Pre-Analytical Errors at the Hematology Bench and Prevention

Patience Erose Modeme[1*] and Samuel Chinweuba Modeme[2]
[1.] Medical Microbiology Laboratory,
Edo State University Teaching Hospital, Auchi, Edo State, Nigeria
[2.] Department of Nursing Science,
Faculty of Applied Health Sciences, Edo State
University, Iyamho, Edo State, Nigeria
*Corresponding author: Patience Erose Modeme,
imhansuomonpatience@gmail.com
ORCID ID: 0009-0003-0914-3753
https://doi.org/10.56201/jbgr.vol.12.no6.2026.pg87.95

Abstract
Pre-analytical errors remain a major challenge in hematology laboratories because they can compromise specimen integrity, distort test results, and adversely affect clinical decision-making. This article examined common pre-analytical errors occurring at the hematology bench during the post-collection to pre-analysis phase and discussed practical strategies for their prevention. The article identified hemolysis, clotted samples, incorrect blood-to-anticoagulant ratios, delayed sample processing, specimen mislabeling or patient misidentification, inadequate mixing of blood samples, improper storage conditions, and sample contamination or dilution as major sources of pre-analytical errors. These errors may result from improper specimen handling, inadequate adherence to standard operating procedures, human factors, transportation delays, and weaknesses in laboratory systems. Their effects include falsely altered hematological parameters, unreliable complete blood count results, increased specimen rejection, repeat testing, diagnostic errors, delayed treatment, increased healthcare costs, and potential risks to patient safety. The article further highlighted preventive measures including strict adherence to standard operating procedures, continuous staff training and competency assessment, accurate patient identification and barcoding, timely specimen transportation and processing, appropriate sample mixing and storage, and effective quality control and quality assurance systems. Automation, laboratory information systems, error monitoring, root cause analysis, and improved communication among healthcare professionals were also identified as important quality improvement strategies. Ultimately, effective control of the pre-analytical phase is essential for maintaining specimen integrity, improving the accuracy and reliability of hematological investigations, and supporting safe and effective patient care.

Keywords: *Pre-analytical errors, Hematology Laboratory, Prevention, Quality Assurance, hematological testing, Patient Safety.*

Introduction

Laboratory investigations are fundamental to effective clinical decision-making, with a substantial proportion of diagnoses and treatment plans relying on the accuracy of test results. In hematology,

tests such as complete blood count and coagulation studies are particularly sensitive to specimen quality. Despite advancements in laboratory technology, errors can still occur throughout the testing process, with recent evidence emphasizing that the pre-analytical phase contributes the largest share of these errors (Iqbal et al., 2023; Mankar et al., 2024).

The pre-analytical phase includes all procedures from specimen collection to preparation for analysis, such as labeling, transportation, storage, and processing. Current studies show that this phase accounts for approximately 46% to 68% of total laboratory errors, largely due to human factors, procedural lapses, and system inefficiencies (Iqbal et al., 2023). Even with the use of automated analyzers, the reliability of hematological results remains highly dependent on proper sample handling, as poor specimen integrity cannot be corrected during analysis.

The post-collection stage at the hematology bench is especially critical because errors introduced at this point directly affect sample quality and test outcomes. Common problems reported in recent studies include insufficient sample volume, clotting, hemolysis, labeling errors, and delays in transportation (Iqbal et al., 2023; Kani et al., 2024). These issues can lead to inaccurate results, delayed diagnosis, unnecessary repeat testing, and increased healthcare costs. Therefore, a clear understanding of pre-analytical errors at this stage is essential for improving laboratory quality and ensuring optimal patient care.

Aim and Objectives

The aim of this article is to examine common pre-analytical errors occurring at the hematology bench during the post-collection to pre-analysis phase and to highlight effective strategies for their prevention in order to improve the accuracy and reliability of hematological test results.

Objectives

The specific objectives of this article are to:

1. Identify the common pre-analytical errors that occur at the hematology bench during the post-collection to pre-analysis phase.
2. Explain the causes and contributing factors responsible for these pre-analytical errors.
3. Describe the effects of pre-analytical errors on hematological test results and clinical decision-making.
4. Discuss practical strategies for preventing pre-analytical errors and improving quality assurance in the hematology laboratory.

Common Pre-Analytical Errors at The Hematology Bench

The hematology bench represents a crucial control point within the total testing process where specimens are received, verified, and prepared for analysis. Errors occurring at this stage remain a major contributor to laboratory inaccuracies, largely because this phase is heavily dependent on manual handling and human intervention. Recent literature consistently shows that the pre-analytical phase accounts for the majority of laboratory errors, often exceeding 60% of total diagnostic inaccuracies (Iqbal et al., 2023; Kani et al., 2024; Winter et al., 2023). These errors significantly affect sample integrity and directly influence hematological outcomes.

Recent comprehensive reviews have further reinforced that pre-analytical failures are dominated by issues related to specimen collection, handling, transport, and processing delays. For example, modern evidence highlights that hemolysis, clotting, insufficient sample volume, and specimen misidentification remain the most frequently reported sources of error in hematology laboratories globally (Lorque et al., 2026; Myke-Mbata et al., 2026). These errors are particularly prevalent in

resource-limited settings where workflow standardization and automation are limited, thereby increasing reliance on manual processes (Myke-Mbata et al., 2026; Kani et al., 2024).

At a broader biological level, the importance of maintaining specimen stability is well established. Modeme and Imhansuomon (2026), in their work on gut microbiota and systemic regulation, emphasized how biological systems are highly sensitive to disruption of equilibrium, leading to altered physiological outcomes. In a comparable manner, blood samples represent highly dynamic biological materials whose integrity can be easily altered by external stressors such as temperature variation, mechanical agitation, and delayed processing. This conceptual understanding reinforces why strict control of pre-analytical conditions is essential for reliable hematological testing.

Common pre-analytical errors at the hematology bench include hemolysis, clotted samples, incorrect blood-to-anticoagulant ratio, delayed sample processing, mislabeling or patient misidentification, inadequate mixing of EDTA samples, improper storage conditions, and sample contamination or dilution (Kani et al., 2024; Lorque et al., 2026; Myke-Mbata et al., 2026). Hemolysis remains one of the most significant causes of sample rejection, often resulting from traumatic venipuncture or vigorous handling during transport. Similarly, clot formation is frequently associated with delayed or inadequate mixing of anticoagulant tubes, leading to fibrin formation that interferes with accurate cell counting.

Incorrect blood-to-anticoagulant ratio remains another persistent challenge, particularly when collection tubes are underfilled or overfilled, resulting in cellular distortion and unreliable hematological indices. Furthermore, delayed processing contributes to cellular degeneration, morphological changes, and altered analyzer readings, particularly affecting leukocytes and red cell indices. Mislabeling and specimen misidentification remain critical safety issues, often leading to diagnostic errors and inappropriate clinical interventions. Studies in recent literature emphasize that such identification errors are among the most preventable yet most dangerous pre-analytical failures (Myke-Mbata et al., 2026; Lorque et al., 2026).

In addition, inadequate sample mixing, improper storage conditions, and contamination from intravenous fluids further compromise specimen quality. These errors are particularly common in high-pressure clinical environments such as emergency departments, where speed often overrides strict adherence to standard operating procedures. Overall, evidence from recent studies indicates that pre-analytical errors not only reduce analytical accuracy but also significantly increase sample rejection rates, healthcare costs, and patient risk (Kani et al., 2024; Winter et al., 2023; Lorque et al., 2026).

Therefore, continuous training, strict adherence to standard operating procedures, automation of identification processes, and implementation of robust quality assurance systems are essential to reduce these preventable errors and improve hematology laboratory reliability.

Effects of Pre-Analytical Errors on Hematological Results

Pre-analytical errors occurring at the hematology bench have profound implications for the accuracy, reliability, and clinical interpretation of laboratory results. Because hematological parameters are highly sensitive to specimen integrity, even minor deviations during the post-collection to pre-analysis phase can produce significant analytical distortions. Recent literature consistently emphasizes that most erroneous laboratory results originate from this stage, thereby directly affecting diagnostic decision-making and patient safety (Iqbal et al., 2023; Kani et al., 2024; Winter et al., 2023). One of the most clinically significant effects of pre-analytical errors is the production of falsely elevated or decreased hematological parameters. For instance, hemolysis leads to the release of intracellular components such as potassium, lactate dehydrogenase (LDH),

and hemoglobin into plasma, which can falsely elevate or distort laboratory readings. This may result in misinterpretation of electrolyte imbalance or hemolytic conditions. Similarly, clotting in EDTA samples can trap platelets and leukocytes, resulting in falsely low platelet counts (pseudothrombocytopenia) and white blood cell counts, which may lead to unnecessary clinical interventions or repeat testing (Kani et al., 2024).

Delays in sample processing significantly alter cellular morphology and viability. Red blood cells may undergo swelling or shrinkage depending on storage conditions, leading to inaccurate mean corpuscular volume (MCV) and hematocrit values. Leukocytes are particularly sensitive to time-dependent degradation, resulting in abnormal differential counts and distorted microscopic appearance. These changes can complicate diagnosis in conditions such as infections, anemia, and hematological malignancies, where accurate cell morphology is essential for clinical interpretation (Winter et al., 2023). Incorrect blood-to-anticoagulant ratios also contribute to clinically misleading results. Underfilled EDTA tubes may cause excess anticoagulant effect, leading to cellular shrinkage and artifactual changes in red cell indices, while overfilled tubes may result in partial clot formation. These inconsistencies compromise the reliability of complete blood count (CBC) parameters, particularly hematocrit, mean corpuscular volume, and platelet indices (Iqbal et al., 2023). Mislabeling and patient identification errors represent some of the most dangerous pre-analytical failures due to their direct impact on patient safety. When samples are incorrectly labeled, laboratory results may be assigned to the wrong patient, leading to misdiagnosis, inappropriate treatment, or delayed clinical intervention. In extreme cases, such errors can result in life-threatening outcomes, especially when critical values are involved. Recent quality assurance studies highlight that identification errors, although preventable, remain a persistent challenge in many clinical laboratories (Myke-Mbata et al., 2026).

Improper sample handling, including inadequate mixing and poor storage conditions, further exacerbates analytical variability. Inadequate mixing leads to platelet aggregation and microclot formation, which interfere with automated analyzer performance and produce inconsistent results. Similarly, exposure to inappropriate temperatures accelerates cellular degradation, affecting both red and white blood cell integrity. These factors collectively reduce the reproducibility and reliability of hematological investigations.

Overall, pre-analytical errors not only compromise laboratory accuracy but also have downstream clinical consequences, including misdiagnosis, inappropriate treatment decisions, delayed therapy, increased healthcare costs, and patient dissatisfaction. The clinical impact is particularly significant in emergency and critical care settings, where rapid and accurate hematological results are essential for patient management. Therefore, minimizing pre-analytical variability is fundamental to ensuring high-quality laboratory medicine and safe clinical practice.

Table 1: Effects of Pre-Analytical Errors and their Clinical Consequences

S/N	Pre-analytical Error	Mechanism of Effect	Effect on Hematological Results	Clinical Consequence
1	Hemolysis	RBC rupture releases intracellular contents into plasma	Falsely increased potassium, LDH, hemoglobin; distorted indices	Misdiagnosis of hemolytic disorders, electrolyte imbalance, sample rejection
2	Clotted samples	Fibrin traps cellular components	Falsely low platelet and WBC counts (pseudothrombocytopenia)	Unnecessary repeat tests, misdiagnosis, inappropriate treatment
3	Delayed processing	Cellular degeneration over time	Altered MCV, WBC morphology, RBC swelling/shrinkage	Diagnostic inaccuracy in anemia, infection, hematologic disorders
4	Incorrect blood-to-EDTA ratio	Excess or insufficient anticoagulant effect	Distorted CBC parameters (MCV, hematocrit, platelet indices)	Misleading hematological interpretation
5	Mislabeling / wrong patient ID	Specimen-patient mismatch	Completely incorrect laboratory report assignment	Severe clinical risk, wrong treatment or intervention
6	Inadequate mixing	Platelet aggregation and microclot formation	Inaccurate platelet count and hematocrit values	False thrombocytopenia or repeat sampling
7	Improper storage conditions	Temperature-induced cellular degradation	WBC lysis, RBC morphological changes	Reduced reliability of differential counts
8	Sample contamination/dilution	IV fluid contamination or improper draw technique	Falsely low Hb, RBC, WBC values	Misinterpretation of patient status, delayed care

Prevention and Quality Improvement

Pre-analytical error prevention in hematology is essential for ensuring accurate diagnostic outcomes, as this phase remains the most vulnerable stage of laboratory testing. Evidence shows that structured quality systems and standardization significantly reduce error rates and improve specimen integrity in hematology laboratories (Iqbal et al., 2023; Kani et al., 2024). Therefore, prevention strategies must focus on both human and system-level interventions.

Standard Operating Procedures (SOPs) and Protocol Adherence

Strict adherence to standardized operating procedures is fundamental in minimizing variability in specimen handling. SOPs provide clear instructions for sample receipt, inspection, mixing, storage, and rejection criteria. When properly implemented, SOPs significantly reduce errors such as hemolysis, clot formation, and incorrect handling (Winter et al., 2023). Consistency in following laboratory protocols ensures reproducibility and reliability of hematological results.

Training and Continuous Competency Assessment

Human factors remain the leading cause of pre-analytical errors, making continuous staff training essential. Regular competency assessments improve adherence to correct phlebotomy and bench practices, including proper tube inversion, correct anticoagulant use, and timely processing. Studies have shown that structured training programs significantly reduce specimen rejection rates and improve laboratory performance (Kani et al., 2024).

Sample Identification and Barcoding Systems

Misidentification of samples is one of the most critical and preventable pre-analytical errors. The use of barcoding systems, dual patient identifiers, and bedside labeling significantly improves traceability and reduces identification errors. Myke-Mbata et al. (2026) emphasized that sample mislabeling remains a major source of laboratory error in low-resource settings, particularly where manual documentation is still in use.

Timely Transport and Processing of Specimens

Delays between sample collection and analysis can lead to cellular degradation and inaccurate hematological results. Efficient transport systems and strict turnaround time (TAT) policies are necessary to maintain sample integrity. Evidence shows that prolonged storage leads to morphological changes in blood cells, affecting CBC accuracy (Winter et al., 2023).

Proper Mixing, Handling, and Storage Conditions

Immediate and gentle inversion of EDTA tubes (8–10 times) is essential to prevent clot formation. Vigorous shaking must be avoided to reduce hemolysis risk. Proper storage temperature must also be maintained to preserve cellular stability. Iqbal et al. (2023) reported that improper mixing and handling are major contributors to rejected hematology samples.

Quality Control (QC) and Quality Assurance (QA) Systems

Internal quality control ensures daily monitoring of analyzer performance, while external quality assurance compares laboratory results with standardized benchmarks. These systems help detect deviations early and ensure consistency in hematological testing. Kani et al. (2024) highlighted that laboratories with strong QA systems demonstrate significantly lower pre-analytical error rates.

Automation and Laboratory Information Systems (LIS)

Automation reduces manual handling errors, particularly in sample identification and data transcription. Laboratory Information Systems enhance specimen tracking, reduce human error, and improve workflow efficiency. These systems are strongly recommended in modern hematology laboratories to improve accuracy and traceability (Myke-Mbata et al., 2026).

Error Monitoring and Root Cause Analysis

Continuous monitoring of laboratory errors allows for early identification of recurring problems. Root cause analysis (RCA) and quality improvement cycles such as Plan–Do–Study–Act (PDSA) help laboratories implement corrective actions and evaluate their effectiveness. This continuous improvement approach is essential for sustainable quality enhancement.

Interprofessional Communication

Effective communication between clinicians, nurses, and laboratory personnel ensures proper test requests and specimen handling. Poor communication is a known contributor to pre-analytical errors such as incorrect test selection and improper sample collection. Improved coordination reduces rejection rates and enhances laboratory efficiency (Iqbal et al., 2023).

In essence, prevention of pre-analytical errors requires a combination of standardization, training, automation, quality assurance, and communication. When effectively implemented, these measures significantly improve the accuracy, reliability, and clinical usefulness of hematological results.

Abstract word count: 228 words
Manuscript word count: 2182 words
Manuscript pages: 9 pages

Conclusion

Pre-analytical errors at the hematology bench remain a major source of laboratory inaccuracy and continue to significantly affect the reliability of hematological test results. This stage of the testing process is particularly vulnerable because it involves multiple manual steps such as specimen handling, identification, transport, and preparation, which are highly prone to human and procedural errors. These errors can significantly distort hematological parameters and lead to incorrect clinical interpretation, resulting in misdiagnosis, delayed treatment, and unnecessary repeat testing. Consequently, patient care outcomes may be compromised if pre-analytical quality is not adequately controlled. Therefore, minimizing pre-analytical errors requires strict adherence to standard operating procedures, continuous staff training, proper sample identification, and effective quality assurance systems. When these measures are consistently applied, the accuracy and reliability of hematological investigations are significantly improved.

Statement and Declarations

Funding

This research received no funding from the public, commercial or nonprofit sector.

Contributions

Both authors contributed fully in the study's conception and design. Both authors read and approved the final manuscript.

Ethical declarations

Competing interest

The authors declare that they have no known competing financial interests or personal relationship that could have appeared to influence the work reported in this paper

Ethical Approval
Not applicable.

Consent to Participate
Both authors consent to participate in the study.

Consent for Publication
Both authors have provided their consent for the publication of this study

References

Iqbal, M. S., Tabassum, A., Arbaeen, A. F., Qasem, A. H., Elshemi, A. G., & Almasmoum, H. (2023). Preanalytical errors in a hematology laboratory: An experience from a tertiary care center. *Diagnostics, 13*(4), 591. https://doi.org/10.3390/diagnostics13040591

Kani, V., Kannan, K., Arumugam, S., & Sonti, S. (2024). Preanalytical errors in hematology: Insights from a tertiary care hospital. *Cureus, 16*(9), e69641. https://doi.org/10.7759/cureus.69641

Lorque, L. L. V., Bonifacio, K. A. M., Padilla, I. G., Panganiban, M. I. S., Persia, A. G. A., Tsai, R. D., & Mabbagu, R. M. (2026). A narrative review on preanalytical sample errors in the hematology section of clinical laboratories. *Asian Journal of Biological and Life Sciences, 12*(2), 230–236. https://doi.org/10.5530/ajbls.2023.12.32

Modeme, S. C., & Imhansuomon, P. E. (2026). Gut microbiota and mental health: Implications for mental health nursing and microbiological research. *International Journal of Health and Pharmaceutical Research, 11*(4), 41–57. https://doi.org/10.56201/ijhpr.vol.11.no4.2026.pg41.57

Myke-Mbata, O. P., Eze, C. C., Okonkwo, U. N., & Adebayo, T. O. (2026). Pre-analytical quality failures in hematology laboratories in low-resource settings: A systematic review. *Journal of Clinical Laboratory Science and Practice, 8*(1), 15–29.

Winter, W. E., Pittman, D. L., & Harris, N. S. (2023). Hematology and coagulation preanalytics for clinical chemists: Factors intrinsic and extrinsic to the sample. *Clinical Biochemistry, 115*, 3–12. https://doi.org/10.1016/j.clinbiochem.2022.11.012