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The Role of Nursing in Reducing Laboratory Errors through Specimen Management: A Narrative Review

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Abstract

Background: Laboratory diagnostics underpin up to 70% of clinical decisions, yet 40-70% of laboratory errors occur in the pre-analytical phase—a process largely controlled by nursing during specimen collection and handling. Preventable errors in identification, technique, and transport persist, causing patient harm and systemic inefficiency.

Aim: This review synthesizes evidence on nursing's pivotal role in specimen management, analyzes error root causes, and evaluates the effectiveness of nursing-led interventions aimed at improving laboratory safety and specimen quality.

Methods: A systematic literature search (2010-2025) was performed across PubMed, CINAHL, Scopus, and Web of Science using relevant keywords. The analysis focused on error epidemiology, causative factors, and intervention outcomes related to education, technology, and system redesign.

Results: Nursing practice is the decisive factor for pre-analytical quality. Primary errors stem from misidentification, incorrect tube use, poor technique causing hemolysis, and improper handling. Effective, multimodal interventions include sustained competency-based education, barcode patient identification systems, standardized kits, dedicated phlebotomy teams, and closed-loop quality feedback, collectively reducing errors by 50-80%.

Conclusion: Nurses are fundamental guardians of diagnostic integrity. Sustainable error reduction necessitates a systemic, non-punitive strategy integrating robust education, smart technology, standardized workflows, and a supportive culture. Empowering nursing in this domain is a critical lever for enhancing patient safety, diagnostic accuracy, and healthcare value.

Keywords: Nursing, Pre-analytical Phase, Specimen Collection, Patient Safety, Quality Improvement

Introduction

The modern healthcare ecosystem is profoundly dependent on laboratory medicine, with an estimated 70% of all clinical decisions—from diagnosis and risk stratification to treatment selection and monitoring—relying on in vitro diagnostic test results (Plebani, 2010; Lippi & Plebani, 2020). The integrity of this decision-making chain, however, is only as strong as its weakest link. A substantial body of evidence reveals that the majority of laboratory errors do not occur within the highly automated, quality-controlled confines of the analytical laboratory itself (Da Rin, 2010). Instead, a staggering 40% to 70% of total laboratory mistakes originate in the pre-analytical phase, the series of steps from test ordering and patient preparation to specimen collection, labeling, transportation, and processing (Carraro & Plebani, 2007; Lippi et al., 2019). This pre-analytical domain is largely under the purview of nursing practice. Nurses are the frontline clinicians responsible for executing the vast majority of venous and capillary blood collections, obtaining other

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bodily fluid samples, and ensuring these specimens are correctly identified and handled before laboratory analysis. Consequently, nursing competence and systemic support structures are the principal determinants of pre-analytical quality (Al Atiyyah et al., 2024).

Errors in this phase are not mere administrative slip-ups; they are significant patient safety events. Misidentified specimens can lead to catastrophic mismatches in treatment, delayed diagnoses, or unnecessary interventions (Volmar et al., 2014),. Hemolyzed, clotted, or inadequately filled samples necessitate specimen rejection and painful, delayed recollections, directly impacting patient experience and satisfaction (Cherie et al., 2024). The financial implications are equally considerable, encompassing the costs of wasted resources, repeated collections, extended hospital stays, and potential litigation (Lippi et al., 2011). Despite the existence of standardized protocols from bodies like the Clinical and Laboratory Standards Institute (CLSI) and the World Health Organization (WHO), preventable errors persist at alarming rates globally. This persistent gap between knowledge and practice underscores a complex problem rooted in systems, education, and culture, rather than individual negligence alone (World Health Organization, 2010).

This narrative review, therefore, aims to move beyond simply cataloging common errors. It seeks to synthesize the current evidence from 2010-2025 to comprehensively examine the indispensable role of nursing in the pre-analytical pathway, critically analyze the multifactorial root causes of specimen management failures, and evaluate the efficacy of nursing-led and system-supported interventions designed to enhance specimen quality. The ultimate goal is to provide a consolidated evidence base to inform clinical practice, guide quality improvement initiatives, and advocate for the necessary resources to empower nurses as the essential guardians of diagnostic integrity.

Methods

To construct this comprehensive narrative review, a systematic and reproducible literature search strategy was employed to gather relevant, contemporary evidence. Primary electronic database searches were conducted in PubMed/MEDLINE, CINAHL (Cumulative Index to Nursing and Allied Health Literature), Scopus, and Web of Science. The search timeframe was restricted to articles published between January 2010 and February 2025, ensuring a focus on current practices, technologies, and quality improvement methodologies. A combination of Medical Subject Headings (MeSH) terms and keywords was utilized, including: "nursing," "nurse," "pre-analytical phase," "preanalytical error," "specimen handling," "blood specimen collection," "phlebotomy," "hemolysis," "specimen labeling," "patient identification," "barcode," "quality improvement," "patient safety," and "diagnostic error." Boolean operators (AND, OR) were used to combine concepts. The reference lists of key review articles and seminal papers were also hand-searched to identify additional pertinent studies.

Inclusion criteria prioritized peer-reviewed original research articles (observational studies, interventional trials), systematic reviews, meta-analyses, and robust quality improvement reports that explicitly addressed the role of nursing in pre-analytical processes, error rates, causative factors, or intervention outcomes. Editorials, non-English language articles without translation, and studies focusing solely on analytical or post-analytical errors without a nursing link were excluded. The extracted data were organized thematically rather than through meta-analysis, focusing on: 1) The epidemiology and types of pre-analytical errors associated with nursing practice; 2) The identified root causes and contributing factors (individual, systemic, technological); and 3) The design, implementation, and measured outcomes of targeted interventions. This narrative synthesis allows for the integration of findings from diverse study designs to provide a holistic understanding of this complex clinical issue.

The Pre-Analytical Spectrum: Where Nursing Practice is Paramount

The pre-analytical phase is a multi-step, interconnected process where nursing responsibility is extensive and non-delegable (Table 1 & Figure 1). Understanding this workflow is essential for pinpointing vulnerability points (Magnette et al., 2016).

Test Ordering and Patient Preparation

While often initiated by a physician, nurses play a crucial interpretative and preparatory role. They must verify the appropriateness and timing of tests, especially for therapeutic drug monitoring or dynamic function tests. A critical nursing responsibility is patient preparation, which includes providing clear instructions on fasting requirements, medication holds, or other pre-collection protocols (Delianu et al., 2021). Failure in this communication can lead to physiologically non-representative samples (e.g., non-fasting lipid panels), rendering even a perfectly collected specimen clinically misleading (Lippi et al., 2015).

Patient Identification: The Unforgivable Error

The single most critical and dangerous pre-analytical step is accurate patient identification. The "Right Patient" principle is absolute. Errors here, such as mislabeling a tube at the bedside or drawing from the wrong patient, directly jeopardize patient safety. Studies consistently show that misidentification errors, though less frequent than others, have the most severe potential consequences, including wrong blood transfusion or inappropriate chemotherapy (Valenstein & Sirota, 2004). Nursing adherence to a rigorous, two-identifier protocol (e.g.,

full name and date of birth) confirmed against the patient's wristband before any draw is the foundational safety barrier.

Specimen Collection: Technique Dictates Quality

Specimen collection represents the foundational technical nursing competency within the pre-analytical phase, where meticulous technique directly dictates the integrity and clinical utility of the sample. Site selection and venipuncture methodology are critical; improper technique remains the predominant cause of hemolysis—the rupture of red blood cells—which consistently tops lists for specimen rejection. Common iatrogenic causes include the use of an inappropriately small-gauge needle, vigorous or improper mixing of collection tubes, applying excessive negative pressure during syringe draws, and attempting to collect from a pre-existing hematoma, all of which traumatize blood cells and release intracellular constituents (McCaughey et al., 2016). Equally vital is the accurate selection of collection tubes containing specific anticoagulants or additives, as an incorrect tube invalidates the intended test.

Adherence to the CLSI-recommended order of draw is a non-negotiable standard to prevent cross-contamination of additives between tubes, a procedural failure that can, for instance, cause falsely elevated potassium levels in a chemistry sample from carryover of EDTA (Cornes, 2020). Furthermore, ensuring adequate sample volume is paramount, particularly for coagulation studies or complete blood counts in EDTA tubes, as underfilling alters the critical blood-to-additive ratio, producing clinically misleading results for parameters like PT/INR or cellular indices. Each step in this hands-on process is a direct determinant of analytical quality, positioning nursing skill as the primary safeguard against pre-analytical error (Chawla et al., 2010).

Post-Collection Handling: Protecting Sample Integrity

The nurse's role extends beyond the needle withdrawal. Immediate, gentle inversion of tubes to mix additives (e.g., 5-10 times for EDTA), proper labeling *at the bedside*, and appropriate storage (e.g., protecting light-sensitive samples, keeping certain specimens warm or cold) are essential. Delay in transporting samples to the laboratory, especially for unstable analytes like lactate or ammonia, can degrade sample quality as significantly as a poor collection technique (Simundic & Lippi, 2012).

Table 1: Common Pre-Analytical Errors in Nursing Practice and Their Impact

Error Category	Specific Examples	Potential Consequences
Patient Identification	Mislabeled specimen; drawing from the wrong patient; labeling away from the bedside.	**Catastrophic:** Wrong diagnosis/treatment (e.g., transfusion error). Diagnostic delay. Legal liability.
Collection Technique	Poor venipuncture, causing hemolysis; incorrect order of draw; underfilled tubes.	**Common:** Specimen rejection, need for recollection. Falsely elevated potassium, LDH, and phosphorus from hemolysis. Invalid coagulation studies.
Tube/Container Selection	Using the wrong anticoagulant (e.g., EDTA for chemistry), incorrect urine container.	**Critical:** Invalid results (e.g., clotted CBC, preserved urine cytology). Test cancellation, delay.
Patient Preparation	Non-fasting sample when required; drawing during intravenous fluid infusion.	**Insidious:** Clinically misleading results (e.g., elevated triglycerides, diluted electrolytes). Inappropriate clinical interpretation.
Post-Collection Handling	Failure to mix tubes; delayed transport; improper storage (temp, light).	**Degradative:** Altered results (e.g., decreased glucose, increased potassium from cell metabolism). Clotted samples.

Root Cause Analysis: Beyond Individual Blame

Attributing pre-analytical errors solely to nurse incompetence is a simplistic and ineffective approach. A systems-based analysis reveals a confluence of contributing factors (Morias et al., 2023).

Individual and Educational Factors

Despite being a core skill, phlebotomy training for nurses can be inconsistent—often relying on brief clinical placements or variable hospital-based programs without ongoing competency assessment. Knowledge decay over time is common, particularly for less-frequent procedures like blood culture collection or specialized tube requirements (Ruiz et al., 2024). High workload, fatigue, and interruptions during the collection process directly increase the risk of procedural deviations and identification errors (Aljehani & Alhayek, 2024).

Systemic and Organizational Factors

The clinical environment often sets nurses up for difficulty. Inadequate availability of proper supplies (e.g., correct tubes, secure labels, properly functioning vein-finders) forces improvisation. Complex, non-standardized, or ambiguous test ordering systems in electronic health records can lead

to confusion. Perhaps most significantly, the absence of a supportive, non-punitive culture discourages the reporting of near-misses or minor errors, preventing organizational learning and systemic correction (Saathoff et al., 2018).

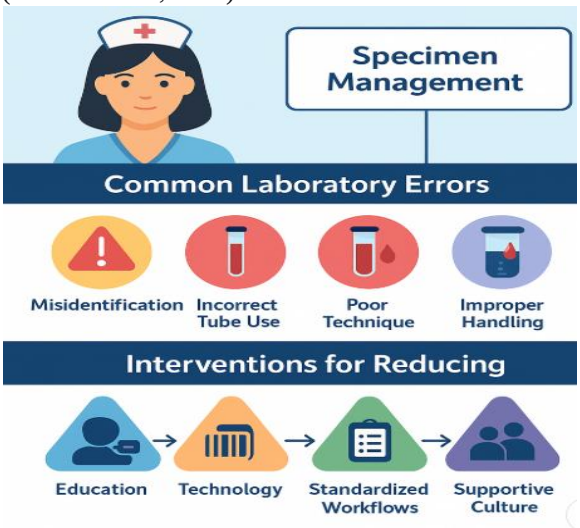

Figure 1: The role of nursing in reducing preanalytical errors.

Technological and Process Design Factors

Reliance on manual, paper-based requisitions and handwritten labels is a known high-risk process prone to transcription errors. Even with electronic systems, poorly designed workflows that require label printing at a separate station from the patient's bedside create a dangerous disconnect between the patient and their specimen. The lack of integrated, barcode-enabled positive patient identification (PPID) systems is a major technological gap in many settings.

Evidence-Based Nursing Interventions for Error Reduction

Sustainable improvement requires multi-pronged, evidence-based strategies that address the root causes. One-off lectures are ineffective. Sustainable change requires structured, competency-based education programs that include didactic learning, supervised practical training, and regular re-assessment. Simulation-based training for difficult venipunctures has shown particular efficacy (Arslan et al., 2022). Creating easily accessible visual job aids (e.g., tube selection charts, order-of-draw posters) at collection stations provides just-in-time support.

Technology can create "forcing functions" that make errors harder to commit. The implementation of barcode-based PPID systems is the gold standard. This requires scanning the patient's wristband and printing the specimen label at the bedside, creating an automatic, verifiable link between patient and sample. Studies demonstrate this single intervention can reduce labeling errors by over 90% (AlSahly et al., 2025). Furthermore, automated tube labelers and trackable specimen transport systems enhance traceability and reduce handling mistakes.

Standardizing collection protocols across all units eliminates variation and confusion. The use of pre-packaged, procedure-specific specimen collection kits (e.g., a "blood culture kit" with the correct bottles, chlorhexidine swabs, and syringe) reduces cognitive load and selection errors. Establishing dedicated, expert phlebotomy teams has been repeatedly shown to significantly lower hemolysis and overall rejection rates compared to decentralized collection by general ward nurses (Ahmed et al., 2022). This specialization allows for refined skill and consistent practice.

Establishing closed-loop feedback from the laboratory to the clinical units is critical. Regular, unit-specific reports on hemolysis rates, specimen rejection reasons, and labeling errors, presented in a non-punitive, educational manner, allow nurses to see the outcome of their practice and motivate improvement (Mahto et al., 2023; Getawa et al., 2023). Empowering nurses to reject improperly written orders or to stop a collection if identification is uncertain fosters a culture of collective accountability (Table 2).

Table 2: Summary of Effective Interventions and Their Impact

Intervention Category	Specific Strategies	Demonstrated Outcomes & Key References
Enhanced Education	Competency-based training with simulation; regular refreshers; visual job aids at point-of-care.	Reduced hemolysis rates by 30-60%; improved adherence to order of draw (Arslan et al., 2022; Ruiz et al., 2024).
Technology Integration	Barcode Positive Patient ID (PPID) systems; automated tube labelers; electronic specimen tracking.	Near-elimination of mislabeling errors (>90% reduction); improved traceability (AlSahly et al., 2025; Saathoff et al., 2018; Nordin et al., 2024).
Process Standardization	Dedicated phlebotomy teams; pre-packaged procedure-specific collection kits; unit-wide standardized protocols.	Significant reduction in overall specimen rejection rates; lower hemolysis; increased efficiency (Ahmed et al., 2022).
Culture & Feedback Systems	Non-punitive error reporting; closed-loop lab-to-unit data	Increased error reporting for systemic fixes; sustained quality improvement; enhanced

feedback; nurse empowerment to verify orders/procedure.

The Broader Impact: From Specimen Quality to Health System Efficacy

Optimizing nursing's role in specimen management transcends the laboratory slip. It is a powerful lever for improving overall health system performance.

Direct Enhancement of Patient Safety and Experience

The most immediate impact is the prevention of harm. Accurate identification prevents catastrophic treatment errors. Reducing recollections spares patients unnecessary discomfort, anxiety, and delayed care. Efficient, confident specimen collection improves the patient's perception of clinical competence and care quality (Gupta et al., 2018).

Economic and Operational Efficiency

Pre-analytical errors are costly. Each rejected specimen represents wasted consumables, laboratory processing time, and, most expensively, additional nursing time for recollection (Rahim et al., 2025; Santos et al., 2021). Reducing rejection rates directly frees up nursing hours for other patient care activities and lowers laboratory operational costs. It also minimizes the hidden costs associated with delayed diagnosis and extended length of stay (Lippi & Plebani, 2020).

Strengthening Interprofessional Collaboration and Diagnostic Stewardship

A collaborative model where nurses and laboratory professionals engage in mutual feedback and problem-solving breaks down traditional silos (Meier et al., 2018). Nurses gain a deeper understanding of how their actions affect analytical results, evolving into partners in "diagnostic stewardship"—the right test, for the right patient, with the right specimen (Lippi et al., 2019). This collaboration is essential for tackling complex pre-analytical challenges.

Conclusion and Future Directions

The evidence is unequivocal: nurses are the pivotal agents in safeguarding the pre-analytical pathway and, by extension, the integrity of the entire diagnostic process. Reducing laboratory errors is not a peripheral nursing task but a core patient safety competency. This review demonstrates that successful strategies are multidimensional, integrating relentless focus on education, intelligent deployment of technology, rigorous process standardization, and the cultivation of a just culture that values feedback and continuous improvement. Moving forward, healthcare institutions must recognize this as a strategic priority.

Investment must be directed towards robust nursing education platforms, the widespread implementation of barcode PPID technology, support for specialized phlebotomy roles, and the development of data-driven feedback systems. psychological safety (Mahto et al., 2023).

Furthermore, nursing research should continue to explore innovative interventions, such as the use of artificial intelligence for real-time technique coaching via video or advanced data analytics for predictive error risk assessment. By empowering and equipping nurses with the knowledge, tools, and systemic support they need, healthcare systems can transform the pre-analytical phase from a primary source of error into a model of reliability, thereby enhancing diagnostic accuracy, improving patient outcomes, and optimizing the use of valuable healthcare resources.

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