

Electronic Identification Systems in Transfusion Safety: A Narrative Review of Effectiveness and Cost-Effectiveness Evidence

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Abstract:

Background: Transfusion safety is fundamental to patient care, yet misidentification and clerical errors persist as significant risks. Electronic identification systems, such as barcoding, radiofrequency identification (RFID), and integrated transfusion management platforms, have been adopted to enhance verification, traceability, and safety. While their clinical benefits are well documented, cost-effectiveness remains a crucial factor, particularly in resource-limited settings. This review examines the effectiveness of electronic identification systems in improving transfusion safety and evaluates their economic viability across various healthcare environments.

Methods: Literature searches were conducted in PubMed and Scopus, supplemented by reports from the World Health Organisation (WHO) and the Association for the Advancement of Blood & Biotherapies (AABB). Publications from 2015 to 2025 were screened for relevance to transfusion safety, error reduction, patient outcomes, and economic evaluation. A narrative synthesis approach was used to integrate findings from both high-income and low-resource settings.

Results: Electronic identification systems consistently reduced the incidence of wrong-blood transfusions, near-miss events, and mislabelling errors. Barcoding improved bedside verification, while RFID enabled real-time tracking of blood products. Cost-effectiveness analyses demonstrated that, despite significant initial investment, long-term savings were achieved through fewer adverse events, reduced litigation costs, and enhanced workflow efficiency. Evidence from high-income countries supports widespread adoption, whereas studies in low- and middle-income settings highlight challenges related to infrastructure, training, and sustainability.

Conclusion: Electronic identification systems enhance transfusion safety and demonstrate favourable cost-effectiveness over time. Their integration into routine practice aligns with international recommendations for patient safety.

Clinical Significance: Electronic identification systems reduce preventable errors and increase efficiency, thereby strengthening patient safety and healthcare quality. Developing scalable and sustainable models for resource-limited settings is essential to ensure equitable access and maximise global impact.

Keywords: blood transfusion safety; electronic identification systems; barcoding; radiofrequency identification (rfid); cost effectiveness; patient safety; blood transfusion errors

1.Introduction

Blood transfusion is a critical therapeutic intervention; however, it presents significant risks when patient identification and component matching are inadequately managed. Transfusion errors continue to be a major source of

preventable morbidity and mortality worldwide. Haemovigilance data from the UK's Serious Hazards of Transfusion (SHOT) scheme reported nearly 1,000 "wrong blood in tube" (WBIT) incidents among 3,833 cases in 2023, highlighting the ongoing risk of misidentification despite established safety

protocols [1]. Similar reports from Europe, North America, and Africa demonstrate that human error in identification processes remains a persistent challenge to transfusion safety [2].

Historically, transfusion safety depended on manual procedures, including double verification of patient identity, paper-based documentation, and staff vigilance. Although these measures reduced risks, they remained inherently susceptible to lapses in attention, communication failures, and clerical errors. The limitations of manual systems led to the development of more reliable, technology-driven solutions [3].

Electronic identification systems (EIS), including barcoding, radiofrequency identification (RFID), electronic cross-matching, and laboratory information systems (LIS), are now integral to modern transfusion practice. Barcoding systems, which link patient wristbands and blood unit labels to bedside scanners, have led to significant reductions in wrong-component transfusions [4]. RFID facilitates real-time tracking of blood products throughout the supply chain, thereby enhancing traceability and accountability [5]. Electronic cross-matching and LIS integration further improve assurance of compatibility and reduce laboratory turnaround times, representing a transition from reliance on human vigilance to system-based safeguards [6,7].

International guidelines strongly endorse these technologies. The World Health Organisation (WHO, 2024) recommends electronic verification as part of its global transfusion safety strategy. The Association for the Advancement of Blood & Biotherapies (AABB, 2025) identifies electronic patient identification and bedside verification as best practices within its standards. In the United Kingdom, NHS Blood and Transplant has introduced national programmes integrating barcoding and electronic transfusion management systems, resulting in measurable improvements in safety outcomes [8,9].

Despite well-documented benefits, adoption of these technologies remains inconsistent, particularly in low- and middle-income countries (LMICs), where infrastructure limitations and financial constraints impede widespread implementation [10,11]. Evaluation of both clinical effectiveness and economic feasibility is therefore essential. Although electronic systems require substantial initial investment in hardware, software, and staff training, evidence suggests that long-term cost savings are achievable through reductions in adverse events, litigation, and improved workflow efficiency [2,12]. In resource-limited settings, cost-effectiveness analyses are especially important for supporting adoption and ensuring sustainability.

This review synthesises the current evidence on electronic identification systems for transfusion safety, with particular emphasis on clinical and cost-effectiveness. By incorporating findings from both high-income and resource-limited settings, it seeks to provide a comprehensive perspective to inform policy, clinical practice, and future research.

2. Types of Electronic Identification Systems

2.1 Barcoding Systems

Barcoding is the most widely adopted electronic identification method in transfusion practice. Patient wristbands, blood unit labels, and bedside scanners encode unique, machine-readable identifiers, which reduce clerical errors associated with handwritten documentation. This system is cost-effective, compatible with existing hospital infrastructure, and has led to significant reductions in “wrong blood in tube” (WBIT) incidents [13]. However, barcoding requires line-of-sight scanning, and damaged or misprinted labels can compromise readability. The effectiveness of barcoding also depends on consistent staff compliance with scanning protocols [4].

2.2 Radiofrequency Identification (RFID)

Radiofrequency identification (RFID) technology enables real-time tracking of blood products through wireless transmission of product information. Each unit is tagged with a microchip that communicates with readers located in storage facilities, laboratories, and clinical areas. RFID provides continuous monitoring of product location and status, supporting vein-to-vein traceability and reducing the risk of misplacement or misidentification [14]. However, implementation of RFID is limited by high costs, infrastructure requirements, and potential interference in environments with multiple electronic signals.

2.3 Electronic Cross-Matching and Laboratory Information Systems (LIS)

Laboratory information systems (LIS) integrate patient serological history, current test results, and transfusion requests to authorise compatibility testing electronically. Electronic cross-matching eliminates the need for manual validation, reducing transcription errors and expediting turnaround times for urgent transfusions. LIS platforms also provide audit trails and support haemovigilance reporting [15]. Limitations include dependence on accurate initial patient identification, vulnerability to cybersecurity threats, and the need for robust IT support and regular system updates.

2.4 Integrated Electronic Transfusion Management Systems

Integrated transfusion management systems combine barcoding, RFID, LIS, and electronic prescribing within a unified platform. These systems provide comprehensive safety assurance by linking laboratory, clinical, and bedside data. They improve communication between teams, support real-time haemovigilance, and align with national reporting frameworks such as the United Kingdom’s Serious Hazards of Transfusion (SHOT) scheme [16]. Implementation is complex, requiring multidisciplinary coordination, substantial financial investment, and integration with legacy hospital IT systems.

2.5 Comparative Strengths and Limitations

Barcoding	Low cost, widely adopted, and reduces clerical errors	Requires line-of-sight, label damage risk, and compliance dependent
RFID	Real-time tracking, vein-to-vein traceability, digital footprint	High cost, infrastructure needs, signal interference
LIS Cross-Matching	Automated validation, audit trails, rapid turnaround	Dependent on accurate initial data, IT vulnerabilities
Integrated Systems	End-to-end safety, haemovigilance support, multidisciplinary linkage	Complex rollout, costly, integration challenges

Table 1: Presents a comparative overview of the electronic identification systems discussed.

3. Effectiveness Evidence

3.1 Reduction in Transfusion Errors

Data from the UK’s Serious Hazards of Transfusion (SHOT) scheme indicate that electronic identification systems significantly reduce wrong component transfusion (WCT) incidents and near-miss events. Hospitals

implementing electronic systems reported substantially fewer errors compared to those using manual processes [17]. A 2025 study of NHS hospitals confirmed that electronic blood transfusion systems reduced mislabelling and wrong blood events, underscoring their role in preventing avoidable harm [2]. Case studies from Oxford Radcliffe Hospitals further demonstrated reductions in transfusion errors and increased productivity after the implementation of electronic systems [18].

3.2 Improvements in Traceability and Accountability

Electronic systems improve vein-to-vein traceability by digitally recording each stage from sample collection to bedside transfusion. RFID and barcoding technologies create audit trails that reinforce accountability and facilitate haemovigilance reporting [7,15]. In the UK, integration with national reporting frameworks such as SHOT has enhanced the accuracy of incident monitoring [4]. In the US and Europe, laboratory information system (LIS)-based solutions have similarly improved traceability, reduced administrative discrepancies, and supported compliance with regulatory standards.

3.3 Impact on Patient Outcomes

Although direct evidence connecting electronic systems to reduced mortality is limited, research demonstrates improvements in morbidity and hospital efficiency. Electronic transfusion systems decrease delays in blood delivery, shorten turnaround times, and minimise wastage [4]. These enhancements indirectly improve patient outcomes by enabling timely transfusions and reducing risks of misidentification. A 2025 BMJ commentary emphasised that widespread adoption of electronic blood management systems in the UK could further minimise patient harm and enhance safety [19].

3.4 Case Studies from High-Income Countries

- United Kingdom: SHOT reports and NHS case studies consistently demonstrate reductions in WCT incidents and improved traceability [20].
- United States: Implementation of LIS and RFID systems in large academic centres has improved transfusion safety and reduced clerical errors, with published audits confirming fewer near-miss events [21].
- Europe: Hospitals in Germany and Scandinavia report successful integration of barcoding and LIS systems, with measurable reductions in mislabelling and improved haemovigilance reporting.

3.5 Evidence from Low and Middle-Income Countries

Adoption of electronic transfusion systems in low- and middle-income countries (LMICs) remains inconsistent. Pilot studies in Nigeria and South Africa indicate that barcoding and LIS systems can reduce mislabelling and enhance traceability, although infrastructure and cost remain significant barriers [22–24]. In India, RFID pilot projects in tertiary hospitals demonstrated improved tracking of blood products, but limited resources constrain scalability [25]. These findings illustrate the potential for electronic systems to improve transfusion safety globally, while emphasising the necessity for context-specific implementation strategies.

3.6 Challenges in Measuring Effectiveness

- Under-reporting: Transfusion errors are often under-reported, limiting the accuracy of effectiveness assessments.
- Variability in Implementation: Differences in system design, staff training, and compliance affect outcomes.
- Attribution: Improvements in patient outcomes may be multifactorial, making it difficult to isolate the impact of electronic systems.
- Resource Constraints: In LMICs, limited infrastructure and funding hinder widespread adoption, complicating comparative evaluations.

4. Cost-effectiveness evidence

4.1 Direct costs: purchase, implementation, training, maintenance

Electronic transfusion systems require upfront capital for hardware (e.g., scanners, RFID readers, blood fridge interfaces), software licences, and

integration with existing hospital IT, as well as ongoing maintenance and support contracts. Implementation typically requires project management, configuration to local workflows, and comprehensive staff training across laboratory and clinical teams, which contributes to initial and recurrent costs [26]. UK experience indicates that staged deployment and leveraging existing infrastructure (e.g., bedside devices and LIS) can mitigate capital outlay, though full integration remains resource-intensive [27]. Maintenance costs include hardware replacement cycles, software updates, and cybersecurity measures to ensure system resilience [23].

4.2 Indirect costs: workflow changes, staff time, IT infrastructure

In addition to procurement costs, indirect costs include workflow redesign, temporary productivity reductions during system adoption, and increased demands on IT infrastructure, such as networking, authentication, and device management. Multi-site case studies demonstrate that achieving consistent scanning compliance and reliable connectivity requires ongoing process refinement and sustained change management, both of which require significant time investment from clinical and laboratory staff [28]. Reports from NHS hospital implementations indicate that integrating blood stock systems, bedside checking, and electronic requesting can streamline workflows after the initial transition, provided there is sufficient IT capacity and user support to prevent bottlenecks [2].

4.3 Economic benefits: avoided adverse events, reduced litigation, improved efficiency

Economic benefits result from preventing wrong-component transfusion (WCT) events and near-miss events, as well as from reductions in rework, wasted blood components, and subsequent harm. SHOT analyses associate electronic identification with a decrease in WCTs, suggesting cost avoidance related to incident investigations, additional patient care, and potential litigation [4]. UK commentary contends that system-level advantages, such as enhanced safety and improved traceability, justify investment by reducing preventable harm and inefficiency on a national scale [19]. Implementation reports from NHS sites highlight improvements in stock visibility and turnaround time, reducing waste and delays and potentially yielding savings in blood utilisation and operational efficiency [2].

4.4 Cost-effectiveness analyses from different healthcare settings

Recent UK health-economic evaluations examine the impact and cost-effectiveness of electronic blood transfusion systems (EBS, EBO, EBF, and traceability platforms), with a focus on stock management, wastage reduction, and service efficiency in NHS hospitals [2]. Comparative analyses from international sites indicate that baseline error rates, local pricing structures, and the maturity of system integration influence cost-effectiveness. Greater benefits are observed where systems are consistently implemented at the bedside and closely integrated with LIS and prescribing systems [23]. These results suggest that institutions with higher pre-implementation error rates or fragmented processes may achieve greater net savings following adoption [29].

4.5 Modelling studies comparing barcoding versus RFID

Both conceptual and applied models generally identify barcoding as the lower-cost option that delivers significant safety improvements. In contrast, RFID provides additional benefits, such as real-time location tracking, automated temperature and chain-of-custody logging, and inventory optimisation, but at a higher capital and integration cost. NHS implementation reports highlight that barcode-based bedside checks substantially reduce identification errors at a relatively modest price. At the same time, the added value of RFID is most pronounced in high-volume centres that prioritise logistics and traceability at scale [2]. International case studies indicate that the cost-effectiveness of RFID depends on the extent to which savings from reduced wastage, search time, and logistics incidents are realised, which varies by context [23].

Barcoding	Low–moderate	Low–moderate	Avoided WCT/near misses; efficient bedside checks	Broad adoption, most hospitals
RFID	Moderate–high	Moderate–high	Inventory optimisation;chain of custody; reduced wastage/search time	High volume, logistics-focused centres

Table 2: Comparative cost Levels and Value Drivers of Barcoding and RFID Systems in Transfusion Safety.

Sources: [2]

4.6 Considerations for resource-limited settings: affordability and sustainability

In resource-constrained settings, cost-effective barcoding integrated with a LIS typically offers the greatest return, due to lower capital requirements and simpler maintenance than RFID. International case studies emphasise the value of phased implementation, local device support, and comprehensive training to maintain compliance and reliability [23]. UK experience further demonstrates that focusing on bedside verification and comprehensive traceability delivers significant safety and efficiency improvements, providing a practical approach for lower-resource environments to achieve cost-effective gains without the need for complete RFID infrastructure [19].

5. Implementation challenges

5.1 Technical barriers: interoperability, infrastructure, and power reliability

Interoperability among bedside systems, laboratory information systems (LIS), electronic prescribing platforms, and enterprise electronic health records remains a persistent challenge, revealing deficiencies in standards, messaging protocols, and device integration. Hospitals frequently encounter obstacles in aligning vendor ecosystems, maintaining reliable network connectivity across wards, and managing large-scale device inventories, including scanners, readers, and workstations. Power reliability and environmental factors, including shielding requirements and electromagnetic interference for RFID, as well as line-of-sight limitations for barcode scanners, further complicate implementation, especially in older facilities and multi-site organisations [23]. Successful integration of transfusion platforms with national frameworks and local governance necessitates phased configuration, comprehensive testing, and continuous technical support to ensure sustained performance and safety [15].

5.2 Human factors: staff training, change resistance, and compliance

Even technically straightforward safety measures, such as bedside barcode scanning, encounter behavioural barriers including inconsistent compliance, workarounds due to time constraints, and variability in training quality. UK haemovigilance data consistently identifies “wrong blood in tube” near-misses as the most frequent category of reports, highlighting the importance of accurate identification and strict adherence to electronic verification protocols. Practical implementations prioritise structured training, human-centred workflow design, visible leadership support, and feedback mechanisms to maintain compliance under operational pressures [4,19]. Multi-site case studies underscore the necessity of co-design with end-users and iterative process improvement to integrate scanning and documentation into routine practice reliably [23].

5.3 Organisational barriers: funding, policy alignment, and leadership commitment

Obtaining both capital and ongoing funding for hardware, software, integration, and support contracts presents a significant barrier, particularly when benefits are distributed across multiple departments rather than a single budget holder. National strategies emphasise the necessity of policy endorsement, robust governance, and cross-organisational coordination to standardise practices and facilitate adoption. Strong executive sponsorship, well-defined accountability, and alignment with transfusion committees and regulatory requirements are consistently identified as key factors for successful implementation and sustainability [15]. International case studies demonstrate that active leadership engagement and explicit prioritisation of

patient identification safety are associated with broader adoption and more consistent bedside use [23].

5.4 Ethical and legal considerations: privacy and data security

Electronic transfusion systems handle sensitive patient identifiers and clinical information, requiring comprehensive data protection measures, stringent access controls, audit trails, and a strong cybersecurity framework. Integration across laboratory, ward, and national reporting systems increases both the potential attack surface and regulatory compliance requirements. Implementers highlight the necessity for role-based access, secure authentication, encryption of data both at rest and in transit, and robust incident response protocols, in addition to clear policies for data retention and secondary use. Governance structures aligned with national transfusion strategies and haemovigilance programs facilitate lawful data processing while maintaining the traceability essential for safety monitoring [15,23].

5.5 Lessons learned from successful implementations

Co-design and phased deployment: Early engagement of clinical and laboratory end-users, along with iterative workflow development prior to scaling, is essential. Implementing a phased roll-out with defined milestones minimises disruption and fosters the development of local champions [23].

- Embed compliance in workflow: Ensure that scanning and electronic verification are the most straightforward options, supported by real-time prompts, auditing, and constructive feedback. Address WBIT near-misses through targeted interventions [4].
- Invest in infrastructure and support: Provide reliable network connectivity, effective device management, and prompt technical assistance. Standardise system configurations to reduce variation and minimise errors [15].
- Align governance and leadership: Leverage national guidelines and transfusion committee oversight to establish expectations, monitor performance, and secure ongoing funding. Visible leadership presence reinforces a culture of safety [15].
- Measure and adapt: Monitor incident trends, compliance rates, and operational metrics. Utilise haemovigilance data to identify residual risks and continuously refine processes [4].

The literature consistently demonstrates that technical readiness, human-centred implementation, and organisational commitment must progress in tandem to achieve the safety benefits associated with electronic identification in transfusion practice.

6. Global perspectives

6.1 Adoption across regions: Europe, North America, Africa, and Asia

Electronic identification system adoption is most advanced in Europe and North America, where barcode-based bedside verification, laboratory information system (LIS) integration, and, in some centres, RFID-enabled traceability are established within large hospital networks. UK implementation studies report widespread deployment of electronic blood transfusion systems across NHS hospitals, featuring robust LIS integration and standardised barcode-based bedside verification; select sites have piloted RFID for inventory and location tracking [15]. In North America, AABB standards formalise electronic identification in pretransfusion processes, allowing validated electronic systems to replace a second sample under strict criteria [1,30]. In Africa and parts of Asia, adoption is variable: tertiary centres are increasingly implementing LIS and barcoding, but national-scale rollouts are limited by infrastructure, funding, and interoperability challenges. Analyses focused on Nigeria highlight the need for nationally

enhanced digital health capacity and policy support to expand the adoption of transfusion informatics [22,31]. Broader digital health reviews in sub-Saharan Africa identify similar barriers, including connectivity, workforce limitations, and policy misalignment, which directly affect transfusion informatics programmes [32].

6.2 International recommendations: WHO, ISBT, and AABB

International organisations consistently recommend robust patient identification and electronic traceability as essential safety practices. AABB Standards specify that validated electronic identification systems can fulfil the “two determinations” requirement for ABO grouping, underscoring their importance in preventing errors during pretransfusion testing [15,30]. The ISBT Resource Library compiles global guidance and WHO documents relevant to blood establishments and patient blood management, demonstrating consensus on electronic processes that enhance traceability, auditability, and haemovigilance [15,33]. UK Transfusion Guidelines explicitly endorse printed wristbands and barcode-enabled electronic checks throughout the transfusion pathway, including sampling, laboratory receipt, issue, and bedside administration, thereby establishing transparent interoperability and compliance expectations among clinical teams [4,34,35].

6.3 National programmes and case examples

The United Kingdom has advanced through coordinated national initiatives that integrate standards, training, and haemovigilance. NHS Blood and Transplant deliver infrastructure, training resources, and data programmes, such as the Blood Stocks Management Scheme, which support large-scale deployment. Hospitals implement LIS-linked bedside systems with barcode verification [4,34]. Studies from NHS hospitals indicate that integrated electronic transfusion systems enhance traceability and reduce identification errors when consistently applied at the bedside, with governance and local leadership providing critical support [36]. Haemovigilance commentaries in BMJ emphasise the necessity of accurate patient identification and advocate for widespread adoption of electronic blood management systems to address frequent near-miss “wrong blood in tube” events reported annually to SHOT [37]. SHOT analyses directly link electronic identification to a reduction in wrong-component transfusion incidents, reinforcing the value of these programmes at the national level [38].

6.4 Relevance for Nigeria and other sub-Saharan African countries

In Nigeria, policy analyses and clinical commentaries underscore the urgent need to enhance transfusion safety and demonstrate the feasibility of improving identification and traceability through LIS and barcode implementation in tertiary centres. However, persistent challenges remain in infrastructure, workforce training, and governance [22,31]. Systematic reviews of digital health adoption across sub-Saharan Africa identify pervasive obstacles, including interoperability, network reliability, power supply, and funding, which significantly impact transfusion informatics programmes. Targeted investments and phased implementation strategies are recommended to develop sustainable capacity [32]. Lessons from UK programmes, such as standardised workflows, e-learning, and governance via national transfusion committees, are adaptable to African contexts. Emphasis should be placed on affordable barcoding integrated with LIS prior to introducing advanced RFID, in alignment with local power and connectivity constraints [4,30].

6.5 Key lessons for global scale-up

* **Standardise workflows and data:** International guidance (AABB, ISBT, WHO) supports harmonised identification steps and validated electronic processes; alignment with these standards eases interoperability and accreditation [15,33].

* **Prioritise bedside compliance:** Evidence from UK implementations shows consistent barcode scanning at the bedside is pivotal to real-world safety gains and incident reduction [4,15,34].

* **Build capacity incrementally:** In resource-limited settings, LIS plus barcoding offers high value; phased deployment with training and governance mitigates infrastructure constraints observed across sub-Saharan Africa [31,32].

* **Leverage national bodies:** Central support (e.g., NHSBT) for training, data, and haemovigilance accelerates adoption and quality improvement; similar structures can catalyse progress in other regions [4,34].

Adoption patterns correspond to the maturity of health systems and the strength of governance. Regions with established standards, LIS infrastructure, and consistent bedside compliance achieve greater integration and measurable safety improvements. In contrast, resource-limited settings benefit from phased, standards-based approaches that prioritise affordability and long-term sustainability.

7. Future Directions

7.1 Integration with artificial intelligence and machine learning for predictive safety

Artificial intelligence (AI) and machine learning (ML) are increasingly utilised to improve transfusion safety. Predictive algorithms can identify patients at higher risk of transfusion reactions, detect potential mismatches, and optimise blood inventory management. Recent reviews suggest that ML models trained on transfusion datasets can predict adverse events and enhance decision support in transfusion practice [39]. Cancelas et al. [40] highlight the significance of AI in clinical transfusion decision-making, while Maynard et al. [39] show that ML applications reduce clerical errors and improve haemovigilance reporting. AI-driven dashboards integrated with laboratory information systems (LIS) can provide real-time alerts, which reduce reliance on manual checks and increase patient safety [41].

7.2 Blockchain for secure transfusion records

Blockchain technology offers decentralised, tamper-proof record keeping with significant potential to enhance transfusion traceability. Recent pilot studies in healthcare data management demonstrate blockchain’s ability to secure transfusion records, promote transparency, and enable cross-institutional data sharing [42,43]. By creating immutable records of blood product movement and patient transfusion history, blockchain can improve haemovigilance and mitigate risks of fraud or misreporting [44]. However, challenges concerning scalability, interoperability, and regulatory acceptance remain [45].

7.3 Mobile health applications for bedside verification

Mobile health (mHealth) applications are currently being evaluated for bedside transfusion verification, employing smartphones and tablets to scan barcodes or RFID tags. These applications integrate with laboratory information systems (LIS) and electronic prescribing systems, which allows clinicians to confirm patient identity and product compatibility in real time [46]. Initial studies in Indian tertiary hospitals indicate improved compliance and reduced near-miss events [23]. Bolton Maggs (2025) provides further evidence of the feasibility of smartphone-based barcode scanning to enhance bedside transfusion safety, though challenges related to device management, connectivity, and cybersecurity persist [1]. In resource-limited environments, mobile solutions may offer a cost-effective alternative to dedicated bedside scanners [2].

7.4 Potential for global harmonisation of transfusion safety standards

International organisations, such as the World Health Organisation (WHO), International Society of Blood Transfusion (ISBT), and AABB, advocate for harmonised standards in patient identification and transfusion traceability [33,47]. Achieving global harmonisation would enhance interoperability, facilitate cross-border data sharing, and strengthen international haemovigilance efforts [47]. The UK’s Serious Hazards of Transfusion (SHOT) scheme and NHS Blood and Transplant programmes exemplify national coordination models that could inform the development of global frameworks [1]. However, harmonisation initiatives must balance the need

for standardisation with sufficient flexibility to accommodate variations in local infrastructure and resource availability [33,47].

7.5 Research gaps: long-term cost effectiveness and scalability in low-resource settings

Although current evidence is promising, significant research gaps remain. Few long-term cost-effectiveness studies have assessed the economic impact of electronic transfusion systems across extended periods and varied healthcare settings [2,19]. In low- and middle-income countries (LMICs), scalability is constrained by infrastructure, financial resources, and workforce training [11]. Pilot studies conducted in Nigeria, South Africa, and India confirm feasibility but also reveal persistent sustainability challenges [11,22]. Future investigations should focus on pragmatic trials, economic modelling, and implementation science to guide adoption in resource-limited environments [48,49].

8. Conclusion

Electronic identification systems, including barcoding, RFID, LIS-based cross-matching, and integrated transfusion management platforms, have consistently demonstrated improvements in transfusion safety across diverse healthcare settings. Evidence from haemovigilance programmes, such as the UK's Serious Hazards of Transfusion (SHOT) scheme, confirms that these technologies reduce wrong-component transfusion (WCT) incidents, mislabelling, and near-miss events, thereby strengthening patient safety and accountability [1]. Implementation studies in NHS hospitals further show that electronic transfusion systems improve traceability, reduce wastage, and enhance operational efficiency, supporting their cost effectiveness in high-income settings [1].

Despite these successes, the literature highlights the necessity of context-specific implementation strategies. Technical barriers, such as interoperability and infrastructure limitations, and human factors, such as staff training and compliance, require tailored approaches to achieve sustainable adoption. Experiences from successful national programmes, such as NHS Blood and Transplant in the UK, underscore the importance of leadership, governance, and phased deployment in integrating electronic systems into routine practice [19].

In low- and middle-income countries (LMICs), pilot studies in Nigeria, South Africa, and India demonstrate the feasibility of barcoding, LIS, and RFID systems. However, scalability is limited by resource constraints, infrastructure challenges, and workforce training needs [50,51]. These findings highlight the urgent need for further research on long-term cost-effectiveness, sustainability, and scalability in resource-limited settings. Pragmatic trials, economic modelling, and implementation science approaches are essential to inform adoption strategies that balance affordability and safety.

From a policy perspective, global harmonisation of transfusion safety standards, as advocated by the World Health Organisation (WHO), International Society of Blood Transfusion (ISBT), and AABB, provides a foundation for interoperability, cross-border data sharing, and enhanced haemovigilance. National health systems should prioritise investment in electronic identification technologies, recognising their dual role in improving patient outcomes and reducing healthcare costs by preventing adverse events and litigation.

In summary, electronic identification systems are fundamental to modern transfusion safety. Their demonstrated effectiveness and cost-efficiency in multiple settings support continued expansion. However, success will require context-specific strategies, ongoing policy support, and targeted research to achieve equitable adoption globally.

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