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Pre-Analytical Errors In Full Blood Count Analysis: A Comprehensive Review

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ABSTRACT
Introduction: The current review of pre-analytical errors in full blood count (FBC) analysis is important for several reasons, FBC is among the most frequently ordered tests worldwide and easily prone to error, so even a small error rate affects many specimens, which are mostly pre analytical, these pre-analytical errors are preventable, recent evidence from laboratory quality indicators revealed that preanalytical errors remain a persistent problem despite years of awareness, underscoring the need for ongoing education and systematic improvements especially in resource-limited laboratory settings in developing country like Nigeria, where there is inadequate trained health workers, lack of model electronic health recording equipment, unavailability of sample collection support devices, lack of automated sample carrier facility, inadequate cold chain and lack of effective power.
Objective: To provide a comprehensive review of pre-analytical errors in full blood count test analysis, examining the pre-analytical errors that occur during every step between test ordering and sample delivery to the laboratory, including patient preparation, sample collection, labeling, transport, and storage. These errors are consequential because hematological parameters are extremely sensitive to even minor deviations in sample handling.
Method: An in-depth appraisal of peer review literatures were carried out studying the pre-analytical errors that occur before reaching the analyzer. Databases including Scopus, ScienceDirect and PubMed were searched using keyswords such as FBC, pre analytical errors, standardized operating procedures, phlebotomy training, quality indicator monitoring, and technology-assisted solutions.
Results: The review observed that full blood count is one of the most frequently requested laboratory investigations in clinical medicine, providing critical information on red blood cells, white blood cells, platelets, and hemoglobin, that despite improvements in automated hematology analyzers and quality control, the reliability of FBC results remains threatened by errors that occur long before the sample even reaches the analyzer. Researches consistently showed that this phase accounts for 60 to 70 percent of all laboratory errors, making it the single most error-prone stage of the entire testing process, the review also indicated that resource limited healthcare environments is included as a major enabling factor to this errors with relevance to sub-Saharan African laboratory settings.
Conclusion: The pre-analytical errors in FBC analysis are not inevitable, but rather largely preventable by the following; commitment to training, procedural discipline, adequate equipment and a shared responsibility between laboratory staff, clinicians and health administrators.

KEYWORDS
Full blood count, Pre-analytical errors

1. Introduction

The study of pre-analytical errors in full blood count (FBC) analysis is important for several reasons, FBC is among the most frequently ordered tests worldwide and easily prone to error, so even a small error rate affects many specimens, which are mostly pre analytical, these pre-analytical errors are preventable, recent evidence from laboratory quality indicators revealed that preanalytical errors remain a persistent problem despite years of awareness, underscoring the need for ongoing education and systematic improvements especially in resource-limited laboratory settings in developing country like Nigeria, where there is inadequate trained health workers, lack of model electronic health recording equipment, unavailability of sample collection support devices, lack of automated sample carrier facility, inadequate cold chain and lack of effective power.

Full blood count is an important hematological test used to evaluate patient's health. It is the most common hematology

related investigation requested in both primary and secondary healthcare settings. It provides an overview of an individual's health. It measures several blood cellular components, including red blood cells, white blood cells, platelets, and hemoglobin. It provides useful information on the production of all blood cells and assesses a patient's oxygen carrying capacity by evaluating RBC indices, hemoglobin, and hematocrit. It also provides useful information about the immune system by evaluating white blood cell count and differentials. The platelet count measures the number of platelets in the blood, which is crucial for diagnosing bleeding disorders and assessing platelet function.

El Brihi and Pathak (2024) confirmed that the FBC is one of the most performed laboratory investigations in medicine, used to evaluate oxygen-carrying capacity, immune function, hemostatic potential, and overall hematological health.

In practice, the FBC is a readily available test with far-reaching clinical utility, potentially monitoring the effects of drug treatment and pre-operative interventions, and aiding in the diagnosis of diseases such as anemia, cancer, clotting issues, infection, and immune system disorders (Erhabor et al., 2021).

Its applications span virtually every clinical specialty from obstetrics to oncology, from emergency medicine to general practice. It is this breadth of application that makes the accuracy of FBC results non-negotiable. When an FBC result is wrong, not because the analyzer malfunctioned, but because the specimen was mishandled, the downstream consequences can be serious.

Despite genuine advances in automated hematology analyzers, greater awareness among laboratory professionals, and tighter quality control programs, pre-analytical errors continue to threaten the reliability of FBC results. Research shows that 60 to 70 percent of all laboratory errors originate in the pre-analytical phase, which is the stage before analysis begins (Nordin et al., 2024). A large contemporary analysis of more than 11 million specimens similarly found that the overwhelming majority of detected laboratory errors arose in the pre-analytical phase (Lin et al., 2025). These errors arise from problems such as hemolysis during blood collection, inadequate EDTA fill volumes, delayed sample processing, and incorrect labeling. They are particularly dangerous because automated analyzers cannot distinguish between a good sample and a poorly collected one. The machine will process both and return a result, but only one of those results reflects the patient's true biology.

The pre-analytical phase encompasses all steps from test ordering to specimen arrival in the laboratory, including patient identification, patient preparation, sample collection, labeling, transport, and storage, to the start of sample analysis (Nordin et al., 2024). These steps are largely performed outside the laboratory, making oversight and standardization particularly challenging (Ramirez-Pereira et al., 2024). Unlike the analytical phase, where precision and accuracy are continuously monitored through internal quality control and external quality assurance programs, the pre-analytical phase remains difficult to audit and control.

Definition and Scope of Pre-Analytical Errors

According to the International Organization for Standardization (ISO, 2022), the pre-analytical (or pre-examination) phase encompasses all processes from the initial test requisition to the start of sample analysis. Consequently, a pre-analytical error is defined as any defect or deviation during these steps, including patient preparation, sample collection, and transport, that has the potential to compromise the quality of the sample or the validity of the final test result. It ranges from something as minor as applying a tourniquet for too long to something as serious as collecting blood from the wrong patient entirely.

Most analytical errors, such as reagent quality issues, instrument failures, and pipetting inaccuracies, often leave identifiable traces like quality control failures, reproducibility problems, and instrument flags. Pre-analytical errors, in contrast, frequently produce results that look entirely plausible. A sample from a haemoconcentrated patient will yield a hemoglobin that is genuinely elevated, but not because the patient is polycythaemic. A haemolysed sample will produce hemoglobin levels that appear valid but reflect the contents of lysed cells rather than the patient's plasma. The

analyzer has no way to know, and neither does the clinician, unless someone in the process asks the right questions.

The importance of addressing these errors cannot be overstated. A wrong platelet count result may lead to unnecessary blood transfusions or withholding of anticoagulant therapy. A falsely elevated white blood cell count could trigger antibiotic treatment in a patient who does not have an infection. A haemolysed sample interfering with hemoglobin measurement might result in a missed diagnosis of anemia in a pregnant woman, with potentially serious consequences for both mother and fetus. These scenarios represent real-world consequences.

2. Method

An in-depth appraisal of peer review literatures were carried out studying the pre-analytical errors that occur before reaching the analyzer. Databases including Scopus, ScienceDirect and PubMed were searched using keyswords such as FBC, pre analytical errors, standardized operating procedures, phlebotomy training, quality indicator monitoring, and technology-assisted solutions.

Total Testing Process

Testing pathway in laboratory medicine is a continuous cycle, also referred to in the literature as Total Testing Process (TTP). This cycle begins when a clinician decides to request a test and ends when that clinician interprets the result and acts upon it. Everything that happens in between ordering, sample collection, labeling, transport, analysis, and reporting is part of this loop (Hawkins, 2012). The TTP comprises three sequential phases: pre-analytical, analytical, and postanalytical (Nordin et al., 2024).

Laboratory quality improvement efforts focused almost entirely on the analytical phase for many years. On the surface, this made sense because the analyzer is where measurements occur, and measurements are what the laboratory exists to do. As a result, laboratories invested heavily in instrument calibration, reagent quality, and internal quality control. These efforts were successful because analytical error rates dropped significantly over the decades. But in focusing so intently on the middle phase of the process, laboratories were, in a sense, looking through the wrong end of the microscope. After careful examination, the data showed that most errors did not occur during analysis. They were happening prior to sample analysis (Hawkins, 2012, Nordin et al., 2024).

Test Ordering

The process begins with the clinician's decision to request an FBC. Errors here include incorrect patient details on the request form, missing or ambiguous clinical information, and inappropriate test selection. While electronic ordering systems have reduced ordering errors in better resourced settings, paper-based requisition systems, which remain prevalent in many Nigerian hospitals, remain vulnerable to transcription errors and illegible handwriting.

Patient Identification

Correct patient identification is the most fundamental patient safety requirement in the preanalytical chain. Before specimen collection, the phlebotomist must verify the patient's identity using at least two unique identifiers, typically the full name and date of birth, or name and hospital number. Failure at this step can result in a sample being collected from the wrong patient or labeled with someone else's details, leading to a wrong blood in tube (WBIT) event that is undetectable by the laboratory and potentially catastrophic for the patient.

Patient Preparation

Several patient-related factors can influence FBC parameters before blood collection. Posture matters. A shift from lying to standing causes plasma to shift into the interstitial space, raising the relative concentration of cells and producing higher hemoglobin and hematocrit values than in a supine patient. In healthy adults, this hemoconcentration amounts to roughly a 7% increase in both hemoglobin and hematocrit on moving from the supine to standing position (Lima-Oliveira et al., 2017). Feriel et al. (2021) report that strenuous exercise induces increases in white blood cells driven by hemoconcentration, fluid shifts, and epinephrine secretion, and also observes higher blood counts in the late afternoon compared to the morning. The study specifically notes that acute heat exposure can cause dehydration, thereby further elevating parameters such as HCT and HGB. These changes

reflect physiology, but without proper preparation and standardized conditions, they will be misread as pathology.

Sample Collection; Phlebotomy

Venipuncture is the most technically demanding step of the pre-analytical phase and the one most directly linked to specimen quality errors. Needle gauge, tourniquet time, blood flow rate, tube fill volume, and post-collection mixing technique all directly affect the integrity of the FBC sample.

Sample Labeling

Samples must be labeled immediately after collection, at the patient's side, using the patient's full name, age, sex, date of birth, hospital number, and the time and date of collection. Labeling a tube away from the patient or labeling it before collection both increase the risk of sample mixup. Even a subtle labeling error can have major consequences in a busy clinical environment (Ernst et al., 2018).

Sample Transport and Storage

EDTA whole blood samples demonstrate varying levels of parameter stability depending on storage temperature and time elapsed since collection. Standard complete blood count (CBC) parameters, including hemoglobin and platelet counts, remain stable for up to 24 hours at room temperature and up to 72 hours when refrigerated at 2°C to 8°C (Hedayati et al., 2017, Jorba et al., 2017). However, automated white blood cell (WBC) differentials and cellular morphology are highly time-sensitive, showing significant degradation and artifact formation after 8 to 12 hours at room temperature (Jorba et al., 2017). Beyond these optimal windows, in vitro artifactual changes occur, such as erythrocyte swelling that artificially elevates mean corpuscular volume (MCV), which can compromise clinical accuracy (Hedayati et al., 2017). External pre-analytical variables, including mechanical agitation during transport or exposure to extreme temperatures, drastically accelerate sample degradation and cell lysis (Hedayati et al., 2017; Jorba et al., 2017).

Types of Pre-Analytical Errors in FBC Analysis

Pre-analytical errors can be broadly divided into patient-related errors arising from the patient's physiological state or failure to follow preparation instructions, and process-related errors arising from deviations in collection, handling, or storage procedures. The following sections cover the most clinically important categories encountered in routine hematology practice, using current evidence to explain their mechanisms and effects.

Hemolysis

Hemolysis is the rupture of red blood cells and release of their intracellular contents and is one of the most common pre-analytical errors in clinical laboratory practice. It can occur via various mechanisms, such as using a needle that is too fine, which causes excessive turbulent shear stress on cells; forceful aspiration or plunger depression during syringe draws; prolonged tourniquet application, leading to venous stasis; underfilling the collection tube; or vigorous agitation after collection. Additionally, temperature extremes during transport have also been documented as a cause.

Visually, hemolysis is characterized by a pink-to-red coloration of the serum or plasma layer. Instrumentally, hemolysis produces a spuriously elevated hemoglobin reading because free hemoglobin released from lysed cells is read by the spectrophotometer as if it were intracellular, while simultaneously showing a reduced red cell count, because intact erythrocytes have been destroyed. The resulting MCHC often exceeds 36.5 g/dL, a physiologically impossible value that should alert laboratory staff immediately.

Incorrect Anticoagulant and Wrong Tube Selection

Full blood count (FBC) analysis requires blood to be collected into dipotassium or tripotassium EDTA tubes, which are universally identifiable by their purple or lavender caps. EDTA prevents coagulation by chelating the calcium ions required by the coagulation cascade without distorting cellular morphology at appropriate concentrations. Collecting blood into any other tube type introduces specific pre-analytical errors that compromise specimen integrity. For instance, utilizing a plain red-top tube initiates complete blood coagulation and fibrin mesh formation, trapping cells and rendering automated FBC analysis impossible (Bayot and Tadi, 2023). Conversely, using a sodium citrate tube (blue top) introduces a liquid anticoagulant that dilutes the specimen by approximately 10%, resulting in falsely low cell counts across all hematological parameters (Akorsu et al., 2023). If a lithium

heparin tube (green top) is utilized, the heparin induces rapid platelet clumping and white cell aggregation, making the automated platelet count and differential entirely unreliable (Akorsu et al., 2023). Finally, blood collected in a fluoride oxalate tube (grey top) undergoes severe osmotic fluid shifts and chemical stress, causing marked red cell distortion that makes accurate morphological assessment impossible (Bayot and Tadi, 2023).

Specimens collected in the wrong tube must be rejected and recollected. There is no analytical workaround for an inappropriate anticoagulant.

Incorrect Blood-to-Anticoagulant Ratio

EDTA tubes are calibrated to a specific blood volume, ensuring a final EDTA concentration of 1.5 mg/mL. Deviation from this ratio, in either direction, has consequences. Underfilling the tube results in an excess of EDTA relative to the blood. This osmotic imbalance causes red cells to shrink, producing a falsely reduced MCV and a spuriously elevated MCHC. More strikingly, exposure to EDTA can induce platelet satellitism, an in vitro immunological phenomenon in which autoantibodies cause platelets to adhere to the surface of neutrophils. This leads to a falsely low platelet count (pseudothrombocytopenia) that can trigger unnecessary clinical investigation (Cattaneo, 2025).

Overfilling the tube has the opposite problem. Insufficient EDTA relative to blood allows the coagulation cascade to proceed partially, leading to fibrin strand formation that traps platelets and white cells, producing falsely low counts for both. It should be noted that the fill line on EDTA tubes is not decorative; it defines a scientifically validated target volume, and specimens should be collected within ten percent of it.

Prolonged Tourniquet Application

Tourniquets are a necessary tool in phlebotomy but can cause pre-analytical error when applied for too long. The recommended maximum tourniquet time is 60 seconds from application to needle insertion. Beyond this, venous stasis develops plasma water leaks into the surrounding interstitial tissue under hydrostatic pressure, and the blood remaining in the vein becomes progressively concentrated. This haemoconcentration effect produces falsely elevated hemoglobin, hematocrit, red cell count, white cell count, and platelet count, with a uniform upward shift across virtually all cellular parameters.

Clotted Specimen

A clotted EDTA specimen is one of the clearest grounds for outright rejection of an FBC request. Clots form when the tube is not mixed promptly and adequately after collection. The standard requirement is eight to ten gentle end-over-end inversions immediately after filling. Vigorous shaking is inappropriate and will cause hemolysis. Clot formation consumes platelets and sequesters white cells within the fibrin network, producing spuriously low counts for both platelets and white cells that cannot be corrected analytically. Visual inspection for clots before processing by tilting the tube and observing for fibrin strands or particulate matter, should be a routine step at the point of reception.

Cold Agglutinins

Cold agglutinins are naturally occurring immunoglobulin M antibodies that, in elevated titers, cause reversible red cell agglutination at temperatures below 37°C. When blood from a patient with significant cold agglutinin activity is collected and stored at room temperature, the red cells clump into aggregates. Automated analyzers encounter these clumps and count each aggregate as a single large erythrocyte, producing a dramatically elevated MCV, a markedly reduced red cell count, and an MCHC that exceeds physiological limits.

The diagnostic clue is an MCHC above 36.5 g/dL alongside a very high MCV and a very low RBC in a patient who does not clinically appear to have severe macrocytic anemia. The correction is straightforward: warming the sample to 37°C for 15 to 30 minutes before re-analysis disperses the agglutinates and normalizes the results.

Delayed Analysis and Improper Storage

Blood is not a stable specimen. From the moment of collection, hematological parameters begin to change as cells age, metabolize, and eventually degrade. The following table summarises the time-dependent changes most relevant to FBC practice:

Time Post-Collection	Parameter Affected	Change Observed
2-4 hours (room temp)	WBC morphology	Nuclear lobulation begins to increase
4-6 hours (room temp)	Platelet count	Progressive decline due to activation
6-12 hours (room temp)	MCV	Red cell swelling (Spurious macrocytosis)
12-24 hours (4°C)	Neutrophil morphology	Vacuolation and toxic granulation artifact
>24 hours (any temp)	All parameters	Unreliable. The sample should be rejected.
Freezing (<0°C)	RBC, platelets	Hemolysis and platelet destruction

Figure 1

Blood films for morphological examination are the most time-sensitive component of FBC analysis. Films should ideally be prepared within 1 to 2 hours of collection from a well-mixed, room-temperature EDTA specimen. Films prepared from stored or cold samples are difficult to interpret reliably and may show artefactual changes that closely mimic genuine pathology.

Impact on FBC Parameters

Each pre-analytical error category produces a specific pattern of FBC parameter distortion. Understanding these patterns is clinically useful in two directions: it allows laboratory scientists to recognize artefactual results before they are reported, and it allows clinicians to question results that are inconsistent with the patient's presentation. The table below provides a consolidated reference:

Pre-Analytical Error	Parameters Affected	Effect	Key Clue
Hemolysis	Hb, RBC, MCHC	Hb falsely high; RBC falsely low	MCHC >36.5 g/dL; pink plasma
EDTA underfill	MCV, MCHC, platelets	MCV falls; MCHC rises; platelet satellitism	MCHC >36.5 g/dL; asymptomatic patient
EDTA overfill	Platelets, WBC	Falsely low	Platelet clumps on film
Clotted sample	Platelets, WBC, Hb	All falsely low	Visible clot or fibrin strands
Prolonged tourniquet	Hb, Hct, RBC, WBC, Plt	All uniformly elevated	No clinical correlation
Cold agglutinins	RBC, MCV, MCHC	RBC very low; MCV very high; MCHC impossible	MCHC >36.5 g/dL; corrects at 37°C
Delayed analysis	MCV, WBC morphology, Plt	MCV rises; morphology degrades	Sample >6 hours old at room temp
IV contamination	All cellular parameters	Uniformly falsely low (dilution)	Sample from IV-line arm

Figure 2

Red Cell Parameters

Hemoglobin is measured using the cyanmethaemoglobin or sodium lauryl sulfate (SLS) method, both of which rely on spectrophotometric absorbance. When hemolysis is present, free hemoglobin in solution contributes to the absorbance signal, producing a falsely elevated hemoglobin result. At the same time, the red cell count falls because intact erythrocytes have been lysed. This results in the paradox of high hemoglobin levels with a low red cell count, which, if not caused by a true hematological condition, should lead to immediate suspicion of hemolysis. The MCV is sensitive to storage conditions: red cells passively absorb water over time in EDTA anticoagulant, causing them to swell and producing a spuriously elevated MCV that can mimic the macrocytosis of vitamin B12 deficiency or folate deficiency.

White Cell Parameters

The total white cell count is generally resistant to most pre-analytical errors, but the differential count and morphological assessment are not. Progressive cellular degradation begins within hours of collection at room temperature, affecting neutrophil nuclear lobulation, monocyte cytoplasmic vacuolation, and lymphocyte nuclear density. These changes can cause automated differential analyzers to misclassify cells, rendering blood film review misleading or uninterpretable. Hematologically significant findings such as toxic granulation, Dohle bodies, or blast cells may be obscured or mimicked by storage artifact, making prompt film preparation a vital clinical priority.

Platelet Parameters

Platelets are the most labile of the three cell lines and are disproportionately affected by preanalytical errors. EDTA-induced pseudothrombocytopenia, caused by EDTA-dependent IgG or IgM antibodies that lead to platelet satellitism around neutrophils, is a significant diagnostic pitfall. The platelet count might appear severely reduced, prompting a hematology referral and a possible bone marrow biopsy, even when the patient's platelet count is completely normal. The solution involves collecting blood in a citrate or heparin tube, which prevents the effect of EDTA dependent antibodies. This is why a routine blood film should always be examined when an unexpectedly low platelet count is found in an asymptomatic patient.

Clinical Consequences of Pre-Analytical Errors; Direct Patient Harm

Clinical consequences of acting on an incorrect FBC result can range from minor, such as an unnecessary repeat blood test, to severe, including inappropriate treatment, delayed diagnosis, or patient harm. At least 50 percent of erroneous laboratory results arising from analytical interference that go unrecognized during validation lead to misdiagnosis and inappropriate management (Mrazek et al., 2020).

The following scenarios demonstrate the clinical importance:

A patient with EDTA-induced pseudothrombocytopenia, whose platelet count is 22 x 10^9/L, may be referred for a bone marrow biopsy and started on corticosteroid therapy, which is an invasive procedure with real risks for a condition that does not actually exist.

A dehydrated patient in the emergency department with a hemoconcentrated FBC showing a normal hemoglobin may be discharged without treatment for an underlying anemia, which could become clinically significant once rehydration occurs.

An oncology patient with a falsely elevated neutrophil count due to an extended tourniquet time might receive a chemotherapy cycle when their actual count drops below the safe threshold, placing them at risk of life-threatening neutropenic sepsis.

Laboratory and Systemic Consequences

Beyond the direct impact on patients, pre-analytical errors place a significant burden on laboratory operations and health systems. Rejected specimens require repeat phlebotomy, which causes patient discomfort, delays diagnosis, and uses extra reagents and staff time. Longer turnaround times affect clinical decision-making, especially in emergency situations. In resourcelimited settings, the cost of repeat testing, both financially and logistically, can be substantial.

Prevention and Quality Management; Standard Operating Procedures

The foundation of pre-analytical quality is the existence and consistent use of clear, evidence based Standard Operating Procedures (SOPs) for every step of the phlebotomy process. SOPs should be developed in accordance with current international guidance, specifically the WHO Guidelines on Drawing Blood: Best Practices in Phlebotomy (World Health Organization, 2010), and reviewed annually or whenever procedural changes occur. This World Health Organization document is globally recognized as a gold standard for phlebotomy procedures. It provides the definitive framework for pre-analytical steps, such as rigorous patient identification, strict tourniquet application time limits to prevent hemoconcentration, and the proper order of draw to avoid sample cross-contamination (World Health Organization, 2010). To be effective, these guidelines must be written in clear language, posted at collection points, and integrated into staff orientation programs. A well-written SOP that is not actively utilized provides no clinical protection; therefore, the institutional culture must firmly support and enforce its daily use.

Phlebotomy Training

Poor phlebotomy technique is the most common factor affecting specimen quality. However, in many healthcare environments, venipuncture is assigned to staff with little formal training and limited supervision. Structured phlebotomy training programs that cover anatomy, technique, tube selection, order of draw, mixing, and labeling, with competency assessed through direct observation, have been shown to measurably reduce specimen rejection rates. In Nigerian hospitals, where pre-analytical error rates in hematology laboratories have been documented at concerning levels, investment in phlebotomy training is among the highest-yield quality improvement interventions available.

Quality Indicators

The International Federation of Clinical Chemistry and Laboratory Medicine (IFCC), through its working group on Laboratory Errors and Patient Safety, has published a model of quality Indicators that laboratories can monitor to identify error-prone steps and track improvement over time. The key pre-analytical indicators relevant to the FBC include the rates of haemolysis, clotted, under-filled, and misidentified specimens. Rather than using numerical fixed targets, the IFCC derives its quality specifications from the distribution of results across participating clinical laboratories. The model establishes three tiers of performance based on percentiles:

Optimum (25th percentile): Represents the top-tier performance achieved by the best laboratories.

Desirable (50th percentile): Represents the median performance level.

Acceptable (75th percentile): Represents the minimum standard for safe, baseline operation. (Sciacovelli et al., 2017).

Technology and Systems

When resources allow, technology can significantly decrease pre-analytical errors. Barcode labeling systems that generate specimen labels at the point of care and connect to the patient's electronic record eliminate transcription errors and mislabeling. Laboratory Information Management System (LIMS) delta-check alerts identify implausible changes between samples that may suggest a sample quality issue. Modern automated hematology analyzers, including the Sysmex XN and Beckman Colter DxH series, incorporate specimen quality indices that detect hemolysis, lipemia, and icterus before analysis, preventing affected results from being reported without flags.

Considerations for Resource-Limited Settings

In sub-Saharan Africa and other resource-limited settings, the pre-analytical landscape faces additional challenges. Inconsistent supply of high-quality EDTA tubes, long and poorly temperature-controlled transport chains, limited access to LIMS, and insufficient laboratory staffing for timely specimen processing. These structural issues increase pre-analytical error rates above those seen in well-resourced settings.

Practical, low-cost interventions appropriate to these contexts include pictorial SOPs with local language adaptations, visual quality checks at reception (assessing for hemolysis, clots, and fill volume before processing), community-based phlebotomy training for primary health workers, and a regional specimen transport network designed to minimize time-to-analysis. The evidence from Ethiopian laboratory studies, which show that pre-analytical errors account for the majority of total laboratory errors in district hospitals, confirms that this is not merely a theoretical concern for Africa but a pressing quality problem.

Conclusion

Pre-analytical errors are the main source of error in clinical laboratory medicine, and Full Blood Count analysis is especially vulnerable because hematological parameters are highly sensitive to even small deviations in specimen handling. This review shows that these errors have various origins, including patient preparation, phlebotomy technique, anticoagulant management, specimen transport, and storage, and they have very specific effects, with each category causing characteristic distortions in identifiable FBC parameters.

The evidence makes it clear that these errors are largely preventable and do not stem from inherent biological complexity. They result from human and system failures that are amenable to intervention. Improved training, enforced SOPs, quality indicator monitoring, and technology assisted safeguards can reduce pre-analytical error rates to a fraction of their current levels. The challenge isn't scientific; the knowledge is there. The real challenge is for institutions to put systems in place that prioritize quality, ensure ongoing training, and hold everyone involved in the pre-analytical chain accountable.

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