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Research Article

Sample Identification and Labeling Errors in Clinical Settings: A Review of Prevention Strategies Involving Nursing and Laboratory Practice

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Abstract:

Sample identification and labeling errors in clinical settings pose significant risks to patient safety and treatment outcomes. These errors can lead to incorrect diagnoses, inappropriate treatment plans, and ultimately compromise patient trust in healthcare systems. The complexity of healthcare environments, combined with high patient volumes and the potential for miscommunication among healthcare professionals, often exacerbates the likelihood of such errors. Effective prevention strategies must, therefore, integrate nursing and laboratory practices to ensure accurate sample identification and labeling. Enhancing communication and adopting standardized protocols can help mitigate the risk of errors, ensuring that each sample is accurately matched to the corresponding patient. Involving nursing staff in the labeling process is crucial, as they are typically the first point of contact for patients and specimens. Training nurses in the importance of meticulous sample handling, as well as providing them with user-friendly labeling technology, can significantly reduce errors. Moreover, laboratory personnel should play a central role in developing comprehensive protocols that outline best practices for sample identification. Regular audits and an emphasis on teamwork between nursing and laboratory departments can foster a culture of safety and accountability. By leveraging technology, such as barcode scanning systems, and implementing robust education programs focused on the significance of correct sample identification, healthcare facilities can minimize the incidence of labeling errors and enhance overall patient care quality.

1. Introduction

In the intricate and high-stakes ecosystem of modern healthcare, the accurate diagnosis and effective treatment of disease rest upon a foundational, yet perilously vulnerable, pillar: the integrity of the specimen. From the moment a clinician decides a laboratory test is necessary, to the point a result is reported and acted upon, the patient's biological sample—be it blood, tissue, urine, or other fluid—embarks on a complex journey. This journey, termed the *total testing process*, is a continuum involving numerous individuals, multiple handoffs, and various technologies across different departments, primarily nursing and clinical laboratory services. At the very heart of this process lies a deceptively simple task: correctly identifying the patient and accurately labeling the specimen container with that identity [1]. The catastrophic potential of failing in this fundamental task cannot be overstated. A mislabeled or unidentified specimen severs the critical link between the diagnostic result and the patient from whom it originated, rendering sophisticated laboratory analyzers and expert pathologists powerless against a cascade of potential harm [2].

Specimen identification and labeling errors represent a profound and persistent threat to patient safety, quality of care, and healthcare efficiency on a global scale. These pre-analytical errors, which occur outside the controlled environment of the laboratory automation line, are notoriously difficult to eliminate because they are rooted in human-system interactions. An erroneously labeled tube of blood can lead to a blood transfusion with incompatible blood, a missed cancer diagnosis due to a switched tissue biopsy, or the administration of toxic chemotherapy based on another patient's results. The consequences span misdiagnosis, inappropriate therapy, delayed treatment, psychological distress, and in the most tragic cases, patient mortality [3]. Furthermore, these errors inflict significant financial burdens on healthcare systems through the costs of repeat testing, extended hospital stays, legal liabilities, and damaged institutional reputation [4]. This review aims to provide a comprehensive examination of sample identification and labeling errors within clinical settings.

2.The Scope and Magnitude of the Problem:

To fully appreciate the challenge, one must first understand what constitutes an identification or labeling error and how frequently they occur. The term encompasses a spectrum of failures, from the complete absence of a label to subtle discrepancies that can be just as dangerous. The Clinical and Laboratory Standards Institute (CLSI) and other regulatory bodies classify these errors into distinct categories. *Mislabeled specimens* occur when a specimen container bears a label intended for a different patient. *Unlabeled specimens* are those arriving at the laboratory without any patient identifier affixed to the container itself. *Mismatched specimens* describe a situation where the information on the specimen label conflicts with the information on the accompanying requisition form or electronic order. *Incompletely labeled specimens* may have a label, but it lacks one or more essential elements, such as a second unique

identifier, the date and time of collection, or the collector's identity.

Quantifying the true incidence of these errors is challenging due to significant underreporting and variations in detection methods. Studies relying on incident reports often capture only the most egregious errors that reach the patient or are discovered by vigilant laboratory staff. However, more proactive methods, such as direct observation of the collection process or systematic auditing of received specimens, reveal a far more alarming picture. Epidemiological data suggest that identification errors occur in approximately 1 in every 100 to 1,000 specimen collections, with certain high-risk settings like emergency departments and intensive care units reporting even higher rates [1, 2]. A landmark study by the College of American Pathologists (CAP) concluded that patient identification errors are the most common cause of serious error in blood transfusion, a finding echoed by international hemovigilance programs [3]. While the error rate may seem numerically small, when considered against the billions of laboratory tests performed annually worldwide, the absolute number of patients placed at risk is staggering. This establishes specimen misidentification not as a rare anomaly, but as a prevalent and systemic risk requiring urgent and sustained intervention.

3. The Cascading Consequences:

The downstream effects of a sample identification error are severe and multifactorial, impacting the patient, the healthcare providers, and the institution. The most direct and grave consequence is *patient harm*. A mislabeled specimen can generate an erroneous result that becomes part of the patient's permanent health record. If this result is acted upon, the patient may receive a treatment that is unnecessary, incorrect, or even harmful. For instance, a potassium result from another patient with renal failure, reported on a healthy patient's record, could trigger aggressive and dangerous interventions for hyperkalemia. Conversely, a critically abnormal result (e.g., a very high glucose or a positive cancer margin) may be missed because it is attributed to the wrong patient, leading to dangerous delays in life-saving therapy. In transfusion medicine, the risk is immediate and often fatal; ABO-incompatible transfusions due to sample errors remain a leading cause of transfusion-related mortality [4].

Beyond physical harm, there are significant consequences for *clinical decision-making and workflow*. When a labeling error is detected by the laboratory, the standard protocol is to reject the specimen and request a recollection. This process delays diagnosis and treatment, causing anxiety for the patient and frustration for the clinical team. It also consumes valuable time for nurses, phlebotomists, and laboratory staff who must investigate the error, communicate with the clinical unit, and process the repeat sample. This inefficiency contributes to increased length of stay and operational costs. From a *legal and ethical* standpoint, these errors breach the fundamental principle of *primum non nocere* (first, do no harm) and can lead to substantial malpractice litigation, with settlements often reaching millions of dollars. The psychological impact on the healthcare workers involved—the "second victim" phenomenon—is also profound, leading to guilt, loss of confidence, and burnout [5]. Finally, repeated errors erode trust between clinical departments and undermine the perceived reliability of the laboratory, which is the diagnostic cornerstone of modern medicine.

4. Root Cause Analysis:

Effective prevention requires a deep, non-punitive understanding of why these errors occur. The etiology is rarely a simple case of individual carelessness; rather, it is almost always the result of a confluence of latent system failures and active human errors within a complex work environment. The Swiss Cheese Model of accident causation aptly illustrates how holes in various layers of defense (policies, technology, supervision, human action) can align to allow an error to reach the patient.

On the *human factors* side, cognitive psychology provides key insights. *Interruption and distraction*are paramount. The nursing and phlebotomy environment is one of constant multitasking, alarms, and competing priorities. A nurse drawing blood may be interrupted by a call light or an urgent request, leading to a lapse in attention where tubes are placed on a tray without immediate labeling, creating prime conditions for mix-ups [6]. *Fatigue and high workload*, especially during night shifts or understaffed conditions, impair vigilance and procedural compliance. *Confirmatory bias* can lead a collector to see what they expect to see on a label, failing to notice a discrepancy. *Inadequate training* or *normalization of deviance*, where shortcuts like pre-labeling tubes become routine, are significant cultural contributors.

The *systemic and environmental factors* are equally critical. *Poorly designed processes* are a major culprit. The common practice of collecting multiple specimens for multiple patients in a single round

(batch collection) without a robust verification system at the point of collection is inherently risky. *Lack of standardized protocols* across different units or hospitals leads to confusion and inconsistent practice. *Inadequate resources*, such as a shortage of label printers, computers on wheels (COWs), or even basic supplies at the bedside, force workarounds. The *physical environment* itself—poor lighting, cluttered work surfaces, noise—can contribute to error. Furthermore, *communication failures* between the ordering physician, the nurse, and the laboratory, especially during verbal or telephone orders, can initiate the error chain before collection even begins. A flawed system sets up even competent, conscientious individuals to fail.

5. Prevention Strategies in Nursing and Phlebotomy Practice

As the primary point of specimen generation, nursing and phlebotomy practice represents the most critical control point for error prevention. Strategies here focus on creating a fail-safe environment and enforcing rigorous protocols at the point of care. The cornerstone of all prevention is the rigorous adherence to *patient identification protocols*. This goes beyond simply checking a wristband. The universal protocol mandates using at least two unique patient identifiers (e.g., full name and date of birth or medical record number) and actively verifying them against the requisition *and* the specimen label *before* collection. This verification must involve the patient (when possible) stating their own identity, not merely the clinician reading the wristband [7].

The single most impactful technological intervention at the bedside is *barcode-assisted specimen collection*. In this system, the patient's identification wristband contains a barcode with their unique identifiers. The nurse uses a portable barcode scanner linked to the laboratory information system (LIS) to scan the patient's wristband. This action automatically populates the correct patient information and generates specimen-specific barcode labels at the bedside, immediately after collection. The system can be designed to not print labels until the patient barcode is scanned, physically preventing pre-labeling. Furthermore, the scanner can verify that the correct tests have been ordered for the right patient at the right time, creating a closed-loop verification system [8]. Studies have consistently shown that implementation of barcode technology can reduce specimen identification errors by over 80% [9].

Standardized specimen collection kits and trays can also reduce cognitive load. Organizing trays with color-coded tubes, requisitions, and labels for one patient at a time, as opposed to batch setups, minimizes the risk of tube mix-ups. The practice of *labeling tubes at the bedside, immediately after drawing the sample, before leaving the patient's side* is a non-negotiable standard that must be culturally enforced. This eliminates the dangerous practice of transporting unlabeled or pre-labeled tubes to a separate station for labeling. Finally, *empowering and training*nursing staff is vital. Education should focus not just on the "how" but the "why," using real case studies to illustrate the catastrophic potential of errors. Phlebotomists and nurses should be trained in error-reduction techniques and feel psychologically safe to report near-misses without fear of reprisal, as these are invaluable learning opportunities [10].

6. The Laboratory Gatekeeper:

While prevention is ideal, the clinical laboratory serves as an essential safety net, tasked with detecting and intercepting misidentified specimens before erroneous results are released. This defensive role requires a combination of technology, vigilance, and stringent policy. The first line of defense is a rigorous *specimen acceptance policy*. Laboratories must establish and enforce clear, unambiguous criteria for rejecting improperly identified specimens. This policy should be developed collaboratively with nursing leadership and widely disseminated. Common rejection criteria include unlabeled specimens, specimens with discrepancies between the label and requisition, and specimens with illegible or incomplete labels. The key is consistent and unwavering application; allowing exceptions for "difficult draws" or "STAT" requests undermines the entire safety system and is ethically indefensible [11].

Automated specimen processing systems have integrated advanced detection features. Modern track lines and centrifuges equipped with barcode readers can automatically compare the specimen tube barcode against the LIS database. Discrepancies or missing labels can trigger an alert, causing the tube to be diverted to an exception handling station. Some systems can even measure the fill volume or cap color to detect a grossly mismatched tube type for the test ordered, providing another layer of validation [12].

For certain high-risk tests, laboratories employ *historical delta check* algorithms. These software tools compare a patient's current result with their previous results for the same analyte. An

extreme, physiologically implausible change (a "delta" flag) may indicate an identification error, sample contamination, or a genuine acute medical event. While not specific to identification errors, a delta check is a powerful prompt for the medical technologist to investigate further before verifying the result [13]. In blood bank and transfusion service, the defense is multilayered and exceptionally strict. *Independent double-checking* of patient identification at sample collection for type and screen, and again at the bedside before transfusion, is mandatory. Many institutions use *electronic blood dispensing systems* that require scanning the patient's wristband and the unit of blood to ensure compatibility, creating another technological barrier to error [14].

7. The Power of Partnership:

The siloed operation of nursing and laboratory departments is a significant barrier to sustainable error reduction. Lasting improvement is only possible through deliberate, structured *interdisciplinary collaboration*. The formation of a *Pre-Analytical Quality Improvement Team* or a *Patient Identification Safety Committee* is a highly effective strategy. This team should include front-line staff from both domains: nurses, phlebotomists, medical technologists, laboratory assistants, and quality officers. Their mandate is to jointly analyze error data (including near-misses), identify common failure points in the end-to-end process, and co-design solutions [15]. When laboratory staff understand the clinical pressures on the nursing unit, and nurses understand the laboratory's validation constraints, solutions become more practical and widely accepted.

This collaborative effort is the engine for *continuous process redesign*. For example, a joint team might redesign the electronic order-to-collection workflow, simplify the specimen requisition form, or standardize the type of tubes used for common test panels across the hospital to reduce confusion. Collaboration also fuels effective *joint education initiatives*. Laboratory scientists can present in nursing orientation programs, and nurse educators can participate in laboratory staff meetings. Shared learning sessions that review real (anonymized) error events foster a shared mental model and a sense of shared responsibility for the patient's diagnostic journey [16].

Ultimately, all these strategies must be underpinned by a *culture of safety*. Leadership from both nursing and laboratory administration must visibly and consistently champion patient identification as an unconditional priority. This culture moves from a punitive, person-centered blame approach to a just culture that recognizes that competent people make mistakes in poorly designed systems. It encourages transparent reporting, values curiosity over blame, and views every error as a systems problem demanding a systems solution [17]. Celebrating successes, such as a reduction in error rates attributed to a new barcode system, reinforces positive behavior and sustains momentum.

8. Technological Frontiers and Innovative Solutions

Beyond the now-established barcode technology, new frontiers in automation and identification are emerging. *Radiofrequency Identification (RFID)* tags offer potential advantages over barcodes. An RFID chip embedded in a patient's wristband and attached to specimen tubes can be read without direct line-of-sight, potentially streamlining the verification process. RFID systems can also track the chain of custody and location of specimens in real-time, adding a layer of security and process control [18]. However, cost, infrastructure requirements, and signal interference in hospital environments remain challenges.

Biometric identification, such fingerprint or vein pattern scanning, is being explored, particularly for outpatient settings or for unconscious patients without identification. While promising for confirming patient identity at registration or collection, its direct application to specimen labeling is less straightforward and raises significant privacy concerns that must be carefully managed [19].

Perhaps the most transformative future solution lies in *specimen provenance* technology. This involves placing a unique molecular or microparticle "tag" into a specimen container at the time of manufacture. At collection, a device would link this unique container tag to the specific patient's identity in the EHR. Any subsequent analysis of the specimen, even decades later, could definitively trace it back to its source patient, virtually eliminating the possibility of misidentification. While still largely in the research and development phase, this represents a potential paradigm shift in specimen integrity [20].

9. Regulatory Frameworks and Accreditation Standards

External pressure and guidance from regulatory and accrediting bodies play a crucial role in driving improvement and ensuring a baseline of safety.

Organizations such as *The Joint Commission (TJC)*in the United States, the *College of American Pathologists (CAP)*, and the *International Organization for Standardization (ISO)*, particularly ISO 15189 for medical laboratories, establish stringent requirements for patient and specimen identification. TJC's National Patient Safety Goals (NPSGs) have long included a goal specifically dedicated to improving the accuracy of patient identification, which directly governs specimen labeling practices [21]. CAP inspection checklists include numerous questions on specimen acceptance criteria, labeling procedures, and competency assessments for phlebotomy.

Accreditation is not merely a bureaucratic hurdle; it provides a structured framework for quality management. The process of preparing for accreditation surveys forces institutions to scrutinize their policies, audit their practices, and address gaps. Laboratories and hospitals that achieve accreditation demonstrate a commitment to standardized, high-quality practices that minimize risk. These standards often mandate the very strategies discussed: use of two identifiers, labeling at the bedside, clear rejection policies, and competency documentation. They provide the external imperative for institutions to invest in necessary technologies like barcode systems and to foster the interdisciplinary collaboration required for compliance [22].

10. Challenges, Barriers, and Limitations to Implementation

Despite a clear understanding of the problem and the existence of effective solutions, significant barriers impede widespread and sustained implementation. The most frequently cited obstacle is *cost*. The initial capital investment for hospital-wide barcode scanning systems, updated LIS interfaces, and RFID infrastructure can be substantial. There are also ongoing costs for maintenance, supplies (e.g., barcode wristbands), and IT support. Hospital administrators may perceive this as a high cost for preventing a statistically "rare" event, requiring quality and safety officers to build a compelling business case that factors in the avoided costs of repeated tests, extended stays, and litigation [23].

Workforce resistance to change is another major hurdle. Introducing new technology changes established workflows and can be perceived as time-consuming, especially in the short term during the learning curve. Nurses may feel that scanning a wristband and printing a label at the bedside adds seconds to a busy draw round. Overcoming this requires meticulous *change management*: involving end-users in the selection and design of the system, providing ample hands-on training, demonstrating leadership support, and, most importantly, sharing data that shows the new process actually saves time in the long run by eliminating recollections and call-backs from the laboratory [24].

Technological and interoperability issues can also stymie progress. Barcode systems from different vendors may not communicate seamlessly with the Electronic Health Record (EHR) or the LIS. Wristband barcodes must be of high quality and durable enough to withstand hospital wear and tear; smudged or torn barcodes render the system useless. Network connectivity issues in some patient areas can disable mobile scanners. These are not mere technical glitches but direct threats to patient safety that require robust IT engineering and support [25]. Finally, in *resource-limited settings* globally, the high-tech solutions may be unattainable. In these contexts, the focus must shift to strengthening low-tech, high-reliability behaviors: strict adherence to the two-identifier rule, non-negotiable bedside labeling, and the use of simple checklists and visual aids to standardize the collection process.

11. Continuous Quality Improvement:

A one-time project to implement barcoding is insufficient. Maintaining and improving specimen identification safety is a perpetual cycle of measurement, analysis, and refinement—the core of *Continuous Quality Improvement (CQI)*. The first step is establishing *key performance indicators (KPIs)*. These must be meaningful and measurable. The most direct metric is the *specimen identification error rate*, typically expressed as the number of mislabeled, unlabeled, or mismatched specimens divided by the total number of specimens received, over a defined time period. Tracking *specimen rejection rates* by reason and by nursing unit provides actionable data on where problems are concentrated. It is equally important to track *near-miss events* (errors caught before the specimen leaves the unit or before a result is reported), as they are more numerous and offer rich learning opportunities without patient harm [26].

Data should be collected proactively, not just from incident reports. Regular *audits of specimen labeling compliance* can be conducted by observers or through review of transported specimens. The data must then be *analyzed and fed back* to frontline staff and unit managers in a timely, non-punitive, and constructive manner. Visual management tools like run charts or control charts displayed in staff areas can show trends over time,

celebrating improvements and highlighting areas needing attention [27].

The CQI process is dynamic. When data indicates a persistent problem in a specific unit (e.g., a high rate of incomplete labels from the ICU), the interdisciplinary team can investigate, perhaps finding a faulty label printer or a confusing new order set as the root cause, and implement a targeted countermeasure. This cycle of Plan-Do-Study-Act (PDSA) ensures that the safety system is not static but adapts to new challenges, new staff, and new technologies, embedding a mindset of perpetual vigilance and improvement into the organizational fabric [28].

12. Future Directions and Research Priorities

While current strategies are effective, the journey towards zero preventable identification errors continues. Future efforts and research should focus on several key areas. First, there is a need for more sophisticated *data analytics and predictive modeling*. By leveraging big data from EHRs, nurse call systems, and staffing levels, could we predict when and where the risk of an identification error is highest (e.g., during shift change on an understaffed unit) and deploy targeted interventions or alerts? [29]. Second, research into *human factors engineering* specific to the phlebotomy environment is crucial. How can we redesign the physical workspace, the tube holder, or the label printer to make the correct procedure the easiest and most intuitive path, thereby minimizing cognitive load and the potential for slips [30]?

Further development and cost reduction of *advanced tagging technologies* like molecular or isotopic tagging for definitive provenance should be supported. Comparative effectiveness research is also needed to evaluate the long-term sustainability and return on investment of different technological bundles (e.g., barcode vs. RFID in various care settings) [31]. Finally, a critical research priority must be the development and validation of *context-appropriate strategies for low-resource settings*. What are the most effective, low-cost, scalable interventions that can dramatically reduce errors in hospitals without reliable electricity or digital infrastructure? Sharing and studying successful models from these settings will benefit global health equity [32].

13. Conclusion:

The integrity of the specimen is the non-negotiable foundation upon which safe, effective, and efficient healthcare is built. Sample identification and labeling errors represent a critical, persistent, and multifaceted vulnerability in this foundation. As this review has detailed, these errors are not the result of incompetent individuals but of fallible humans working within complex, high-pressure systems that often lack adequate safeguards. The consequences—patient harm, diagnostic delay, financial waste, and eroded trust—are too severe to accept as an inevitable cost of doing business.

The path forward is clear and must be walked with determination. It requires a dual-pronged, collaborative attack on the problem. At the sharp end, nursing and phlebotomy practice must be fortified with uncompromising protocols, supported by fail-safe technologies like barcode-assisted collection, and grounded in a culture that prioritizes safety over speed. At the receiving end, the laboratory must act as a vigilant gatekeeper, enforcing strict acceptance policies and employing technological tools to detect discrepancies. Bridging these two worlds is the essential work of interdisciplinary collaboration, shared learning, and a unified commitment to the patient.

Achieving and sustaining a significant reduction in specimen identification errors is challenging. It demands financial investment, persistent leadership, thoughtful change management, and an unwavering commitment to continuous quality improvement. However, the alternative—resigning ourselves to a steady stream of preventable harms—is ethically and professionally untenable. By harnessing technology, optimizing processes, and, most importantly, fostering a culture of shared responsibility and safety, healthcare systems can transform this critical weakness into a demonstrable strength. The goal is not just to reduce an error rate on a chart, but to ensure that every diagnostic result unequivocally belongs to the patient for whom it is intended, thereby safeguarding the very covenant of trust at the heart of the healing relationship.

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