Workflow Gaps in Blood Banking and Transfusion Automation: A Narrative Review

Dr. Aashna Gupta*

Senior Resident, PGIMS Rohtak, Haryana, India

aashna.gupta23@yahoo.com

Abstract: Automation in blood banking and transfusion services has improved workflow efficiency and safety, but several gaps continue to affect transfusion practices. This narrative review examines workflow gaps in blood banking and transfusion automation using secondary evidence from clinical, technological, and health systems literature. The review covers pre-analytical, analytical, and post-analytical stages, including patient and sample identification, analyser–information system connectivity, bedside verification, and post-transfusion documentation. The review found that incomplete technology integration, poor system interoperability, inconsistent workflow practices, and human-factor issues remain major challenges. These gaps may contribute to transfusion errors, delays, reduced traceability, and operational inefficiencies. The review concludes that automation alone is insufficient to ensure transfusion safety. Integrated digital systems, continuous staff training, and strong organisational support are essential for improving workflow efficiency and patient safety.

Keywords: Blood Banking, Transfusion Automation, Patient Safety, Human Factors, Health Information Systems, Workflow Gaps.

1. INTRODUCTION

Blood banks and transfusion services play an integral part within the healthcare system, providing safe, timely and sufficient blood and blood components to the patients of varying medical indications. Safety and quality assurance are of vital importance throughout the blood banking process, as it may affect patient outcomes. Any error from the donor registration process to the transfusion administration may cause serious complications and can affect patient safety. Blood banks have been increasingly introducing automation in their pre-analytical, analytical, and post-analytical processes to increase accuracy, efficiency, and traceability. Automated technologies have aided in the donor registration, blood grouping, compatibility testing, inventory management, and documentation of the transfusion process, thereby alleviating manual handling and enhancing operational efficiency. In spite of these improvements, several blood banks still use partly manual or semi-automated process workflows, making them vulnerable to human error and inefficiency in the workflow process (Varghese *et al.,* 2024).

There have been recent studies that pinpoint key workflow gaps in transfusion automation. Current systems are frequently not fully integrated or modelled, making the process of capturing and managing important transfusion activities challenging. Important functions like serological testing, emergency transfusion and documentation are often not adequately integrated into automated systems. Furthermore, interoperability problems with instruments, data exchange and sample handling are very common in the pre- and post-analytical phases, causing delays, repetitive work and persisting reliance on manual work (Pérez-Aliaga *et al.*, 2024).

New technologies, like artificial intelligence (AI) and machine learning (ML), can also help to improve transfusion decision-making, prediction and workflow management. They have, however, been limited in practice because of poor data integration, complexity of the work and user acceptance (Imamoglu *et al.,* 2023). Consequently, the extent to which these technologies can be realised in clinical practice is often not fully realised. The challenges suggest a need for a more comprehensive awareness of gaps in workflow within the blood bank and transfusion automation. To enhance safety, boost efficiency, and enable successful technology integration, it is considered important to identify limitations in technology integration, workflow design, and operations. Hence, this paper is aimed at reviewing and evaluating the gaps in the workflows of blood banking and transfusion automation based on evidence drawn from clinical, technological and health systems literature that can identify important barriers and highlight opportunities for improving transfusion safety and workflow efficiency.

2. RESEARCH METHODOLOGY

This study uses a narrative literature review to examine workflow gaps in blood banking and transfusion automation based on secondary data. Relevant studies published between 2010 and 2025 were identified through PubMed, Scopus, Web of Science, Google Scholar, and ScienceDirect. The search used keywords such as blood banking, blood transfusion, automation, workflow gaps, transfusion safety, laboratory information systems, artificial intelligence, and workflow efficiency. The inclusion criteria covered peer-reviewed articles, reviews, and reports published in English and related to blood banking, transfusion workflows, and automation. Unrelated studies, duplicates, non-English publications, and articles with unclear methodology were excluded. The selected literature was analysed using a qualitative

thematic approach, focusing on major themes such as workflow inefficiencies, system integration, data management, and user acceptance. The findings were organised thematically to present a clear overview of existing workflow gaps in blood banking and transfusion automation.

3. THEMATIC REVIEW

3.1 Pre-Analytical Process Inefficiencies and Their Implications for Safety, Efficiency, and Quality

The laboratory phase of transfusion is the most vulnerable to errors because it comprises both manual and semi-automated processes such as patient consent, sample collection, labelling, and transport. A significant number of transfusion-related errors are known to occur in this phase primarily because of the lack of standardisation and variance in the process. These limitations are not just process- or procedural-based but also reflect the overall process design shortcomings and integrating technologies. In consequence, even highly specialised blood transfusion services remain susceptible to avoidable errors that jeopardise patient safety and compromise the reliability of their services.

One key problem during this stage is continued patient and sample misidentification. Such errors, like wrong blood in tube (WBIT), most likely arise from incorrect sampling labelling and inadequate checking at the time of sample collection (Murphy *et al.*, 2013). The failure to implement, or an intermittent failure to use, bar-coded identities, adds to this risk, especially in busy healthcare settings. These errors, therefore, breach safety practices, which can result in incompatible transfusions, and impact efficiency through the need for duplicate sampling and diagnostic tests.

This next element relates to the interoperability of donor, hospital and laboratory information systems. Many systems could benefit from manual data entry into multiple systems, which increases the chance of data entry and system integration errors (Fung *et al.*, 2017). It impairs workflow processes, increases processing time and decreases efficiency. In addition, the lack of data integration and continuity impairs traceability, hampers the ability to maintain accurate sample status in the transfusion process, and affects safety monitoring and quality control.

Sample transfer and handling also make a substantial contribution to pre-analytical inefficiencies. Inefficient transfer, sub-optimal storage and monitoring options, and lack of live

tracking requirements for samples can impact sample quality and test results. Global observations have shown that suboptimal monitoring at this level can lead to the risk of suboptimal diagnostic reporting and impact transfusion decision-making (World Health Organization (WHO), 2017). This situation not only affects efficiency but it also hampers the reliability of laboratory results, which are vital for transfusion safety.

Behavioural aspects also amplify pre-analytical workflow deficiencies. Lack of training, failure to follow standard operating procedures and difficult working conditions can result in procedural variations. Workers may inadvertently skip safety protocols or use 'workarounds', which create opportunities for error. These human factors illustrate that technological changes are not, in and of themselves, sufficient; they could benefit from skilled human interaction and adherence to protocol. Inadequate attention to human factors can negatively impact efficiency and safety.

The pre-analytical stage highlights how vulnerable points can impact several aspects within transfusion services. Failure at this level not only places patient safety and the overall efficiency and quality of the transfusion process at risk but also affects its entire workflow. Increasing the rigour of all the processes, patient and specimen identification, introduction of digital systems and adequate training of staff are required to enhance safe and efficient transfusion practice with quality.

3.2 Limitations in Analytical Automation

Automation has improved the diagnostic component of blood banking, including blood grouping, antibody screening and cross-matching. This has enhanced the reliability, standardisation and efficiency of the tests performed. But despite these technological advancements, there still remain workflow gaps that limit the impact of automation. These issues are primarily linked to system-from integration, manual system management and the inability to completely automate testing. As such, the testing process remains with imperfections that impact not only efficiency but also safety and quality for transfusion (Yazer & Waters, 2011).

For example, there is often a disconnect between automated instruments and laboratory information management systems. For many blood banks, the transfer of test results for validation, verification, or transcription remains a manual process. This break in the digital process adds time to the testing process and raises the risk of errors. As a result, the potential benefits gained from automation are adversely affected, and result reporting may be delayed, thereby affecting time-sensitive transfusion support in critical cases.

A subsequent critical issue is that of unexpected cases. Automated equipment provides fast and accurate results during a normal blood group test but typically diverts samples that display unexpected serological reactions to human interpretation. This human reliance is not conducive to a continuous workflow and can be a potential source of delay in the laboratory. In a high-throughput laboratory, this can lead to delays in testing and increased workload for technicians, which, in turn, can lead to inefficiency and lack of test result consistency.

Quality assurance processes during the analytical phase also play a key role in inefficient workflows. For example, instrument systems must be calibrated, maintained and have constant reagent checks to guarantee accuracy. Poor integration of these activities into the testing process can result in downtime for testing and lower laboratory productivity. Failure to adhere to quality control standards also has direct implications for the safety and quality of transfusion services, as test results generated may not be accurate.

Additionally, people play a role in the quality of the analytical workflow. Differences in staff skill level, a lack of training in interacting with automated systems, and poor knowledge of error flags or troubleshooting procedures can contribute to the underuse and misuse of technology. Such factors may adversely affect automation and utilisation but may lead to errors. During busy periods, increased workload and reduced turnaround time may compromise protocols, raising safety and quality concerns.

The analytical phase indicates that automation cannot fix workflow issues without appropriate integration and training in automated processes and ensuring consistent quality management and reporting standards. Current deficiencies risk patient safety (due to diagnostic errors), efficiency (due to workflow disruptions) and quality of patient services (due to lack of consistency and reliability of laboratory processes). This calls for a compound integration of automation and process management with a human-centred approach to systems design.

3.3 Post-Analytical and Transfusion-Stage Workflow Gaps

Post-analytical and transfusion is the last and most important phase of transfusion, involving the provision of feedback from the laboratory to patient care. This stage refers to result transmission, blood component issue, administration and post-transfusion follow-up. While automation has improved many aspects of this phase, there are still some workflow issues that remain, mainly due to communication breakdowns, variable integration, and clinical practice. These gaps impact patient safety, as failure here can result in adverse or even fatal consequences (Goodnough *et al.*, 2013).

One significant issue is communication between the laboratory and the clinical area. In some healthcare facilities, transfusion information, including compatibility, blood availability, and albumin administration information, is not electronically integrated. This issue is associated with a reliance on verbal communication, which can lead to information delays, miscommunications and information loss. Near-miss transfusions and incorrect transfusions, which have major implications for patient safety (Narayan & Carter, 2019), often result from these communication breakdowns.

A further information gap is the absence of effective bedside verification. While barcode scanning and electronic identification systems are available, they are variable. Without electronic verification standards, manual processes handle the final steps in identity verification, leading to transfusion errors. The delivery of the right blood component to the right patient at the right time relies on integrated verification systems, making the process difficult without such systems and resulting in safety and quality issues (Kaufman *et al.*, 2015).

There are also inefficiencies in the delivery of blood components. Inefficient transport, absence of real-time monitoring and coordination between different hospital departments can result in delays, especially during emergencies. This may hinder an efficient reaction and potentially harm patient outcomes. Global guidelines prioritise efficient logistics and integrated systems for timely transfusion service, but such practices are not always the case (World Health Organization (WHO), 2021).

Documentation and monitoring after transfusion also pose quality and safety challenges. Poor or tardy documentation of transfusion information, events and outcomes impairs haemovigilance. Incomplete or inaccurate information hampers trend analysis, error investigation and corrective action. Research indicates incomplete documentation may negatively affect quality assurance and hampers our ability to learn from transfusion experiences and improve practice (Randall & Obstetric, 2019).

This post-analytical and transfusion stage suggests the combined effects of failures related to communication, verification, logistics, and documentation on transfusion quality. This negatively affects patient safety by increasing the risk of error; may reduce efficiency in the transfusion process through time delays and coordination breakdowns; and may reduce the quality of service delivered by negating traceability and improvement processes. The transfusion process can be improved through integrated IT solutions, confirmed positive identification, better communication tools and enhanced post-transfusion monitoring.

3.4 Technology Integration and Interoperability Issues

Technology integration and interoperability are central to the effectiveness of automation in blood banking and transfusion services. Despite the availability of advanced digital tools, many healthcare systems continue to operate with fragmented platforms, including laboratory information systems, hospital information systems, and transfusion management software.

These systems often lack seamless connectivity, resulting in discontinuities in data flow and workflow execution. Such fragmentation limits the ability of automation to deliver its full benefits and may contribute to vulnerabilities that directly affect patient safety and operational performance (Sittig & Singh, 2010).

A key issue is the absence of standardised data exchange mechanisms across different technological platforms. Variations in system architecture, vendor-specific designs, and lack of uniform communication protocols hinder interoperability. Consequently, the inefficient sharing of critical transfusion-related data in real time results in delays in decision-making and a greater reliance on manual data handling. These inefficiencies slow down operations and increase the likelihood of transcription errors and incomplete information transfer, thereby compromising both safety and quality of care (Adochiei & Petroiu, 2025).

Another significant limitation is the partial implementation of automation across the transfusion workflow. Certain stages, such as laboratory testing, may be highly automated, but other components like blood distribution, bedside verification, and documentation often remain semi-manual. This uneven adoption may contribute to workflow gaps and reduce overall system efficiency. The lack of end-to-end integration may hinder continuous tracking and coordination, weakening traceability and increasing the risk of errors across different stages of the transfusion process.

Data security and cybersecurity concerns further complicate integration efforts. As transfusion services increasingly rely on interconnected digital systems, the risk of data breaches, unauthorised access, and system disruptions becomes more prominent. Weak cybersecurity frameworks can compromise sensitive patient and transfusion data, affecting both system reliability and trust. Addressing these risks is considered important to ensure safe and uninterrupted operation of integrated healthcare technologies (Kruse *et al.,* 2017).

Organisational and infrastructural constraints may contribute to interoperability challenges. High implementation costs, limited technical expertise, and lack of strategic planning often delay or restrict the adoption of fully integrated systems. Without strong institutional support and coordinated efforts, even advanced technologies fail to achieve meaningful improvements in workflow efficiency and transfusion safety.

Overall, gaps in technology integration and interoperability represent a fundamental barrier to optimising automated transfusion systems. These issues compromise patient safety through incomplete or delayed information exchange, reduce efficiency due to fragmented workflows, and weaken service quality by limiting traceability and consistency. A comprehensive approach involving standardised data protocols, secure digital infrastructure, and coordinated system design is considered important to overcome these challenges and enhance the effectiveness of transfusion automation.

3.5 Human Factors and Organizational Constraints

Automation in blood banking and transfusion is dependent on human factors. Although sophisticated technologies are available to support operations, workflows remain inefficient due to human-systems interaction issues, such as inappropriate use, system workarounds and failure to follow standard operating procedures. Research indicates that many errors in transfusion services are not due to technology, but rather human factors in complex systems. Such problems reflect that automation is not enough for ensuring safety and efficiency without human interaction and system integration.

A key human-factors-related issue is the training and assessment of skills when operating automated systems. Skilled automation users need to be familiar with system signals, constraints and exception management. Poorer training can be associated with ineffective use of the system, slower decision-making and continued reliance on manual processes, thereby leading to inefficiency and more risk of error (Lescoutra-Etchegaray & Comoy, 2014). Inadequate training in automation technologies negatively impacts safety and quality.

Other factors such as workload, staffing and time pressures also compound workflow issues. During periods of busy activity, health professionals may depart from standard operating procedures or workarounds to provide timely patient care. Although they may offer short-term efficiencies, these practices place a greater cognitive load on the user, increasing the potential for transfusion error, especially when operating in urgent and after-hours care (Carayon *et al.*, 2014). These examples highlight the challenges of operational pressures on safety and consistency in transfusion.

A further area of risk is the lack of communication between multidisciplinary teams. Lack of communication between doctors, nurses, blood bank technicians and other support staff

frequently **is associated with** delays, misunderstanding of transfusion orders and inaccurate documentation. These gaps impact efficiency and are a prominent cause of near misses in transfusion services (The Joint Commission, 2015). Poor information sharing not only affects workflow but also is a significant cause of patient harm.

Lack of technological acceptance and user input into system design further complicate workflows. When healthcare professionals are not involved in the implementation of automated systems, they may find these systems difficult to understand. This situation is **associated with** poor acceptance and variable usage. Failure to design systems with end users in mind will limit the ease of use and adoption of the system, which may negatively affect efficiency and care quality.

Cultural and leadership factors also play a critical role in human-factor-related workflows. Organisations that lack a safety culture, do not focus on quality improvement processes, and lack leadership commitment are more likely to suffer from operational inefficiencies. Cultures that foster accountability and learning, and that embrace and adhere to standardised processes and procedures, play a critical role in reducing errors and enhancing system performance. Improvements in these areas are important for improving the safety and effectiveness of transfusion services (Frankel *et al.*, 2017).

Table 1. Human Factors Challenges in Transfusion

Factor	Workflow Gap	Impact on Safety, Efficiency, and Quality	Suggested Mitigation Strategies
Inadequate training	Improper use of automated systems	Increased errors, workflow delays, and reduced reliability	Regular staff training, competency assessments, and refresher programs
High workload	Skipping or incomplete safety checks	Higher risk of transfusion errors and near-miss events	Adequate staffing, workload distribution, and workflow planning
Poor communication	Delayed or incorrect transfer of information	Reduced efficiency and increased risk to patient safety	Standardized communication protocols and team coordination
Resistance to technology	Limited adoption of automated systems	Inconsistent workflows and	User training, staff involvement, and technical support

		reduced service quality	
Weak safety culture	Non-compliance with standard protocols	Repeated errors and compromised patient safety	Strong leadership, monitoring, and promotion of safety practices

3.6 System-Level Implications of Workflow Gaps in Blood Banking and Transfusion Automation

In assessing workflow gaps in blood banking and transfusion automation, the overall effect of these gaps is not limited to errors but has wider implications and may affect safety, efficiency, and quality. These include pre-analytical, analytical and post-analytical stages and have a negative impact on automated transfusion systems. Incomplete integration and non-compliance with established processes exacerbate the potential for transfusion errors, such as the wrong blood type and wrong patient. These incidents underscore the necessity of supplementing automation with coordinated and managed workflows to ensure patient safety.

Gaps in workflows severely impact operational efficiency. Discontinuities, manual workarounds and delays in communication and information sharing may contribute to longer turnaround times, which delay blood component availability and the time to transfusion. This is particularly concerning in urgent situations where rapid transfusion is crucial. These lead to delays, which not only impact patient care but also place additional strain on health care providers, creating a vicious cycle of inefficiency and potential errors.

Workflow deficiencies may contribute to poor quality and consistency of transfusion practices. Ongoing coordination of sample collection, testing, and recording may affect the quality of blood laboratory results and blood components. This situation results in duplicate testing, variability in clinical decision-making, and inconsistencies in transfusion practices. As a result, the potential cost-benefit of automation standardisation and accuracy is undermined, impacting patient outcomes.

From a financial perspective, inefficiencies in these workflows come at a significant cost. Inefficiencies result in unnecessary resource use through repeated testing, unnecessary wastage of blood components and extra manpower to error-proof and rectify the situation. This

in turn decreases the cost-benefit of these automation technologies and their long-term viability in high-throughput healthcare settings.

A further important consequence is the diminished efficacy of traceability and haemovigilance. Issues in workflows, particularly in documentation and data management, limit the capacity to trace blood components through the transfusion process. This may reduce the ability to track adverse events, detect underlying problems and take timely corrective measures. Consequently, the capacity for quality improvement and risk reduction remains limited.

In summary, workflow gap assessment identifies that gaps are systemic and affect not only individual steps in the transfusion process but potentially the entire transfusion service. Addressing these gaps requires a comprehensive approach that integrates technological advancements with standardised workflows, effective communication, skilled personnel, and strong organisational support. Only then can automation technologies be fully harnessed to improve safety, efficiency and quality in blood banking and transfusion services.

4. SYSTEM IMPLICATIONS

Blood banking and transfusion automation workflow issues have far-reaching implications for patient safety, operational efficiency and service quality. Inconsistencies in workflow during pre-analytical, analytical, and post-analytical procedures create the potential for transfusion-related error, such as patient misidentification, testing delays, and documentation errors. These gaps can have a direct impact on patient outcomes and decrease the trust and effectiveness of transfusion services. Fragmented workflows, manual workarounds and communication delays also impact operational efficiency. These problems slow down the turn-around time, reduce the availability of blood components and also generate additional workload for healthcare providers, particularly in an emergency transfusion situation. There are also deficiencies in the transfusions workflow which adversely affect quality and consistency in transfusion practices. Limited coordination, repeated testing and inadequate documentation lead to lower traceability and lower haemovigilance systems. Moreover, the inefficiencies drive up the operating expenses of the organisation through resource wastage, redoing tasks and extra manpower needs. In general, gaps in workflow processes produce a problem across the system that may affect more than just the individual processes. These gaps need to be addressed to enhance transfusion safety, efficiency, and quality blood banking services.

5. RECOMMENDATIONS

The following practical suggestions are put forward to enhance the efficiency of transfusion work and improve transfusion safety:

- **Digital integration**: Blood banks need to enhance integration between their LIS, HIS and transfusion management systems to enable smooth real-time data flow and minimise manual data transfer.
- Consistent use of barcode patient and sample identification throughout all areas – bedside transfusion verification – to enhance traceability and identification errors.
- **Staff training:** Staff should be provided with regular training, competent testing, and refresher courses to enhance staff confidence and compliance with standard operating procedures with automated systems.
- **Strengthening of haemovigilance**: The documentation and monitoring system for adverse events post-transfusion should be strengthened to facilitate reporting of adverse events, facilitate traceability and allow for continuous quality improvement.

User-focused design of systems, standardised communication processes, and leadership support are crucial for the successful introduction of automation technologies.

6. LIMITATIONS

There are some limitations of this study. Narrative review, first of all, is an interpretive review of the published literature, and it is not systematically done. Second, selection bias may also exist, as the included studies were selected based on their relevance and availability, which could have affected the results. Third, the review does not encompass quantitative synthesis or meta-analysis, which would enable the measurement of the magnitude of workflow gaps or compare outcomes statistically. Nevertheless, the review offers a helpful overview of certain problems in blood banking and transfusion automation and suggests practical approaches to enhance safety, efficiency and quality of service.

7. CONCLUSION

Through this review, it will be highlighted that while automation has contributed to a high level of accuracy and efficiency in blood banking and transfusion services, there are still some important workflows that need to be addressed in both pre- and post-analytical, as well as analytical processes. Some of the key difficulties are insufficient system integration, interoperability restrictions, human factor concerns, and non-uniform compliance with standard protocols, all of which may impact patient safety and workflow efficiency. The conclusion is that there are no risks of transfusion that can be eliminated by automation. The success of improvement depends on the combined efforts of integrated digital systems, competent staff, communication, and organisational practices. Future recommendations include further development of interoperability, continuing professional education, enhancing haemovigilance, and introducing new technologies like artificial intelligence in well-defined workflows. Meeting these priorities will be vital to the improvement of patient safety, the use of resources and the quality of transfusion care.

References

1. Adochiei, F. C., Țoi, F. A., Adochiei, I. R., Argatu, F. C., Serițan, G., & Petroiu, G. G. (2025). *HL7 FHIR-Based Open-Source Framework for Real-Time Biomedical Signal Acquisition and IoMT Interoperability*. Applied Sciences, 15(23), 12803.

2. Carayon, P., Wetterneck, T. B., Rivera-Rodriguez, A. J., Hundt, A. S., Hoonakker, P., Holden, R., & Gurses, A. P. (2014). *Human factors systems approach to healthcare quality and patient safety*. Applied Ergonomics, 45(1), 14–25.

3. Elhaj, S. A., Odeh, Y., Tbaishat, D., Rjoop, A., Mansour, A., & Odeh, M. (2024). *Informing the state of process modeling and automation of blood banking and transfusion services through a systematic mapping study*. Journal of Multidisciplinary Healthcare, 17, 473–489.

4. Frankel, A., Haraden, C., Federico, F., & Lenoci-Edwards, J. (2017). *A framework for safe, reliable, and effective care*. Cambridge, MA: Institute for Healthcare Improvement.

5. Fung, M. K., Eder, A. F., & Spitalnik, S. L. (Eds.). (2017). *Technical Manual* (19th ed.). Bethesda, MD: AABB.

6. Goodnough, L. T., Levy, J. H., & Murphy, M. F. (2013). *Concepts of blood transfusion in adults*. The Lancet, 381(9880), 1845–1854.

7. Imamoglu, G., Topcu, Y. I., & Aydin, N. (2023). *A systematic literature review of the blood supply chain through bibliometric analysis and taxonomy*. Systems, 11(3), 124.

8. Joint Commission. (2015). *Sentinel event data: Root causes by event type*. Oakbrook Terrace, IL: The Joint Commission.

9. Kaufman, R. M., Djulbegovic, B., Gernsheimer, T., Kleinman, S., Tinmouth, A. T., Capocelli, K. E., … Tobian, A. A. (2015). *Platelet transfusion: A clinical practice guideline from the AABB*. Annals of Internal Medicine, 162(3), 205–213.

10. Kruse, C. S., Frederick, B., Jacobson, T., & Monticone, D. K. (2017). *Cybersecurity in healthcare: A systematic review of modern threats and trends*. Technology and Health Care, 25(1), 1–10.

11. Lescoutra-Etchegaray, N., Sumian, C., Culeux, A., Durand, V., Gurgel, P. V., Deslys, J. P., & Comoy, E. E. (2014). *Removal of exogenous prion infectivity in leukoreduced red blood cell units by a specific filter designed for human transfusion*. Transfusion, 54(4), 1037–1045.

12. Narayan, S., Poles, D., Bellamy, M., Spinks, C., Mistry, H., & Carter-Graham, S. (2019). *The 2018 Annual SHOT Report*. Manchester: Serious Hazards of Transfusion (SHOT).

13. Pérez-Aliaga, A. I., Ayerra, I., Sánchez-Guillén, J., Lopez, F. J., Puente, F., Aranda, A., … Garcés, C. (2024). *Routine results of an algorithm for managing the production of blood components*. Vox Sanguinis, 119(6), 541–547.

14. Randall, D. A., Patterson, J. A., Gallimore, F., Morris, J. M., Simpson, J. M., McGee, T. M., … Obstetric Transfusion Steering Group. (2019). *Haemoglobin trajectories during pregnancy and associated outcomes using pooled maternity and hospitalization data from two tertiary hospitals*. Vox Sanguinis, 114(8), 842–852.

15. Sittig, D. F., & Singh, H. (2010). *A new sociotechnical model for studying health information technology in complex adaptive healthcare systems*. BMJ Quality & Safety, 19(Suppl. 3), i68–i74.

16. Varghese, A., Thilak, K., & Thomas, S. M. (2024). *Technological advancements, digital transformation, and future trends in blood transfusion services*. International Journal of Advances in Medicine, 11(2), 147–152.

17. Waters, J. H., Dyga, R. M., Waters, J. F., & Yazer, M. H. (2011). *The volume of returned red blood cells in a large blood salvage program: Where does it all go?* Transfusion, 51(10), 2126–2132.

18. World Health Organization. (2017). *Global status report on blood safety and availability 2016*. Geneva: WHO.

19. World Health Organization. (2021). *Educational modules on clinical use of blood*. Geneva: WHO.