practices like autologous blood transfusion, cell salvage, and the use of antifibrinolytic agents. Additionally, effective anticoagulation and coagulation management are paramount to prevent clot formation within the circuit and maintain appropriate coagulation levels to prevent excessive bleeding. Monitoring and adjusting anticoagulation levels, typically with heparin, are essential for optimizing patient outcomes while minimizing complications [4,5].

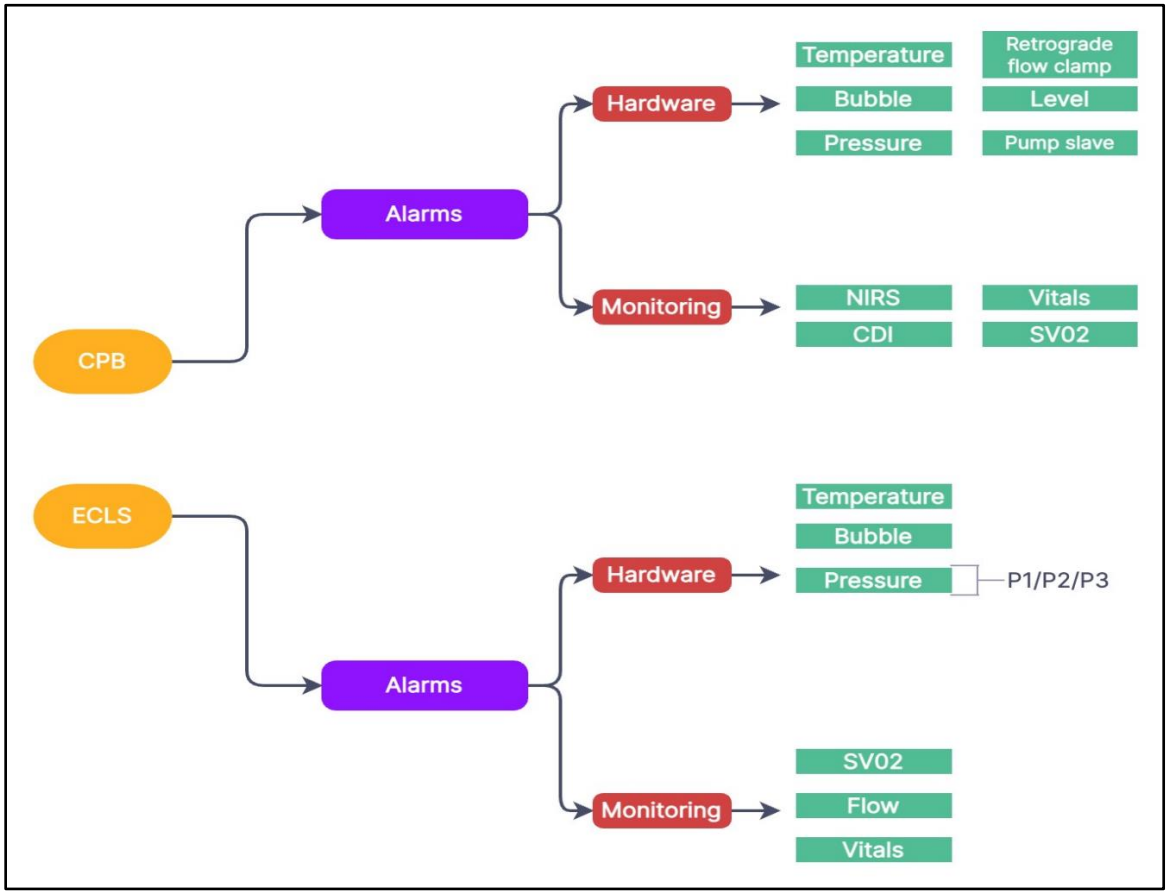

Figure 1: Illustration of clinical component of perfusion safety.

Non-clinical aspects of perfusion safety

Non-clinical aspects of perfusion safety encompass a comprehensive set of elements that are vital to the overall success and well-being of the perfusion team and, ultimately, the patient. These elements extend beyond the technical aspects of perfusion and focus on the organizational, procedural, and human factors that collectively ensure a safe and efficient perfusion process.

Checklists and protocols

An integral part of non-clinical perfusion safety is the utilization of up-to-date checklists and well-established protocols. These documents serve as standardized guides for perfusionists, ensuring that critical steps and safety measures are consistently followed. Checklists and protocols help minimize the risk of human error and enhance the overall quality of perfusion procedures.

Robust training structure

A robust and continuous training structure is essential for perfusionists. This involves initial training to acquire essential skills and knowledge, as well as ongoing education to stay current with advancements in the field. Training programs empower perfusionists to adapt to new technologies and procedures, enhancing the ability to provide safe and effective care.

Positive and progressive culture

Fostering a positive and progressive culture within the perfusion team is pivotal. This culture encourages open communication, continuous learning, and a commitment to safety. It values the input of all team members, from perfusionists to support staff, and promotes a shared dedication to the highest standards of patient care.

Team dynamics

Effective team dynamics play a crucial role in perfusion safety. This includes ensuring sufficient staffing levels to handle the demands of each procedure, as well as well-organized on-call arrangements for emergencies.

A cohesive team that communicates seamlessly and collaborates efficiently contributes to the safe execution of perfusion procedures and enhances patient outcomes [6,7].

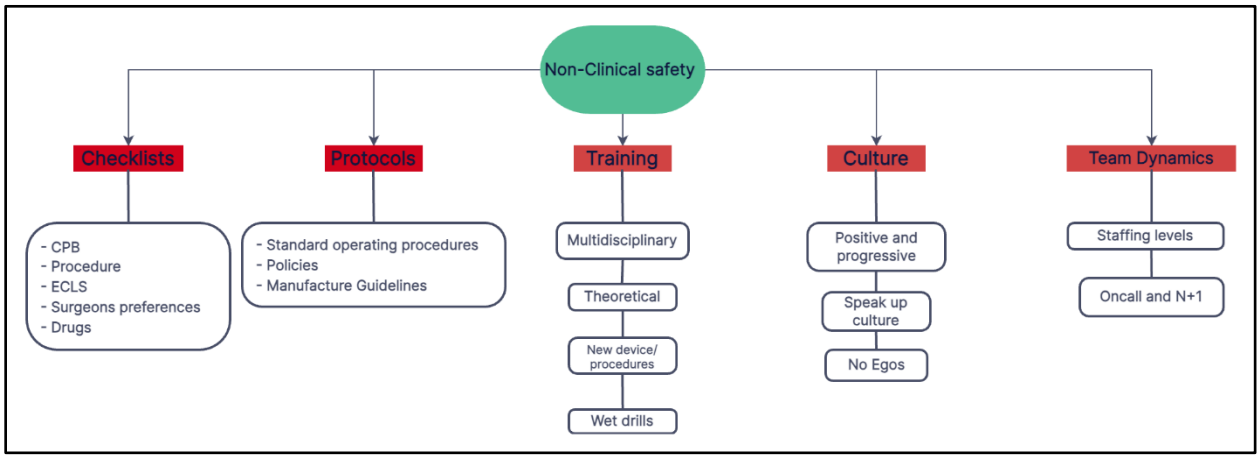

Figure 2: Illustration of non-clinical aspects of perfusion safety.

Improving safety as a perfusion department

The enhancement of safety within the Perfusion department necessitates the establishment of an organizational framework operating at the departmental level. This structural framework assumes a central role in orchestrating changes in clinical practice, the assimilation of novel perfusion equipment, and the expansion of service provisions, all while prioritizing patient safety as the paramount objective.

Effective communication constitutes a foundational component of this framework, ensuring that any proposed alterations are transparently communicated to all pertinent team members within the Perfusion department. Collaboration, involving the active engagement of diverse stakeholders such as perfusionists, clinicians, administrators, and auxiliary staff, is fundamental, after discussions and coordination concerning envisioned any changes to the department. Prior to the implementation of any modifications, a review of the proposed changes is imperative highlighting potential advantages, associated risks, and implications for patient safety. This critical appraisal phase serves to identify potential challenges and formulate mitigation strategies. Finally, the ultimate stage of this safety structure necessitates the solicitation of approval from key stakeholders, encompassing senior management, departmental leadership, and experts in quality assurance and patient safety. Such collective endorsement ensures seamless alignment between the proposed changes and the overarching safety objectives of the Perfusion department. In adhering to this structured approach, the Perfusion department not only fortifies its commitment to safety but also cultivates a culture of unwavering dedication to the welfare of patients, wherein meticulous evaluation, proactive hazard mitigation, and the unwavering centrality of patient safety endure as cardinal principles in the face of dynamic shifts in clinical practices, technological advancements, and evolving service modalities [8,9].

Complications

Perfusion-related complications constitute significant concerns during cardiothoracic surgery and ECLS applications, as that can profoundly affect patient outcomes. These interventions, which frequently involve CPB and ECMO, are essential life-saving measures for patients with severe cardiac and respiratory conditions. Hemolysis, thrombosis, coagulopathy, and the systemic inflammatory response syndrome (SIRS) are some of the common adverse events that can occur during these procedures [10]. Moreover, ECLS applications come with its own set of complications, including cannulation issues, vascular problems, oxygenator dysfunction, and the potential for organ dysfunction, particularly in the renal and hepatic systems [11,12]. To prevent and mitigate these complications, healthcare providers should employ monitoring techniques, optimize circuit design, tailor anticoagulation strategies, and receive specialized training [11]. These measures are essential for ensuring the safe and effective use of CPB and ECMO in cardiothoracic surgery and ECLS applications, and ongoing research and refinement of best practices are critical for improving patient outcomes [11,13].

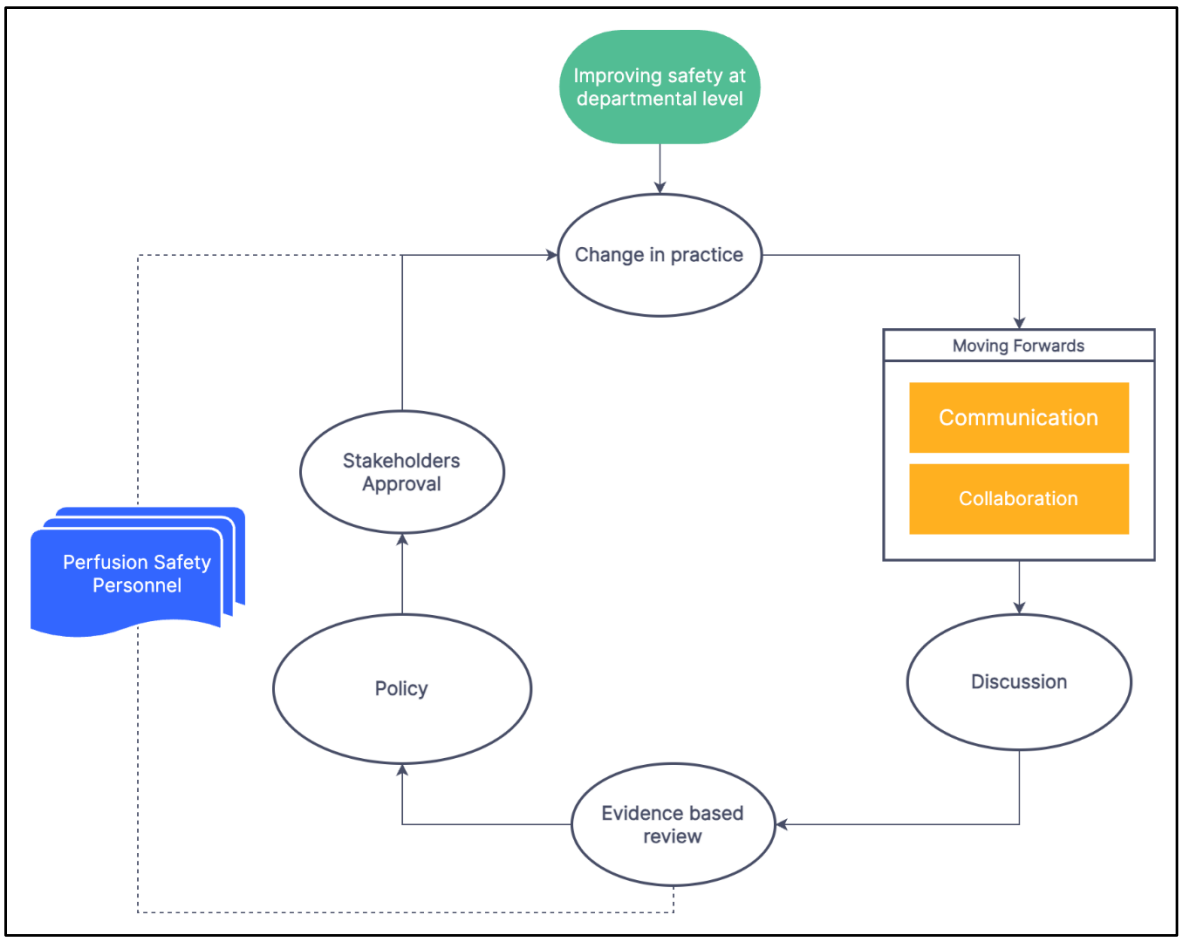

Figure 3: Illustration of improving safety as a perfusion department.

In the study conducted by Zegers, et al., [14] an examination of adverse events and potentially preventable deaths in Dutch hospitals provided insights into the prevalence and preventability within cardiac procedures. This research highlights the importance of identifying preventable events to enhance patient safety and improve outcomes in cardiac perfusion. It underscores the necessity for robust incident reporting systems and the adoption of standardized terminology and definitions to facilitate communication among healthcare professionals involved in cardiac procedures.

A separate study by David A Palanzo identified areas for potential improvement in safety practices during cardiac perfusion procedures. The study emphasizes the implementation of safety protocols and the need for technological advancements and education to enhance perfusion outcomes. It specifically highlights the importance of refining perfusion equipment and techniques, incorporating computer assistance and automation, and ensuring precise communication and vigilance throughout procedures [14,15].

A meta-analysis examined outcomes and complications of ECMO in adult patients [16] by reviewing published studies, the analysis provided a comprehensive assessment of complications and mortality occurring during

or after ECMO. This information is crucial for understanding the risks associated with ECMO therapy and guiding clinical decision-making. Another study investigated hemorrhagic complications during ECMO [17]. Hemostasis was evaluated using standard coagulation tests and rotational thromboelastometry. The researchers aimed to elucidate the pathophysiological mechanisms of ECMO-associated hemorrhagic complications and the impact on coagulation parameters. Understanding these mechanisms can help optimize coagulation management during ECMO support.

A systematic review focused on venovenous ECMO treatment outcomes and complications in adults [18]. The review aimed to provide insights into trends in VV ECMO outcomes based on large case series. This information is valuable for assessing the effectiveness and safety of VV ECMO in treating refractory respiratory failure. In the context of COVID-19, a meta-analysis examined neurological complications in COVID-19 patients receiving ECMO support [19]. This study specifically investigated the risk of stroke in COVID-19 patients on ECMO. Given the increasing use of ECMO for COVID-19-related respiratory failure, understanding neurological complications is essential for optimizing patient care and outcomes.

These studies collectively contribute to the understanding of ECMO-related complications. By identifying risk factors, providing management algorithms, and assessing outcomes, that provide valuable insights for healthcare professionals involved in ECMO therapy. It is important to consider these findings in clinical practice to enhance patient safety and improve ECMO outcomes.

Quality improvement initiatives

Quality improvement initiatives play a crucial role in enhancing patient outcomes and optimizing the use of resources in cardiovascular procedures involving CPB, ECMO, ventricular assist devices (VAD), and blood conservation techniques.

One study by Zhang, et al., [20] assessed the impact of a comprehensive blood conservation program on transfusion practices and outcomes in patients undergoing CPB [20]. The program included restrictive transfusion protocols, ultrafiltration, cell salvage, and a modified minimal extracorporeal circulation system. The study reported a significant decrease in red blood cell transfusion rates after implementing the program, highlighting the effectiveness of quality management in reducing transfusion requirements [20].

In the context of ECMO, Suzuki, et al., [21] described a simplified blood salvage technique for the ECMO circuit [21]. The technique aimed to maximize blood salvage without the need for special equipment. This approach aligns with blood conservation strategies commonly employed during CPB. By implementing such techniques, healthcare providers can reduce the need for blood transfusions and potentially improve patient outcomes. Blood gas monitoring is another area of interest for quality improvement initiatives. Ottens, et al., [22] conducted a randomized trial to investigate the role of in-line blood gas monitoring in improving perfusion management during CPB [22]. The study utilized the CDI™500 device for

continuous monitoring. Findings from the study could provide valuable insights into optimizing perfusion management and enhancing patient safety during CPB procedures.

Furthermore, Khan, et al.,[23] reported on the implementation of blood conservation strategies in open-heart surgery patients requiring CPB [23]. By employing multiple departments in a coordinated effort, this aimed to improve transfusion rates and reduce blood product usage. This approach highlights the significance of interdisciplinary collaboration in achieving quality improvement goals. The adverse effects of CPB, such as hemodilution, have led researchers to explore modified techniques. Yang, et al., [24] introduced a modified CPB system with low priming volume to minimize hemodilution during open cardiac surgery [24]. This retrospective study examined the impact of reduced priming volume on patient outcomes. The findings suggested that minimizing priming volume could potentially mitigate the adverse effects of CPB and improve patient outcomes.

To further enhance blood conservation efforts, Hodge, et al., [25] employed quality improvement methodologies to increase the administration of autologous blood products in cardiac surgery [25]. Through multidisciplinary collaboration, these methodologies identified challenges surrounding autologous blood delivery and implemented strategies to optimize its use. This study demonstrates the importance of implementing systematic quality improvement approaches in achieving blood conservation goals. Improving quality when employing CPB, VADs, and ECMO necessitates a multifaceted approach that addresses multiple elements of patient care and device management. Several measures can be used to improve outcomes and improve patient safety.

First and foremost, proper patient selection and preoperative examination are essential. To detect any contraindications or circumstances that may impair the procedure's outcome, a complete assessment of the patient's health status, comorbidities, and risk factors should be performed [26]. Based on the features of the patient, customized treatment plans and tactics can be devised.

Secondly, standardized protocols and best practices should be followed during the perioperative period. These protocols may include infection prevention measures, hemodynamic management strategies, anticoagulation protocols, and weaning strategies [26]. Adherence to established guidelines and consensus statements can help ensure consistency and promote optimal patient outcomes.

Thirdly, continuous monitoring of patients is essential to detect any changes in the condition promptly. This monitoring may involve the use of advanced hemodynamic monitoring techniques, such as invasive pressure monitoring and cardiac output measurements, to guide decision-making and optimize device performance [27]. Regular assessment of device function, including pump flow rates, pump parameters, and alarms, is crucial for early detection of device malfunction or complications.

Incident reporting plays an important part in safety improvement. A study examined the

perspectives of perfusionists on incident reporting within the field of perfusion, with a specific focus on the Australia and New Zealand College of Perfusionists' (ANZCP) Perfusion Incident Reporting System (PIRS-2). Findings revealed that while there was a high likelihood of perfusionists reporting incidents to PIRS-2, actual reporting rates remained relatively low, with only 22% of respondents having submitted reports in the year leading up to the survey. "Unit culture" emerged as a significant barrier to reporting, with regional variations in the extent to which it was cited. Interestingly, New Zealand perfusionists reported incidents at a notably higher rate than the Australian counterparts, possibly due to differences in healthcare legislation. Despite these challenges, the study underscored the value of incident reports to individual practice and called for a cultural shift toward learning from successful outcomes, emphasizing the need for user-friendly reporting systems, simplicity in reporting processes, and continuous feedback to enhance the reporting culture within the perfusion community [28]. Furthermore, a multidisciplinary approach involving a team of healthcare professionals with expertise in critical care, cardiac surgery, cardiology, perfusion, and nursing is vital. Collaboration among team members fosters effective communication, promotes knowledge sharing, and ensures coordinated care delivery [29]. Regular team meetings, quality improvement initiatives, and educational programs can further enhance the expertise and performance of the team.

Additionally, ongoing research and technological advancements play a significant role in improving quality. Studies focusing on device design, development of new materials, and innovative management strategies contribute to enhancing outcomes. Research efforts should continue to investigate areas such as exercise training for patients with VADs, long-term management protocols, and complications associated with these devices.

Current challenges and future directions

Cardiopulmonary bypass (CPB), VADs, ECMO are all effective treatments for a variety of heart diseases. The use, however, is not without difficulties, and current research and innovations attempt to overcome these issues and pave the road for future enhancements.

Device design and durability are one of the major issues in the field of VADs and ECMO. Initial VAD designs aimed to mimic the heart's function through pulsatile pumps, but the large size, weight, and limited durability posed significant limitations [30]. This led to the development of continuous flow (CF) design, which is now the predominant approach in LVADs [30]. However, long-term complications such as infections and thrombotic events associated with these devices remain major concerns [31]. Another critical challenge in LVAD therapy is patient selection. Appropriate patient selection is crucial for optimal outcomes, as adverse events and burdens for both patients and caregivers persist despite advancements in device technology [32]. Comprehensive evaluations, including clinical, anatomical, and psychological factors, is necessary to identify suitable candidates for LVAD implantation. Moreover, the perioperative management of patients with mechanical circulatory support devices, including ECMO and LVADs, presents unique challenges. Anesthetic support and surgical interventions

in these patients require specialized protocols and expertise. Guidelines and best practices have been developed to enhance perioperative care for patients with these devices [33].

Future directions in the field of mechanical circulatory support devices focus on improving device durability, minimizing adverse events, and refining patient selection criteria. Research efforts aim to develop smaller, more efficient, and reliable devices that can provide long-term support while reducing the risk of infections and thrombotic events.

Furthermore, advancements in biomaterials, device engineering, and computational modeling hold promise for enhancing device design and optimizing blood flow characteristics. The field of Perfusion still faces numerous unresolved issues and uncertainties that require attention. One of these areas pertains to the treatment of cardioplegia, where standardization is lacking. Various aspects such as the mode of delivery, temperature, blood ratio, hot shots, solution, and top-up times exhibit significant variations across different practices.

Establishing standardized guidelines in these areas would enhance consistency and optimize patient outcomes. Additionally, heparin dosages differ among different centers, and the dosing of protamine involves multiple mathematical formulas, indicating a need for greater uniformity [34]. The use of cell saver technology is another aspect that lacks consensus. While some centers employ cell savers for every case, others do not. Defining specific guidelines for the appropriate utilization of this technique, such as when to bag pump blood as whole blood or employ cell saver technology, would help guide practitioners. Similarly, cooling and warming strategies, along with temperature monitoring, should be based on evidence rather than individual preferences. Techniques like antegrade cerebral perfusion (ACP), retrograde cerebral perfusion (RCP), and deep hypothermic circulatory arrest (DHCA) still contain numerous ambiguities despite its frequent utilization.

Research and evidence in these areas, aligned with the guidelines provided by the European Association for Cardio-Thoracic Surgery (EACTS), would help address questions regarding the preferred approach, monitoring parameters (such as CVP or radial pressures), temperature settings, and optimal flow rates. Standardizing cannulas specific to these techniques would also contribute to improved practice [35].

Disposable equipment is another crucial aspect in which standardization and improvement are needed. Surgeons often continue using disposables which are familiar with from the training, but it is important to evaluate if there are more advanced alternatives available that can enhance patient care.

Embracing change and exploring the potential for improvement in this area should be encouraged. Despite the increased level of education in Perfusion, including the availability of master's level programs, there remains a gap in research within the field. It is crucial to determine why such gaps exist and to foster a community-driven effort to address these questions. Perfusionists should strive to be proactive in staying updated with training and skills, utilizing surveys and collaborative platforms to learn from each

other and adapt the practices accordingly [36]. To tackle these challenges, it is essential to promote a culture of collaboration and knowledge exchange within the Perfusion community. Establishing multidisciplinary teams that bring together experts from various domains can help address the gaps in understanding and ensure safe and standardized practices. Encouraging research initiatives and facilitating funding for studies in critical areas of Perfusion will further advance the field and lead to evidence-based guidelines. Professional organizations and societies can play a significant role in supporting ongoing education, training, and skill development for Perfusionists. By fostering a sense of ownership and shared responsibility, the community can strive to answer the unresolved questions and continuously improve patient care and outcomes in the field of Perfusion.

Contributions from major players

Major perfusion societies and boards, including AmSECT, SCPS, and EBCP, have made significant contributions to improving perfusion safety standards and quality. These organizations have developed guidelines, standards, and initiatives to ensure the provision of safe and effective perfusion care. Here is an essay summarizing the contributions.

The American Society of ExtraCorporeal Technology (AmSECT) has played a crucial role in advancing perfusion safety standards. AmSECT has developed Standards and Guidelines for Perfusion Practice, which serve as a comprehensive resource for perfusionists [37]. These guidelines aim to standardize care, improve patient safety, and minimize risks associated with perfusion. AmSECT has also recognized the importance of pediatric perfusion and has developed a pediatric-specific document [39].

Moreover, AmSECT has established the Safety Committee, which focuses on promoting perfusion safety. The committee has implemented various initiatives, including a student essay contest, to raise awareness about patient safety and encourage the pursuit of excellence in perfusion practice [38].

These efforts contribute to fostering a culture of safety within the perfusion community. The Society of Clinical Perfusion Scientists (SCPS) and The College of Clinical Perfusion Scientists (CCPS) are the professional bodies representing perfusionists in Great Britain and Ireland [36]. These organizations actively promote the advancement of perfusion practice and patient safety. That provide educational resources, training programs, and professional development opportunities for perfusionists, ensuring the highest standards of care are met.

SCPS and CCPS have also been involved in research and innovation, aiming to enhance perfusion techniques and technologies. By collaborating with other scientific and medical societies, which also contribute to the development of evidence-based practices and improves perfusion safety standards [36]. The European Board of Cardiovascular Perfusion (ECCP) is another prominent organization dedicated to enhancing perfusion safety and quality in Europe. ECCP has established professional standards and competencies for cardiovascular perfusionists, ensuring a high level of expertise and patient care across European countries.

These organizations offer certification programs and continuing education opportunities to support ongoing professional development. In conclusion, major perfusion societies and boards, including AmSECT, SCPS, and ECCP, have made significant contributions to improving perfusion safety standards and quality. Through the development of guidelines, educational initiatives, and collaborative efforts, these organizations have played a vital role in standardizing care, enhancing patient safety, and promoting excellence in perfusion practice. The ongoing dedication to advancing perfusion techniques and technologies ensures the provision of safe and effective perfusion care for patients worldwide.

Conclusion

In conclusion, this literature study provides a comprehensive overview of perfusion quality and safety within the context CPB and circulatory devices.

It emphasizes the evolution of perfusion techniques and the pivotal role of advancements in circuit design, standardized practices, and safety measures. Critical factors, including equipment, personnel, and management strategies, are highlighted as essential for safe and effective perfusion procedures.

The examination of adverse events underscores the need for proactive measures, with quality improvement initiatives and collaboration among perfusion communities as key drivers for enhancing safety. Addressing knowledge gaps and exploring emerging technologies are avenues to further elevate perfusion safety and patient care. By implementing these insights, healthcare professionals can continually enhance patient outcomes in cardiac surgery.

References

1. Brum R, Rajani R, Gelandt E, Morgan L, Raguseelan N, Butt S, et al. Simulation Training for Extracorporeal Membrane Oxygenation. Ann Card Anaesth. 2015;18(2):185-90. PubMed | CrossRef
2. Kurusz M. Perfusion Safety: New Initiatives and enduring principles. Perfusion. 2011;26 Suppl 1:6-14. PubMed | CrossRef
3. Gourlay T. Historical Development of Minimised Cardiopulmonary Bypass. In Minimized Cardiopulmonary Bypass Techniques and Technologies. Woodhead Publ. 2012:3-16.
4. Miclăuș T, Valla V, Koukoura A, Nielsen AA, Dahlerup B, Tsianos GI, et al. Impact of Design on Medical Device Safety. Ther Innov Regul Sci. 2020;54(4):839-49. PubMed | CrossRef
5. Ratwani RM, Adams KT, Kim TC, Busog DN, Howe JL, Jones R, et al. Assessing Equipment, Supplies, and Devices for Patient Safety Issues. Patient Safety. 2023;5(1): 2689-0143.
6. Kennedy-Metz LR, Barbeito A, Dias RD, Zenati MA. Importance of high-performing teams in the cardiovascular intensive care unit. J Thorac Cardiovasc Surg. 2022 Mar;163(3):1096-1104. PubMed | CrossRef
7. Han S, Choi S, Park J, Kweon S, Oh SJ, Shakya HB, et al. The Teamwork Structure, Process, and Context of a Paediatric Cardiac Surgery Team in Mongolia: A Mixed-Methods Approach. Int J Health Plann Manage. 2022;37(4):2224-239. PubMed | CrossRef
8. Medtronic. (n.d.). Cardiopulmonary Products. Medtronic.com. Retrieved. 2023.
9. Researchgate.net. Retrieved. 2023.
10. Murphy GS, Hessel EA 2nd. Perioperative Myocardial Infarction During Noncardiac Surgery. Anest. 2000;92(3):1023-8.
11. Extracorporeal Life Support Organization. ELSO Guidelines for Cardiopulmonary Extracorporeal Life Support. Extracorporeal Life Support Organization. 2017:1-26.

12. Ranucci M, Ballotta A, Kandil H, et al. The Procoagulant Profile of Cardiac Surgical Patients with Postoperative Acute Kidney Injury. Crit Care. 2012;16(3):R110.
13. Schmidt M, Tachon G, Devilliers C, Muller G, Hekimian G, Bréchot N, et al. Blood Oxygenation and Decarboxylation Determinants During Venovenous ECMO for Respiratory Failure in Adults. Intensive Care Med. 2013;39(5):838-46. PubMed | CrossRef
14. Zegers M, de Bruijne MC, de Keizer B, Merten H, Groenewegen PP, van der Wal G, et al. The Incidence, Root-Causes, and Outcomes of Adverse Events in Surgical Units: Implication for Potential Prevention Strategies. Patient Saf Surg. 2011;5:13. PubMed | CrossRef
15. Palanzo DA. Perfusion Safety: Defining the Problem. Perfusion. 2005;20(4):195-203. PubMed | CrossRef
16. Zangrillo A, Landoni G, Biondi-Zoccai G, Greco M, Greco T, Frati G, et al. A Meta-Analysis of Complications and Mortality of Extracorporeal Membrane Oxygenation. Crit Care Resusc. 2013;15(3):172-8. PubMed | CrossRef
17. Popugaev KA, Bakharev SA, Kiselev KV, Samoylov AS, Kruglykov NM, Abudeev SA, et al. Clinical and Pathophysiologic Aspects of ECMO-Associated Hemorrhagic Complications. PLoS One. 2020;15(10):e0240117. PubMed | CrossRef
18. Kim JH, Pieri M, Landoni G, Scandroglio AM, Calabrò MG, Fominskiy E, et al. Venovenous ECMO Treatment, Outcomes, and Complications in Adults According to Large Case Series: A Systematic Review. Int J Artif Organs. 2021;44(7):481-488. PubMed | CrossRef
19. Kannapadi NV, Jami M, Premraj L, Etchill EW, Giuliano K, Bush EL, et al. Neurological Complications in COVID-19 Patients with ECMO Support: A Systematic Review and Meta-Analysis. Heart Lung Circ. 2022;31(2):292-298. PubMed | CrossRef
20. Zhang Q, Zhao W, Gao S, Yan S, Diao X, Wang Y, et l. Quality Management of a Comprehensive Blood Conservation Program During Cardiopulmonary Bypass. Ann Thorac Surg. 2022;114(1):142-150. PubMed | CrossRef
21. Suzuki Y, Roach J, Leyva YR, DeAnda A Jr, Levy G. Simple and Effective Blood Salvage Technique for Extracorporeal Membrane Oxygenation Circuit. ASAIO J. 2021;67(9):e150-e152. PubMed | CrossRef
22. Ottens J, Tuble SC, Sanderson AJ, Knight JL, Baker RA. Improving Cardiopulmonary Bypass: Does Continuous Blood Gas Monitoring have a Role to Play? J Extra Corpor Technol. 2010;42(3):191-8. PubMed | CrossRef
23. Khan JH, Green EA, Chang J, Ayala AM, Barkin MS, Reinys EE, et al. Blood and Blood Product Conservation: Results of Strategies to Improve Clinical Outcomes in Open Heart Surgery Patients at a Tertiary Hospital. J Extra Corpor Technol. 2017;49(4):273-282. PubMed | CrossRef
24. Yang K, Huang H, Dai R, Zhang J, Wei X, Gao F, et al. Modified Cardiopulmonary Bypass with Low Priming Volume for Blood Conservation in Cardiac Valve Replacement Surgery. J Cardiothorac Surg. 2023;18(1):56. PubMed | CrossRef
25. Hodge AB, Preston TJ, Fitch JA, Harrison SK, Hersey DK, Nicol KK, et al. Quality Improvement Methodologies Increase Autologous Blood Product Administration. J Extra Corpor Technol. 2014;46(1):45-52. PubMed | CrossRef
26. Hayward C, Adachi I, Baudart S, Davis E, Feller ED, Kinugawa K, et al. Global Best Practices Consensus: Long-Term Management of Patients with Hybrid Centrifugal Flow Left Ventricular Assist Device Support. J Thorac Cardiovasc Surg. 2022;164(4):1120-1137.e2. PubMed | CrossRef
27. Severin R, Sabbahi A, Ozemek C, Phillips S, Arena R. Approaches to Improving Exercise Capacity in Patients with Expert Rev Med Devices. 2019;16(9):787-798. PubMed | CrossRef
28. Willcox TW, Baker RA. Incident Reporting in Perfusion: Current Perceptions on PIRS-2. J Extra Corpor Technol. 2020;52(1):7-12. PubMed | CrossRef
29. Salas De Armas IA, Patel JA, Akay MH, Patel MK, Rajagopal K, Karabulut MN, et al. Off-Pump Continuous-Flow Left Ventricular Assist Device Implantation. Tex Heart Inst J. 2021;48(1):e197033. PubMed | CrossRef
30. Miller L, Birks E, Guglin M, Lamba H, Frazier OH. Use of Ventricular Assist Devices and Heart Transplantation for Advanced Heart Failure. Circ Res. 2019;124(11):1658-1678. PubMed | CrossRef
31. Han J, Trumble DR. Cardiac Assist Devices: Early Concepts, Current Technologies, and Future Innovations. Bioengineering (Basel). 2019;6(1):18. PubMed | CrossRef
32. Kanwar MK, Bailey S, Murali S. Challenges and Future Directions in Left Ventricular Assist Device Therapy. Crit Care Clin. 2018;34(3):479-492. PubMed | CrossRef

33. Notarianni A, Tickoo M, Bardia A. Mechanical Cardiac Circulatory Support: An Overview of the Challenges for the Anesthetist. Curr Anesthesiol Rep. 2021;11(4):421-428. PubMed | CrossRef
34. Morris JA Jr, Carrillo Y, Jenkins JM, Smith PW, Bledsoe S, Pichert J, et al. Surgical Adverse Events, Risk Management, and Malpractice Outcome: Morbidity and Mortality Review is Not Enough. Ann Surg. 2003;237(6):844-51;851-2. PubMed | CrossRef
35. Thana U and Tepsuwan T. Safety of Wet-Primed Cardiopulmonary Bypass Circuits During Extended Standby: Safety of Wet-Primed CPB. *Chiang Mai Med Jl*. 2023;59(2);61-4.
36. Eaton RG, Shah VS, Dornbos D 3rd, Zaninovich OA, Wenger N, Dumont TM, et al. Demographic Age-Related Variation in Circle of Willis Completeness Assessed by Digital Subtraction Angiography. Brain Circ. 2020;6(1):31-37. PubMed | CrossRef
37. Oldeen ME, Angona RE, Hodge A, Klein T. American Society of ExtraCorporeal Technology: Development of Standards and Guidelines for Pediatric and Congenital Perfusion Practice (2019). World J Pediatr Congenit Heart Surg. 2021;12(1):84-92. PubMed | CrossRef
38. Perfusion safety. (n.d.). Amsect Org. Retrieved. 2023.