CHAPTER 14

Arterial Puncture Procedures

NAACLS ENTRY-LEVEL PHLEBOTOMIST COMPETENCIES

- **3.6** Discuss the properties of arterial blood, venous blood, and capillary blood.
- **4.2** Describe the types of patient specimens that are analyzed in the clinical laboratory.
- **4.3** Define the phlebotomist's role in collecting and/or transporting these specimens to the laboratory.
- **6.00** Follow standard operating procedures to collect specimens.

KEY TERMS

Do Matching Exercise 14-1 in the WORKBOOK to gain familiarity with these terms.

- abducted
- ABGs
- anaerobic
- arteriospasm
- brachial artery
- collateral circulation
- embolism
- embolus
- femoral artery
- FiO_2
- hypovolemia
- hypoxia
- L/M
- modified Allen test
- radial artery
- steady state
- thrombus
- ulnar artery
- vasovagal response

OBJECTIVES

Upon successful completion of this chapter, the reader should be able to:

1. Demonstrate knowledge of practices, terminology, hazards, and complications related to arterial blood collection, and identify and analyze arterial puncture sites according to site-selection criteria and the advantages and disadvantages of each site.
2. Describe arterial blood gas (ABG) procedure, including patient assessment and preparation, equipment and supplies, and commonly measured ABG parameters.
3. Perform the modified Allen test, explain how to interpret results, and describe what to do based on the results.

Overview

Arterial blood composition is more consistent throughout the body than that of venous blood, which varies relative to the metabolic needs of the area it serves. However, arterial puncture is technically difficult and potentially more painful and hazardous than venipuncture. Consequently, arterial specimens are *not* normally used for routine blood tests. The primary reason for performing arterial puncture is to obtain **arterial blood gas (ABG)** specimens. To ensure accurate test results and the safety of the

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patient, those who collect arterial specimens must have thorough knowledge of all aspects of collection and special training in arterial puncture procedures. This chapter focuses on personnel who may be required to perform arterial puncture, arterial puncture sites, and site-selection criteria, including advantages and disadvantages of using each site. Also covered are ABGs and the analytes measured; ABG specimen collection, including radial ABG procedure; and arterial puncture hazards, complications, sampling errors, and specimen rejection criteria.

FYI In addition to direct puncture of an artery, arterial specimens can be collected from an indwelling arterial line using a needleless blood sampling device such as the VAMP (Venous Arterial Blood Management Protection system).

Personnel Who Perform Arterial Puncture

Paramedical personnel (healthcare workers other than physicians) who may be required to perform arterial puncture include nurses, medical technologists and technicians, respiratory therapists, emergency medical technicians, and level II phlebotomists. Phlebotomists who collect arterial specimens must have extensive training involving theory, demonstration of technique, observation of the actual procedure, and performance of arterial puncture with supervision before performing arterial punctures on their own. Personnel who perform ABG testing are designated level I or level II depending on their formal education, training, and experience. Level II personnel supervise level I personnel and perform testing as well. For quality assurance purposes, individuals who perform arterial puncture must undergo periodic evaluation. Those who do not meet acceptable standards must have remedial instruction and be reevaluated before being allowed to collect arterial specimens independently.

Site-Selection Criteria

Several different sites can be used for arterial puncture. The criteria for site selection include the following:

- Presence of **collateral circulation** or blood flow. This means that the site is supplied with blood from more than one artery, so blood circulation is maintained if one vessel is obstructed or damaged. Collateral circulation is the primary site-selection criterion for arterial puncture. It can be evaluated using a portable ultrasound instrument (**Figure 14-1**) or, for the radial artery, by performing a simple test called the modified Allen test.
- Absence of inflammation, irritation, edema, hematoma, lesion, or wound, or of a recent arterial puncture at the site.
- Artery accessibility and size. The more accessible and larger an artery is, the easier it is to palpate and puncture.
- Type of tissue surrounding the puncture site. The chosen artery should be in an area that is relatively insensitive to pain, that poses a minor risk of injuring adjacent structures or tissue during puncture, that helps fix or secure the artery to keep it from rolling, and that allows adequate pressure to be applied to the artery after specimen collection.

Figure 14-1 SONOSITE PX point-of-care ultrasound system displaying a brachial artery imaged with a high-frequency linear transducer.

Image provided courtesy of FUJIFILM Sonosite.

CAUTION *Never* select a site in an arm with an AV shunt or fistula. It is a patient's lifeline for dialysis and should not be disturbed; also, venous and arterial blood mix together at the site.

Arterial Puncture Sites

The three main sites where arteries are accessed for specimen collection are, in order of selection, the underside of the wrist, the antecubital area of the arm, and the groin. The arteries accessed in these areas are described next.

The Radial Artery

Based on selection-site criteria, the **radial artery** is the first-choice site for arterial puncture, which makes it the preferred and most commonly used arterial puncture site in adults. It is located in the underside of the wrist on the thumb side (**Figure 14-2**). Although smaller than arteries at other sites, it is easily accessible in most patients.

WORKBOOK See the arm labeling exercise in WORKBOOK Labeling Exercise 14-1.

KEY POINT Arteries are located by feeling for a pulse. The radial pulse can be felt on the underside of the wrist on the thumb side, approximately 1 inch above the wrist crease.

Advantages

Using the radial artery to collect ABGs and other arterial specimens has a number of advantages. For example:

- The biggest advantage is the presence of good collateral circulation. Under normal circumstances, both the radial artery and the **ulnar artery** (see Figure 14-2) supply the hand with blood. If the radial artery is accidentally damaged by an arterial puncture, the ulnar artery will still supply the hand with blood. Consequently, the ulnar artery is normally off-limits for arterial specimen collection.
- It is normally easy to palpate because it lies fairly close to the surface of the skin.
- There is less chance of hematoma formation following specimen collection because the radial artery can easily be compressed over the ligaments and bones of the wrist.
- There is a reduced risk of accidentally puncturing a vein or damaging a nerve because no major veins or nerves are immediately adjacent to the radial artery.

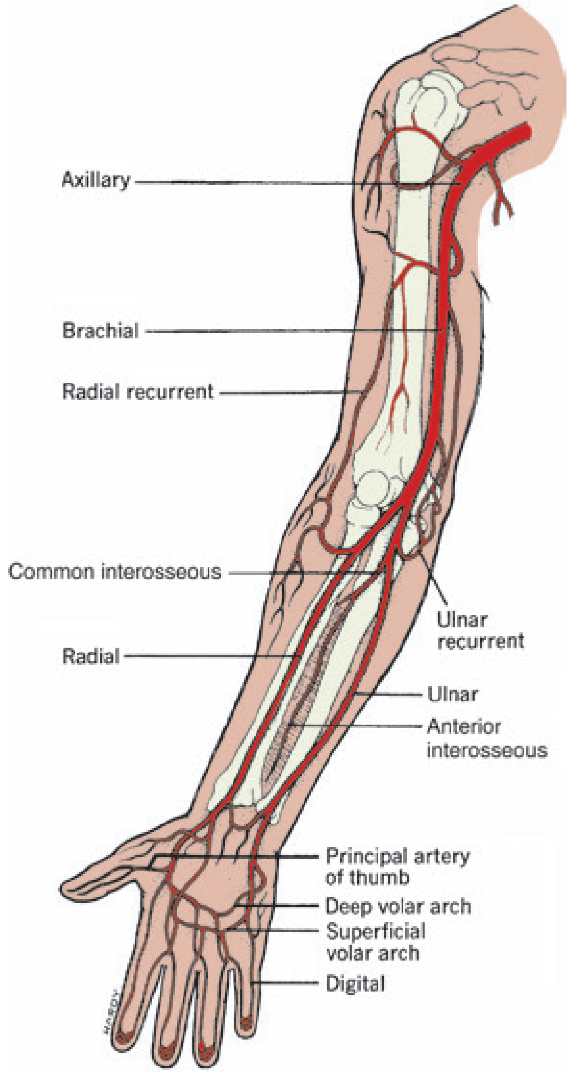

Figure 14-2 Arteries of the arm and hand.

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CAUTION You must verify adequate circulation via the ulnar artery before puncturing the radial artery. If ulnar blood flow is weak or absent, *do not* puncture the radial artery.

FYI The radial artery is named after the radial bone in the lateral aspect (thumb side) of the lower arm, and the ulnar artery is named after the ulna, the large bone in the lower arm on the side opposite the thumb.

Disadvantages

Disadvantages of using the radial artery for collecting ABG and other arterial specimens include the following:

- Considerable skill is required to puncture the radial artery successfully because of its small size.

- It may be difficult or impossible to locate on patients with **hypovolemia** (decreased blood or fluid volume) or low cardiac output.

FYI Cardiac output is the amount of blood pumped by the heart in 1 minute, which for the average adult is 5–8 L.

The Brachial Artery

The **brachial artery** (see Figure 14-2) is the second choice for arterial puncture. It is an alternative artery for arterial puncture if the radial arteries are not available. It is located in the medial anterior aspect of the antecubital fossa near the attachment of the biceps muscle.

KEY POINT The brachial pulse can be felt just above the bend of the elbow on the inside of the arm, approximately in line with the ring finger.

Advantages

Advantages of using the brachial artery to collect ABGs and other arterial specimens include the following:

- It is large and relatively easy to locate and palpate.
- It is sometimes the preferred artery if a large volume of blood must be collected.
- It is often less painful than a radial artery puncture.

Disadvantages

Disadvantages of using the brachial artery to collect ABGs and other arterial specimens include the following:

- It has no direct collateral circulation and should be used with caution.
- It is deeper and can be harder to puncture than the radial artery.
- It may be difficult to palpate on obese patients.
- It lies close to the basilic vein, which could result in obtaining a venous sample by mistake.
- It also lies close to the median nerve, which, if accidentally hit by the needle, could cause the patient to experience extreme discomfort and possible nerve damage.
- Unlike the radial artery, no underlying ligaments or bone support compression of the brachial artery, resulting in an increased risk of hematoma formation following the procedure. A hematoma in this area can cause compression injuries to the brachial artery and the median nerve.

MEMORY JOGGER The brachial artery lies medial to the biceps tendon, and the median nerve lies medial to the brachial artery. The mnemonic TAN can help you remember this order. Starting from the antecubital area, "T" stands for tendon, "A" for artery, and "N" for nerve.

KEY POINT According to the Clinical and Laboratory Standards Institute (CLSI), the brachial artery in children, especially infants, is not commonly used because it is harder to palpate and lacks adequate collateral circulation.[1]

The Femoral Artery

The **femoral artery** (**Figure 14-3**) is the largest artery used for arterial puncture. It is located superficially in the groin, lateral to the pubic bone. Femoral puncture is performed primarily by physicians and specially trained emergency room personnel and is generally used only in emergency situations or when no other site is available.

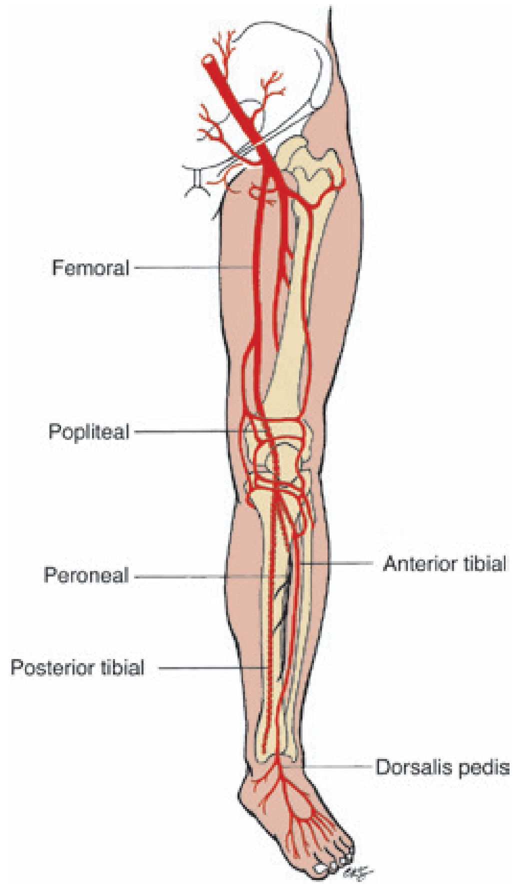

Figure 14-3 Arteries of the leg.

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WORKBOOK See the leg labeling exercise in WORKBOOK Labeling Exercise 14-1.

Advantages

Advantages of using the femoral artery to collect ABGs and other arterial specimens include the following:

- It is large and easily palpated and punctured.
- It is sometimes the only site where arterial sampling is possible, especially on patients who are hypovolemic or have low cardiac output, or during cardiac resuscitation.

Disadvantages

Disadvantages of using the femoral artery to collect ABGs and other arterial specimens include the following:

- It has poor collateral circulation.
- It lies close to the femoral vein, which may be inadvertently punctured and result in the collection of a venous specimen instead of an arterial one.
- There is increased risk of infection and difficulty in achieving aseptic technique because of its location and the presence of pubic hair.
- Dislodging plaque buildup from the inner artery walls of older patients is a possibility.
- The femoral artery requires extended monitoring for hematoma formation or hemorrhage after puncture.

Other Sites

Other sites where arterial specimens may be obtained include the scalp, umbilical, and posterior tibial arteries in infants, and the dorsalis pedis arteries in adults. The phlebotomist is not normally trained to perform arterial punctures at these locations or to obtain specimens from cannulas, catheters, or other indwelling devices at these or any other locations.

Arterial Blood Gases

As mentioned, the main reason for performing arterial puncture is to obtain blood specimens for ABGs, which are collected to evaluate respiratory function. Arterial blood is the best specimen for evaluating respiratory function because of its normally high oxygen content and consistency of composition.

ABG evaluation is used in the diagnosis and management of respiratory disorders such as lung disease to provide information about a patient's oxygenation, ventilation (air entering and leaving the lungs), and acid–base balance. It is also used in the management of electrolyte and acid–base balance in patients with diabetes and other metabolic disorders, and in critically ill and injured patients who need respiratory intervention.

FYI Capillary blood, which is similar to arterial blood in composition if the puncture site is warmed before specimen collection, is sometimes used for blood gas analysis, especially in infants.

KEY POINT One sign that ABG testing is needed is **hypoxia** (low levels of oxygen in the tissues), which causes symptoms such as confusion, difficulty breathing, and cyanosis.

ABG specimens are very sensitive to the effects of preanalytical/preexamination errors; therefore, accurate patient assessment and proper specimen collection and handling are necessary to ensure accurate results.

KEY POINT For accurate results, an ABG specimen must not be exposed to air. Consequently, the specimen must be collected in an **anaerobic** (without air) manner, which must be maintained throughout the collection, handling, and testing process.

Most ABG testing instruments directly measure hydrogen ion activity (pH), partial pressure of carbon dioxide ($PaCO_2$), and partial pressure of oxygen (PaO_2). Values for plasma bicarbonate (HCO_3), base excess (or deficit), and oxygen (O_2) saturation can be determined by calculation. Other clinically useful analytes that may be measured include total hemoglobin (tHb), oxyhemoglobin saturation (O_2Hb), and saturation of abnormal hemoglobins such as carboxyhemoglobin (COHb) and methemoglobin (metHb).

Table 14-1 provides descriptions and reference ranges of commonly measured ABG analytes. Many instruments also measure other critical care analytes, such as sodium, potassium, chloride, ionized calcium, and glucose, on the same specimen.

WORKBOOK Test yourself on these ranges with WORKBOOK Knowledge Drill 14-7.

Table 14-1 Commonly Measured Arterial Blood Gas Analytes

Analyte	Reference Range	Description
pH	7.35–7.45	A measure of the acidity or alkalinity of the blood; used to identify a condition such as acidosis or alkalosis.
PaO_2	80–100 mm Hg	Partial pressure of oxygen in arterial blood. A measure of how much oxygen is dissolved in the blood. Indicates if ventilation is adequate. Decreased oxygen levels in the blood increase the respiration rate and vice versa.
$PaCO_2$	35–45 mm Hg	Partial pressure of carbon dioxide in arterial blood. A measure of how much carbon dioxide is dissolved in the blood. Evaluates lung function. Increased CO_2 levels in the blood increase the respiratory rate and vice versa. Respiratory disturbances alter $PaCO_2$ levels.
HCO_3	22–26 mEq/L	Bicarbonate. A measure of the amount of bicarbonate in the blood. Evaluates the bicarbonate buffer system of the kidneys. Metabolic and respiratory disturbances alter HCO_3 levels.
O_2 saturation	97–100%	Oxygen saturation. The percent of oxygen bound to hemoglobin. Determines if hemoglobin is carrying the amount of oxygen it is capable of carrying.
Base excess (or deficit)	(−2)–(+2) mEq/L	A calculation of the nonrespiratory part of acid–base balance based on the $PaCO_2$, HCO_3, and hemoglobin.

FYI Some references use the abbreviations "PO_2" and "PCO_2" instead of "PaO_2" and "$PaCO_2$." Although these abbreviations are interchangeable, the latter two are more specific because they refer to the partial pressure of these gases in arterial blood.

ABG Specimen Collection

Test Requisition

As with any other test, a physician's order is needed before ABG specimens are collected. In addition to normal patient identification information, specific information concerning conditions at the time of collection must be documented on the test requisition for meaningful interpretation of results. Such information includes current body temperature, respiratory rate (respiration or breathing rate), ventilation status, and **fraction of inspired oxygen (FiO_2)**, which for room air is 0.21, or prescribed flow rate in **liters per minute (L/M)**. Required requisition information may vary according to regulatory requirements and institutional policy. Typical ABG requisition information is listed in **Box 14-1**.

Equipment and Supplies

Personal Protective Equipment

Because of the possibility of blood spray during arterial puncture, personal protective equipment (PPE) needed by the blood drawer when collecting arterial

Box 14-1 Typical ABG Requisition Information

Required Information

- Patient's full name
- Medical record or identification number
- Age or date of birth
- Room number or other patient location
- Date and time of test collection
- Fraction of inspired oxygen (FiO_2) or flow rate in liters per minute (L/M)
- Body temperature
- Respiration rate
- Clinical indication for specimen collection (e.g., FiO_2 or mechanical ventilation change)
- Blood drawer's initials
- Requesting physician's name

Supplemental Information as Required by Institutional Policy or Regulatory Agencies

- Ventilation status (i.e., breathing spontaneously or mechanically supported)
- Method of ventilation (i.e., pressure support) or delivery (i.e., cannula or mask)
- Sampling site and type of procedure (i.e., arterial or capillary puncture or indwelling catheter)
- Patient activity and position
- Working diagnosis or ICD (International Classification of Diseases) code

specimens includes a fluid-resistant lab coat, gown, or apron; gloves; and face protection.

Specimen Collection Equipment and Supplies

ABG specimen collection equipment (**Figure 14-4**) includes a safety needle, special heparinized syringe, and cap or other devices to plug or cover the syringe after specimen collection to maintain anaerobic conditions.

KEY POINT Needles for radial ABG collection are typically 22-gauge or smaller; larger diameter needles may be too large to access the artery. Although smaller needles (e.g., 25-gauge) lessen pain and the likelihood of arteriospasm and hematoma, they can increase the chance of producing bubbles during the draw and specimen hemolysis.

Commercially available ABG syringes typically contain special filters that vent residual air and seal on contact with blood, or they may have air bubble removal caps that provide a safe way to remove bubbles from the specimen. ABG equipment is commonly available in sterile prepackaged kits that contain a heparinized syringe, capping device, and safety needle. ABG collection equipment and supplies are listed in **Box 14-2**.

KEY POINT ABG specimens are collected in syringes rather than tubes because evacuated tube pressure can affect test results.

Figure 14-4 ABG equipment.

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Box 14-2 ABG Collection Equipment and Supplies

- **Antiseptic** such as isopropanol or chlorhexidine sponges or pads for site cleaning.
- **Local anesthetic** to numb the site (optional); 1% lidocaine without epinephrine is recommended.
- **1- or 2-mL plastic syringe** with a 25- or 26-gauge 1/2- to 5/8-in.-long needle for administration of anesthetic solution (optional). Either the syringe or the needle should contain a safety device to prevent accidental needlesticks.
- **Sharp, short-bevel hypodermic needle** in 20- to 23-gauge or 25-gauge and 5/8 to 1 1/2 in. in length, depending on the collection site, the size of the artery, and the amount of blood needed. Typically, a 22-gauge 1-in. needle is used for radial and brachial puncture, and a 22-gauge 1 1/2-in. needle is used for femoral puncture. The needle should have a safety feature to prevent accidental needlesticks or be used with a safety syringe or other collection devices with a safety feature.
- **Special glass or plastic 1- to 5-mL self-filling syringe** or other collection device (prefilled with the appropriate amount and type of dry lyophilized heparin salt) selected according to the type of tests ordered, the method of analysis, and the amount of blood required. The syringe or other collection device should contain a safety feature to prevent accidental needlesticks or be used with a safety needle.
- **Luer-tip normal or bubble removal cap** or other suitable device to cover the end of the syringe after needle removal to maintain anaerobic conditions within the specimen.
- When applicable, coolant capable of maintaining the specimen at a temperature between 1° and 5°C to slow the metabolism of white blood cells (WBCs), which consume oxygen. (A container of crushed ice and water large enough to completely submerge the syringe barrel is typically used.)
- **2- × 2-in. gauze squares** or pads to hold pressure over the site until bleeding has stopped.
- **Self-adhering gauze bandage** to wrap the site after bleeding has stopped.
- **Identification and labeling materials** such as waterproof labels and indelible ink pens or markers.
- **Puncture-resistant sharps container** to dispose of used needles and syringes.

Patient Preparation

Identification and Explanation of Procedures

The blood drawer must properly identify the patient (see Chapter 8), explain the procedure, and obtain the patient's consent. The patient must be treated in a pleasant, professional, and reassuring manner to minimize apprehension or anxiety. Anxiety can lead to hyperventilation, breath holding, or crying, which can compromise test results by lowering $PaCO_2$ and increasing pH.

KEY POINT Being well organized and proceeding without delay can help to minimize patient anxiety.

Patient Preparation and Assessment

The patient must be relaxed and in a comfortable position. They should be lying in bed or seated comfortably in a chair for a minimum of 5 minutes or until breathing has stabilized. (Outpatients may take longer to stabilize.) Required collection conditions must be verified and documented on the requisition per institution policy. In addition, it should be determined whether the patient is on anticoagulant therapy. If an anesthetic is to be used, it should be confirmed that the patient is not allergic to it.

Steady State

Current body temperature, breathing pattern, and the concentration of oxygen inhaled affect the amount of oxygen and carbon dioxide in the blood. Consequently, a patient should have been in a stable or **steady state** (i.e., no exercise, suctioning, or respirator changes) for at least 20–30 minutes before the blood gas specimen is obtained. This is especially important for patients with abnormal respiratory function, such as those with chronic lung disease. Except for certain emergency situations, ABG collection should not be performed until a steady state that meets required collection conditions has been achieved. If steady state has not been reached, results may not reflect the true status of the patient.

VIDEO Check out the Modified Allen Test Procedure video at the Navigate Premier site that accompanies this textbook.

Modified Allen Test

It must be determined that the patient has collateral circulation via the ulnar artery before arterial puncture is performed. The **modified Allen test** is an easy way to assess collateral circulation before collecting a blood specimen from the radial artery. It is performed without the use of special equipment. A positive test result means that the ulnar artery is freely open and able to supply blood circulation to the arm. If the test result is positive, arterial puncture can be performed on the radial artery. A negative test result means that the ulnar artery cannot supply adequate blood flow to the arm if the radial artery is inadvertently damaged during arterial puncture. If the test is negative, arterial puncture should not be performed on that arm, and the patient's nurse or physician should be notified of the problem. The procedure for the modified Allen test is described in **Procedure 14-1**.

FYI The Allen test was named after Edgar V. Allen, a physician who proposed it as a noninvasive way to evaluate arterial blood flow to the hands in patients with an inflammatory condition that affected arteries and veins in the hands and feet. Both hands were tested at the same time in the original test. The test was altered in 1952 to test the collateral circulation of one hand, becoming what is now known as the modified Allen test.

PROCEDURE 14-1 Modified Allen Test

PURPOSE: To assess collateral circulation through the ulnar artery

EQUIPMENT: None

Step	Explanation
1. Have the patient make a tight fist.	A tight fist partially forces blood from the hand and blocks blood flow, causing temporary blanching until the hand is opened.

(continues)

PROCEDURE 14-1 Modified Allen Test *(continued)*

Step	Explanation
2. Use the middle and index fingers of both hands to apply pressure to the patient's wrist, compressing both the radial and ulnar arteries at the same time.  © Wolters Kluwer.	Pressure over both arteries is needed to obstruct blood flow, which is required to assess blood return when pressure is released. **Note:** If the patient is unable to make a fist, the hand can be held above heart level for 30–60 seconds during Steps 2 and 3.
3. While maintaining pressure, have the patient open the hand slowly. It should appear blanched or drained of color.  © Wolters Kluwer.	A blanched appearance of the hand verifies temporary blockage of both arteries. **Note:** The patient must not hyperextend the fingers when opening the hand because this can cause decreased blood flow and misinterpretation of results.
4. Lower patient's hand and release pressure on the ulnar artery only.	The ulnar artery is released while the radial is still obstructed to determine whether the ulnar artery will be able to provide blood flow if the radial artery is injured during ABG collection.
5. Assess Results *Positive Allen test result*: The hand flushes pink or returns to normal color within 15 seconds.  © Wolters Kluwer.	A positive test result indicates return of blood to the hand via the ulnar artery and the presence of collateral circulation. If the Allen test result is positive, proceed with ABG collection.

PROCEDURE 14-1 Modified Allen Test *(continued)*

Step	Explanation
Negative Allen test result: The hand *does not* flush pink or return to normal color within 15 seconds.	A negative test result indicates inability of the ulnar artery to adequately supply blood to the hand, and therefore the absence of collateral circulation. If the Allen test result is negative, the radial artery should not be used, and another site must be selected.
6. Record results on the requisition.	Verification that the Allen test was performed.

KEY POINT For many tests, a negative result is good; this is *not* the case with the modified Allen test. For this test of collateral circulation, a negative test result is *not* good because it means the patient does not have collateral circulation. It also means that another site must be chosen for the arterial specimen collection.

WORKBOOK Do WORKBOOK Skills Drill 14-3 to reinforce your mastery of the steps of the Allen test procedure.

Administration of Local Anesthetic

The advent of improved thin-walled needles has made the routine administration of anesthetic (a drug that dulls pain by causing loss of sensation) before arterial puncture unnecessary. However, it may be a reassuring option for some patients, especially children, who are fearful of the procedure. A fearful patient may respond by breath holding, crying, or hyperventilating, all of which may affect blood gas results. In addition to minimizing or preventing such patient reactions, local anesthesia may also prevent vasoconstriction. The recommended local anesthetic for ABG collection is 1% lidocaine without epinephrine; however, it may cause prolonged bleeding in patients on anticoagulant therapy. Consequently, a physician's order is generally required before an anesthetic is used. The procedure for preparing and administering local anesthetic is described in **Procedure 14-2**.

KEY POINT Administration of lidocaine may dampen the strength of the palpable pulse.

PROCEDURE 14-2 Preparing and Administering Local Anesthetic

PURPOSE: To prepare and administer local anesthetic prior to arterial puncture

EQUIPMENT: Gloves, 25- to 26-gauge needle,[a] 1-mL syringe,[a] 1% epinephrine-free lidocaine, alcohol wipes, sharps container

Step	Rationale
1. Verify absence of allergy to anesthetic or its derivatives.	Allergy to lidocaine or its derivatives can cause a life-threatening reaction.
2. Sanitize hands and put on gloves.	Hand hygiene aids in infection control. Gloves provide a barrier to blood-borne pathogen exposure.
3. Attach needle to the syringe.	A safety needle (or syringe with a safety device) must be used to reduce the chance of accidental needlestick.
4. Clean stopper of anesthetic bottle with an isopropyl alcohol wipe.	The stopper must be cleaned with an antiseptic to prevent contamination.

(continues)

PROCEDURE 14-2 Preparing and Administering Local Anesthetic (*continued*)

Step	Rationale
5. Insert needle through bottle stopper and withdraw anesthetic.	0.25–0.5 mL of lidocaine is adequate for most adult applications.
6. Carefully replace needle cap and leave the syringe in a horizontal position.	Protects needle sterility and prevents contamination and leakage of the anesthetic.
7. Clean and air-dry site. Cleaning the site with antiseptic helps avoid contaminating the patient with skin-surface bacteria picked up during needle entry.	Letting the site dry naturally permits maximal antiseptic action, prevents contamination caused by wiping, and avoids stinging on needle entry from residual alcohol.
8. Insert needle of anesthetic syringe into the intradermal layer of skin over proposed arterial puncture site at an angle of approximately 10 degrees.	The anesthetic must be injected directly over the puncture site for optimal effect.
9. Pull back slightly on the plunger.	Verifies that a vein was not inadvertently penetrated. (If blood appears in the syringe, withdraw the needle, discard both needle and syringe, prepare a fresh needle and syringe, and repeat the procedure in a slightly different spot.)
10. Slowly expel contents into the skin, forming a raised wheal.	Appearance of the wheal verifies proper application of the anesthetic.
11. Withdraw needle, and immediately activate needle safety device.	Immediate activation of needle safety device helps prevent accidental needlesticks.
12. Discard needle and syringe as a unit in sharps container.	Discarding the needle and syringe as a unit is a safety protocol.
13. Wait 1–2 minutes before proceeding with arterial puncture.	It takes 1–2 minutes for the anesthetic to take full effect. (The anesthetic wears off in 15–20 minutes.)
14. Note anesthetic application on the requisition.	Use of anesthetic must be documented on the requisition.

[a]Either the needle or syringe must have a safety feature to prevent needlesticks.

CAUTION Some individuals are allergic to lidocaine and its derivatives, so the absence of allergy must be determined before it is used.

Radial ABG Procedure

Puncture of the radial artery can be performed only if it is determined that there is collateral circulation provided by the ulnar artery and the site meets other selection criteria previously described. The major points of radial ABG procedure are explained next.

Position the Arm

Position the patient's arm out to the side, away from the body (**abducted**), with the palm facing up and the wrist supported. (Place a rolled towel under the wrist to provide support.) Ask the patient to extend the wrist at approximately a 30-degree angle to bring the artery closer to the surface of the skin, and stretch and fix the tissue over the ligaments and bone of the wrist.

Locate the Artery

Use the index finger of your nondominant hand to locate the radial artery pulse proximal to the skin crease on the thumb side of the wrist. Palpate the artery to determine its size, direction, and depth. Take your time palpating the artery to verify the optimal point of entry, which is where the pulse is strongest. It may be necessary to use ultrasound to find the artery if the pulse is weak.

CAUTION *Never* use the thumb to palpate because it has its own pulse, which can be misleading.

Clean the Site

Prepare the site by cleaning it with alcohol or another appropriate antiseptic. Allow the site to air-dry, being careful not to touch it with any unsterile object.

Prepare Equipment

Attach a safety needle to a preheparinized syringe unless the needle and syringe are preassembled, and set the syringe plunger to the proper fill level if applicable. Put on gloves if they were not previously put on, and clean the gloved nondominant finger so that it does not contaminate the site when relocating the pulse before needle entry.

Insert the Needle

Pick up and hold the syringe or collection device in your dominant hand as if you were holding a dart. Uncap and inspect the needle for defects. (Discard and replace it if flawed.) Relocate the artery by placing the index finger of the opposite hand directly over the pulse. Ask the patient to keep the wrist extended but relaxed as much as possible during the procedure. Warn the patient of imminent puncture. Direct the needle away from the hand, facing into the arterial blood flow, and insert it bevel-up into the skin at a 45-degree angle (femoral puncture requires a 90-degree angle) approximately 5–10 mm distal to the index finger that is locating the pulse.

CAUTION *Do not* direct the needle toward the side of the wrist because the radial nerve lies lateral to the radial artery.

Advance the Needle into the Artery

Slowly advance the needle, directing it toward the pulse beneath your index finger. When the artery is pierced, a "flash" of blood will appear in the needle hub. When the flash appears, stop advancing the needle. *Do not* pull back on the syringe plunger. The blood will pump, or pulse, into the syringe under its own power unless a needle smaller than a 23-gauge is used or the patient has low cardiac output. In either case, a gentle pull on the plunger may be required. Hold the syringe very steady until the desired amount of blood (typically 2–3 mL) is collected. If the artery is missed, slowly withdraw the needle until the bevel is just under the skin before redirecting the needle into the artery.

CAUTION *Do not* probe. Probing is painful and can damage the artery or cause hematoma or thrombus formation.

Withdraw the Needle and Apply Pressure

When the desired amount of blood has been obtained, withdraw the needle, immediately place a folded clean and dry gauze square over the site with one hand, and simultaneously activate the needle safety device with the other hand. Apply firm pressure to the puncture site for a minimum of 3–5 minutes. Longer application of pressure is required for patients on anticoagulant therapy or those with coagulation disorders.

CAUTION *Never* allow the patient to apply the pressure; a patient may not apply it firmly enough. In addition, *do not* replace use of manual pressure for the required length of time with the application of a pressure bandage.

Remove Air, Cap Syringe, and Mix Specimen

While applying pressure to the site with one hand, use your free hand to remove the safety needle and discard it into a sharps container. Handle the specimen carefully to avoid introducing air bubbles into it because they can affect test results. Hold the syringe upright, and gently tap it to allow any air bubbles to rise to the top. If any air bubbles are present, immediately eject them from the specimen. Air bubbles in the sample will negatively affect test results. If the equipment has an air bubble removal cap, follow manufacturer's instructions. Cap the syringe and gently but thoroughly mix the specimen by inversion or rotation to prevent clot formation. Label the specimen.

FYI Testing with a point-of-care testing (POCT) instrument (e.g., i-STAT®) is performed according to manufacturer's instructions immediately after air bubble removal. Results are typically recorded by the instrument and transmitted to the lab automatically.

Check the Site

After applying pressure for 3–5 minutes, check the site. The skin below the site should be normal in color and warm to the touch, with no evidence of bleeding or swelling. If bleeding, swelling, or bruising is noted, reapply pressure for an additional 2 minutes. Repeat this process if necessary until you are certain that bleeding has stopped.

CAUTION *Never* leave the patient if the site is still bleeding. If bleeding does not stop within a reasonable time (e.g., after several additional 2-minute pressure applications), notify the patient's nurse or physician.

If bleeding has stopped and the site appears normal, check the pulse distal to the site. If the pulse is absent or faint, or the patient complains of numbness at the site, alert the patient's nurse or physician immediately because a thrombus may be blocking blood flow. If the site appears normal and the pulse is normal, apply an elastic bandage with moderate pressure and make a notation as to when the bandage may be removed; this should not exceed 15 minutes.

Wrap-Up Procedures

Make certain the specimen has been properly labeled before leaving the patient's bedside. Dispose of used equipment properly. Remove gloves and face protection, and wash or decontaminate hands with sanitizer. Thank the patient. If ABG testing has already been performed by POCT instrumentation, verify that the results have been recorded and transmitted to the lab, and omit the last step (transportation and handling).

WORKBOOK Complete Workbook Skills Drill 14-4 to see how well you know the steps of radial ABG collection.

Transportation and Handling

Transport the specimen according to laboratory protocol and deliver it to the laboratory as soon as possible. Most testing sites require delivery within 15 minutes of collection. According to CLSI, blood gas specimens collected in plastic ABG syringes can be transported at room temperature, provided that the specimen will be analyzed within 30 minutes.[1] If the patient has an elevated leukocyte or platelet count, the specimen should be analyzed within 5 minutes of collection. If a delay in analysis is expected beyond either of the mentioned limits, the specimen should be collected in a heparinized glass syringe and cooled as soon as possible by placing it in ice slurry. Specimens for electrolyte testing in addition to ABG evaluation should not be cooled because cooling affects the diffusion of potassium (an electrolyte) in and out of the cells and makes potassium results unreliable. Such specimens should be transported and tested as soon as possible. The complete procedure for collection of radial ABGs is shown in **Procedure 14-3**.

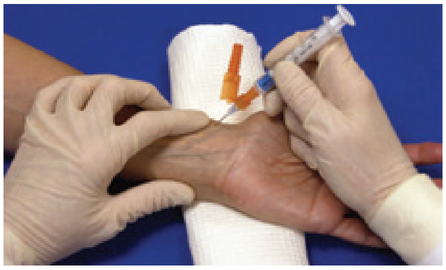
PROCEDURE 14-3 Radial ABG Procedure

PURPOSE: To obtain an ABG specimen from the radial artery by syringe

EQUIPMENT: Gloves, antiseptic prep pads, heparinized blood gas syringe, cap and appropriate needle, gauze pads, self-adhesive bandaging material, permanent ink pen, coolant if applicable, sharps container

Step	Rationale
1. Receive and accession test request.	The requisition must be reviewed for completeness of information and required collection conditions, such as oxygen delivery system and FiO_2 or L/M.
2. Approach, identify, obtain consent from, and prepare patient.	Correct approach to the patient, identification, obtaining consent, and preparation are essential. Preparing the patient by explaining the procedure in a calm and reassuring manner encourages cooperation and reduces apprehension. (Hyperventilation due to anxiety, breath holding, or crying can alter test results.)
3. Check for sensitivities to latex and other substances.	Increasing numbers of individuals are allergic to latex, antiseptics, and other substances.
4. Assess steady state, verify collection requirements, and record required information.	Required collection conditions must be met and must not have changed for 20–30 minutes before collection. Test results can be meaningless or misinterpreted and patient care compromised if conditions have not been met. The patient's temperature, respiratory rate, and FiO_2 affect blood gas results and must be recorded along with other required information.
5. Sanitize hands, and put on gloves.	Proper hand hygiene plays a major role in infection control, protecting the phlebotomist, patient, and others from contamination. Gloves provide a barrier to blood-borne pathogen exposure. Gloves may be put on at this point or later, depending on hospital protocol.

PROCEDURE 14-3 Radial ABG Procedure (*continued*)

Step	Rationale
6. Assess collateral circulation.  © Wolters Kluwer.	Collateral circulation must be verified by the modified Allen test, an ultrasonic flow indicator, or both. Proceed if the result is positive; choose another site if negative.
7. Position arm, and ask patient to extend wrist.	The arm should be abducted with the palm up and the wrist extended approximately 30 degrees to stretch and fix the soft tissues over the firm ligaments and bone. (Avoid hyperextension because it can eliminate a palpable pulse.)
8. Locate radial artery, and clean the site.	The index finger is used to locate the radial pulse proximal to the skin crease on the thumb side of the wrist; palpate it to determine size, depth, and direction. An arterial puncture site is typically cleaned with alcohol or another appropriate antiseptic and must not be touched again until the phlebotomist is ready to access the artery.
9. Administer local anesthetic (optional).	See Procedure 14-2. Document anesthetic application on the requisition.
10. Prepare equipment and clean gloved nondominant finger.	Assemble ABG equipment and set the syringe plunger to the proper fill level if applicable. Gloves must be put on at this point (if not done already) and the nondominant finger cleaned so that it does not contaminate the site when relocating the pulse before needle entry.
11. Pick up equipment and uncap and inspect needle.	The syringe is held in the dominant hand as if holding a dart. The needle must be inspected for defects and replaced if any are found.
12. Relocate radial artery, ask patient to relax the wrist, and warn patient of imminent puncture.	The artery is relocated by placing the nondominant index finger directly over the pulse. Warning the patient helps prevent a startle reflex. A relaxed fist ensures smooth needle entry.
13. Insert needle at a 45-degree angle, slowly direct it toward the pulse, and stop when a flash of blood appears.  © Wolters Kluwer.	A needle inserted at a 45-degree angle, 5–10 mm distal to the finger that is over the pulse should contact the artery directly under that finger. When the artery is entered, a flash of blood normally appears in the needle hub or syringe. **Note:** If a needle smaller than a 23-gauge is used, it may be necessary to pull gently on the syringe plunger to obtain blood flow.

(continues)

PROCEDURE 14-3	Radial ABG Procedure (*continued*)
Step	**Rationale**
14. Allow syringe to fill to proper level.	Blood will normally fill the syringe under its own power, which is a sign that the specimen is indeed arterial blood (see exception in Step 13).
15. Place gauze, remove needle, activate safety feature, and apply pressure.	A clean folded gauze square is placed over the site so that firm manual pressure can be applied by the phlebotomist immediately on needle removal and for 3–5 minutes thereafter. The needle safety device must be activated as soon as possible to prevent an accidental needlestick.
16. Remove and discard syringe needle.	For safety reasons, the specimen must not be transported with the needle attached to the syringe. The needle must be removed and discarded in the sharps container with one hand while site pressure is applied with the other.
17. Expel air bubbles, cap syringe, mix and label specimen.  © Wolters Kluwer.	Air bubbles in the specimen can affect test results and must be expelled per manufacturer's instructions. While the phlebotomist is still holding pressure, the specimen must be capped to maintain anaerobic conditions, mixed thoroughly by inversion or rotating to prevent clotting, and labeled with the required information.
18. Check patient's arm, and apply bandage.	The site is checked for swelling or bruising after pressure has been applied for 3–5 minutes. If the site is warm and appears normal, the pulse is checked distal to the site to confirm normal blood flow. If pulse and site are normal, an elastic bandage is applied with moderate pressure, and the time that it should be removed is noted. **Note:** If the pulse is weak or absent, the patient's nurse or physician must be notified immediately.
19. Dispose of used and contaminated materials, remove gloves, and sanitize hands.	Used and contaminated items must be disposed of per facility protocol. Gloves must be removed and hands sanitized as an infection control precaution.
20. Thank patient, and transport specimen to the lab as soon as possible.	Thanking the patient is courteous and professional behavior. Prompt delivery of the specimen to the lab protects specimen integrity.

KEY POINT WBCs and platelets in a blood specimen continue to consume oxygen. A high WBC or platelet count means that oxygen will be consumed at a higher rate than in a specimen with a normal WBC or platelet count. The rate of oxygen consumed depends on handling temperature, length of time involved, and the amount of oxygen in the specimen initially. Cooling slows down oxygen consumption by the cells.

ABG Collection from Other Sites

Collection of ABGs from brachial, femoral, and other sites is similar to the procedure for radial ABGs. Because phlebotomists are not normally trained to collect specimens from these sites, specific procedures are not given in this text. Phlebotomists may, however, be asked to provide the equipment and assist in labeling and transporting specimens collected from these sites by others (e.g., an emergency room physician).

Hazards and Complications of Arterial Puncture

Arterial puncture, like any invasive procedure, is associated with hazards and complications. Most can be avoided with proper technique, while some cannot be avoided. Complications or other adverse events observed by the blood drawer should be documented and reported to the patient's nurse or physician according to facility protocol. Examples of hazards and complications are described next.

WORKBOOK Quiz yourself on these important points by doing WORKBOOK Knowledge Drill 14-4.

Arteriospasm

Pain or irritation caused by needle penetration of the artery muscle and even patient anxiety can cause a reflex (involuntary) contraction of the artery, referred to as an **arteriospasm**. The condition is transitory but may make it difficult to obtain a specimen. To help minimize the chance of arteriospasm, reassure the patient by fully explaining the procedure and its purpose, and answering questions to help relieve patient anxiety.

Artery Damage

Repeated punctures at the same site can damage the artery, resulting in swelling, which can lead to partial or complete occlusion (blockage or obstruction) of the vessel. In rare cases, repeated punctures have led to aneurysm (a blood-filled bulge from a weakened wall) of the artery.

Discomfort

Some discomfort is generally associated with arterial puncture, even with the use of a local anesthetic. Usually this is minor and temporary. Extreme pain during arterial puncture may indicate nerve involvement, in which case the procedure should be terminated.

Hematoma

Blood is under considerable pressure in arteries and is initially more likely to leak from an arterial puncture site than a venipuncture site. Fortunately, arterial puncture sites tend to close more rapidly because of the elastic nature of the arterial wall. The probability of hematoma formation is greater in patients receiving anticoagulant therapy and in older patients, because arterial elasticity normally decreases with age. Multiple punctures to a single site also increase the chance of hematoma formation and should be avoided. Proper site selection, precise needle insertion, and adequate pressure applied by the phlebotomist following needle withdrawal are essential to minimize the risk of hematoma formation.

KEY POINT Needle size also plays a role in hematoma formation. The greater the needle diameter, the larger the puncture opening, the greater the chance of leakage, and the greater the need for precise needle insertion.

Infection

Localized infection can result from improper site preparation, contamination of the site before specimen collection, or choosing a site where inflammation or infection is present. Careful site selection, proper antiseptic preparation of the site, and avoiding activities that can contaminate the site before and after specimen collection minimize the chance of infection.

Numbness

Numbness of the hand or wrist can be a sign of impaired circulation, or nerve irritation or damage due to an error in technique, such as improper redirection of the needle when the artery is missed. Numbness must be addressed immediately by alerting the patient's nurse or physician.

Thrombus Formation

Injury to the intima or inner wall of the artery can lead to **thrombus** (blood clot) formation. A thrombus may grow until it blocks the entire lumen of the artery, obstructing blood flow and impairing circulation. A thrombus can also be the source of an **embolus** (circulating undissolved matter, such as a blood clot), which may cause a thrombus, clot, or **embolism** (obstruction of a blood vessel by an embolus) to appear in another area of the body. If thrombus formation is suspected, the patient's nurse or physician must be alerted immediately.

Vasovagal Response

A **vasovagal response**—faintness or loss of consciousness related to hypotension caused by a nervous system response (increased vagus nerve activity)—or abrupt pain or trauma can occur during arterial puncture. If a patient feels faint or faints during arterial puncture, remove the needle immediately, activate the safety device, hold pressure over the site, and follow syncope procedures (these are discussed in Chapter 9)

WORKBOOK Have some fun and see if you can find vasovagal among the scrambled words in WORKBOOK Knowledge Drill 14-2.

Sampling Errors

Factors that can affect the integrity of a blood gas sample and lead to erroneous results include the following.

Air Bubbles

Air bubbles must be immediately and completely expelled from the sample; oxygen from the air bubbles can diffuse into the sample and CO_2 can escape from the sample, compromising test results.

KEY POINT Secure attachment of the needle to the syringe can help minimize the chance of air bubble production.

Delay in Analysis

Blood cells continue to metabolize or consume oxygen and nutrients and to produce acids and carbon dioxide in the specimen at room temperature. In addition, blood gases can diffuse through the plastic wall of the syringe. If the specimen remains at room temperature for more than 30 minutes, the pH, blood gas, and glucose values will not accurately reflect the patient's status. Processing the specimen as soon as possible after it is collected helps ensure the most accurate results. Optimal time of analysis is within 10 minutes of collection.

Improper Mixing

Inadequate or delayed mixing of the sample can lead to clotting, making the sample unacceptable for testing. Undetected microclots can lead to erroneous results and ABG instrument malfunction.

Improper Syringe

Use only syringes especially designed for ABG procedures. The use of regular plastic syringes will lead to erroneous values. Use of commercially available ABG kits can eliminate this source of error.

Obtaining Venous Blood by Mistake

Markedly inaccurate ABG values will result if a venous sample is obtained by mistake. Normal arterial blood is bright red in color, whereas venous blood is a darker bluish-red color. However, it is sometimes difficult to distinguish between arterial and venous blood in poorly ventilated patients because their arterial blood may appear as dark as venous blood. The best way to ascertain that a specimen is arterial is to observe the blood pulsing into the syringe. In some instances, such as low cardiac output, a specimen may have to be aspirated (withdrawn by pulling back the syringe plunger). In these cases, it is difficult to be certain that the specimen is truly arterial.

Use of Improper Anticoagulant

Heparin is the accepted anticoagulant for blood gas specimens. Oxalates, ethylenediaminetetraacetic acid (EDTA), and citrates may alter results, especially pH. Use of commercially available ABG kits, which come with heparinized syringes, eliminates this problem.

Use of Too Much or Too Little Heparin

Too much heparin in the syringe can result in acidosis of the specimen and cause erroneous results. Too little heparin can result in clotting of the specimen. Use of commercially available kits that contain preheparinized syringes eliminates this source of error.

Criteria for ABG Specimen Rejection

Improperly collected, handled, or transported ABG specimens can produce erroneous results that negatively affect patient care. Consequently, specimens with obvious problems will be rejected by laboratory personnel. Examples of typical criteria used to reject ABG specimens for analysis are shown in **Box 14-3**.

WORKBOOK Test your grasp of chapter concepts with the WORKBOOK Knowledge Drill 14-3 True/False Activity.

Box 14-3 Typical Criteria for Rejection of ABG Specimen

- Air bubbles in the specimen
- Clotted specimen
- Hemolysis of the specimen (if electrolytes are ordered)
- Improper or absent ID or other labeling requirements
- Improper transportation temperature
- Inadequate volume of specimen for the test (QNS [quantity not sufficient])
- Prolonged delay in delivery to the lab
- Wrong type of syringe used

Study and Review Questions

EXAM REVIEW See the EXAM REVIEW for more study questions.

1. The primary reason for performing arterial puncture is to:
   a. determine hemoglobin levels.
   b. evaluate arterial blood gases.
   c. measure potassium levels.
   d. obtain calcium values.

2. The first-choice location for performing arterial puncture is the:
   a. brachial artery.
   b. ulnar artery.
   c. femoral artery.
   d. radial artery.

3. ABG supplies include:
   a. 18-gauge needles.
   b. antibiotic bandages.
   c. heparinized syringes.
   d. nonlatex tourniquets.

4. Commonly measured ABG parameters include:
   a. chloride.
   b. glucose.
   c. $PaCO_2$.
   d. sodium.

5. A phlebotomist has a request to collect an ABG specimen while the patient is breathing room air. When the phlebotomist arrives to collect the specimen, the patient is still on a ventilator. What should the phlebotomist do?
   a. Call the phlebotomy supervisor and ask how to proceed.
   b. Consult with the patient's nurse to determine what to do.
   c. Draw the ABG and note the oxygen setting on the request.
   d. Take the patient off the ventilator and draw the specimen.

6. The purpose of the modified Allen test is to determine:
   a. blood pressure in the ulnar artery.
   b. whether collateral circulation is present.
   c. whether the patient is absorbing oxygen.
   d. the clotting time of both arteries.

7. Which of the following is an acceptable angle of needle insertion for radial ABGs?
   a. 10 degrees
   b. 20 degrees
   c. 45 degrees
   d. 90 degrees

8. Which of the following complications associated with arterial puncture is caused by abrupt pain or trauma?
   a. Arteriospasm
   b. Hematoma
   c. Numbness
   d. Vasovagal response

9. Which of the following can cause erroneous ABG values?
   a. An air bubble was left in the specimen.
   b. Blood had to be aspirated into the syringe.
   c. The patient fainted during the procedure.
   d. The specimen was mixed by inverting it.

10. Which of the following would cause you to suspect that a thrombus had formed in the artery while you were collecting an ABG?
    a. A hematoma quickly forms at the site.
    b. The patient complains of extreme pain.
    c. Skin surrounding the site is a pale color.
    d. The pulse distal to the site is very weak.

11. Which is the *best* way to determine that a blood specimen is arterial?
    a. It has lots of air bubbles
    b. It is bright red in color
    c. It needs to be aspirated
    d. It pulses into the syringe

12. The term for a reflex contraction of an artery is:
    a. arteriospasm.
    b. hypovolemia.
    c. transitory thrombus.
    d. vasovagal response.

13. Heparin is used in arterial sample collection to:
    a. increase blood flow in the area.
    b. numb the area around the site.
    c. prevent clotting of the specimen.
    d. stabilize the oxygen content.

14. Prior to ABG collection, a patient should have been in a steady state for at least:
    a. 5–10 minutes.
    b. 10–15 minutes.
    c. 15–20 minutes.
    d. 20–30 minutes.

15. When performing the modified Allen test, which artery is released first?
    a. Brachial
    b. Femoral
    c. Radial
    d. Ulnar

Case Studies

WORKBOOK See the WORKBOOK for more case studies.

CASE STUDY 14-1. COMPLICATIONS OF ABG COLLECTION

A phlebotomist has a requisition to collect an ABG specimen from a patient in the cardiac care unit (CCU). The phlebotomist identifies the patient and records the required requisition information. The patient has an IV in the left arm near the wrist, so the phlebotomist chooses the right arm. The patient is having difficulty breathing and appears quite restless and agitated. The phlebotomist performs the modified Allen test. The result is positive. The phlebotomist attempts puncture of the radial artery. The patient moves his arm as the needle is inserted, and it misses the artery. The phlebotomist redirects the needle several times and finally hits the artery. The blood pulses into the syringe but is dark reddish-blue in color. The phlebotomist completes the draw, removes the needle, and holds pressure over the site, at the same time activating the needle safety device, removing the needle, and capping the syringe, being careful not to introduce air bubbles into it. After holding pressure for 5 minutes, the phlebotomist checks the pulse distal to the site. The pulse is barely discernible.

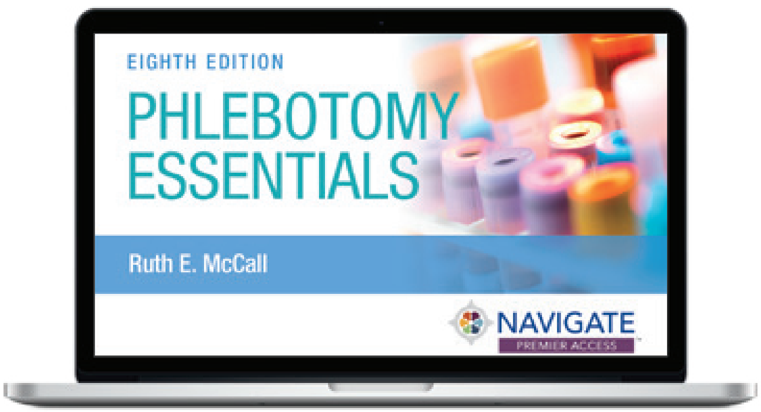
Questions

1. What should the phlebotomist do if the pulse is barely discernible?
2. What might be affecting the pulse?
3. How might the patient have contributed to the problem?
4. How might the phlebotomist's technique have contributed to the problem?
5. Can the phlebotomist be certain that the specimen is arterial?

Navigate

To support your learning, review the online materials. The Navigate Premier Access included with each new print copy of this book offers a wealth of resources. These include:

- eBook with interactive questions
- Videos
- TestPrep
- Audio glossary
- Terminology flashcards
- Open educational resources
- Math practice
- Slides in PowerPoint format
- And more!



Review this skill video for this chapter:

- Modified Allen Test Procedure

Other resources available for separate purchase include these excellent resources:

- *Phlebotomy Exam Review, Eighth Edition*—certification-style questions to prepare for testing. Includes a comprehensive mock exam, and a pretest with detailed explanations and analysis to evaluate your knowledge, an online exam simulator, and much more.
- *Student Workbook for Phlebotomy Essentials, Eighth Edition*—a variety of exercises to remember essential information and enhance critical thinking skills, including matching, labeling exercises, knowledge and skills drills, crossword puzzles, review questions, and case studies.

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