

A Review on Safety and Best Practices in Blood Collection and Handling

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Abstract:

Blood collection and handling are foundational elements of clinical diagnostics, forming the basis for over 70% of medical decisions globally. Ensuring safety and following best practices during each phase, pre-collection, collection, and post-collection, are essential for reliable and accurate laboratory results. This review explores critical aspects of the blood collection process, focusing on minimizing errors, protecting both patients and healthcare workers, and maintaining specimen integrity. Pre-collection safety measures such as proper patient identification, equipment preparation, hygiene of the staff, and accurate site selection reduce the chances of contamination and ensure correct patient-sample matching. During collection, employing aseptic techniques, using the correct order of draw, selecting the appropriate blood tubes, and effective labeling are key to preserving sample quality and avoiding diagnostic delays. Patient comfort is also emphasized to improve compliance and reduce procedural complications. Post-collection handling addresses biohazard management, appropriate storage conditions, temperature control, and transport protocols that prevent hemolysis, clotting, or contamination. These practices reduce pre-analytical errors, which constitute a major proportion of total laboratory errors. The article further discusses challenges faced in clinical settings, including human error, insufficient training, needle-stick injuries, and improper transport procedures. Recent advancements such as the introduction of safety-engineered devices, barcode labeling, and digital tracking systems, have significantly improved process efficiency and safety. Guidelines from recognized bodies like the World Health Organization (WHO), Clinical and Laboratory Standards Institute (CLSI), and Centers for Disease Control and Prevention (CDC) are incorporated to support global standardization. By reviewing the latest literature and practice guidelines, this article provides a comprehensive resource for medical professionals. Adhering to these evidence-based protocols can substantially reduce diagnostic inaccuracies, safeguard healthcare providers from blood borne pathogens, and ultimately enhance patient care and laboratory service quality.

Key words: Pre-analytical errors, Sample handling, Best laboratory practices, Aseptic technique

Introduction to Blood Collection and Handling

Blood collection serves as a vital procedure in both diagnostic and therapeutic settings, contributing to approximately 70% of clinical decisions worldwide. Whether for routine blood tests, disease diagnosis, or therapeutic drug monitoring, the process must be carried out with precision and safety to ensure valid results. The pre-analytical phase including patient identification, sample collection, and labeling holds the highest probability for error in laboratory testing. Studies have shown that nearly 46–68% of total laboratory errors occur during this phase, often due to improper handling or collection techniques (1). These mistakes can have serious implications such as delayed diagnosis, unnecessary repeat testing, and even patient

harm. Maintaining the safety of both patients and healthcare providers during blood collection is essential. One of the major concerns for medical staff is the risk of occupational exposure to bloodborne pathogens like hepatitis B virus (HBV), hepatitis C virus (HCV), and human immunodeficiency virus (HIV). The World Health Organization estimates that up to 40% of hepatitis B and C infections in healthcare workers are attributable to needlestick injuries (2). This risk is significantly higher in countries with limited access to safety-engineered devices or insufficient training programs. Therefore, adopting universal precautions, using personal protective equipment (PPE), and implementing post-exposure prophylaxis (PEP) protocols are critical to reducing these risks. International guidelines emphasize standardization in blood collection procedures to ensure both safety and quality. The World Health Organization (WHO) recommends specific practices in its Best Practices in Phlebotomy document, including correct patient positioning, use of sterile equipment, and proper disposal of sharps (3). Similarly, the Clinical and Laboratory Standards Institute (CLSI) provides detailed protocols under the GP41-A7 guideline, promoting the use of closed-system blood collection devices, pre-labeled tubes, and continuous staff training (4). Such measures not only improve specimen quality but also reduce the likelihood of exposure and contamination. Recent technological advancements also support improved safety and reliability in blood collection. Barcode-based labeling systems, for example, help reduce specimen misidentification, which is a common issue in manual systems. Moreover, devices like safety needles, vacuum extraction tubes, and automatic lancets have greatly reduced the risk of injury and contamination. Continuous research and adaptation of best practices based on evidence from high-impact studies are essential for sustaining improvements in blood collection and handling procedures globally (5). These advancements ensure that the process remains efficient, patient-centered, and aligned with international safety standards.



Figure1. Blood collection and handling process

Pre-Collection Safety Measures

Ensuring accurate patient identification is the first and most critical step in the pre-collection phase of blood sampling. Misidentification can lead to serious medical errors, including incorrect diagnosis and inappropriate treatment. According to the Clinical and Laboratory Standards Institute (CLSI), all patients must be identified using at least two independent identifiers, such as full name and date of birth, before specimen collection begins (6). Verbal confirmation from the

patient (when possible) and cross-checking with documentation help avoid errors. In healthcare settings where barcoding systems are available, electronic patient identification further enhances accuracy and traceability of specimens (7). Proper equipment preparation is equally essential for minimizing errors and ensuring safety during blood collection. All necessary materials vacutainer tubes, needles, tourniquets, alcohol swabs, gloves, and gauze should be assembled and checked for integrity before initiating the procedure. The use of sterile, single-use equipment significantly reduces the risk of infections and cross-contamination. Studies have shown that using safety-engineered devices, such as retractable needles or needleless systems, can reduce needlestick injuries by up to 76% (8). Furthermore, expired or damaged items must be discarded and replaced to maintain procedural sterility. Hand hygiene and personal protective equipment (PPE) are essential for protecting both healthcare workers and patients from infectious agents. The WHO emphasizes that proper hand washing or sanitization must be performed before and after every patient contact, even when gloves are used (9). Gloves, masks, and lab coats serve as a barrier against bloodborne pathogens but are not a substitute for hand hygiene. Staff must be trained to follow infection control protocols strictly, including the safe disposal of used sharps and contaminated materials in designated containers. Consistent adherence to these practices lowers the transmission risk of HBV, HCV, and HIV in clinical settings (10). Site selection for venipuncture should be guided by both anatomical landmarks and patient-specific factors. The antecubital fossa is the most common site due to ease of access and relatively low complication risk. However, areas with signs of infection, edema, or recent venipuncture should be avoided. Proper skin antisepsis using 70% isopropyl alcohol or chlorhexidine must be performed and allowed to dry completely before needle insertion to reduce microbial entry (11). In pediatric or geriatric populations, alternative veins or micro-sampling methods may be more appropriate. Careful site selection not only reduces patient discomfort but also helps in collecting high-quality specimens with minimal hemolysis or clotting.

Best Practices During Blood Collection

Adherence to aseptic technique is essential during blood collection to prevent infection and maintain sample integrity. Aseptic technique involves hand hygiene, wearing sterile gloves, disinfecting the venipuncture site with 70% isopropyl alcohol (or chlorhexidine in some cases), and avoiding contact with the puncture site once cleaned. The needle must remain sterile throughout the procedure, and any breach in sterility requires replacement of equipment (12). Failure to follow aseptic precautions can result in local infections, contaminated samples, or in rare cases, bloodstream infections. These risks are significantly minimized when standard infection prevention protocols are strictly implemented (13). Selecting the correct blood collection tube is another critical aspect of proper phlebotomy. Each tube contains specific additives such as anticoagulants, clot activators, or preservatives designed for different tests. Using the wrong tube may lead to clotting, hemolysis, or inaccurate test results. For example, EDTA tubes are ideal for hematological tests but inappropriate for coagulation profiles. Therefore, phlebotomists must be familiar with color codes and their corresponding additives, and select tubes according to the test requisition form (14). Proper mixing of tubes (usually by gentle inversion) is also important to activate additives and prevent clot formation. Following the recommended order of draw is crucial to prevent cross-contamination of additives between tubes. The CLSI guideline outlines the correct sequence: blood culture bottles, non-additive tubes, coagulation tubes (light blue), serum tubes (with or without clot activator), heparin tubes (green), EDTA tubes (lavender), and fluoride/oxalate tubes (gray) (15). Drawing tubes out of order may lead to false laboratory results such as prolonged clotting times if EDTA contaminates a coagulation tube. Maintaining this order preserves the reliability of test outcomes and reduces the likelihood of repeat collections. Labeling is another vital step in ensuring patient safety and

sample traceability. Each tube should be labeled immediately after collection, in the presence of the patient, using at least two patient identifiers typically full name and medical record number or date of birth (16). Handwritten labels are discouraged where electronic systems are available, as barcoding significantly reduces labeling errors. Furthermore, minimizing patient discomfort through proper technique such as selecting the appropriate gauge needle, avoiding multiple punctures, and ensuring effective communication enhances patient satisfaction and reduces anxiety. Comfort measures also include allowing the antiseptic to dry fully to avoid stinging and ensuring hemostasis post-procedure with gentle pressure and appropriate bandaging (17).

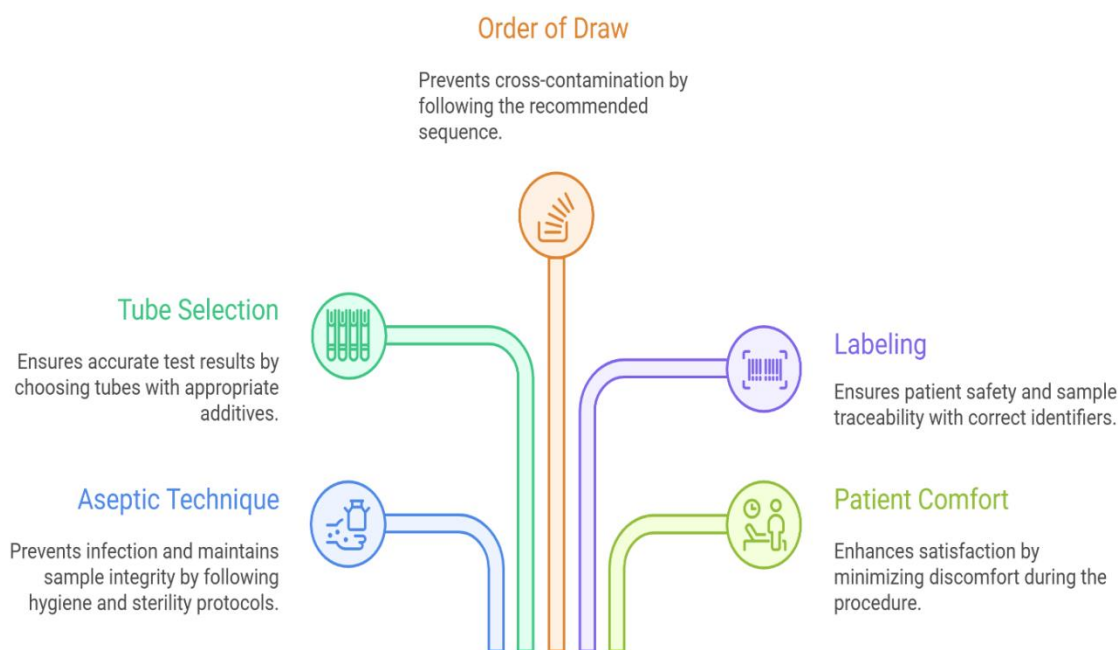


Figure 2. How to ensure proper blood collection

Post-Collection Handling and Transportation

Once the blood sample is collected, correct post-collection handling becomes essential to preserve specimen integrity and ensure reliable diagnostic results. Proper storage conditions such as temperature control and timely processing must be maintained based on the test type. For instance, complete blood counts (CBC) using EDTA tubes should be analyzed within 6 hours if kept at room temperature, while glucose samples in fluoride tubes are stable for 24 hours. Certain serum analytes may degrade rapidly if not centrifuged and separated from cells within two hours of collection. Failure to follow recommended storage conditions may lead to false test results, sample rejection, or repeat phlebotomy procedures. Biohazard precautions are necessary for all specimens, as blood may carry infectious agents such as HBV, HCV, or HIV. The Occupational Safety and Health Administration (OSHA) mandates that all blood samples be handled as potentially infectious, following Universal Precautions (18). This includes the use of gloves, face protection if splashes are anticipated, and disposal of waste in clearly labeled biohazard containers. Proper decontamination of surfaces and safe handling of sharps are equally important. Specimen tubes must be securely capped, and leaks should be avoided by using sealed transport bags with absorbent material to contain spills in case of breakage or leakage (19). Transportation standards ensure that blood specimens reach the laboratory intact and uncontaminated. The Clinical and Laboratory Standards Institute (CLSI) and WHO recommend using temperature-controlled, clearly labeled, and puncture-resistant transport containers.

Specimens requiring refrigeration, such as certain coagulation profiles or hormone assays, should be transported on ice packs, while others must be kept at room temperature (20). Timeliness is also critical; for example, samples for blood gas analysis should be transported and analyzed within 30 minutes to avoid significant changes in gas values. During transport, shaking or vigorous handling of tubes must be avoided as it may result in hemolysis or clotting. Preventing hemolysis and contamination is one of the key challenges in post-collection phases. Hemolysis rupture of red blood cells can falsely elevate potassium, lactate dehydrogenase (LDH), and other analytes, leading to inaccurate reporting. Common causes include rough handling, excessive delay before centrifugation, improper needle size, or drawing blood through an IV line (21). To prevent contamination, collection tubes must remain sealed until analysis, and the use of appropriate clot activators or anticoagulants must be verified. Laboratory personnel must be trained to recognize compromised samples and reject or request recollection when necessary. These post-collection best practices are vital for maintaining test quality and patient safety.

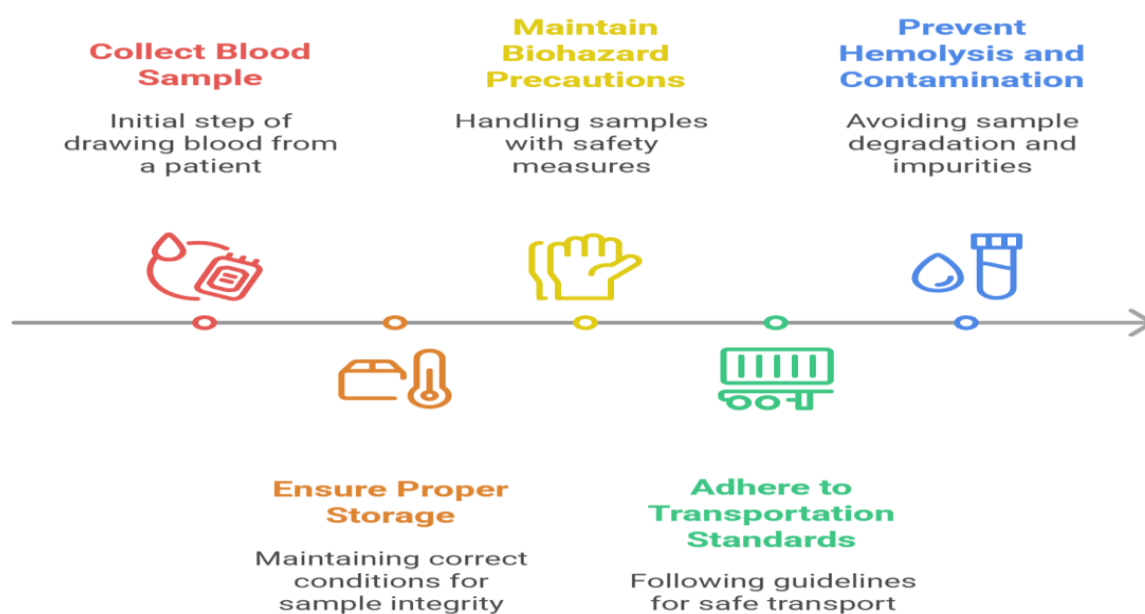


Figure 3. Post collection blood sampling handling

Challenges, Errors, and Recommendations

Despite the standardization of phlebotomy procedures, several challenges persist that compromise sample quality and patient safety. One of the most prevalent issues is pre-analytical error, which includes improper patient identification, wrong tube selection, mislabeling, and delayed transportation. Studies have shown that pre-analytical errors account for over 60% of total laboratory mistakes, leading to test rejection, repeat collections, and diagnostic delays (22). These errors can have serious consequences, especially in critical care or emergency settings where timely results are vital for clinical decision-making. Several risk factors contribute to these errors, including inadequate training, high staff workload, poorly maintained equipment, and non-compliance with protocols. In resource-limited settings, lack of safety-engineered devices and proper storage facilities further aggravate the situation. Additionally, human factors such as distraction, fatigue, and poor communication between departments increase the probability of mistakes (23). Pediatric and geriatric populations are also at higher risk due to challenging

venous access and fragile veins, requiring skilled handling and experience from healthcare providers. To address these challenges, recent advancements in blood collection and handling aim to improve accuracy and reduce risks. The implementation of barcode and RFID labeling systems has significantly reduced specimen misidentification (24). The use of closed-system collection devices, pre-analytical automation, and real-time sample tracking software have improved workflow and reduced manual handling errors. Moreover, vein visualization tools like infrared and ultrasound-guided devices help ensure successful venipuncture, especially in patients with difficult access. Simulation-based training has also emerged as a powerful tool to enhance phlebotomy skills and standardize techniques across staff (25). To ensure safety and accuracy, international organizations have issued various evidence-based guidelines. The World Health Organization (WHO) and the Clinical and Laboratory Standards Institute (CLSI) recommend implementing quality assurance programs that include continuous staff education, regular audits, and error tracking mechanisms (26). Institutions are encouraged to develop clear Standard Operating Procedures (SOPs), promote a culture of safety, and invest in phlebotomy-specific certification programs. Emphasis should also be placed on communication among laboratory, nursing, and clinical teams to reduce errors during specimen requisition and transport. Collectively, these strategies help elevate the quality and safety of blood collection practices in diverse healthcare settings.

Table 1: Key Lessons and Best Practices in Blood Collection and Handling

Phase	Key Practice	Common Errors	Lesson Learned
1.Pre-Collection	Confirm patient identity using two identifiers	Misidentification, wrong patient specimen	Always cross-verify patient details verbally and with documentation
	Prepare and check all required sterile equipment	Using expired or unsterile tools	Use safety-engineered, single-use equipment only
	Ensure proper hand hygiene and wear PPE	Skipping hand hygiene, reusing gloves	Hand hygiene is non-negotiable for infection prevention
2.During Collection	Use aseptic technique and disinfect site properly	Touching site after cleaning, not letting antiseptic dry	Maintain asepsis to avoid contamination and infection
	Follow correct order of draw and tube selection	Tube mix-up, additive contamination	Know tube color codes and their correct sequence
	Label specimens in front of the patient	Labeling after leaving the room, handwriting errors	Label immediately with full name and ID using barcodes when available
3.Post-Collection	Store samples at recommended temperature	Storing serum with whole blood, delayed centrifugation	Know sample stability and test requirements
	Use sealed biohazard bags for transport	Leaking tubes, broken seals during transport	Secure and double-check packaging for biohazard safety
	Avoid vigorous	Hemolysis, clot	Gently invert tubes and

	shaking or delay in processing	formation	transport within recommended time
4.Ethical & Legal	Obtain informed consent	Drawing without permission or patient awareness	Consent is both a legal and ethical obligation
	Maintain confidentiality	Sharing patient data or visible labels in public areas	Always protect patient identity and medical data
5.Training & Improvement	Conduct regular training and audits	Lack of SOPs, outdated practices	Continuous education and quality checks reduce errors

Ethical and Legal Considerations in Blood Collection

Ethical and legal responsibilities play a critical role in the process of blood collection, ensuring that patient rights, safety, and dignity are preserved. Informed consent is the foundation of ethical phlebotomy practices. Patients must be fully informed about the purpose, procedure, potential discomfort, and risks associated with blood collection before giving their voluntary consent. In many healthcare systems, verbal consent is considered sufficient for routine phlebotomy; however, documentation is strongly recommended, especially in clinical trials or research settings (27). Collecting blood without consent or through coercion is not only unethical but also legally punishable under patient rights and medical negligence laws. Privacy and confidentiality must also be strictly maintained throughout the blood collection process. This includes securing patient records, labeling specimens without revealing personal identifiers, and ensuring that discussions related to the procedure are conducted discreetly. According to international healthcare laws and the General Data Protection Regulation (GDPR), unauthorized disclosure of patient information even unintentionally can result in legal action against the healthcare provider or institution (28). Therefore, training staff in confidentiality protocols is essential. Furthermore, phlebotomy procedures must align with national and institutional guidelines to prevent malpractice. For example, repeated failed attempts, inappropriate site selection, or collecting samples under unsanitary conditions can lead to tissue damage, infection, or psychological distress, for which the patient may seek legal redress (29). In vulnerable populations such as children, the elderly, or individuals with cognitive impairment, obtaining guardian or caregiver consent is also legally and ethically necessary. Healthcare professionals are expected to maintain professionalism, empathy, and competence in all interactions. Ethical blood collection also includes equitable access to services. In some regions, biases or resource disparities affect how and when patients receive phlebotomy services. It is the responsibility of healthcare systems to ensure that all individuals regardless of socioeconomic status, race, gender, or disability have fair access to safe and respectful care. Integrating ethics training into phlebotomy and laboratory education programs can significantly improve the quality of care, reduce legal risk, and strengthen patient-provider trust (30).

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