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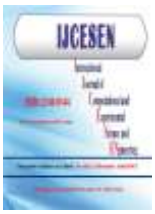

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Research Article

Blood Sample Collection and Handling: Roles of Nursing and Laboratory Professionals

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Abstract:

Blood sample collection is a critical process in clinical diagnostics, requiring meticulous attention to detail to ensure accuracy and reliability of test results. Nurses play a pivotal role in this process, as they are often the first healthcare professionals to interact with patients during sample collection. Their responsibilities include preparing the patient, selecting the appropriate collection site, using aseptic techniques, and ensuring the correct use of collection tubes. Adequate patient preparation, including explaining the procedure and alleviating anxiety, helps ensure a smooth collection process. Moreover, nurses are responsible for documenting the procedure and any pertinent patient information, thereby facilitating effective communication between healthcare teams. Laboratory professionals complement the efforts of nursing staff by focusing on the post-collection handling of blood samples. Their responsibilities include managing the transportation, processing, and storage of samples to maintain integrity and prevent contamination. Proper labeling and timely analysis are critical to yield accurate laboratory results. Laboratory professionals must adhere to standard operating procedures and quality control measures to mitigate errors. Collaboration between nursing and laboratory teams is essential to optimize patient care, streamline workflows, and ensure that diagnostic results are delivered promptly and accurately for effective decision-making in treatment plans.

1. Introduction

In the intricate ecosystem of modern healthcare, the diagnostic process forms the cornerstone of clinical decision-making, therapeutic intervention, and patient management. At the heart of this process lies the humble blood sample, a biological specimen of immense informational value. The journey of a blood sample from the patient's vein to the analytical instrument and, ultimately, to the clinician's report is a complex, multi-stage pipeline. This pipeline is most vulnerable not during the high-technology phase of machine analysis, but during the initial, hands-on phases of collection, handling, and transport—collectively termed the pre-analytical phase. Extensive research and quality audits consistently demonstrate that the pre-analytical phase is the leading source of errors in laboratory diagnostics, accounting for an estimated 60-70% of all mistakes that impact test results [1, 2]. These errors can stem from a myriad of factors, including incorrect patient identification, improper specimen collection techniques, use of wrong collection tubes, inadequate mixing, improper storage conditions, and delays in transport. The consequences of such errors are far-reaching, leading to misdiagnosis, unnecessary repeat testing, delayed treatment, increased patient anxiety, and substantial financial burdens on healthcare systems [3].

This critical pre-analytical pathway is not governed by a single profession but is a shared, interdependent responsibility between two key pillars: nursing professionals and laboratory professionals. While their direct interactions with the sample occur at different stages, their roles are deeply symbiotic, requiring a seamless handoff underpinned by mutual understanding, standardized protocols, and clear communication [2].

2. The Role of Nursing Professionals:

The process begins long before the needle touches the skin. Proper patient preparation is essential to ensure the analytical result reflects the patient's physiological state rather than temporary artifacts introduced by diet, activity, or medication. Nurses must provide clear instructions to patients regarding fasting requirements (typically 8-12 hours for tests like glucose and lipids), medication schedules (e.g., timing of therapeutic drug monitoring), and, when necessary, posture (e.g., for renin or aldosterone) [4]. Equally, if not more critical, is the absolute necessity of accurate patient identification. This is the most fundamental error-prevention step. Best practice mandates using a minimum of two unique patient identifiers—such as full name, date of birth, or medical record number—and verifying them against the patient's wristband and test requisition form before any procedure begins [5]. This step must be performed actively with the patient's participation, not merely by checking a chart at the nursing station.

The choice of equipment and technique is guided by the tests ordered, the patient's condition, and venous accessibility. Nurses must select the appropriate needle gauge; a larger gauge (e.g., 21G) is suitable for most adults to ensure smooth blood flow and minimize hemolysis, while a smaller gauge (e.g., 23G) may be necessary for fragile veins or pediatric patients [6]. The selection of blood collection tubes is a science in itself. Each tube type, distinguished by its cap color, contains specific additives designed for particular tests: lavender-top (EDTA) for hematology, light blue-

top (citrate) for coagulation studies, serum separator tubes (SST) for chemistry, and so on. Using the wrong tube can invalidate results; for instance, drawing a coagulation sample in an EDTA tube will erroneously prolong clotting times due to calcium chelation [7]. Furthermore, the order of draw is a critical protocol designed to prevent cross-contamination of additives between tubes. The standardized sequence, typically beginning with blood culture bottles or citrate tubes, then proceeding to serum tubes, heparin tubes, EDTA tubes, and finally glycolysis-inhibiting tubes, must be meticulously followed [8].

The actual venipuncture requires technical skill and anatomical knowledge. After applying a tourniquet to engorge veins, the nurse selects an appropriate site, typically the median cubital, cephalic, or basilic veins in the antecubital fossa, avoiding areas with hematomas, infection, or compromised circulation [9]. Following proper antiseptic cleaning with an agent like 70% isopropanol (or chlorhexidine for blood cultures), the venipuncture is performed smoothly to minimize trauma. During filling, tubes should be allowed to fill completely by vacuum to ensure the correct blood-to-additive ratio, which is especially crucial for coagulation studies [10]. Vigorous shaking of tubes must be avoided; instead, they should be gently inverted 5-10 times immediately after collection to ensure proper mixing of blood with the additive. Failure to mix can lead to microclots in EDTA tubes or inadequate anticoagulation in citrate tubes.

The nurse's responsibility extends beyond drawing the blood. Immediately after collection, the tourniquet must be released and pressure applied to the site. Each sample must be labeled accurately at the patient's bedside with the required information (patient identifiers, date, time, collector's initials). Labeling after leaving the bedside is a dangerous practice that invites error [11]. For certain tests, special handling is required at the point of care; for example, samples for arterial blood gas analysis must be placed on ice immediately to halt cellular metabolism, and samples for cryoglobulins must be kept at 37°C during transport to prevent precipitation [12]. The nurse must also ensure timely transportation to the laboratory, as delays can cause glycolysis (lowering glucose), leakage of intracellular components (increasing potassium), or deterioration of labile analytes.

3. The Role of Laboratory Professionals:

The first laboratory action is a thorough inspection of the received specimen. This involves verifying that the information on the label matches the requisition form, checking for proper sample type and volume, and inspecting the specimen for visual clues of unsuitability. Laboratory professionals are trained to identify gross hemolysis (pink or red serum/plasma), icterus (dark yellow), lipemia (milky), or the presence of small clots [13]. They also check for improper containers, expired collection tubes, and inadequate sample volume. This step is a critical triage; accepting a compromised specimen risks generating misleading data. Laboratory policies guide the professionals to either reject the specimen, requiring recollection, or to accept it with a comment to the clinician about potential interference [14].

For many tests, the blood must be processed to obtain the fluid component for analysis. This involves centrifugation, a step with precise parameters. The speed, time, and temperature of centrifugation are defined for different test types. For instance, coagulation samples are typically centrifuged at high speed for a defined period to obtain platelet-poor plasma, while over-centrifugation of serum samples can cause hemolysis [15]. After centrifugation, laboratory staff must carefully aliquot (portion) the serum or plasma into secondary tubes, ensuring no transfer of cells or fibrin clots. This step often involves using automated decappers and aliquoters in high-volume settings to improve efficiency and safety. Throughout processing, maintaining proper sample identification through barcode systems is paramount to prevent sample mix-up [16].

Not all tests are performed immediately. Laboratory professionals are responsible for storing specimens under conditions that preserve analyte stability. This may involve refrigeration (2-8°C) for most chemistry tests, freezing at -20°C or -80°C for hormones or special chemistry tests, or keeping at room temperature for hematology cell counts [17]. They must manage complex storage inventories and retrieval systems. Furthermore, in large laboratories or hub-and-spoke networks, they may be responsible for packaging specimens for transport to reference laboratories, adhering to national and international regulations for the transport of biological substances (e.g., IATA regulations), which include triple packaging, absorbent material, and clear labeling [18].

While the actual machine analysis is highly automated, laboratory professionals oversee this phase. They load specimens onto analyzers, monitor instrument performance through quality control procedures, and troubleshoot errors. Their deep understanding of methodology allows them to identify pre-analytical issues that manifest during analysis, such as clot flags in hematology analyzers or sample integrity flags in chemistry instruments [19]. Before releasing results, they perform a final

verification, correlating results with patient demographics, previous results (delta checks), and clinical information when available, which can sometimes flag a pre-analytical issue that was not visually apparent [20].

4. Shared Responsibilities and Communication

Both departments must collaborate in the development, periodic review, and updating of phlebotomy and sample handling SOPs. Laboratory professionals provide the technical expertise on sample requirements, stability, and interference, while nursing professionals provide practical insights into clinical workflow, patient comfort, and feasibility. This joint ownership ensures protocols are both scientifically sound and clinically applicable [21].

Ongoing education is vital. Laboratory professionals should participate in training nursing staff on updates in tube types, order of draw, and special handling requirements. Conversely, nurses can educate laboratory staff on challenges in difficult draws (e.g., in oncology or geriatric patients) to foster understanding. Competency assessment for phlebotomists, often involving direct observation and written exams, is a joint responsibility to ensure standards are maintained [22].

Open, non-punitive communication channels are the bedrock of error reduction and continuous improvement. When the laboratory rejects a specimen, the feedback to the nursing unit must be clear, constructive, and timely, explaining the reason (e.g., "clotted specimen," "insufficient volume for coagulation studies") to prevent recurrence [23]. Similarly, nurses should feel empowered to contact the laboratory for clarification on test requirements or to report issues with collection supplies. Regular inter-departmental meetings are an effective forum for addressing recurring problems and sharing data on pre-analytical error rates [24].

Both groups should actively participate in quality improvement projects aimed at reducing pre-analytical errors. This can involve tracking key performance indicators (KPIs) like specimen rejection rates, hemolysis rates, or mislabeled specimen rates, and using root cause analysis tools (e.g., fishbone diagrams, Pareto charts) to identify underlying causes and implement corrective actions [25].

5. Common Pre-Analytical Errors and Their Prevention

Understanding common errors illuminates the practical importance of both roles.

Identification and Labeling Errors. Misidentification of a patient or mislabeling of a tube remains a catastrophic error with the highest potential for patient harm. Prevention relies on strict adherence to the "two identifier" rule and bedside labeling. Barcode-based patient identification systems integrated with electronic health records can significantly reduce this risk [26].

Sample Collection Errors. These include hemolysis (often from using a small needle, drawing from a hemolyzed line, or forcing blood into a syringe), clotting (inadequate mixing or slow draw), and use of incorrect additives. Prevention requires proper technique, training, and verification of tube selection against the test menu [27].

Sample Handling and Transport Errors. Examples are excessive delay in transport, exposure to extreme temperatures, or improper orientation (e.g., not keeping a blood culture bottle upright). Prevention involves clear protocols, efficient logistics, and the use of monitored transport systems [28].

Quality Assurance and Accreditation Standards

The work of both professions operates within a framework of rigorous quality standards. Accreditation bodies like the College of American Pathologists (CAP), The Joint Commission (TJC), and the International Organization for Standardization (ISO 15189) set stringent requirements for the pre-analytical phase [29]. These standards mandate documented procedures, competency records, equipment validation, and continuous monitoring of pre-analytical key indicators. Compliance is a joint endeavor, as assessors will evaluate processes from the patient bedside to the laboratory bench.

6. Technological Advancements and Future Directions

Technology is reshaping the pre-analytical landscape. Closed-loop automated phlebotomy devices that integrate patient ID verification, tube selection, and labeling are emerging [30]. Robotic systems in laboratories for sorting, centrifuging, and aliquoting samples reduce manual handling errors [31]. Enhanced tube labeling with 2D barcodes containing extensive data and electronic tracking of samples from draw to analysis improve traceability [32]. Furthermore, point-of-care testing (POCT), often managed by nursing staff but supported by laboratory oversight, moves analysis closer to the patient, altering but not eliminating the need for rigorous sample handling protocols [33].

7. Conclusion:

The journey of a blood sample is a testament to the silent, often unseen collaboration between nursing and laboratory professionals. The nurse, as the initial guardian, holds the responsibility of extracting a pristine and accurately identified sample from the complex human system. The laboratory professional, as the subsequent custodian, bears the responsibility of preserving the integrity of that sample and transforming it into reliable, actionable data. Their roles are distinct in action but unified in purpose: to ensure that the diagnostic information guiding a patient's care is an accurate reflection of their clinical truth. Breaches in this chain of custody, at any point, compromise the entire diagnostic endeavor. Therefore, fostering a culture of mutual respect, continuous education, open communication, and shared accountability is not merely an administrative goal but an ethical imperative. In the high-stakes world of modern medicine, the synergy between the nurse at the bedside and the scientist at the bench is, and will remain, a fundamental pillar of quality, safety, and effective patient care. This partnership ensures that the vital link between the patient and the precision of laboratory medicine remains strong, trustworthy, and focused on the ultimate goal of healing.

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