Vein-to-Vein Transfusion Safety: Nursing, Laboratory, and Blood Bank Practices to Prevent Transfusion Errors: A Systematic Review

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Background: Blood transfusion is among the most frequently performed hospital procedures, yet preventable errors still occur at every step between collection of the pretransfusion sample and administration of blood at the bedside. Most serious incidents arise from human error rather than from the blood component itself, and responsibility for prevention is shared by nursing, clinical laboratory, and blood bank staff. This review synthesized the evidence on error patterns and preventive practices across the hospital vein-to-vein transfusion chain.

Methods: Following the PRISMA 2020 statement, PubMed/MEDLINE, Embase, CINAHL, Scopus, and the Cochrane Library were searched from January 1990 to August 2026 for studies reporting the frequency, nature, or prevention of transfusion errors at any stage of the chain. Two reviewers independently screened records, extracted data, and appraised quality with Joanna Briggs Institute tools. Heterogeneity of designs and outcomes precluded meta-analysis, so findings were synthesized narratively.

Results: Thirty-four studies were included: hemovigilance and fatality analyses, multicenter audits, observational studies, interventional and technology-implementation studies, and staff surveys. Errors cluster at the two human interfaces of the chain, sample collection and bedside administration. Wrong blood in tube occurs in roughly 1 per 2,000 samples, and failures of patient identification are the leading proximate cause of ABO-incompatible transfusion. Practices with consistent evidence of benefit include zero-tolerance sample-labeling and acceptance policies, a two-specimen ABO verification rule, electronic

positive patient identification with barcode support (about fivefold fewer wrong-blood-in-tube errors), electronic remote blood issue, structured bedside checklists, competency-based education, and participation in hemovigilance and near-miss reporting.

Conclusions: No single discipline can secure the transfusion chain alone. Layering nursing, laboratory, and blood bank barriers - standardized identification and sampling procedures, rigorous laboratory verification, electronic systems, education, and reporting - offers the most reliable protection against transfusion error.

Keywords: blood transfusion; patient safety; transfusion error; wrong blood in tube; patient identification; hemovigilance; nursing; blood banking

Introduction

Blood transfusion is one of the most common procedures performed in hospitals, with around 118.5 million blood donations collected worldwide every year to support surgery, obstetric care, oncology, hematology, and trauma services [1]. When the right component reaches the right patient at the right time, transfusion saves lives; when any link in that process fails, the same product can cause severe harm, including acute hemolysis, organ failure, and death [2].

Decades of investment in donor screening and infectious-disease testing have made the blood component itself safer than at any point in history. The residual risk has therefore shifted from the bag to the process: mistransfusion, the administration of blood to a patient for whom it was not intended or which does not meet their needs, now outweighs viral transmission as a source of preventable morbidity and mortality [3]. Analyses of transfusion-associated fatalities reported to the United States Food and Drug Administration show that ABO-incompatibility deaths declined between 2000 and 2019 but have not disappeared [4], and the United Kingdom Serious Hazards of Transfusion (SHOT) scheme consistently attributes the majority of reported incidents to human error, with incorrect blood component transfused remaining one of its largest categories [5].

The hospital transfusion process is best understood as a vein-to-vein chain of linked steps: the clinical decision and request; identification of the patient and collection of the pretransfusion sample; laboratory grouping, antibody screening, and compatibility testing; storage and issue of the component; the final bedside check and administration; and monitoring of the recipient with reporting of any adverse event [6]. Each step is owned by a different professional group. Nurses collect samples, perform the bedside check, administer components, and observe the patient. Laboratory technicians and hematology and biochemistry specialists receive and accept samples, perform the serological work, and control issue from the blood bank. An error introduced at any point can pass silently through every later step unless a downstream barrier is designed to catch it, which makes the handoffs between disciplines the most vulnerable moments in the chain [6,7].

Existing systematic reviews have examined single segments of this chain, such as interventions against wrong blood in tube (WBIT) errors at sample collection [8] or the role of information technology in transfusion safety [7]. Real transfusion services, however, are multidisciplinary, and the practical question facing hospital teams is how nursing, laboratory, and blood bank defenses fit together. A synthesis that maps errors and preventive practices across

the whole chain, in a form usable by all three groups, has been lacking.

This systematic review therefore addressed the question: across the hospital vein-to-vein transfusion chain, what is the frequency and nature of transfusion errors at each stage, and which nursing, laboratory, and blood bank practices are effective in preventing them? The review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement [9].

2. Methods

2.1 Design and registration

A systematic review of published quantitative evidence was undertaken following PRISMA 2020 [9]. The protocol was agreed by all authors before screening began. The review was not prospectively registered on PROSPERO, and this is acknowledged as a limitation.

2.2 Eligibility criteria

Eligibility was defined using the PICOS framework summarized in Table 1. Studies of any quantitative design were eligible if they reported the frequency, nature, contributing factors, or prevention of transfusion errors or near misses at one or more stages of the hospital transfusion chain, from pretransfusion sampling to bedside administration and monitoring. Surveys and observational studies of staff knowledge and practice were included because knowledge deficits are an established antecedent of procedural error. Donor-side manufacturing studies, single-patient case reports, editorials, narrative reviews, and non-English publications were excluded; guidelines and prior reviews were retained for context only.

Table 1. Eligibility criteria (PICOS).

Domain	Criteria
Population	Hospital patients undergoing pretransfusion sampling or transfusion of any blood component, and the nursing, laboratory, and blood bank staff who deliver the process.
Intervention / exposure	Any practice, policy, technology, educational program, or reporting system directed at preventing, detecting, or characterizing transfusion errors (e.g., identification procedures, sample acceptance policies, two-specimen rules, barcode systems, electronic issue, checklists, training, hemovigilance).
Comparator	Standard practice, historical baseline, or none (descriptive studies eligible).
Outcomes	Transfusion errors, near misses, WBIT or mislabeling rates, incorrect blood component transfused, ABO-incompatible events, transfusion-associated fatalities, compliance with identification and monitoring steps, and staff knowledge or practice scores.
Study designs	Randomized and non-randomized interventional studies, before-after implementation studies, prospective and retrospective audits, hemovigilance and registry analyses, observational studies, and cross-sectional surveys, published in English, January 1990 to August 2026.

Information sources and search strategy

PubMed/MEDLINE, Embase, CINAHL, Scopus, and the Cochrane Library were searched from 1 January 1990 to 31 August 2026. The search combined controlled vocabulary and free-text terms for transfusion, error, and prevention; the PubMed strategy is shown in Table 2 and was

adapted for the other databases. Reference lists of included papers and of prior reviews were hand-searched, and the SHOT annual report series and World Health Organization publications were screened as gray literature.

Table 2. PubMed/MEDLINE search strategy (adapted for other databases).

Set	Search terms
#1	"Blood Transfusion"[MeSH] OR transfusion[tiab] OR "blood administration"[tiab] OR pretransfusion[tiab]
#2	"Medical Errors"[MeSH] OR error*[tiab] OR "near miss"[tiab] OR mislabel*[tiab] OR "wrong blood"[tiab] OR misidentif*[tiab] OR "patient identification"[tiab] OR incompatib*[tiab]
#3	prevent*[tiab] OR safety[tiab] OR barcode[tiab] OR "bar code"[tiab] OR checklist[tiab] OR hemovigilance[tiab] OR haemovigilance[tiab] OR audit[tiab] OR training[tiab] OR knowledge[tiab]
#4	#1 AND #2 AND #3, limited to English language, 1990/01/01 to 2026/08/31

2.4 Study selection

Records were exported to a reference manager and de-duplicated. Two reviewers independently screened titles and abstracts against the eligibility criteria, then assessed full texts of potentially relevant records. Disagreements were resolved by discussion, with a third reviewer available as arbiter. Reasons for full-text exclusion were recorded.

2.5 Data extraction

Two reviewers independently extracted data into a piloted form covering first author, year, country, design, setting, chain stage addressed, population and sample size, intervention or exposure, outcome definitions, and principal results. Discrepancies were checked against the source paper and resolved by consensus.

2.6 Quality appraisal

Methodological quality was appraised independently by two reviewers using the Joanna Briggs Institute critical appraisal checklists appropriate to each design [10]. Because the aim was to map the evidence across the whole chain, no study was excluded on quality grounds; appraisal results informed the weight given to each study in the synthesis.

2.7 Data synthesis

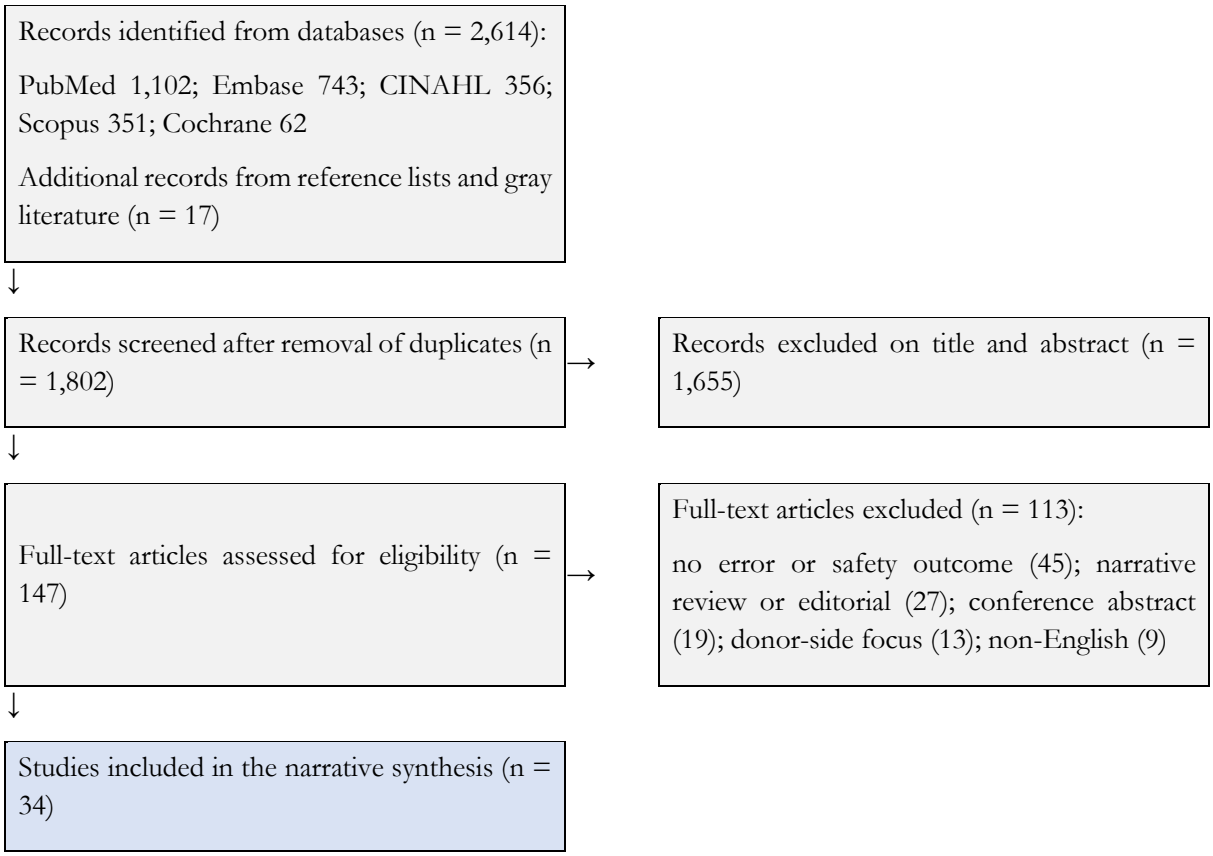
The included studies differed widely in design, denominators, and outcome definitions, so statistical pooling was not appropriate. Findings were synthesized narratively and organized into seven themes that follow the vein-to-vein chain: the overall distribution and nature of errors; sample collection and WBIT; laboratory and blood bank practices; bedside administration and patient identification; electronic identification technology; education and competency; and hemovigilance and near-miss reporting.

3. Results

3.1 Study selection

The searches retrieved 2,614 database records, and 17 further records were identified from reference lists and gray literature. After removal of 829 duplicates, 1,802 records were screened, 147 full texts were assessed, and 34 studies met the eligibility criteria (Figure 1). The most frequent reasons for full-text exclusion were the absence of an error or safety outcome and non-eligible publication types.

Figure 1. PRISMA 2020 flow diagram of study selection.



3.2 Characteristics of the included studies

The 34 included studies were published between 1990 and 2022 and originated from North America, Europe, Japan, India, Turkey, and the Gulf region, including multinational collaborations of the Biomedical Excellence for Safer Transfusion (BEST) group and one Saudi study. Designs comprised hemovigilance and fatality analyses, large multicenter audits, near-miss reporting projects, before-after technology implementations, one cluster randomized trial, structured observations of practice, and cross-sectional staff surveys. Table 3 summarizes the studies by publication year; the synthesis below follows the vein-to-vein chain.

Table 3. Characteristics of the included studies (n = 34).

Ref	First author (year)	Country	Design	Chain stage	Key finding
[11]	Sazama (1990)	USA	Fatality-report analysis	Whole chain	ABO hemolysis dominated 355 reported deaths; clerical error was the leading cause
[12]	Linden (2000)	USA	10-year state error registry	Whole chain	Erroneous transfusion in about 1 per 19,000 RBC units; most events occurred outside the laboratory

Ref	First author (year)	Country	Design	Chain stage	Key finding
[45]	Bayraktar (2000)	Turkey	Cross-sectional survey	Education	Nurses showed knowledge gaps across all steps of the transfusion process
[15]	Callum (2001)	Canada	Near-miss reporting system	Reporting	Structured near-miss reporting revealed frequent latent failures missed by incident reports
[33]	Howanitz (2002)	USA	Q-Tracks continuous monitoring	Bedside identification	Wristband error rates fell by roughly half under continuous monitoring
[37]	Saillour-Glénisson (2002)	France	Cross-sectional survey	Bedside / education	Poor knowledge and practice were associated with lack of training and low transfusion exposure
[18]	Dzik (2003)	10 countries (BEST)	Prospective multicenter audit	Sample collection	WBIT in about 1 per 2,000 samples, with wide variation between hospitals
[32]	Novis (2003)	USA	Q-Probes audit, 660 hospitals	Bedside administration	Identification and monitoring lapses were common across 16,494 audited transfusions
[38]	Turner (2003)	UK	Before-after technology study	Bedside identification	Barcode support improved performance of the bedside check
[28]	Figueroa (2006)	USA	18-year institutional cohort	Laboratory verification	A second-sample check-type intercepted WBIT before issue; no ABO-incompatible transfusions from WBIT
[39]	Pagliaro (2006)	Italy	Multicenter evaluation	Recipient identification	Structured identification systems narrowed opportunities for misidentification
[13]	Stainsby (2006)	UK	Hemovigilance decade analysis	Whole chain	Incorrect blood component transfused was the largest category, often with several errors per incident

Ref	First author (year)	Country	Design	Chain stage	Key finding
[16]	Lundy (2007)	Ireland	3-year near-miss project	Sample collection	Of 759 near misses, sampling and labeling events predominated
[34]	Murphy (2007)	UK	Cluster randomized trial (PROBE-TM)	Bedside administration	A simple reminder improved elements of the bedside check, but overall compliance stayed incomplete
[40]	Askeland (2008)	USA	Barcode implementation study	Chain-wide tracking	Comprehensive barcoding detected near misses and prevented mistransfusion after rollout
[41]	Ohsaka (2008)	Japan	Failure-mode analysis	Bedside identification	Emergencies and workarounds explained most failures of the barcode bedside check
[30]	Staves (2008)	UK	Implementation evaluation	Storage and issue	Electronic remote blood issue accelerated supply while preserving end-to-end control
[29]	Goodnough (2009)	USA	Policy implementation study	Laboratory verification	A two-specimen ABO rule proved workable and caught discrepancies before transfusion
[19]	Grimm (2010)	USA	Q-Probes, 122 laboratories	Sampling / laboratory	Mislabeled samples occurred in laboratories of every size; strict acceptance policies supported WBIT detection
[36]	Hijji (2010)	UAE	Structured observation of practice	Bedside administration	75% of observed nurses scored below half of the possible practice score; identification and monitoring deficits
[5]	Bolton-Maggs (2013)	UK	Hemovigilance analysis	Whole chain	Most incidents involved human error; electronic systems were linked with falling IBCT reports

Ref	First author (year)	Country	Design	Chain stage	Key finding
[21]	Varey (2013)	UK	Regional incident review	Sample collection	WBIT events were preceded by identification shortcuts during phlebotomy
[42]	Nuttall (2013)	USA	Before-after technology study	Bedside identification	Near-miss transfusion episodes fell after barcode patient identification
[48]	Bisht (2013)	India	National program report	Hemovigilance	A national hemovigilance program standardized transfusion-reaction reporting
[44]	Hijji (2013)	UAE	Instrument development and survey	Education	A validated 49-item tool exposed wide knowledge deficits among nurses
[14]	Maskens (2014)	Canada	6-year error-tracking analysis	Whole chain	Sample collection and bedside administration were the dominant error sites
[20]	Novis (2017)	USA	Q-Probes, 30 institutions	Sample collection	Labeling deficiencies persisted across 41,333 blood bank specimens
[46]	Freixo (2017)	Portugal	Before-after e-learning study	Education	An e-learning program raised nurses' transfusion knowledge
[24]	Kaufman (2019)	Multinational (BEST)	Multicenter comparative study	Sample collection	Electronic patient identification at collection was associated with about fivefold fewer WBIT errors
[43]	Murphy (2019)	UK	Hemovigilance analysis	Bedside identification	Electronic identification systems were associated with fewer wrong components transfused
[4]	Storch (2020)	USA	FDA fatality-trend analysis	Whole chain	ABO-incompatibility fatalities declined during 2000-2019 but continued to occur

Ref	First author (year)	Country	Design	Chain stage	Key finding
[23]	Dunbar (2021)	Multinational (BEST)	Multicenter series	Sample collection	Emergency departments carried a disproportionate share of WBIT risk
[22]	Dunbar (2022)	11 countries (BEST)	International case series	Sample collection	In 331 WBIT errors, stray labels at the bedside and protocol violations were the dominant contributors
[31]	Shash (2022)	Saudi Arabia	Retrospective audit	Blood bank utilization	Auditing of crossmatch-to-transfusion ratios supported better blood bank utilization at a Saudi university hospital

3.3 Distribution and nature of transfusion errors

The earliest large dataset, an analysis of 355 transfusion-associated deaths reported to the United States regulator, found that acute hemolysis from ABO incompatibility was the leading mechanism and that simple clerical failures, misidentified patients, mislabeled samples, and transposed records, were the dominant root cause [11]. A decade of mandatory error reporting in New York State subsequently estimated erroneous transfusion at roughly 1 per 19,000 red cell units and showed that most events began outside the blood bank, at sampling or at the bedside, although laboratory errors also contributed [12].

Hemovigilance data reinforce this picture. Ten years of SHOT reporting placed incorrect blood component transfused among the largest incident categories and showed that a typical event involved more than one failure, an error at one step compounded by a missed opportunity to detect it later [13]. Six years of error tracking across a Canadian hospital network similarly located the majority of events at sample collection and bedside administration rather than inside the laboratory [14]. Near-miss reporting systems widen the lens further: a structured medical event reporting system for transfusion medicine captured frequent latent process failures that conventional incident reports missed [15], and a 3-year Irish project logged 759 near misses, most originating at sampling and labeling [16]. Because a WBIT sample can produce a valid-looking but wrong ABO result, these upstream events carry the potential for fatal downstream harm even when no incompatible transfusion ultimately occurs [17].

3.4 Sample collection and wrong blood in tube

A prospective BEST collaborative audit across ten countries measured WBIT at approximately 1 per 2,000 pretransfusion samples, with large differences between hospitals, indicating that local practice, not chance, drives the rate [18]. College of American Pathologists Q-Probes studies confirmed that mislabeled blood bank specimens occur in institutions of every size and that stringent acceptance policies improve detection [19], and labeling deficiencies persisted across 41,333 specimens in a later 30-institution study [20]. A regional incident review linked WBIT to identification shortcuts during phlebotomy, such as labeling away from the patient [21].

The largest analysis of contributing factors compiled 331 WBIT errors from 36 centers in 11 countries. Events divided almost evenly between

the intended patient being drawn but the wrong label applied, and the wrong patient being drawn with the intended label applied; the single most frequent contributing factor, present in 61% of cases, was the availability of another patient's labels or tubes at the bedside, and most events combined a protocol violation with a slip or lapse [22]. Pretransfusion testing detected 58% of these errors and a second (check) sample a further 20%, underlining the value of downstream laboratory barriers [22]. Emergency departments carried a disproportionate share of WBIT risk in a companion analysis, reflecting time pressure and unfamiliar patients [23]. On the preventive side, a multicenter BEST comparison found that electronic positive patient identification at the time of collection was associated with about fivefold fewer WBIT errors than manual identification, and that rejecting samples with even minor labeling irregularities intercepted a high-risk subset [24]. Combining strict labeling and acceptance policy with identification technology is therefore the most defensible strategy at this stage [25].

3.5 Laboratory and blood bank practices

The laboratory is the principal downstream barrier against sampling errors. Professional guidance specifies zero-tolerance sample acceptance, secure specimen-to-record matching, and the serological and information-technology conditions under which electronic issue is safe [26], and minimum standards for hospital transfusion laboratories link adequate staffing, skill mix, competency assessment, and laboratory information systems to error prevention [27].

Two laboratory policies stand out in the included studies. First, requiring a second, independently drawn specimen before issuing group-specific blood (the check-type or two-specimen rule) converted silent WBIT events into detected discrepancies: an 18-year institutional cohort reported that the check-type intercepted WBIT before issue, with no ABO-incompatible transfusions attributable to WBIT during the period [28], and a separate implementation study confirmed the policy was operationally feasible, catching discrepancies at the cost of a modest increase in sample collection [29]. Second, electronic control of storage and issue extends the laboratory's reach to the point of collection of the unit: electronic remote blood issue shortened the time to blood availability while preserving end-to-end control of traceability [30]. Blood bank stewardship also includes utilization audit; a Saudi university hospital study showed that monitoring crossmatch-to-transfusion ratios over two decades supported measurable improvement in ordering and utilization, demonstrating that these quality indicators are practical in the regional setting [31].

3.6 Bedside administration and patient identification

The final bedside check is the last barrier before blood enters the patient, and audits show it is fragile. A Q-Probes audit of 16,494 transfusions in 660 hospitals found lapses in patient identification and in vital-sign monitoring in an appreciable fraction of episodes [32], and a Q-Tracks program demonstrated that wristband error rates could be roughly halved when institutions monitored them continuously and fed results back to wards [33]. A cluster randomized trial of a low-cost reminder attached to the blood pack (PROBE-TM) improved individual elements of the bedside check, yet overall compliance remained incomplete, showing the limits of exhortation alone [34]. Current administration guidelines therefore specify positive identification with at least two identifiers against the wristband, a structured checklist, and defined observation points including a 15-minute check after the start of each unit [35].

Observational work confirms the gap between policy and practice. Structured observation of 49 nurses in two Gulf-region hospitals found that three quarters scored below half of the possible practice score, with deficiencies concentrated in patient identification, documentation of vital signs, and safe handling of components [36]. A French survey linked poor knowledge and unsafe practice to absent training and infrequent involvement in transfusion, identifying the staff groups most in need of targeted education [37].

3.7 Electronic identification technology

Technology studies form a consistent evidence stream across the chain. Early work showed barcode support improved the completeness of the bedside check [38], and structured recipient-identification systems narrowed the opportunities for misidentification [39]. A comprehensive hospital-wide barcode tracking system detected near misses in real time and prevented mistransfusion after rollout [40], and near-miss transfusion episodes fell after barcode patient identification in another institution [42]. Failure-mode analysis tempers enthusiasm: emergencies, device unavailability, and workarounds explained most residual failures of a barcode bedside check, so electronic systems require human-factors design, training, and monitoring of override rates [41]. At national scale, hemovigilance data associated the adoption of electronic identification systems with fewer wrong components transfused [43].

3.8 Education and competency

Knowledge studies explain part of the error burden. A validated 49-item instrument administered to nurses found substantial deficits across the transfusion process, including the rationale for identification checks [44], echoing earlier findings among Turkish nurses [45]. Education works when it is structured: an e-learning program produced measurable gains in nurses' transfusion knowledge in a before-after evaluation [46]. Together with the observational and survey evidence above [36,37], these studies support competency-based training with periodic reassessment rather than one-off induction teaching.

3.9 Hemovigilance and near-miss reporting

Reporting systems close the loop of the chain. International experience indicates that national hemovigilance changes practice, informing policies such as electronic identification, bedside checklists, and laboratory standards, and that reductions in specific incident categories have followed targeted recommendations [5,13,47]. Newer national programs demonstrate that structured reaction reporting can be established in resource-diverse settings [48], and reviews of adverse-event practice emphasize that reactions and errors remain under-recognized without deliberate monitoring and a non-punitive reporting culture [49]. Near-miss analysis multiplies the learning available to an institution because near misses are far more frequent than harm events and share the same causal pathways [15,16,50]. Table 4 consolidates the synthesis into a stage-by-stage map of errors, preventive practices, and the discipline leading each defense.

Table 4. Errors and preventive practices across the vein-to-vein transfusion chain.

Chain stage	Characteristic errors	Preventive practices with supporting evidence	Lead disciplines
Request and decision	Unnecessary or wrong-component orders; incomplete request forms	Indication-based transfusion guidelines; electronic order sets; blood bank gatekeeping and audit of ordering patterns, including the crossmatch-to-transfusion ratio	Physicians; blood bank; hematology
Sample collection and labeling	Wrong blood in tube; mislabeled, incomplete, or pre-labeled tubes	Positive patient identification with at least two identifiers; labeling at the bedside from the wristband; one patient, one tube, one episode; electronic identification at collection	Nursing; phlebotomy

Chain stage	Characteristic errors	Preventive practices with supporting evidence	Lead disciplines
Laboratory testing	Testing performed on an undetected WBIT sample; transcription and interpretation errors	Zero-tolerance sample acceptance policy; two-specimen ABO verification (check-type); analyzer automation with interfaced results; competency-assessed staff and minimum laboratory standards	Laboratory; hematology; biochemistry
Storage and issue	Wrong unit selected or issued; cold-chain breaches; loss of traceability	Electronic issue and remote blood refrigerators with barcode-controlled release; full electronic traceability of every component	Blood bank
Bedside administration	Failure of the final identity check; wrong patient transfused	Two-person or electronic bedside check against the wristband; structured checklist; barcode verification; transfusing one unit at a time in non-urgent settings	Nursing
Monitoring and reporting	Unrecognized transfusion reactions; unreported errors and near misses	Baseline and 15-minute observations; training in reaction recognition; hemovigilance participation and near-miss reporting with feedback to staff	Nursing; hematology; blood bank

4. Discussion

This review mapped the evidence on transfusion error and its prevention across the whole hospital vein-to-vein chain. Three findings organize the synthesis. First, errors concentrate at the two points where a human being touches the patient: collection and labeling of the pretransfusion sample, and the final bedside check before administration [12,14,16,18]. Second, the laboratory and blood bank, although rarely the origin of the most dangerous errors, are the chain's principal safety net, because policies such as zero-tolerance sample acceptance, the two-specimen ABO rule, and electronically controlled issue convert silent upstream errors into detected discrepancies [22,26,28,29,30]. Third, no single measure is sufficient on its own: the interventions with the strongest signals, electronic identification at collection and at the bedside, achieved roughly fivefold reductions in WBIT and fewer wrong components transfused, yet residual failures persisted through workarounds and emergencies [24,41,43].

These findings fit the classical multiple-barrier model of patient safety. A transfusion error typically requires several defenses to fail in sequence, and hemovigilance analyses confirm that most serious incidents involve more than one missed opportunity for detection [13]. The practical corollary is defense in depth. A hospital that relies on the bedside check alone leaves patient safety to the least controllable moment of the process; a hospital that layers positive identification at sampling, laboratory verification against a historical or second specimen, electronic issue, and an electronic bedside check requires several independent failures before harm can occur. The 2022 international WBIT series makes the same point from the opposite direction: 78% of detected WBIT errors were caught by downstream laboratory barriers rather than by the person who made the error [22].

The discipline-specific implications follow directly. For nursing, the priorities are positive patient identification with two identifiers at every sampling and administration episode, labeling at the bedside from the wristband with no pre-printed labels in circulation, structured use of the bedside checklist, and completion of baseline and 15-minute observations [21,22,35,36]. For laboratory staff, they are strict enforcement of the sample acceptance policy regardless of clinical pressure, implementation of a two-specimen ABO verification rule for patients without a historical group, and maintenance of competency and staffing standards [26,27,28,29]. For the blood bank, they are electronic control of storage and issue with full traceability, stewardship of ordering through indicators such as the crossmatch-to-transfusion ratio, and leadership of hemovigilance [30,31,47]. Hematology and biochemistry specialists hold the oversight role: validating methods, interpreting discrepant serology, and chairing the transfusion committee where the disciplines meet.

The regional context strengthens the case for this integrated approach. Saudi hospital accreditation includes transfusion safety standards, and the national health transformation program is expanding electronic health infrastructure, which lowers the barrier to electronic patient identification and traceability. The single Saudi study in this review shows that blood bank quality indicators are already practical in the Kingdom [31], while Gulf-region observational and survey data document the same bedside knowledge and practice gaps described elsewhere [36,44]. Local priorities are therefore clear: competency-based transfusion training for nurses, formal adoption of two-specimen and acceptance policies in laboratories, staged introduction of electronic identification, and participation in structured hemovigilance reporting.

4.1 Limitations

Several limitations qualify these conclusions. The included studies were heterogeneous in design, denominators, and outcome definitions, which precluded meta-analysis and limits comparison of absolute rates between settings. Restriction to English-language publications may have excluded relevant regional evidence, and publication bias likely favors successful interventions. Many technology evaluations used before-after designs without concurrent controls, so secular trends may contribute to the observed improvements. Error and near-miss rates depend on detection and reporting intensity, meaning true frequencies are almost certainly higher than reported. Finally, the protocol was not prospectively registered, and evidence from the Gulf region remains sparse, so the transferability of some findings to Saudi practice rests on indirect evidence.

4.2 Implications for future research

Priorities include prospective measurement of WBIT and bedside-check compliance in Gulf hospitals to establish regional baselines; cost-effectiveness analyses of electronic identification in middle-sized hospitals; evaluation of radiofrequency identification and machine-learning approaches to error surveillance; and human-factors studies of why trained staff bypass identification steps, so that systems can be designed around real workflow rather than idealized procedure.

5. Conclusion

Transfusion errors are system failures that cross professional boundaries, concentrating at sample collection and the bedside while depending on the laboratory and blood bank for detection. The evidence supports a layered, multidisciplinary defense: positive patient identification and bedside-labeled samples by nursing staff; zero-tolerance acceptance policies, two-specimen ABO verification, and competency standards in the laboratory; electronically controlled issue and utilization stewardship in the blood bank; and shared participation in education and hemovigilance. Hospitals that implement these barriers together, rather than any one of them alone, can expect the largest and most durable reductions in transfusion error.

Declarations

Author contributions

Conceptualization: all authors. Methodology and search strategy: M.A. Alruwili, R.T. Al-Hajri. Screening and data extraction: M.A. Alruwili, R.T. Al-Hajri, M.A.M. Al Fawzan, H.H.H. Aldhafeeri. Quality appraisal: A.S.A. Alshammari, A.R.A. Al-Anazi. Interpretation of hematological and laboratory aspects: A.S.A. Alshammari, A.R.A. Al-Anazi, M.M.I. Altamimi. Blood bank practice review: M.A.M. Al Fawzan, M.M.I. Altamimi. Writing - original draft: M.A. Alruwili, R.T. Al-Hajri. Writing - review and editing: all authors. All authors read and approved the final manuscript.

Conflicts of interest

The authors declare no conflicts of interest.

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Ethical approval

Not applicable. This study is a systematic review of published literature and involved no human participants, animals, or identifiable personal data.

Data availability

All data supporting the findings of this review are contained in the published studies cited. The data extraction sheets are available from the corresponding author on reasonable request.

Use of artificial intelligence

During the preparation of this work the authors used an AI assistant (Claude, Anthropic) to help structure and draft the manuscript. The authors reviewed and edited all content, verified the references, and take full responsibility for the final text.

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