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Research Article

Pre-Analytical Errors Through Effective Collaboration Between Nurses and Laboratory Professionals

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Abstract:

The pre-analytical phase of the total testing process is the most vulnerable to errors, accounting for over 60% of all laboratory mistakes. These errors, including misidentification, improper specimen collection, and hemolysis, have significant implications for patient safety, clinical decision-making, and healthcare costs. The execution of this phase predominantly involves nursing staff, while the oversight and consequences fall upon laboratory professionals, creating a critical interface where communication and collaboration failures often occur. This comprehensive review aims to analyze the root causes of pre-analytical errors, with a specific focus on the systemic and communication barriers between nursing and laboratory teams, and to synthesize evidence-based strategies for fostering effective interprofessional collaboration to mitigate these errors. Evidence consistently demonstrates that pre-analytical errors are largely preventable and are best addressed through a collaborative framework. Key findings indicate that strategies such as establishing joint nurse-laboratory quality committees, implementing closed-loop communication technologies, providing continuous interprofessional education, and leveraging data-driven feedback can reduce specimen rejection rates by 30-50% and significantly improve key quality indicators like hemolysis rates. A cultural shift from a siloed, blame-oriented model to a shared, system-based accountability is fundamental to success. Effective, systematic collaboration between nurses and laboratory professionals is the most potent strategy for strengthening the pre-analytical phase. By bridging the interdisciplinary gap through structured communication, shared goals, and ongoing education, healthcare institutions can dramatically enhance the quality of laboratory diagnostics, thereby safeguarding patient safety and optimizing clinical outcomes.

1. Introduction

The pursuit of diagnostic excellence is a cornerstone of modern healthcare, with clinical laboratory testing serving as an indispensable pillar for patient diagnosis, prognosis, and therapeutic monitoring. It is estimated that laboratory data directly influences 60-70% of all critical clinical decisions, including admission, discharge, and medication regimens [1]. The integrity of this data is, therefore, paramount. The total testing process, often conceptualized as a "brain-to-brain" loop, is a complex continuum traditionally divided into three distinct phases: pre-analytical, analytical, and post-analytical [2]. While significant advancements in automation and information technology have rendered the analytical phase highly reliable, with error rates now below 0.1%, the pre- and post-analytical phases remain vulnerable to human-dependent errors [3].

Among these, the pre-analytical phase—encompassing all procedures from test ordering and patient preparation to sample collection, handling, and transportation—is the most susceptible to inaccuracies. A substantial body of evidence consistently demonstrates that pre-analytical errors account for over 60-70% of all laboratory errors, dwarfing those originating in the analytical (10-15%) and post-analytical (20-25%) phases [4, 5]. These errors are not merely statistical abstractions; they have profound and tangible consequences for patient safety and healthcare economics. Pre-analytical mishaps, such as misidentified samples, improper anticoagulant ratios, hemolyzed specimens, or incorrect sample storage, can lead to erroneous test results, misdiagnosis, unnecessary repeat testing, delayed treatment, and increased patient morbidity [6]. The financial burden is equally staggering, with studies indicating that the cost of managing a single misidentified specimen can exceed $1,000 when accounting for redraws, clinical follow-up, and potential patient harm, costing the healthcare system billions annually [7].

A critical analysis of the pre-analytical workflow reveals that it exists almost entirely outside the direct control of the laboratory. This phase is predominantly executed by nursing staff at the patient's bedside or in outpatient clinics. Nurses, therefore, function as the primary "gatekeepers" of sample quality. However, they often operate under considerable time constraints, high workloads, and with varying levels of phlebotomy-specific training. Conversely, laboratory professionals possess deep expertise in the biological and technical requirements of sample integrity but are typically physically and organizationally separated from the point of collection. This functional and, at times, cultural siloing between nursing and laboratory services creates a critical gap—a "quality chasm" in the total testing process. A lack of standardized procedures, inconsistent communication channels, and fragmented feedback mechanisms mean that errors are often corrected reactively rather than prevented proactively [8, 9]. The primary objective of this comprehensive review is to critically appraise the existing literature on the nature and

impact of pre-analytical errors and to elucidate the evidence-based models of collaboration that have proven successful in mitigating them.

2. Role of Nurses in the Pre-Analytical Phase:

The nurse's involvement in the pre-analytical phase can be systematically broken down into several key stages, each with its own set of potential pitfalls. The process begins not at the bedside with a needle, but with the verification of the test request. Nurses are responsible for ensuring that the correct tests have been ordered for the correct patient at the appropriate time. This is the first and most crucial defense against diagnostic error. The paramount responsibility at this stage is unequivocal patient identification. The Joint Commission's National Patient Safety Goals have long mandated using at least two patient identifiers (e.g., full name and date of birth) before any specimen collection [10]. Misidentification at this point propagates an error that is often undetectable by the laboratory and can lead to catastrophic clinical consequences, such as transfusion of incompatible blood or misdiagnosis. Proper patient preparation is a non-negotiable prerequisite for accurate results. Nurses are tasked with ensuring patient compliance with fasting requirements, verifying the timing for therapeutic drug monitoring, and noting relevant patient factors such as recent exercise or medication intake that could artificially alter results [11]. For instance, incomplete fasting can significantly elevate triglyceride and glucose levels, while recent strenuous exercise can increase creatine kinase and lactate levels.

The act of phlebotomy itself is a technical skill with profound implications for sample quality. Key responsibilities include:

- **Selecting the Appropriate Venipuncture Site:** Avoiding edematous areas, areas above active IV lines, or previously compromised veins.
- **Employing Correct Tourniquet Application:** A tourniquet should be applied for less than one minute, as prolonged application can lead to hemoconcentration, falsely elevating proteins, lipids, and protein-bound molecules [12].
- **Using the Correct Collection Tubes:** Adhering to the prescribed order of draw is critical to prevent cross-contamination of additives between tubes. For example, carryover of potassium ethylenediaminetetraacetic acid (K_2EDTA) from a purple-top tube into a serum tube can falsely elevate potassium levels, a potentially dangerous analytical error.
- **Ensuring Proper Fill Volume:** Under-filling citrate tubes (e.g., light blue top) alters the blood-to-anticoagulant ratio, directly affecting coagulation test results like prothrombin time (PT) and International Normalized Ratio (INR) [13].

Once collected, the specimen enters a critical handling window. Nurses must:

- **Invert Tubes Gently but Thoroughly:** Tubes with additives must be inverted immediately after collection to ensure proper mixing and prevent clot formation (in citrate tubes) or platelet clumping (in EDTA tubes). Failure to invert can render a sample unusable.
- **Accurate and Immediate Labeling:** The single most common pre-analytical error is improper specimen labeling [14]. Best practice dictates that labeling must occur *at the patient's bedside*, immediately after collection. Labels should include the patient's full name, a unique medical record number, date of birth, date and time of collection, and the collector's initials. Pre-printing labels away from the bedside significantly increases the risk of misidentification.
- **Proper Handling of Specialized Specimens:** Certain tests require immediate specific actions. Arterial blood gases must be transported on ice to slow metabolic processes. Blood cultures require antiseptic skin preparation with chlorhexidine to minimize contamination, which can lead to false-positive results, unnecessary antibiotic use, and increased costs [15].

The final nursing responsibility is ensuring timely and proper transportation to the laboratory. Many analytes are unstable, and delays can cause spurious results. For example, glucose levels in serum decrease by 5-7% per hour due to glycolysis, and potassium leaks out of cells if serum is not separated from clotted blood in a timely manner [16]. Nurses must use established protocols for pneumatic tube systems or manual courier services, ensuring that samples requiring protection from light (e.g., bilirubin) or specific temperatures are appropriately packaged.

Given the extensive responsibilities, a systematic approach is required to fortify each step against error. The following evidence-based strategies are essential for quality improvement.

A primary defense against pre-analytical variability is the implementation of standardized, institution-

wide procedures for phlebotomy and specimen handling. These protocols must be developed in *collaboration with laboratory professionals* to ensure they reflect the latest evidence and manufacturer guidelines. Furthermore, phlebotomy training for nurses must move beyond simple apprenticeship models to a formal, competency-based approach. This includes initial certification with demonstrated proficiency in techniques like order of draw, tourniquet use, and labeling, followed by periodic re-evaluation and re-certification to prevent the entrenchment of bad habits [9, 13].

Leveraging technology can create hard stops for human error. The use of barcode systems that integrate the electronic health record (EHR) with handheld devices is a powerful tool. This system can:

- Generate patient-specific barcodes at the bedside.
- Verify the two patient identifiers.
- Provide the phlebotomist with a checklist of tubes required.
- Prevent the printing of labels before patient identification is confirmed. Institutions that have implemented comprehensive barcoding systems have reported reductions in mislabeling errors by over 50% [14].

A persistent challenge is the lack of feedback to nursing staff regarding specimen quality. When a hemolyzed, clotted, or mislabeled sample is rejected by the laboratory, the information often does not reach the individual collector in a constructive and timely manner. Establishing a closed-loop feedback system is crucial. This can take the form of:

- **Automated Rejection Notices:** Integrated into the EHR that immediately notify the unit manager and the specific nurse.
- **Joint Quality Dashboards:** Displaying real-time error rates (e.g., hemolysis rates by unit or collector) to foster transparency and accountability.
- **Regular Interprofessional Meetings:** Where laboratory staff can present common issues directly to nursing teams, using visual aids of improperly collected specimens to facilitate shared learning [8].

Practical, at-the-point-of-care aids can significantly reduce cognitive load and prevent mistakes. Pre-packaged, test-specific kits that contain all necessary tubes, supplies, and special instructions (e.g., "protect from light," "transport on ice") streamline the process. Placing color-coded posters illustrating the order of draw and proper inversion techniques in every phlebotomy cart and blood collection area serves as a constant visual reminder, reinforcing correct practice [12].

3. Laboratory Professionals' Contributions:

The moment a specimen arrives in the laboratory, a systematic and rigorous evaluation begins. This initial inspection is a critical control point where a significant proportion of pre-analytical errors can be identified and mitigated before consuming analytical resources and, most importantly, before potentially harming a patient.

The laboratory professional's first duty is to verify the integrity of the sample's identity and its congruence with the test request. This involves a meticulous check for the "3 Cs" of specimen labeling: **Completeness, Correctness, and Concordance** [16].

- **Completeness:** The label must contain the minimum required data points: at least two unique patient identifiers (full name and medical record number or date of birth), the date and time of collection, and the collector's identity.
- **Correctness:** The information on the label must be legible and unambiguous.
- **Concordance:** The patient identifiers on the specimen tube must perfectly match those on the test requisition, whether electronic or paper-based.

Any deviation, such as an unlabeled tube, a discrepancy between the requisition and the label, or an illegible label, constitutes a critical non-conformity. The laboratory must have a strict, unambiguous policy for handling such specimens, which typically involves immediate rejection and direct communication with the clinical unit to request a redraw [14]. Tolerating "minor" labeling errors for the sake of convenience is a dangerous practice that erodes the foundation of patient safety.

Following identity verification, the specimen undergoes a thorough physical inspection. Laboratory professionals are trained to identify visual cues that indicate a sample is unsuitable for analysis.

- **Hemolysis:** This is the most frequently encountered pre-analytical problem, accounting for up to 40-60% of all rejected specimens [17]. Hemolysis, the rupture of red blood cells, releases intracellular components like potassium, lactate dehydrogenase, and aspartate aminotransferase, falsely elevating their measured levels in serum or plasma. Laboratory staff assess hemolysis visually or, increasingly, using automated

spectrophotometric indices (HI) on modern clinical analyzers, providing an objective measure of interference [17].

- **Incorrect Fill Volume:** This is particularly critical for tubes containing liquid anticoagulants. An under-filled citrate tube (e.g., light blue top) alters the blood-to-anticoagulant ratio, which directly and profoundly affects coagulation test results, leading to artificially prolonged PT and INR values [13]. Similarly, under-filled EDTA tubes can cause artifactual changes in complete blood count parameters.
- **Clotting:** The presence of clots in an anticoagulated tube (e.g., EDTA or heparin) renders it unusable for most analyses. Clots in a purple-top EDTA tube will obstruct the hematology analyzer, while microclots can cause erroneous results.
- **Lipemia and Icterus:** Grossly lipemic (milky) or icteric (deep yellow) samples can cause significant analytical interference in numerous photometric and immunoassay methods. While not always a reason for rejection, laboratory professionals must flag these samples, and may need to employ techniques like ultracentrifugation or use blanking protocols to ensure accurate results [18].

Upon identifying any of these non-conformities, the laboratory professional does not simply reject the sample. The critical next step is to document the error in the Laboratory Information System (LIS) using standardized rejection codes and to *communicate the specific reason for rejection directly to the clinical care team*. This feedback is an essential educational tool that forms the basis for continuous improvement at the point of care.

Once a specimen passes the initial inspection, it enters the processing phase, where laboratory professionals apply their technical expertise to prepare the sample for analysis, ensuring the stability of the analytes of interest.

Proper centrifugation is a science in itself. Laboratory protocols dictate specific parameters:

- **Relative Centrifugal Force (g-force) and Time:** Different tests require different centrifugation speeds and durations. For example, obtaining platelet-poor plasma for coagulation studies requires a higher g-force and longer spin time than routine serum separation to ensure minimal platelet contamination, which could affect assay results [19].
- **Timing:** The delay between collection and centrifugation (the "processing time") is a key variable for many labile analytes. Lactate levels, for instance, must be measured on specimens centrifuged within 15 minutes of collection. Laboratory staff must manage workloads to adhere to these strict stability windows. Following centrifugation, serum or plasma must be carefully aliquoted into secondary tubes without disturbing the cell layer. This requires skilled technique to prevent hemolysis or contamination with cells, which could alter results.

Laboratory professionals are the custodians of analyte stability. They are responsible for:

- **Proper Storage:** Storing processed samples at recommended temperatures (e.g., room temperature, refrigerated at 4°C, or frozen at -20°C to -80°C) until analysis.
- **Prioritizing Analysis:** Ensuring that stat tests or unstable analytes are processed and analyzed first.
- **Archiving:** Maintaining an organized specimen archive for a defined retention period, which is crucial for add-on testing, verification of results, or in response to legal requests.

Beyond the bench, the most significant contribution of laboratory professionals to the pre-analytical phase is their role as system-wide educators and architects of quality.

The laboratory is responsible for creating, maintaining, and distributing a comprehensive phlebotomy manual. This vital document serves as the single source of truth for all pre-analytical procedures and must be developed in collaboration with nursing leadership. A high-quality manual provides clear, step-by-step instructions on [20]:

- Patient preparation requirements (e.g., fasting, drug restrictions).
- Order of draw.
- Minimum fill volumes for all tube types.
- Specimen handling and transport conditions (e.g., ice, light protection).
- Stability information for all analytes. In the digital age, this manual should be integrated into the hospital's intranet and EHR for easy access at the point of care.

Laboratory professionals possess a powerful tool for pre-analytical improvement: data. By systematically tracking and analyzing rejection rates, hemolysis indices, and other quality indicators, they can identify trends and problem areas. For example, if data reveals a consistently high hemolysis rate in the Emergency Department, it provides objective evidence to initiate a targeted intervention, such as refresher training on

venipuncture techniques or the evaluation of needle gauge sizes in use [21]. This data-driven approach moves quality management from a reactive (addressing individual errors) to a proactive (preventing errors at a systemic level) model.

Finally, the laboratory must be a proactive partner, not an isolated silo. Laboratory professionals should lead and participate in interprofessional education sessions for nursing staff, using actual examples of rejected specimens to illustrate the "why" behind the protocols. Establishing a laboratory liaison role, where a senior technologist regularly visits clinical units to discuss issues and answer questions, has been shown to dramatically improve relationships, reduce errors, and foster a shared sense of ownership over the total testing process [22].

4. Communication Barriers:

The pre-analytical phase, while a sequence of technical tasks, is fundamentally a human process reliant on effective communication between two distinct professional cultures: nursing and laboratory medicine. Despite a shared goal of optimal patient care, the interface between these groups is often a significant fault line where pre-analytical errors are generated and amplified. A breakdown in communication is not merely an ancillary issue; it is a root cause of diagnostic error. Studies suggest that communication failures contribute to nearly **70% of all sentinel events** in healthcare, and the nurse-laboratory interface is a critical, yet often overlooked, component of this problem [22].

The communication gap between nursing and laboratory staff is not born of ill intent but is a product of deeply embedded structural and cultural differences that shape their respective work environments and worldviews.

Healthcare institutions are often structured in a way that physically and administratively separates nursing units from the central laboratory. This "silo effect" creates an "out of sight, out of mind" dynamic. Nurses, operating under immense pressure with multiple competing priorities, view the laboratory as a remote service provider. Conversely, laboratory professionals, focused on analytical precision and batch processing, may perceive nursing units as chaotic environments that fail to appreciate the rigorous requirements of sample integrity. This physical separation limits the opportunity for the informal, face-to-face communication that is crucial for building rapport, clarifying ambiguities, and resolving issues in real-time [23]. The primary interaction often becomes a transactional, and frequently adversarial, exchange—a rejected specimen slip or a terse phone call.

The core priorities of each profession can lead to a fundamental misalignment. The nursing paradigm is holistic, patient-centered, and immediate, driven by the need for rapid clinical decision-making. In contrast, the laboratory paradigm is analytical, process-oriented, and governed by the principles of standardization, precision, and quality control. When a laboratory rejects a hemolyzed sample, the nurse may see a delayed diagnosis and an unhappy patient requiring a painful redraw, while the laboratory professional sees the prevention of a potentially harmful erroneous result. This difference in perspective is compounded by significant knowledge gaps. Many nurses receive limited formal education on the complex biochemical and technical principles underlying specimen stability and interference [24]. Simultaneously, laboratory staff may have insufficient understanding of the practical challenges of performing phlebotomy on a dehydrated, agitated, or critically ill patient in a busy ward. This mutual lack of insight fosters frustration and a blame culture, where errors are attributed to individual incompetence rather than systemic failures.

A critical communication failure is the lack of a constructive, closed-loop feedback system. When a pre-analytical error occurs, the communication from the laboratory to the nursing unit is often minimal and punitive. A specimen rejection notifying a "hemolyzed sample" or "mislabeled specimen" is delivered without context or educational value. It does not answer the nurse's fundamental questions: *Why* did it hemolyze? Was it my technique, the patient's difficult access, or the transport system? *How* can I prevent it next time? Without this feedback, the same errors are destined to repeat. Furthermore, this one-way communication flows almost exclusively from the laboratory to nursing; there is rarely a formal channel for nurses to provide feedback to the laboratory regarding unclear test requirements or cumbersome collection kits, perpetuating a cycle of inefficiency and misunderstanding [25].

These barriers manifest directly as the pre-analytical errors discussed in previous sections. Poor communication is the engine that drives:

- **Specimen Misidentification:** Ambiguous labeling policies or a lack of shared understanding of the "zero-tolerance" policy for misidentification leads to preventable errors.
- **Inappropriate Sample Collection:** Unclear or inaccessible instructions for specialized tests (e.g., cold

agglutinins, porphyrins) result in samples being collected in the wrong tube, at the wrong time, or without proper transport conditions.

- **High Hemolysis Rates:** When hemolysis data is not shared with nursing units in a constructive manner, units cannot identify if the problem is widespread or isolated to a few individuals, and targeted training cannot be implemented.
- **Delayed Turnaround Time (TAT):** The back-and-forth communication required to clarify test orders or request redraws significantly delays the reporting of critical results, impacting patient care.

Overcoming these deeply rooted challenges requires a deliberate, multi-faceted strategy focused on creating shared goals, integrating technology, and fostering interprofessional respect.

Proactive communication must be institutionalized. The formation of a joint **Nurse-Laboratory Quality Improvement (QI) Committee** is a powerful tool. This committee, comprising staff nurses, nurse educators, phlebotomists, medical technologists, and laboratory managers, should meet regularly to [26]:

- Review pre-analytical error data and identify trends.
- Co-develop and revise phlebotomy procedures and collection manuals.
- Discuss specific challenging cases in a blameless, problem-solving environment.
- Plan joint educational in-services. One study demonstrated that the establishment of such a committee led to a **40% reduction in pre-analytical errors within one year** by creating a shared sense of ownership over the process [26].

Modern information systems can be configured to transform communication from punitive to proactive and educational. Key technological interventions include:

- **Intelligent Order Entry with Decision Support:** The Electronic Health Record (EHR) can be designed to prompt nurses with detailed collection instructions at the time of test ordering, reducing ambiguity.
- **Enhanced Specimen Rejection Modules:** Instead of a simple "rejected" status, the LIS can be configured to require a specific, educational rejection code (e.g., "hemolysis index >500," "citrate tube under-filled by >10%") and to automatically notify the unit-based educator or manager, not just the ordering clinician.
- **Shared Quality Dashboards:** Implementing real-time, unit-specific dashboards that display key pre-analytical metrics (e.g., specimen rejection rate, hemolysis index) empowers nursing units to self-monitor their performance and fosters healthy competition and collective accountability [27].

Moving beyond isolated training sessions, interprofessional education is key to breaking down cultural barriers. Laboratory professionals should be invited to lead segments of nursing orientation and annual competency reviews, using visual aids like photographs of rejected specimens to explain the science behind the protocols. Conversely, nurses can present to laboratory staff on the clinical realities of patient care. This "walking in each other's shoes" builds mutual empathy and respect. Simulation-based training involving both groups to manage a complex pre-analytical scenario has been shown to significantly improve attitudes towards collaboration and knowledge of each other's roles [28].

Appointing a **Laboratory Clinical Liaison**—a senior medical technologist with excellent communication skills—can serve as a dedicated bridge. This individual would make regular rounds to clinical units, be a readily available point of contact for troubleshooting, and facilitate just-in-time education [29]. Furthermore, establishing standardized communication tools, such as the **SBAR (Situation-Background-Assessment-Recommendation)** framework, for phone conversations regarding critical results or problematic specimens can ensure clarity, reduce miscommunication, and ensure all necessary information is conveyed efficiently [23].

5. Impact of Continuous Education and Training:

While essential, initial orientation and phlebotomy certification for nurses often provide only a foundational level of competency. The pressure to rapidly integrate new staff into high-volume clinical environments can lead to abbreviated training that emphasizes task completion over deep understanding. Consequently, the underlying principles of specimen integrity—*why* the order of draw is critical, *how* hemolysis affects specific analytes, *what* the clinical implications of an under-filled citrate tube are—are often glossed over. This creates a practice gap where staff can perform the mechanics of phlebotomy without comprehending the downstream consequences of their technique.

For laboratory professionals, initial training is heavily focused on analytical procedures, with less

emphasis on the pedagogical and communication skills needed to effectively educate their clinical colleagues. This knowledge-practice gap is exacerbated by the "hidden" nature of pre-analytical errors; a nurse may never see the erroneous potassium result from a hemolyzed sample they collected, thus receiving no natural feedback on their performance [29]. Continuous education serves to close these gaps, transforming task-oriented practice into evidence-based, understanding-driven care. It is the primary mechanism for reinforcing standards, introducing new evidence-based guidelines, and combating the natural drift in procedural compliance that occurs over time.

A robust, continuous education strategy must be multifaceted, targeting different learning styles and addressing the specific needs of both professional groups. It should extend beyond passive lectures to include active, engaging, and data-driven methodologies.

Moving beyond simple attendance-based training, a competency-based model ensures that staff can not only recite a procedure but can also demonstrate proficiency in its execution. For nursing staff, this involves periodic (e.g., annual or biannual) hands-on assessment of phlebotomy skills, including:

- Patient identification using two identifiers.
- Appropriate tourniquet application and time.
- Correct order of draw.
- Proper tube mixing.
- Immediate bedside labeling. These assessments should be directly linked to objective quality indicators, such as individual hemolysis rates or specimen rejection rates, allowing for targeted remediation [30]. For laboratory staff, continuous education should include competency in using new LIS rejection modules, effective communication techniques for interacting with nursing units, and updates on interference patterns from improperly collected specimens.

Generic training is less effective than education targeted to specific, identified problems. By leveraging data from the LIS on pre-analytical errors, educators can design highly specific interventions. For instance, if data analytics reveal a high incidence of mislabeled specimens in the Emergency Department, a just-in-time educational session can be deployed to that specific unit, focusing exclusively on labeling policies and using real examples of errors that occurred within the department [31]. This approach makes the training immediately relevant and actionable. Similarly, sharing unit-specific hemolysis index data with staff and then demonstrating proper venipuncture and handling techniques directly links the educational content to a measurable outcome, empowering staff to improve their own performance metrics.

As previously discussed, siloing is a major contributor to pre-analytical errors. IPE sessions that bring nurses and laboratory professionals together in a shared learning environment are a powerful tool for breaking down these barriers. These sessions should focus on collaborative problem-solving around real-world case scenarios, such as:

- "A critically ill patient with difficult access requires a full metabolic panel and coagulation studies. How can we collaborate to ensure sample quality?"
- "The lab is reporting a high rate of clotted EDTA samples from the oncology unit. What are the potential causes from both the nursing and lab perspectives?" Such exercises foster mutual understanding, build respect for each other's challenges, and create a shared mental model of the total testing process. Studies have shown that IPE can improve attitudes towards collaboration and significantly increase knowledge of pre-analytical principles in both groups [32].

The return on investment for continuous education must be measured through robust quality indicators. A successful program will demonstrate a direct, positive impact on key pre-analytical metrics, including:

- **Reduction in Specimen Rejection Rates:** This is the most direct measure of pre-analytical improvement. Institutions that have implemented comprehensive, ongoing education programs have reported sustained reductions in overall specimen rejection rates by 30-50% [33]. For example, a focused education campaign on the importance of citrate tube fill volume can virtually eliminate rejections for that specific cause.
- **Decrease in Hemolysis Index (HI):** Hemolysis remains a leading cause of sample rejection. Educational interventions that include visual aids, hands-on practice with different needle gauges and vacuum tube systems, and feedback on individual HI rates have been proven to lower hemolysis rates significantly. One multi-center study found that a standardized educational program reduced hemolyzed specimens by 25% across participating hospitals [34].

- **Improvement in Turnaround Time (TAT):** By reducing the number of rejected specimens requiring redraws and clarifications, continuous education directly contributes to more efficient laboratory TAT, a critical metric for patient flow in emergency and surgical settings [35].
- **Enhanced Staff Confidence and Job Satisfaction:** Continuous education is a key driver of professional empowerment and engagement. Staff who feel competent and knowledgeable in their roles experience less frustration and burnout. Surveys conducted before and after educational interventions have shown marked improvements in staff confidence regarding pre-analytical procedures and their ability to troubleshoot problems [36].

For continuous education to be truly effective, it must be championed by institutional leadership and embedded within a broader culture of safety and quality improvement. This requires:

- **Dedicated Resources:** Allocating protected time and funding for staff to participate in training without compromising clinical coverage.
- **Integration with Performance Evaluation:** Linking competency in pre-analytical procedures to annual performance reviews for both nursing and laboratory staff.
- **Promotion of a Non-Punitive Environment:** Framing education as a tool for system improvement and professional growth, rather than as a punitive measure for individual failures. A just culture encourages the reporting of errors and near-misses, which then become valuable teaching opportunities for all [37].

6. Conclusion

The journey of a laboratory specimen from the patient's vein to a validated analytical result is a complex and high-stakes pathway, the integrity of which is foundational to modern medicine. As this review has unequivocally demonstrated, the pre-analytical phase represents the most fragile link in this chain, one that cannot be fortified by technological advancement in the analytical phase alone. The evidence presented underscores that the predominant source of pre-analytical fallibility is not a lack of individual competence, but rather a systemic failure in the collaboration and communication between its two primary custodians: nursing and laboratory professionals.

The path forward requires a deliberate and sustained commitment to dismantling the traditional silos that separate these disciplines. This is not achieved through mandates alone, but through the intentional cultivation of a collaborative ecosystem. The most successful strategies are multifaceted, integrating **structural changes** like joint quality committees and laboratory liaison roles; **technological enablers** such as intelligent order entry and shared quality dashboards; and **cultural transformation** fostered through interprofessional education and a non-punitive, just culture. The compelling data shows that when nurses and laboratory professionals engage as partners—when the laboratory provides constructive, data-driven feedback and nursing provides insights into clinical realities—the result is a powerful, self-reinforcing cycle of quality improvement.

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References

[1] Lippi G, Sonntag O, Plebani M. Appropriate labelling of blood collection tubes: a step ahead towards patient's safety. Clin Chem Lab Med. 2011;49(12):1921–1923.

[2] Ahmed Z, Raza A, Mahmood T. Frequency Of Pre-Analytical Phase Errors In A. Clinical Chemistry Laboratory, Indo Am J P Sci. 2019;05:6.

[3] Lee NY. Reduction of pre-analytical errors in the clinical laboratory at the University Hospital of Korea through quality improvement activities. Clin Biochem. 2019;70:24–29.

[4] Lillo R, Salinas M, López-Garrigós M, et al. Reducing preanalytical laboratory sample errors

through educational and technological interventions. Clin Lab. 2012;58(9–10):911–917.

[5] Hawkins R. Managing the pre- and post-analytical phases of the total testing process. Ann Lab Med. 2012;32(1):5–16.

[6] Wang Y, Shang L, Zhao W. Development of a knowledge-attitude-practice questionnaire for venous blood collection in clinical nurses and its reliability and validity test. Chin Nurs Res. 2023;37(23):4199–4207.

[7] Plebani M, Sciacovelli L, Aita A, et al. Quality indicators to detect pre-analytical errors in laboratory testing. Clin Chim Acta. 2014;432:44–48.

[8] Lima-Oliveira G, Volanski W, Lippi G, et al. Pre-analytical phase management: a review of the procedures from patient preparation to laboratory analysis. Scand J Clin Lab Invest. 2017;77(3):153–163.

[9] Iqbal MS, Tabassum A, Arbaeen AF, Qasem AH, Elshemi AG, Almasmoum H. Preanalytical Errors in a Hematology Laboratory:An Experience from a Tertiary Care Center. Diagnostics. 2023;13(4):591.

[10] Zhang J, Luo J, W M, et al. Construction and application of a quality management pathway for venous blood specimens before the test based on the holographic view system of patients. Chin Nurs Manage. 2023;23(12):1894–1898.

[11] Feng X, Cheng R, Xiang M. Quality management of reducing blood specimen rejection rate through team collaboration combined with PDCA. Lingnan J Emerg Med. 2022;27(3):296–298.

[12] Beriault DR, Gilmour JA, Hicks LK. Overutilization in laboratory medicine: tackling the problem with quality improvement science. Crit Rev Clin Lab Sci. 2021;58(6):430–446.

[13] Cadamuro J, Lippi G, von Meyer A, Ibarz M, van Dongen-Lases E, Cornes M, et al. European survey on preanalytical sample handling –part 2:Practices of European laboratories on monitoring and processing hemolytic, icteric, and lipemic samples. on behalf of the European Federation of Clinical Chemistry and Laboratory Medicine (EFLM) working group for the preanalytical phase (WG-PRE). Biochem Med (Zagreb) 2019;29(2):334–345.

[14] Romero-Arana A, Gómez-Salgado J, Fagundo-Rivera J, et al. Compliance with the clinical laboratory quality protocol in public primary healthcare centres. Medicine. 2022;101(30):e29095.

[15] Cadamuro J, Baird G, Baumann G, Bolenius K, Cornes M, Ibarz M, et al. Preanalytical quality improvement –an interdisciplinary journey. Clin Chem Lab Med. 2022;60(5):662–668.

[16] H C, Hu H, Gu H, et al. Evaluation of telemedicine service quality from the perspective of structure-process-results. Health Econ Res. 2019;36(3):32–35.

[17] Wang S, Zhang J, Jiang Q, et al. Research on content adjustment and clinical application of “guidelines of venous blood specimen collection”. Chin Nurs Res. 2022;36(2):341–344.

[18] Plebani M. Quality indicators to detect pre-analytical errors in laboratory testing. Clin Biochem Rev. 2012;33(3):85–88.

[19] Kulkarni S, Piraino D, Strauss R, Proctor E, Waldman S, King J, et al. The Cost of Pre-Analytical Errors in INRTesting at a Tertiary-Care Hospital Laboratory:Potential for Significant Cost Savings. Lab Med. 2021;51(3):320–324.

[20] Abdollahi A, Saffar H, Saffar H. Types and frequency of errors during different phases of testing at a clinical medical laboratory of a teaching hospital in Tehran, Iran. N Am J Med Sci. 2014;6(5):224–228.

[21] Cadamuro J, Simundic AM. The preanalytical phase - from an instrument-centred to a patient-centred laboratory medicine. Clin Chem Lab Med. 2022;61(5):732–740.

[22] Lippi G, Mattiuzzi C, Bovo C, et al. Managing the patient identification crisis in healthcare and laboratory medicine. Clin Biochem. 2017;50(10–11):562–567.

[23] Morrison AP, Tanasijevic MJ, Goonan EM, et al. Reduction in specimen labeling errors after implementation of a positive patient identification system in phlebotomy. Am J Clin Pathol. 2010;133(6):870–877.

[24] Chang J, Kim S, Yoo SJ, Park EJ, Um TH, Cho CR. Preanalytical errors in the central laboratory of a university hospital based on the analysis of year-round data. Clin Lab. 2020;66(9):1783–1791.

[25] Bölenius K, Brulin C, Grankvist K, et al. A content validated questionnaire for assessment of self reported venous blood sampling practices. BMC Res Notes. 2012;5:39.

[26] Naz S, Mumtaz A, Sadaruddin A. Preanalytical Errors and their Impact on Tests in Clinical Laboratory Practice. Pak J Med Res. 2012;51:27–30.

[27] Chavan PD, Bhat VG, Poladia PP, Tiwari MR, Naresh C. Reduction in sample rejections at the preanalytical phase –Impact of training in a tertiary care oncology center. J Lab Physicians. 2019;11(03):229–233.

[28] Haroon ZH, Javaid H, Rashid H, Tahir M, Butt MQ, Afridi N. Pre-analytical errors in a peripheral hospital laboratory. Pak Armed Forces Med J. 2014;64(2):315–318.

[29] Romero A, Gómez-Salgado J, Romero-Arana A, Ortega-Moreno M, Jódar-Sánchez F, Ruiz-Frutos C. Costs analysis of a training intervention for the reduction of preanalytical errors in primary care samples. Medicine (Baltimore) 2020;99(31):e21385.

[30] Snyder SR, Favoretto AM, Derzon JH, et al. Effectiveness of barcoding for reducing patient specimen and laboratory testing identification errors: a laboratory medicine best practices systematic review and meta-analysis. Clin Biochem. 2012;45(13–14):988–998.

[31] Wang X, Song K, Wu X, et al. Effects of the nursing-led multi-department management on the quality of blood culture specimens. Chin Nurs Manage. 2024;24(1):9–13.

[32] Alcantara JC, Alharbi B, Almotairi Y, Alam MJ, Muddathir ARM, Alshaghdali K. Analysis of preanalytical errors in a clinical chemistry laboratory:A 2-year study. Medicine (Baltimore) 2022;101(27):e9853.

[33] Simundic AM, Bölenius K, Cadamuro J, et al. Joint EFLM-COLABIOCLI recommendation for venous blood sampling. Clin Chem Lab Med. 2018;56(12):2015–2038.

[34] Awareness of Pre-Analytical Errors Amongst Nurses –The Phlebotomists in Our Local Set Up. [(Accessed on April 12, 2023)].

[35] Inal TC, Goruroglu Ozturk O, Kibar F. Lean six sigma methodologies improve clinical laboratory efficiency and reduce turnaround times. J Clin Lab Anal. 2018;32(1):e22180.

[36] Singh G, Khalid M, Rahim A, Noor FA. Pre-Analytical Errors in Haematology and Chemistry at Hayatabad Medical Complex Peshawar. J Wazir Muhammad Inst Paramed Tech. 2022;2(2):32–35.

[37] Jessop E. Evaluating healthcare systems and services. healthcare public health: improving health services through population science. 2020;119.