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Preanalytical Errors that Occur Before Specimen Collection

by

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Do you think that it doesn't really matter how you draw blood specimens as long as you get the blood? Do you think that most of the "rules" about phlebotomy are really just guidelines? Do you think that if something is wrong with the specimen, the laboratory will find it before they report out the result? If you answered "yes" to any of these questions, you could be one of the reasons that hospitalization is the 7th leading cause of death in the US.¹

When blood specimens are not collected properly the results that the physician receives may not even closely resemble the patient's actual condition. If a physician treats a patient based on a result from an improperly collected specimen, the patient could be overmedicated, undermedicated, misdiagnosed or generally mismanaged. For example, the laboratory can't look at the results and tell that the tourniquet has been left on too long. If the patient actually has a potassium level that is too low for surgery, but is tested to be normal because of what happens to the blood when the tourniquet is left on longer than one minute, the patient may die on the table. Still think how you draw blood doesn't matter?

It is critical for all who draw blood specimens to realize that most collection errors that alter results are impossible for the laboratory to detect. Although testing personnel can detect some collection errors before erroneous results are released, most are never caught. That's why it's important for those who draw blood specimens to realize how critical their collection practices are to the patient's health. Whether it's an inpatient or an outpatient draw, a quality result is not possible without a quality specimen.

It has been estimated that specimen collection errors cost the average 400-bed hospital \$200,000/year in recollections and medication errors.² Preanalytical errors can be broken down into three groups: those that occur *before*, *during* and *after* physically obtaining the specimen.

The volume of material that exists in the literature on preanalytical errors is enormous. It is beyond the scope of this article to discuss all potential errors.

What this article attempts to discuss are those errors that are felt to occur most frequently prior to needle insertion or capillary puncture, are easiest for collectors to control, and have the most profound effects on the specimen result.

Phlebotomy will never be automated. That's one of the reasons it is critical for all who draw blood specimens to be properly trained and continually educated. Because blood collection is a manual procedure, up to 56% of all the errors that can occur to a specimen and its result occur during the *preanalytical* phase, which includes specimen collection, processing and transportation.^{3,4}

Errors that Occur Before Collection

Preanalytical errors consist of those errors that occur in the ordering and accessioning, specimen collection, processing, transportation, storage and pre-testing phases of blood testing. This phase is probably the most complex and the most difficult to control, especially at a time when phlebotomy responsibilities are being deployed to departments and personnel outside of the laboratory. Because of their complexity and the impact they can have on patient management, these and other preanalytical errors are worthy of our continuous interest so that we might be better at identifying, understanding and eliminating them through sound blood collection and handling practices. This list summarizes the errors we will be exploring.

Errors that Occur Before Collection

- Misidentification
- Time of Collection
 - Fasting Tests
 - Chronobiology
 - Medication
 - Blood Cultures
- Coordination with Other Treatments/Conditions
- Vascular Access Devices
- Exercise
- Posture
- Tourniquet Time
- Site Preparation

Misidentification

The pre-collection error that is the most important and can result in patient death if performed improperly is patient misidentification. All patients must be properly identified prior to specimen collection in a manner that assures the specimen received is from the intended patient. The proper manner of patient identification cannot and must not be compromised under any circumstances.

According to a CAP Q-Probe conducted in 1995 on 4 million wristbands, five percent contained erroneous information. Another study in 1998 found the error rate to be as high as 16 percent in some facilities.² Adhering to the standards for patient identification as set forth by the Clinical and Laboratory Standards Institute (CLSI) provides assurance that the patient to be drawn is the intended patient and prevents collectors from falling victim to errors that may have occurred in the preparation and application of patient arm bracelets. According to CLSI, proper inpatient identification consists of:⁵

Step 1: Ask patients to give their full name, address, identification number, and/or birth date. If the patient is unconscious or unable to respond, ask a member of the patient's care team or family to verify the patient's identification and compare it with the order requisition and arm bracelet. Document the name of the verifier. If the arm bracelet is not attached to the patient, it is invalid and cannot be used. Even if the identifying bracelet is attached to the bed, it does not constitute reliable identification of the individual in the bed. Nor do names written on water pitchers, bed tags, or posted charts.

When confirming patients' names by soliciting a verbal response, the collector must ask patients to state their name in full. This must come in the form of the question: "Could you tell me your name, please?" Asking

patients to affirm their name as in “Are you John Smith?” is not acceptable. Any patient in any state of consciousness can respond in the affirmative. Patients hard of hearing may say “yes” just to be polite.

Under no circumstances should the patient’s identity be assumed on the basis of his/her location. For example, a document containing a test order shows John Williams, to be in Bed 3. If the patient in Bed 3 does not have an identifying bracelet affixed to his/her person and is incoherent or unresponsive, it cannot be assumed John Williams is actually the patient lying in Bed 3. In this case, it is the collector’s duty to find someone responsible for the patient to verify the patient’s identity. The verifier’s name must be documented in the event that the patient is misidentified.

The risk of patient misidentification is highest in hospital emergency departments (ED) where a flurry of activity descends upon traumatized patients. Although it may be pragmatic to rely on verbal identification from the ED team until such devices can be applied, facilities that affix a temporary number around the patient’s wrist or ankle until more exact information can be obtained provide the best protection against patient misidentification.

As with inpatient identification, ED patients unable to speak their names and without reliable identification must be identified by a healthcare professional responsible for the patient. Refer to your facility's policy for proper patient identification in such settings.

Step 2: Compare the information given with the information on the request form and the information on the identification bracelet. The information contained on a patient’s arm bracelet should be compared to the hard copy of the order for the blood test that identifies the patient and what tests are to be drawn. This hard copy can come in the form of preprinted labels, a work list, or another form that puts down in writing the name and location of the patient, the identification number, the date and time of intended collection, and the tests that are to be drawn. In addition to comparing the patient’s name, a second identifier should be used to match the order with the intended patient to protect against cases in which two patients have the same name. Supplemental identification in the form of a hospital number, medical records number, and the like can be used for this purpose. Any discrepancies must be investigated and resolved before the specimen is collected.

Outpatient Identification

Step 1: Ask patients to give their full name, address, identification number, and/or birth date. Do not ask them to affirm a name you provide.

Step 2: Compare the information given with the information on the request form.⁵

Just as inpatients’ arm bracelets may be incorrect, documents that outpatients present to the collector may belong to another patient. Therefore, phlebotomists should ask patients to state their full name and compare it with the information on the documents they provide upon arrival to the drawing station.

Time of Collection

Errors can occur if specimens are drawn at the wrong time of day. Such time-dependent considerations include dietary intake, chronobiology (the body’s natural clock), medication metabolism, and coordinating collections with the patient’s condition and other treatments.

Fasting Tests

In terms of dietary considerations, we have to remember that most normal reference ranges are established on fasting patients, i.e. a 12-hour overnight complete dietary restriction with the exception of water and medications. The reference range is the range of numbers accompanying the patient's result, representing what is considered to be "normal" in healthy patients for each test. So when we draw a specimen from a non-fasting patient, the physician is not comparing apples and apples. For many tests, this is not critical. For others

such as glucose and lipids, however, it is. All specimens ordered to be collected as fasting should be drawn accordingly. If the patient is not fasting for lab work that is ordered to be drawn in a fasting state, the physician should be consulted as to whether or not to proceed with the collection. At the very least, the non-fasting state of the patient should be noted with the results so the physician can properly interpret the values.

Chronobiology

Some blood levels are subject to diurnal variations, that is they vary naturally according to the patient's biological clock. For example, serum iron levels can be as much as 30 percent lower in the evening than in the morning.³ Other analytes that vary according to the time of day include:

Analytes that Exhibit Diurnal Variation^{4,6,7}

| | |
|---------------------|--------------|
| Acid Phosphatase | Iron |
| Adrenocorticotropin | Leutenizing |
| Aldosterone | Hormone |
| Bilirubin | Prolactin |
| BUN | Progesterone |
| Catecholamines | Testosterone |
| Cortisol | TSH |
| FSH | Triglyceride |
| Growth Hormone | Uric Acid |

Not all of these tests vary to a clinically significant degree, but some, like cortisol, must be drawn according to a strict timetable. Phlebotomists must be aware of tests that have time-dependent drawing requirements and adhere to them. In order to keep current, those who collect blood specimens should periodically review their facility's manual on specimen requirements so that all results provide meaningful data to the physician.

Medication

When physicians request the blood level of therapeutic drugs, it is to make sure the patient's dosage is correct. Drawing the specimen at the wrong time may skew the results and lead the physician to change the patient's dosage so that they are either over-medicated or under-medicated. Therefore, it's important to draw the specimen when it has reached an optimum concentration in the bloodstream. This is difficult when you consider that every therapeutic drug has its own pharmacokinetics. In fact, the time some medications take to reach their maximum effective concentrations depends on the form in which the drug was administered, and other variables.

Therefore, it's difficult to apply everything there is to know about monitoring therapeutic drugs. If anything comes close to a "rule of thumb," it's that blood sampling should be conducted *just before the next dose* unless otherwise ordered. In the case of outpatients, however, this is not always possible and the physician will have to interpret the results by comparing the time of collection with his or her prescribed schedule of drug dosage.

Blood cultures

The timing of blood culture collections is critical to harvesting the causative agent of bacteremia. Some bacteria shed into the bloodstream continuously, and for them timing the collection is not critical. The concentration of others, however, rises and falls through the course of the day in a fairly predictable rate followed by fever spikes 30-60 minutes later.⁴ Monitoring the temperature spikes, therefore, helps us to

anticipate when the next shedding of bacteria is likely to occur and enables us to collect a blood culture when we are most likely to harvest the causative organism(s).

Few physicians employ this predictive tool, however. Most orders to collect blood cultures come without regard to time, but either randomly or whenever the patient's fever exceeds a predetermined temperature. Collectors who are presented with a timed blood culture collection order, however, should recognize the importance of strictly adhering to the requested time of draw, and respond quickly to fever-triggered collection orders.

Coordination with Treatments/Conditions

We all know that patients are subject to a wide variety of procedures, therapies and tests other than what the laboratory performs. Many of these can have a dramatic impact on the results the laboratory produces. The existing therapy that interferes with collecting quality specimens the most is the infusion of intravenous fluids. CLSI recommends avoiding draws from arms with infusing fluids if possible.⁵ If not possible, the consensus in the literature is to shut off the IV for two minutes, tighten the tourniquet below the IV, and draw the specimen below the tourniquet, discarding the first 5 mL of blood.^{5,8,9} The discard is not included in the CLSI standards, but if collectors have the luxury of doing so without compromising the collection, it is a good idea. Regardless, an entry should be made in the patient's records accompanying the result that the specimen was drawn from the same side as infusing fluids.

CLSI advises against drawing above an active IV, even if it has been temporarily discontinued.⁵ If the analytes being tested also exist in the IV fluid that had been entering the vein, the results can be falsely elevated, leading to negative patient outcomes.¹⁰⁻¹¹ Drawing blood at the same time dyes for radiological procedures are being or have been recently infused should be avoided if possible.

Vascular Access Devices

Vascular access devices (VADs) such as IV lines, central venous catheters, and arterial lines are convenient devices from which to obtain blood specimens without subjecting the patient to a venipuncture. Such blood collections require coordination with the patient's immediate caregiver, i.e., a nurse or member of the IV therapy team. However, such draws are associated with:^{8,9}

1. Increased likelihood of blood culture contamination;
2. Contamination of specimens with IV fluids;
3. High rate of hemolysis compared to venipunctures;
4. Potential to introduce air embolism into bloodstream;
5. Risk of introducing bacteria into bloodstream;
6. Risk of line occlusion.

In addition, such draws always require discarding a volume of blood to assure the specimen is free of the infusing fluids and, therefore, risks iatrogenic anemia (anemia induced by medical procedures). Because of the potential for such specimens to be compromised and the risks to the patient, phlebotomists should avoid drawing from VADs whenever possible. When not possible, collectors should diligently seek to minimize the sources of preanalytical error inherent to such draws.

To prevent IV fluids from contaminating specimens, such draws require calculated volumes of collected blood to be discarded prior to obtaining the specimen to be tested. Because the first blood withdrawn from vascular access devices contains the infusing IV fluids, it is important to calculate the appropriate volume to be discarded according to the device.

Each vascular access device has a "dead space volume," which is the volume of fluid that the line contains. To obtain a blood specimen free from the interferences that IV fluids can impart, CLSI recommends discarding twice the dead space volume for non-coagulation testing and 5 mL of blood or six times the dead

space volume for coagulation studies.⁵ Deviations from these guidelines risk contamination of specimens and erroneous results.

Hemolysis appears to be an inherent quality of vascular access draws rather than of technique and is difficult to prevent. Minimizing plunger pressure when drawing with a syringe may reduce the degree of hemolysis. However, avoiding line draws whenever possible is the best way to prevent hemolysis and the other errors inherent with such draws.

Many studies have been published showing a high rate of hemolysis from line draws as compared to venipunctures. One study showed the hemolysis rate in blood drawn during IV starts to be significantly higher (13.7%) than for blood drawn by venipuncture (3.8%).¹² Other studies have shown:

- The difference in hemolysis rates between specimens drawn from ED personnel versus laboratory phlebotomists to be 12.4% (ED personnel) versus 1.6% (phlebotomists).¹³
- The hemolysis in ED samples drawn by venipuncture to be <1% while those drawn during IV starts to be 20%.¹⁴
- The hemolysis rates for specimens drawn through IV catheters using a syringe to be 9% versus 22% when a tube holder/vacuum tube combination was used.¹⁴
- The hemolysis of samples drawn during IV starts using 5ml tubes to be nearly 50% lower than when samples were collected in the same manner using 10 mL tubes (2% versus 1.1% respectively).¹⁵
- Blood drawn through 20-24 gauge IV catheters are more than seven times as likely to be hemolyzed than blood drawn through 14- to 16-gauge canulas, and 3.6 times as likely as blood drawn through an 18-gauge canula.¹⁶

Exercise

Exercise can have a profound effect on many tests. Therefore, it's best to avoid collecting a blood specimen right after the patient has had a strenuous workout. The levels that can increase temporarily include the following:^{4,6,7,17,18,19}

| | |
|--------------|--------------------------------------|
| • ACTH | • HDL |
| • Bilirubin | • LDH |
| • CK | • Percentage of neutrophils in a CBC |
| • Cortisol | • Uric acid |
| • Creatinine | • WBC count |

For most inpatients, this is not an issue. However, outpatients are more likely to have engaged in strenuous activity immediately prior to coming to the draw station for a blood test. For example, patients often combine trips to a hospital for blood work and physical therapy or cardiac rehabilitation exercise. Therefore, phlebotomists who become aware that their patient has just finished a workout or strenuous exercise should make a notation to accompany the results so that the physician can interpret them in the proper context.

Patients should be instructed not to pump their fist prior to specimen collection. One study showed that having patients pump their fists to make their veins visible for collection can induce changes in the blood, particularly potassium and ionized calcium.⁴ Collectors should not only discourage this habit in their patients, but to inform them of the potential for fist pumping to alter their results so that they don't repeat the behavior in the future; the next phlebotomist might not be aware of the effects it can have on specimen quality.

Patient Posture

Just as most normal reference ranges are established from fasting patients, they are typically established on an ambulatory (up and walking around) patient population as well. Most inpatients have their specimens drawn while lying in bed, however. Therefore, their results are usually being compared against what is normal for healthy ambulatory adults. For most tests, that is not critical, but for others, it is.

When your patient goes from lying down to standing up, the body knows that it's going to take some extra effort to keep the brain supplied with blood now that it has to pump uphill to get there. It responds by releasing hormones into the bloodstream that increase the blood pressure. With the increase in blood *pressure*

comes a decrease in blood *volume*. This occurs because water and smaller compounds migrate through the capillary beds into the tissue to escape the sudden increase in pressure. Large substances like cells, proteins and compounds attached to protein however, can't pass through the capillary walls as readily, so they remain in the bloodstream. The sudden porosity of the capillary beds acts as a fishnet, trapping only the larger blood components in the veins. The word for this effect is *hemoconcentration*. Drawing specimens during this change results in a higher test result than if the patient were drawn while recumbent.^{6,8,9,20-22} Conversely, when a patient goes from upright to recumbent, the blood is subject to a dilutional effect due to water moving from the tissue into the circulation. It has been reported that cholesterol levels are up to 12 percent lower and triglycerides 17 percent lower in patients drawn after being recumbent for 5 minutes.^{6,19} Those analytes affected by changes in posture are listed here:^{4,6}

Posture-Sensitive Analytes

| | |
|----------------------|----------------|
| Albumin | Catecholamines |
| Aldosterone | Cholesterol |
| Alkaline Phosphatase | Drugs |
| ALT | Renin |
| Angiotensin | Total Protein |
| Antidiuretic hormone | Triglycerides |
| Bilirubin | |
| Calcium | |

Although all of these have been shown to be posture-sensitive, not all are subject to clinically significant changes. Because some of these may have specific requirements for patient posture in your facility's collection manual, adhering to them is imperative. Collectors must understand the importance of those tests that specify the patient be recumbent before collection and be aware of their own facility's policy about drawing posture-sensitive analytes.

Tourniquet time

Hemoconcentration also occurs if we leave the tourniquet on too long, altering the concentration of the same analytes that are affected by posture changes. The longer it takes to find and access a vein, the greater the affect hemoconcentration is having on the patient's test results. According to CLSI, tourniquets should not be left on longer than one minute.⁵ Beyond that, hemoconcentration begins to alter the results of the tests to be conducted on the specimens drawn.

But minimizing the time a tourniquet is applied can be difficult if the patient's veins are difficult to find. Phlebotomists can employ strategies, though, that assist them in finding difficult veins and adhering to the restriction on tourniquet application. Phlebotomists should take their time to perform a thorough survey and find a suitable vein. If the survey takes more than one minute, the tourniquet must be released prior to puncture for at least two minutes so that the blood in the vein about to be accessed can equilibrate and hemoconcentration can disperse. Before releasing the tourniquet, the phlebotomist should make a mental note of where the vein lies in relation to certain skin markers like freckles, skin creases or the contour of the skin. Then release the tourniquet, allow two minutes to pass, re-tighten the tourniquet, and relocate the vein using the guideposts established earlier. This technique should significantly reduce the amount of time it takes to relocate the vein and allow the collector to remain compliant with the one-minute rule.

There is significant debate about when collectors should release the tourniquet, i.e., when the vein is accessed or when the venipuncture is complete. After reviewing all the available literature, CLSI concludes that, if possible, the tourniquet should be released soon as the vein is accessed to minimize the effects of hemoconcentration.⁵ Collectors are advised to comply whenever possible. However, in some cases releasing the tourniquet upon venous access will interrupt the flow of blood into the collection tubes or syringe. If the successful completion of the puncture is at risk, the collector must make a professional judgment and perform

the procedure according to what is determined to be in the best interest of the patient, realizing that not all drawing situations allow for compliance. Knowing the effects of excessive tourniquet time, however, should implore us to release the tourniquet upon venous access whenever so doing does not jeopardize the collection.

Site Preparation

Collectors can significantly alter test results if the draw site is cleansed improperly. When cleansing a site with alcohol, it is important that the site is allowed to dry before puncturing. If alcohol is not allowed to dry and gets into the specimen during the puncture, it introduces a hemolytic agent into the specimen, which can cause erroneous results or specimen rejection.^{8,9}

False positive blood cultures are the bane of every hospital. When the site is not cleansed properly or is re-contaminated by palpation after the site is prepped, the results may suggest the patient is septic when in fact he or she is not. As a result, the physician is put in the uncomfortable position of sending the patient home on the assumption of a false-positive result or keeping the patient for a few extra days of antibiotic therapy just in case. One study shows that false-positive blood cultures can increase a patient's stay for a median of 4.5 days and add over \$5,000 of unnecessary hospital, pharmacy and laboratory charges.²³

When you consider the delay to the patient in returning to their families and jobs, the human cost to the patient is incalculable.

To minimize the potential to contaminate a blood culture during collection, adhere to the following practices:

1. Cleanse the site thoroughly with a friction scrub for at least 30-60 seconds;
2. Allow the antiseptic to remain in contact with the skin for at least 30 seconds prior to puncture;
3. Do not repalpate a cleansed site.

Summary

Many errors are committed that change the patient's test result before the needle is even inserted. Many patients suffer needlessly when those who collect blood specimens do not take the importance of their work seriously. Phlebotomists who adhere to proper technique and the CLSI standards for specimen collection can minimize these common errors and deliver high-quality specimens to the laboratory for testing, specimens that accurately reflect the patient's condition. Learned and dedicated phlebotomists are allies of the entire healthcare team. Those who minimize preanalytical errors by applying the knowledge gained in this article can take pride in knowing that the specimens they collect are of a high quality and that their contribution to the care their patients receive is as meaningful and significant as that of any other healthcare professional.

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