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Impact of Structured Interventions on Reducing Labeling Errors in Inpatient Sample Collection: A One-Year Quality Improvement Study in a Multispecialty Hospital

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ABSTRACT

Background:
Labeling errors in inpatient sample collection are a critical and preventable threat to patient safety within hospital settings. These errors occur when the patient's identity is inaccurately recorded, mismatched, or omitted on laboratory specimens, leading to serious consequences such as misdiagnosis, delayed or incorrect treatment, transfusion mismatches, repeated invasive procedures, and even medico-legal implications. The World Health Organization and Joint Commission International have identified specimen labeling accuracy as a key patient safety indicator. Despite the integration of digital tools and standard protocols, labeling errors remain one of the most common types of pre-analytical laboratory errors, accounting for a significant proportion of total laboratory mistakes. A notable increase in labeling errors during the first half of 2024 at a multispecialty hospital prompted this study aimed at identifying root causes and evaluating targeted interventions.

Objective:
To assess the incidence and contributing factors of labeling errors and evaluate the effectiveness of structured interventions particularly the Similar Name Alert Protocol (SNAP) and Automated Tube Labeling System (ATLS) implemented to reduce these errors.

Methods:
A retrospective and prospective observational study was conducted from January to December 2024 in a multispecialty hospital in central Kerala. Labeling error data were collected via incident reporting systems and

verified by ward audits. A root cause analysis using the 5 Whys technique was performed, followed by the implementation of targeted interventions in July 2024.

Results:
A rising trend in labeling errors was observed from January (5 cases) to June (11 cases). Post-intervention data showed a reduction: 10 in July, 8 in August, down to 2 in December. The effectiveness of SNAP and ATLS, along with bedside labeling reinforcement and staff training, was evident.

Conclusion:
Structured protocols, technological aids, and continuous staff engagement significantly reduced labeling errors. Long-term success depends on sustained monitoring, auditing, and protocol adherence.

Keywords:
Labeling errors, inpatient safety, patient identification, SNAP protocol, automated tube labeling, quality improvement

INTRODUCTION

Patient identification errors in hospitals are a globally acknowledged challenge, particularly in processes involving specimen collection, where accuracy is paramount. Labelling errors, although preventable, account for a significant proportion of adverse events in clinical practice (1,2). Mislabelled samples can result in erroneous test results, inappropriate therapeutic decisions, delayed or missed diagnoses, and in severe cases, patient morbidity or mortality (3,4). The consequences of such errors can be both clinically and legally significant, undermining the credibility of healthcare institutions and compromising patient trust (5,6).

Accurate patient identification and proper sample labeling are essential components in minimizing medical errors and ensuring patient safety. These steps form the cornerstone of reliable diagnostic and therapeutic workflows (1,7,8). Even a single mislabeling incident can cause substantial harm, particularly in critical care settings or when dealing with similar patient names, high sample volumes, or urgent interventions (9). Strict adherence to standardized labeling protocols not only preserves the accuracy and validity of laboratory results but also promotes a culture of safety, accountability, and patient-centered care within healthcare systems (10).International health bodies have long recognized the critical importance of this issue. The World Health Organization's (WHO) Patient Safety Solution #2, introduced in 2007, underscores the importance of accurate patient identification and has since become a global framework guiding patient safety practices (11). Similarly, the Joint Commission's National Patient Safety Goal (NPSG.01.01.01) mandates the use of at least two identifiers to confirm patient identity before sample collection or treatment administration (12), forming a benchmark for safety protocols in hospitals across the United States. These global directives have inspired health systems worldwide, including in India, to implement similar strategies tailored to their unique healthcare environments (13,14).

Despite these efforts, labeling errors remain a persistent problem across healthcare facilities in India. These errors fall under the broader category of pre-analytical errors, which are estimated to account for up to 70% of all laboratory-related mistakes (15). Labeling issues including patient misidentification, incomplete labels, and data entry errors are among the most common and preventable forms of pre-analytical failures (16). A study conducted at a tertiary care center in South India analyzing over 118,000 blood samples reported an overall pre-analytical error rate of 0.43%, with labeling errors contributing approximately 0.02% of all samples (17). Similarly, a laboratory audit at a teaching hospital in Delhi revealed that 1.2% of rejected samples were due to labeling discrepancies, contributing to an overall specimen rejection rate of 2.1% (18). Another report from a tertiary care hospital in western Uttar Pradesh documented a total pre-analytical error rate of 2.32%, with labeling errors alone accounting for 7.06% of these cases (19). These findings reinforce that labeling errors, although often perceived as operational oversights, have serious implications for diagnostic accuracy and clinical outcomes (20).

Kerala, a state known for its relatively advanced healthcare indicators, is not immune to such challenges. While state-level data on labeling errors are scarce, smaller institutional audits have revealed concerning trends. A quality assessment exercise conducted in a government medical college in Kerala reported that approximately 2–3% of inpatient samples were affected by labeling or related pre-analytical discrepancies (21). The increasing

frequency of labeling errors noted in a multispecialty tertiary care hospital in Kerala during the first half of 2024 raised serious concerns about the robustness of existing protocols. These observations highlighted gaps in operational efficiency, staff compliance, and monitoring systems, necessitating a structured inquiry into the root causes and preventive strategies (20-23).

Against this backdrop, the present study was designed with the dual purpose of identifying the frequency and causes of inpatient labeling errors and evaluating the effectiveness of targeted interventions. Building on the foundation laid by international safety guidelines and previous literature, the study incorporated both system-based and behavioral interventions to mitigate these errors. Two core interventions were introduced: the Similar Name Alert Protocol (SNAP) and the Automated Tube Labeling System (ATLS). SNAP was developed to address errors stemming from patients with identical or phonetically similar names. It involved placing visual alerts on patient files and physical signage near bedside areas and nursing stations. This approach was modeled on best practices recommended by WHO and the Institute for Safe Medication Practices (ISMP) (24,25).

The second major intervention, ATLS, aimed to reduce human error by integrating barcode-based labeling directly linked to the hospital information system (HIS). This system allowed for automatic label generation with real-time patient data, minimizing manual entry and reducing the chances of duplication or mismatch. In addition to these, several supportive safety practices were instituted: reinforcement of bedside labeling protocols, structured management of label strips, periodic audits of sample labeling quality, and continuous staff training on patient identification procedures.

We hypothesized that the combined implementation of these interventions would result in a significant reduction in labeling errors and foster a sustainable culture of safety and precision in sample collection practices. This study thus serves not only as a quality improvement initiative for a single institution but also as a potential model for replication in other hospital settings across Kerala and India.

Materials and Methods

This survey-based, observational, and interventional study was conducted over a period of one year, from January to December 2024, at a 500-bed multispecialty tertiary care hospital in Kerala, India. The study encompassed all inpatient wards, including general medicine, general surgery, cardiology, and pediatrics. Data on labeling errors were collected retrospectively and prospectively using the hospital's incident reporting system and were further cross-validated with ward-level audit records. For the purpose of this study, a "labeling error" was defined as any sample sent to the hospital laboratory with incorrect, mismatched, or missing patient identification on the label.

To identify the root causes of labeling errors, the 5 Whys technique was employed. Error trends were analyzed monthly using tabulated data and graphical visualization. The root causes identified included patients with similar-sounding names, improper cutting of label strips, placement of incorrect labels in patient files, omission of bedside labeling, and peak-time workload pressures, especially during early morning sample collection.

In response, a series of structured interventions were implemented starting in July 2024. The Similar Name Alert Protocol (SNAP) was introduced to address errors caused by similar patient names, involving the use of visual alerts such as colored stickers, signage, and special documentation in handover sheets, along with strategic staff reassignment. The Automated Tube Labeling System (ATLS) was implemented to reduce manual entry errors by introducing point-of-care label printing using barcode technology integrated with the hospital information system (HIS). Bedside labeling was reinforced through a mandatory protocol requiring patient identification verification followed by immediate labeling at the bedside. Standardized label strip management practices were introduced, including proper cutting and periodic documentation audits conducted by the ward in-charge. Additionally, staff received regular training through induction sessions, morning safety huddles, and ongoing compliance monitoring.

Labeling errors were tracked monthly throughout the study period, and the data were analyzed using descriptive statistics to compare trends before and after the interventions. Statistical analysis was performed using IBM SPSS Statistics (version 22), enabling comparison of error frequencies across the pre- and post-intervention phases to assess the effectiveness of implemented strategies.

RESULTS

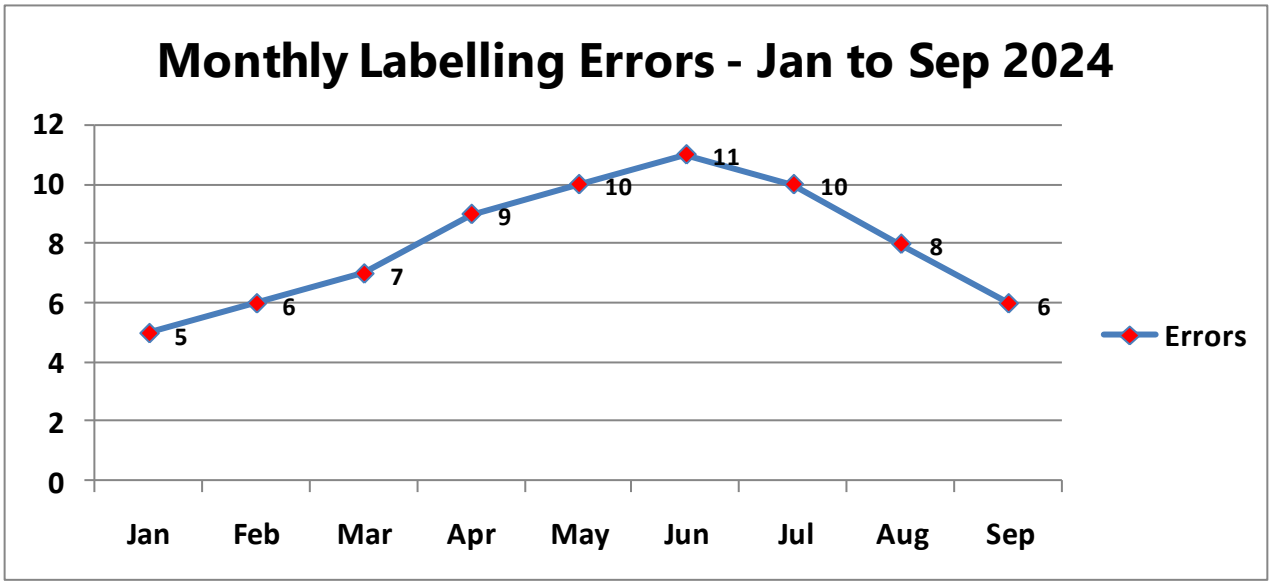
The data collected from January to December 2024 reveal a compelling and structured trend in the occurrence of labeling errors in inpatient sample collection. As shown in **Table 1**, the first half of the year witnessed a steady and concerning rise in error frequency from 5 incidents in January to a peak of 11 in June. This upward trend reflects systemic vulnerabilities and lapses in patient identification protocols during the pre-intervention period. Contributory factors likely included staff overload during morning blood collection, similar patient names within shared wards, and non-adherence to bedside labeling practices. These issues culminated in increased mislabeling of specimens, directly jeopardizing patient safety.

Table 1: Monthly Distribution of Labeling Errors (January–December 2024)

MONTHS	NUMBER OF ERRORS
January	5
February	6
March	7
April	9
May	10
June	11
July	10
August	8
September	6
October	5
November	3
December	2

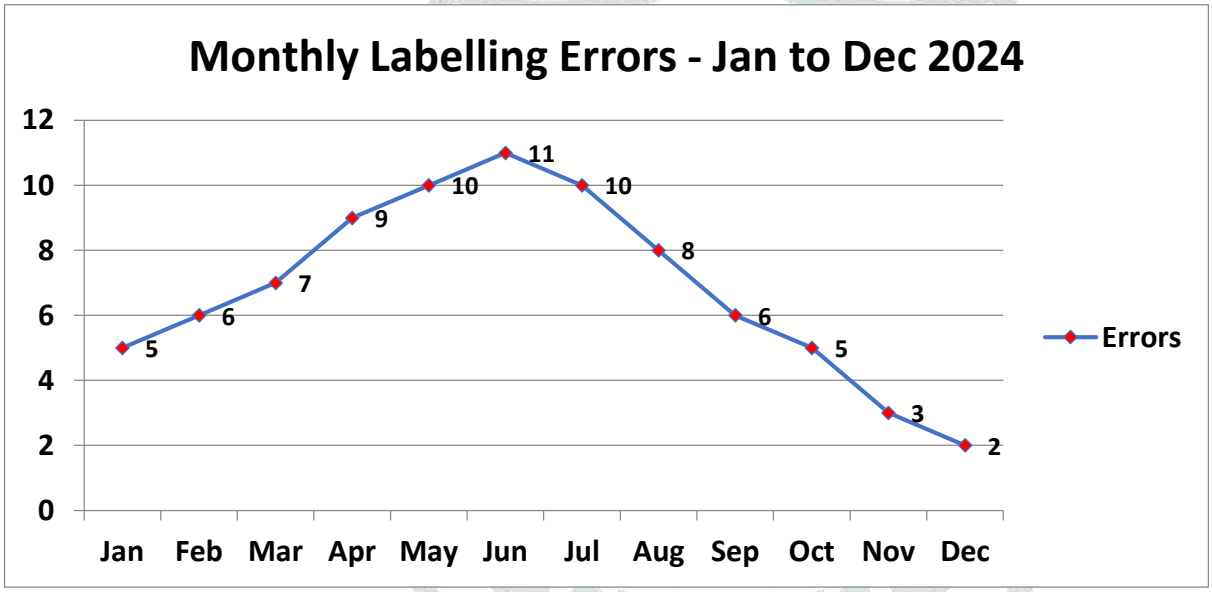
The initiation of corrective interventions in July namely the Similar Name Alert Protocol (SNAP), Automated Tube Labeling System (ATLS), and reinforcement of bedside labeling protocols marked a turning point in the trajectory of labeling errors. Though July still recorded 10 incidents, this plateau following June's peak suggests the beginning of a behavioral and procedural shift. Importantly, the full effect of the interventions became evident in subsequent months, as shown in **Figure 1**, where the error rate began a consistent descent: 8 in August, 6 in September, followed by 5 in October, 3 in November, and finally reaching 2 by December.

Figure 1: Monthly Labelling Errors Trend (January–September 2024)



This downward trajectory, visually captured in **Figure 2**, indicates the positive impact of structured interventions. While the immediate reduction in July was modest, the progressive decline across the latter half of the year confirms that the new protocols required a brief acclimatization period before yielding full benefits. The initial lag is explainable by the natural time required for staff training, adaptation to the ATLS system, and embedding of SNAP alerts into routine workflow. The ultimate reduction from 11 errors in June to just 2 in December an 81.8% decrease underscores the success of the multi-pronged strategy.

Figure 2: Monthly Labeling Errors Trend (January–December 2024)



Overall, the observed data pattern validates the effectiveness of combining technological tools (ATLS) with visual alerts (SNAP) and reinforcement of correct bedside practices. Moreover, it highlights the importance of sustained training and leadership commitment. The results suggest that without these interventions, the upward trend would likely have continued, increasing the risk to patient safety. Thus, the figures and tabulated data collectively illustrate a clear case for scaling these interventions hospital-wide and establishing continuous audit mechanisms to sustain the improvements achieved.

DISCUSSION

Current study reinforces that even in resource-constrained environments, targeted interventions based on global patient safety principles can significantly reduce medical errors. Our results support previous literature that emphasizes the role of human factors, environmental stressors, and system inadequacies in labelling errors. Before intervention, the progressive monthly increase in labelling errors aligned with patterns seen in other tertiary care settings globally(1-3).

Prior to intervention, we observed a progressive monthly increase in labeling errors a trend consistent with reports from other tertiary care settings worldwide. A study reported that labeling errors in clinical laboratories can reach rates as high as 1 in every 1,000 specimens, potentially leading to diagnostic errors, patient mismanagement, or even adverse events (4). Studies from India have also shown a high prevalence of pre-analytical errors, especially in overburdened hospital environments (5,6). Increased workload, multitasking, poor staffing ratios, and lack of standardized protocols contribute substantially to the error burden (7–9).

Root cause analysis in our study revealed multiple contributing factors, including similar-sounding patient names, absence of double-checking protocols, inadequate supervision, and fatigue-induced oversight during high-volume shifts. These findings echo previous studies indicating that 70% of laboratory-related errors originate in the pre-analytical phase, with mislabeling being a major culprit (10,11). Human errors in specimen labeling are not random but are exacerbated by cognitive overload, distractions, and lack of redundancy checks (12).

In our intervention phase, the Safe Naming and Alert Protocol (SNAP) adapted from WHO and ISMP guidelines proved instrumental in addressing these root causes. The protocol's emphasis on using two patient identifiers, alert stickers for similar names, and highlighted cross-checks during staff handovers is aligned with The Joint Commission's National Patient Safety Goal NPSG.01.01.01, which mandates active patient verification at the time of sample collection (13). Evidence suggests that double identifiers can reduce specimen-related errors by nearly 80% when used consistently (14,15).

Moreover, our introduction of the Automated Tube Labeling System (ATLS) brought in process automation at the bedside, thus reducing dependency on memory and manual transcription. Studies from technologically advanced hospitals have demonstrated that automated labeling at the point of care can reduce labeling errors by 50–75%, enhance traceability, and ensure accountability (16,17). For example, a study in a UK hospital found a 62% reduction in errors after deploying bedside automation tools, highlighting the role of technology in mitigating human error (18).

Despite implementation of these interventions in July, a gradual rather than immediate decline in errors was observed. This phenomenon aligns with behavior change theories, which suggest that sustained change requires time, reinforcement, and adaptation to new workflows (19). It also mirrors findings from other implementation science studies, where interventions only begin to show substantial impact after an initial adaptation period (20,21). Our weekly audits, morning huddles, and feedback sessions provided continuous reinforcement, which literature shows to be vital for sustaining adherence and fostering accountability (22).

A noteworthy outcome of this study was the observed behavioral shift among nurses and ward staff. There was a marked improvement in proactive identification of look-alike names, avoidance of pre-labeling, and commitment to bedside specimen labeling. This aligns with WHO's global patient safety strategy, which emphasizes the development of a "safety culture" a collective commitment by leaders and staff to prioritize safety over competing goals (22, 23). Studies from high-performing hospitals indicate that a safety culture, bolstered by leadership engagement and frontline ownership, leads to long-term reductions in adverse events (24,25).

Furthermore, our experience supports the Health Belief Model, which posits that individuals are more likely to adopt protective behaviors (like labeling correctly) when they perceive a risk and believe in the efficacy of interventions (26). Through case-based discussions during safety huddles, we highlighted the risks of mislabeling, which seemed to enhance the perceived severity among staff and encouraged adherence. Our study also demonstrates the power of simple, low-cost interventions when tailored to the local context. While many high-income countries rely on expensive electronic medical record (EMR)-linked automation, we demonstrated that customized visual cues, behavior-focused training, and leadership involvement could achieve meaningful change in a middle-income setting. Previous studies in similar contexts, such as in Brazil and South Africa, have also emphasized the effectiveness of contextually adapted low-cost patient safety interventions (27–29). Despite the positive outcomes, our study has limitations. The single-center design limits generalizability. Multicenter studies would better validate the scalability and external validity of our findings. Additionally, while reported labeling errors declined, we cannot exclude the possibility of underreporting, especially in early intervention phases. Future research may benefit from anonymous reporting systems or the use of trigger tools to identify potential errors (30). Randomized controlled designs or interrupted time series analyses could also strengthen causal inferences.

Moreover, our study focused exclusively on inpatient wards. Extending the interventions to outpatient departments, emergency services, and operation theatres could offer a more comprehensive understanding of labeling practices across diverse hospital units. Integration of labeling safety into electronic health record systems, with barcode-based verification, could also further reduce the error rate, as demonstrated in studies from Taiwan and Canada (31).

CONCLUSION

This study contributes to the growing body of evidence supporting structured, system-level interventions to reduce medical errors. It underscores the feasibility and impact of applying WHO-recommended patient safety strategies in resource-limited settings. A combination of automation, behavioral nudges, visual cues, and a

strong culture of safety proved effective in reducing labeling errors over time. The success of our intervention provides a replicable model for similar hospitals facing patient safety challenges due to resource constraints.

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