

Procedures for the Collection of Arterial Blood Specimens; Approved Standard— Fourth Edition



This document provides principles for collecting, handling, and transporting arterial blood specimens to assist with reducing collection hazards and ensuring the integrity of the arterial specimen.

A standard for global application developed through the NCCLS consensus process.



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Abstract

Collection of a blood specimen, as well as its handling and transport, are key factors in the clinical laboratory analysis and ultimately in delivering quality patient care. NCCLS document H11—*Procedures for the Collection of Arterial Blood Specimens* serves a dual purpose: to reduce the potential hazard to the patient and to maintain the integrity of the arterial blood specimen. Collecting arterial blood is not only technically difficult but also imposes a degree of risk for the patient. Arterial blood is also one of the specimens most sensitive to preanalytic effects. This standard will be particularly valuable to those involved in blood specimen collection, such as clinical laboratory directors, respiratory therapists, physicians, physicians in training, nurses, medical technologists, exercise physiologists, phlebotomists, and perfusionists.

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Foreword

This standard has been written for use by clinical laboratory directors, respiratory therapists, medical technologists, physicians, physicians in training, nurses, exercise physiologists, phlebotomists, perfusionists, and any others who may collect or be involved with the collection of arterial blood specimens for clinical laboratory analysis. The preanalytical phase of the laboratory path of workflow includes the collection of blood specimens for clinical laboratory analysis. This is one of the initial critical steps in providing clinical laboratory services for quality patient care. Without the proper and efficient collection of specimens, laboratory results would have little value.

The collection of arterial blood is not only technically difficult, but can be painful and hazardous for the patient. Therefore, it is essential that individuals performing arterial puncture be familiar with the proper techniques, with the hazards/complications of the procedure, and with the necessary precautions.

Arterial blood is one of the specimens most sensitive to preanalytic effects. Improper patient assessment, test requisition, collection or transport of a specimen of arterial blood intended for pH, and blood gas analysis can alter the gas tensions, or pH, or both. In addition to pH/gases analysis, instruments are now available for the specific measurement of pH/gases and other critical care analytes (e.g., sodium, potassium, chloride, ionized calcium, glucose, hematocrit, hemoglobin) on the same arterial whole-blood specimens. Therefore, scrupulous attention to the principles outlined in this standard is mandatory to eliminate a major potential source of erroneous laboratory results.

This publication has been written for the primary purpose of reducing the potential hazards to the patient and increasing the integrity of the arterial blood specimen. The primary focus of this standard is arterial puncture with a discussion of arterial cannulation. While providing some specific guidelines, it is not intended to provide an exhaustive discussion of related subjects, such as pH/blood gas analysis and the technical implications of improper sampling.

NCCLS is dedicated to quality clinical laboratory services, and this standard covers one of the many areas in which standards are being developed to help achieve this end.

The revisions in this version of the H11 standard are intended principally to delineate between quality system essentials (QSEs) related to and the path of work flow for arterial blood collection. The previous edition (H11-A3) was published for wide and thorough review in the NCCLS consensus-review process. The objective of this review was to obtain specific input on the utility and applicability of the recommendations provided for arterial blood collection techniques. However, a “Summary of Consensus Comments” has not been included in this approved, fourth-edition document as all comments received as a result of the consensus review process were editorial in nature.

The Area Committee on Clinical Chemistry and Toxicology urges users to submit comments related to experience in using H11-A4 to assure future editions reflect the “state of the art.”

Key Words

Arterial blood, arterial cannula/catheter, arterial puncture, blood collection, blood gas, blood gas analysis, oxygen tension, pH

Procedures for the Collection of Arterial Blood Specimens; Approved Standard—Fourth Edition

1 Scope

This standard has been written for the primary purpose of reducing the potential hazards to the patient and medical personnel and to increase the clinical usefulness of the arterial blood specimen. It has been written for use by clinical laboratory directors, respiratory therapists, physicians, physicians in training, nurses, exercise physiologists, perfusionists, and any others who may collect, or be involved with the collection of, arterial blood specimens.

It addresses collection of whole blood specimens from arterial sites with emphasis on reducing the potential hazards to the patient and to medical personnel. The specimen collection procedures are intended to provide appropriate whole blood samples for blood gas, electrolyte, and metabolite determinations.

2 Introduction

Arterial blood is the substance presented to all organs for their metabolic needs; its composition is uniform throughout the body. The composition of venous blood is conditioned by the metabolic activity of the tissue which it drains and therefore varies among different parts of the body and at different times (e.g., depending on muscular activity). The largest difference between arterial and venous blood is its oxygen content, but pH, carbon dioxide content, packed cell volume, and the concentrations of lactic acid, plasma chloride, glucose, ammonium and other metabolites also vary. All differences between arterial and venous blood are exaggerated when the general or local circulation is impaired. Arterial blood therefore is the preferred specimen for all these determinations and it is essential for evaluating respiratory and metabolic functions.

All individuals performing arterial puncture should be familiar with the hazards/complications of the procedure and with precautions designed to prevent hazards to the patient or to the laboratorian, or alteration of the results of the laboratory test. For example, anxiety or excitement of the patient alters the breathing pattern which will change the gas tensions within less than a minute. There must be attention to detail in the precollection and postcollection phases of arterial sampling to maintain the integrity of test results.

3 Standard Precautions

Because it is often impossible to know what might be infectious, all patient and laboratory specimens are treated as infectious and handled according to “standard precautions.” Standard precautions are guidelines that combine the major features of “universal precautions and body substance isolation” practices. Standard precautions cover the transmission of all infectious agents and thus are more comprehensive than universal precautions which are intended to apply only to transmission of blood-borne pathogens. Standard and universal precaution guidelines are available from the U.S. Centers for Disease Control and Prevention (*Guideline for Isolation Precautions in Hospitals*. Infection Control and Hospital Epidemiology. CDC. 1996;17(1):53-80 and *MMWR* 1988;37:377-388). For specific precautions for preventing the laboratory transmission of all infectious agents from laboratory instruments and materials and for recommendations for the management of exposure to all infectious disease, refer to the most current edition of NCCLS document [M29](#)—*Protection of Laboratory Workers from Occupationally Acquired Infections*.

4 Definitions

Oxygen content of blood, ctO₂ – The sum of the substance concentrations of the oxygen bound to hemoglobin as O₂Hb plus the amount dissolved in blood (intra- and extracellular).

Partial pressure – *Of a component in a solution*, the pressure that would exist in a hypothetical ideal gas phase, in equilibrium with the solution.

pH – The symbol for the negative (decadic) logarithm of the {relative molal} hydrogen ion activity (α_{H^+}); **NOTE:** Historically, pH arose as a symbol for the “power of hydrogen.”

Sample (patient) – In this document, a sample taken from the patient specimen and used to obtain information by means of a specific laboratory test; **NOTE:** ISO 15189 defines sample as “one or more parts taken from a system, and intended to provide information on the system, often to serve as a basis for decision on the system or its production;” **EXAMPLE:** A volume of serum taken from a larger volume of serum.¹

Specimen – Biological material which is obtained in order to detect or to measure one or more quantities. (EN 375)²

Total carbon dioxide//Total CO₂ – The combination of all of the various forms of carbon dioxide in the plasma in equilibrium with whole blood.

5 Quality System Essentials

5.1 Personnel

Job qualifications, job descriptions, and processes for selection, orientation, training, and assessing the competence and overall performance of personnel should be clearly defined.

There should be a process for training instructors, as well as new and existing employees. Training should be provided for new employees when new procedures are being implemented or changed, and when training needs are identified. (Please refer to NCCLS document [GP21—Training and Competence Assessment](#) for additional information.)

5.2 Process Control/Process Improvement

[Table 1](#) provides examples of substances that may interfere with the measurement of blood gases, electrolytes, and/or other metabolites.³

NOTE: It is critical that the operator check with the manufacturer not only for known or interfering substances, but for assistance in recognizing the effects of a previous unknown material.

Table 1. Interfering Substances for Blood Gas/Electrolyte/Metabolite Systems

| Substance | Blood Gases | Electrolytes | Glucose/Lactate |
|--|-------------|--------------|-----------------|
| Ice (cooling) | 0 | + | 0 |
| Excessive heparin ^{4,a} | + | + | 0 |
| Sodium thiopental | pH | + | 0 |
| Benzalkonium chloride | pH | + | 0 |
| Ascorbic acid | 0 | 0 | ± |
| Uric acid | 0 | 0 | ± |
| Dopamine | 0 | 0 | ± |
| Dobutamine | 0 | 0 | ± |
| Flaxedil | 0 | 0 | + |
| Ethanol | 0 | 0 | + |
| Acetaminophen | 0 | 0 | ± |
| Isoniazide | 0 | 0 | ± |
| Thiocyanate | 0 | 0 | ± |
| Hydroxyurea | 0 | 0 | ± |
| Sodium fluoride | 0 | 0 | ± |
| Potassium oxalate | 0 | 0 | ± |
| ± = Interference is concentration dependent and may vary with sensor design 0 = No effect + = Notable effect | | | |

5.3 Documents and Records

5.3.1 Documents

Blood gas test request forms should be designed to capture required information or provide space for needed information to be recorded.

5.3.2 Records

A test request form should be completed at the time the blood specimen is obtained. Ideally, for meaningful clinical interpretations of the results (realizing in some situations not all of this data will be available). The data listed below should be available for meaningful clinical interpretation of results, and must reflect the conditions at the time of specimen collection:^b

- patient's full name;

NOTE: Unidentified emergency patients should be given some temporary but clear designation until positive identification can be made (see NCCLS document [H3—Procedures for the Collection of Diagnostic Blood Specimens by Venipuncture](#) for additional information).

- identification number;
- birth date/age;
- location of the patient;
- date and clock time of sampling;

^a Heparin is a weak acid and thus, if excessive, will effect the pH directly and the PCO₂ indirectly.

^b Institutions will need to follow various regulatory and state requirements as to what information needs to be collected.

- fraction of inspired oxygen (F_{IO_2}) or prescribed flow rate in liters per minute (L/M);
- body temperature;
- clinical indication⁵ (e.g., F_{IO_2} , mechanical ventilation changes);
- respiratory rate;
- name or initials of person who obtained the specimen; and
- name of physician requesting the test.

Additional data should be included as required by regulatory or institutional policies, for example:

- ventilatory status (i.e., spontaneously breathing or mechanically supported);
- mode of ventilation (i.e., pressure support) or delivery device (i.e., cannula or mask);
- site and manner of sampling (i.e., arterial puncture, capillary puncture, or indwelling catheter);
- position and/or activity; and
- working diagnosis.

5.4 Assessment

Periodic assessment of the quality system, including comparison of the QSEs against internal and external benchmarks, should be carried out to ensure that it is effectively meeting the intent of its stated requirements. Quality indicators should be identified and monitored for all operations across the path of workflow and QSEs (see Table 2). Action should be taken when the information from indicators demonstrates unacceptable performance.

Table 2. Published Laboratory Quality Indicators*

| Operating System or QSE | Quality Indicators |
|-------------------------------|--|
| Patient Assessment | <ul style="list-style-type: none"> • Practice guideline implementation • Duplicate test ordering |
| Test Request | <ul style="list-style-type: none"> • Ordering accuracy • Accuracy of order transmission • Verbal order evaluation |
| Specimen Collection/Labeling | <ul style="list-style-type: none"> • Wristband evaluation |
| Specimen Transport | <ul style="list-style-type: none"> • Transit time • Stat transit time |
| Specimen Receiving/Processing | <ul style="list-style-type: none"> • Blood gas sample acceptability • Chemistry sample acceptability |
| QSE: Personnel | <ul style="list-style-type: none"> • Competence evaluation • Employee retention |
| QSE: Process Control | <ul style="list-style-type: none"> • Safety |
| QSE: Occurrence Management | <ul style="list-style-type: none"> • Incidents |
| QSE: Internal Assessment | <ul style="list-style-type: none"> • Onsite inspections/assessments • Self-inspections/assessments |

* Please refer to the most current edition of NCCLS document [HS4—Application of a Quality System Model for Respiratory Services](#) for additional information on published quality indicators.

6 Path of Workflow for Collection of Arterial Specimens

6.1 Test Ordering

The process of ordering an arterial blood specimen begins with correct patient identification and the generation of an order form specific to the patient and tests required. The written order should include the specimen collection time, oxygen delivery system, oxygen levels (e.g., F_{IO_2} or L/M), and methods of ventilatory support or be consistent with an approved protocol. Additional tests, such as electrolytes, should also be included in the order. The specimen draw time should allow for an adequate period for a “steady state” to be reached when the patient is on supplemental oxygen. Interpretation of the reported data, unless the condition is emergent and results are needed immediately (i.e., in a “code” or trauma situation), may be impacted if the specimen is not collected under steady state conditions.

6.2 Patient Preparation

6.2.1 Patient Identification

Correct patient identification is absolutely essential. The methods for identifying patients when collecting blood specimens under a variety of circumstances are obtained from the most current version of NCCLS document [H3](#)—*Procedures for the Collection of Diagnostic Blood Specimens by Venipuncture*.

6.2.2 Patient Assessment

Patient assessment and clarification of the clinical indication (e.g., F_{IO_2} , mechanical ventilation changes) for the test should be made prior to obtaining the specimen.

The patient’s temperature, breathing pattern, and the concentration of oxygen in the inspired air (F_{IO_2}) influence the amounts of oxygen and carbon dioxide in the blood and therefore, should be stabilized and recorded to ensure reliable clinical interpretation of the results.⁶

6.2.2.1 Required Collection Conditions

Confirm that all precollection conditions have been met such as ordered F_{IO_2} , delivery devices, and mechanical ventilator settings. If the F_{IO_2} has been changed, wait at least 20 to 30 minutes to achieve a steady state, before taking a blood specimen.⁷⁻⁹ This is most important in patients who have chronic lung disease resulting in an abnormal ventilation/perfusion ratio.

6.2.2.2 Documentation

All required and optional data should be included on the requisition form per institutional policy.

6.2.2.3 Explanation of Procedures

Explain to the patient what will be done in a pleasant and reassuring manner. Blood gas values will be temporarily altered by hyperventilation due to anxiety, breath holding, vomiting, or crying. The patient should relax in a comfortable position, lying in bed or seated in a comfortable chair for at least five minutes or until breathing is stabilized. Longer than five minutes may be required for outpatients to obtain a stable condition.

6.3 Selection of the Site for Arterial Puncture

6.3.1 Criteria for Selection of the Site

- (1) Presence of adequate collateral blood flow (to decrease the complication of lack of blood flow distal from the puncture site);
- (2) Accessibility and size of artery; and
- (3) Periarterial tissue (fixation of artery, danger of injury to adjacent tissues).

6.3.2 Sites of Arterial Puncture

Users should refer to [Appendix A](#) for arterial specimen collection site anatomic diagrams.

6.3.2.1 Radial Artery

The radial artery, although small, is easily accessible at the wrist in most patients and, in current practice, is the most commonly used site for arterial puncture in clinical situations. It is easily compressed over the firm ligaments at the wrist; therefore, the incidence of hematomas is relatively low. Collateral circulation to the hand is normally provided by the ulnar artery, which may be absent in some individuals. The Modified Allen Test (see [Section 6.5.2.1.1](#)) may be helpful in evaluating this collateral circulation.¹⁰ Inadequate blood supply to the hand may suggest the need to select another site for the puncture.⁵ The “passive patient technique” may be performed for infants and children.¹¹

6.3.2.2 Brachial Artery

The brachial artery is also used for arterial puncture. It may be preferred for larger volumes. It may be more difficult to puncture due to the deeper location between muscles and connective tissues. Proper positioning of the arm with hyperextension improves the position of the brachial artery for puncture. It is not supported by firm fascia or bone and, in obese patients, may be very difficult to palpate. Effective compression of the puncture site is more difficult because of the deep location in the soft tissues. The incidence of hematoma formation may be more common than at the radial site.

The brachial artery is not commonly used in infants or children. Particularly in infants, it is harder to palpate than the radial artery and there is no collateral circulation.^{11,12}

In the antecubital fossa, the median nerve lies medial to the brachial artery which lies medial to the biceps tendon.

NOTE: This anatomic layout can be easily remembered by the mnemonic TAN. The order from lateral to medial is T = tendon, A = artery, and N = nerve.

6.3.2.3 Femoral Artery

The femoral artery is a large vessel which usually is superficially located in the groin and easily palpated and punctured. Generally, this is the last site selected in clinical practice. Disadvantages are poor collateral circulation to the leg and increased chance of infection if the site is not thoroughly cleansed; presence of pubic hair makes aseptic technique more difficult. In newborn infants, the hip joint and femoral vein and nerve lie so close to the artery that injury to these structures is a hazard which may contraindicate this procedure. By contrast, puncture of the femoral artery in older infants and children is relatively easy and safe.

Femoral sampling sites for blood collection are located in a triangular space at the upper part of the thigh, bounded by the sartorius and adductor longus muscles and the inguinal ligament, with a floor formed laterally by the iliopsoas muscle and medially by the pectineus muscle. Contained within this area, placed laterally to medially, are the femoral nerve, femoral artery, and femoral vein.

NOTE: This anatomic layout can be easily remembered by the mnemonic NAVEL which breaks down into N = nerve, A = artery, V = vein, E = empty space, and L = lymphatic.

6.3.2.4 Capillaries

A warmed capillary specimen approximates an arterial specimen. It is utilized to assess acid base balance in the adequacy of ventilation. However, heel puncture blood from newborn infants does have limitations for the accurate assessment of oxygen saturation. The capillary Po_2 may correlate poorly with the actual Pao_2 . This may be especially true when the capillary Po_2 is greater than 60 mm Hg. At this range, the associated Pao_2 is unpredictably higher.^{13,14} In the absence of obtaining an arterial specimen, a noninvasive monitor such as a pulse oximeter or transcutaneous oxygen monitor may be used with the capillary specimen to monitor oxygenation.¹⁵

6.3.2.5 Dorsalis Pedis Arteries

The *dorsalis pedis arteries* can be employed for arterial puncture or catheter, although this is not commonly done.

6.3.2.6 Umbilical Arteries

The *umbilical arteries* remain open during the first 24 to 48 hours of life. Since these are large arteries, and since the need for measuring oxygen and carbon dioxide in arterial blood arises frequently in sick infants in this age group, the umbilical arteries are often catheterized in newborn infants. The umbilical arteries constrict rapidly after birth unless kept open by a catheter; therefore, blood cannot be obtained with a needle. The site of sampling by catheter depends on placement of the catheter tip which should be in the descending aorta and at a site that is not opposite the orifice of any major artery supplying abdominal viscera.¹⁶

The decision as to location of the catheter tip varies in different neonatal centers. Disagreement exists as to whether the optimal location is at the bifurcation of the aorta (opposite L4-5) or approximately 1 cm above the level of the diaphragm (T6-10). Reasons cited for either preference relate to the types of complications encountered.

6.3.2.7 Posterior Tibial Artery

The posterior tibial artery can be cannulated for monitoring and sampling. This site is more commonly seen with pediatric and newborn patients when the radial or umbilical arteries are not options. The posterior tibial artery branches from the popliteal artery and supplies blood to the lower leg and foot. As it descends down the leg, it approaches the tibial side of the leg, lying posterior to the tibia with its lower portion located between the medial malleolus and the medial process of the calcaneal tuberosity.

6.4 Equipment

All equipment should be used in accordance with the manufacturer's instructions.

The following equipment is required to collect an arterial blood specimen:

- **Antiseptic supplies.** Suitable antiseptic supplies (e.g., isopropanol sponges) are required for cleansing the puncture site.
- **Gauze pads.** Clean gauze pads (e.g., 2 x 2 inch) are appropriate for use.
- **Coolant.** If blood gas analysis will not be performed within 30 minutes after specimen collection, prepare a container with ice water or other coolant capable of maintaining a temperature of 1 to 5 °C and large enough for immersion of the barrel of the syringe or collection device.
- **Engineered sharps.** Equipment with engineered sharps injury protections that allow for one-handed removal of the needle. Luer-tip caps or other suitable capping devices for the blood specimen syringe or collection device.
- **Disposal container.** A puncture-resistant disposal container in which to place used needles, disposable syringes with attached needles, or other collection devices. The container should be made of rigid plastic, metal, or stiff cardboard, and must have a lid and be clearly marked as a biohazard.
- **Hypodermic needles.** Preferably short-bevel, 20- to 25-gauge needles with a length from 5/8 to 1-1/2 inch (depending on selection site) are acceptable for arterial puncture. The following equipment is required to collect an arterial blood specimen:

NOTE: Shorter needles are preferred for radial arteries, longer needles for brachial or femoral punctures. Smaller gauge needles (25) may require gentle aspiration in order for blood to flow into the collection syringe.¹⁷ Excessive suction is not recommended because arterial blood drawn for the purpose of blood gas analysis should not be exposed to low subatmospheric pressure (or air in case of air leakage). Excessive suction (by aspiration) may also draw in capillary blood, causing a mix. Since the capillary is the area of gas exchange, capillary blood can have very different pH and gas values than arterial blood (especially oxygen). This mixture will almost certainly cause erroneous results.

- **Collection devices.** In most instances, the ideal collection device for percutaneous arterial blood sampling is a 1-, 3-, or 5-mL self-filling, plastic, disposable syringe, prefilled with an appropriate amount and type of lyophilized heparin salt or other suitable anticoagulant. The choice of the type of heparin depends on the specific analytes to be determined and the method of analysis.

NOTE: Leukocytes in shed blood continue to consume oxygen at a rate depending on storage temperature, storage time and the level of the initial oxygen of the blood sample.^{18,19} Before the era of plastic syringes (mostly polypropylene) it was customary to collect blood gas samples in glass syringes, and to ice these samples immediately to slow down the metabolic rate of the leukocytes, which in turn minimizes a reduction in oxygen levels. Glass is impermeable to gases unlike polypropylene and other polymer material of which plastic syringes are made.²⁰ Earlier studies suggested clinically significant errors in oxygen values when plastic syringes were used.^{21,22} Investigators of later studies found similar changes in oxygen values and identified certain conditions which will exacerbate or attenuate these changes: 1) the degree of oxygen-hemoglobin binding (e.g., shifts of the position of the oxygen-hemoglobin dissociation curve); 2) the initial Po₂ values; 3) the amount of total hemoglobin; and 4) time and especially the temperature during storage.²³⁻²⁷

Based on these findings it is recommended that plastic syringes containing blood for the purpose of blood gas and/or electrolyte analysis should not be iced but kept at room temperature and should be analyzed within 30 minutes of collection. Oxygen and carbon dioxide levels in blood kept at room temperature for 30 minutes or less are minimally affected except in the presence of an elevated leukocyte or platelet count. Those samples and blood collected for special studies (Alveolar-arterial oxygen tension difference (P(A-a)O₂) or “shunt” studies) should be analyzed immediately or within

five minutes after collection. If a prolonged time delay before analysis is anticipated (more than 30 minutes), the use of glass syringes and storage in ice water is recommended.

NOTE: Syringes stored in ice water cannot be used for electrolyte determinations as temperature effects on diffusion in and out of red blood cells render unreliable potassium results. Storage in ice water is applicable only to blood gas measurements.

- **Miscellaneous.** Adequate materials for specimen identification, recording, etc.

6.5 Procedure

6.5.1 Hazards/Complications of Arterial Puncture⁵

6.5.1.1 Vasovagal Response

Patients can have a vasovagal reaction which may result in a loss of consciousness. The procedure for dealing with a patient who has fainted or is unexpectedly nonresponsive is to:

- (1) Notify the designated first-aid-trained personnel.
- (2) Where practical, lay the patient flat or lower his/her head and arms if the patient is sitting.
- (3) Loosen tight clothing.

6.5.1.2 Arteriospasm

This is a reflex constriction of the artery in response to pain or other stimuli; occasionally it may be induced by anxiety. Although it is transient, it may make it impossible to obtain blood, even though the needle is properly located in the lumen.

6.5.1.3 Hematoma

Because of the higher pressure in the arteries compared to veins, more blood is apt to leak through the puncture site. On the other hand, elastic tissue in the arterial wall tends to cause closure of the puncture more rapidly. Elastic tissue decreases with age and certain disease states; therefore, the danger of hematoma is greater in older people. The larger the diameter of the needle and therefore, the puncture, the greater the probability of blood leakage. The risk of hematoma or external bleeding is increased in patients receiving anticoagulant therapy, or individuals with serious coagulopathies (e.g., end stage hepatic disease, oncology patients).

6.5.1.4 Thrombosis and Embolism

This is most likely to happen if a needle or cannula is left in place for some time. A thrombus (adherent clot) forms if the intima (inner wall) of the vessel is injured. The thrombus grows gradually and may obstruct the entire lumen of the vessel (embolism) and the needle. The incidence of obstruction of an artery by a thrombus is directly related to the size of the cannula and the duration of cannulation and inversely related to the diameter of the artery²⁸ and the rate of blood flow in the artery.

Thrombi may occur both in arteries and in veins but have more serious consequences in arteries, since most superficial veins—which are used for puncture—have collateral vessels ensuring adequate circulation whereas some arteries do not. Distant emboli may result from thrombi.

The presence or absence of collateral vessels determines the safety of the procedure and should be a prime consideration in selecting the site of the arterial puncture.

6.5.1.5 Collection Safety

Whenever possible, sharps with engineered sharps injury protections should be implemented for arterial blood collection to reduce the risk of accidental sharps injuries. Please refer to the most current version of NCCLS documents [M29—Protection of Laboratory Workers from Occupationally Acquired Infections](#) and [X3—Implementing a Needlestick and Sharps Injury Prevention Program in the Clinical Laboratory](#) for additional details.

6.5.2 Single Arterial Puncture

6.5.2.1 Performance of the Puncture

Gather all required equipment and supplies (see [Section 6.4](#)). If you are not using a preheparinized device, refer to [Appendix B](#).

6.5.2.1.1 Radial Artery

Before this site is selected, the presence of adequate collateral circulation via the ulnar artery may be assessed by a modified Allen test or with a Doppler ultrasonic flow indicator²⁹ or both.

(1) Modified Allen Test¹⁰

The patient tightly closes the hand to form a fist. Pressure is then applied at the wrist, compressing and obstructing both the radial and ulnar arteries. The hand is then opened (but not fully extended), revealing a blanched palm and fingers. The obstructing pressure is next removed only from the ulnar artery, while the palm and fingers, including the thumb, are observed. They should become flushed within 15 seconds as the blood from the ulnar artery refills the empty capillary bed. If the ulnar artery does not adequately supply the entire hand (a negative Allen test), the radial artery should not be used as a puncture site. An alternate artery should be selected.

(2) If the Allen test is positive, the radial artery may be punctured.

The arm should be abducted with the palm facing up and the wrist extended about 30 ° to stretch and fix the soft tissues over the firm ligaments and bone. If necessary, use a rolled towel or pad for positioning of the extremity.

(3) Locate the artery just proximal to the skin crease at the wrist. Transillumination of the wrist with a fiber optic light source may aid in locating the radial artery and outlining the palmar arch in young infants.^{30,31} Place a finger carefully over the artery and palpate for the size, direction, and depth of the artery. With use of the fiber optic light, care should be taken that the infant's skin is not burned.

(4) Prepare the puncture site aseptically. Be certain that after cleansing, the puncture site is not touched again except with gloved fingers.

(5) Hold the collection device or syringe in one hand as one would hold a dart and place a finger of the other hand over the artery at the exact point where the needle should enter the **artery** (not the skin). Puncture the skin about 5 to 10 mm distal to the finger directly over the artery with the bevel of the needle up, at an angle of approximately 30 to 45 ° against the blood stream. (See [Figure 1](#).)

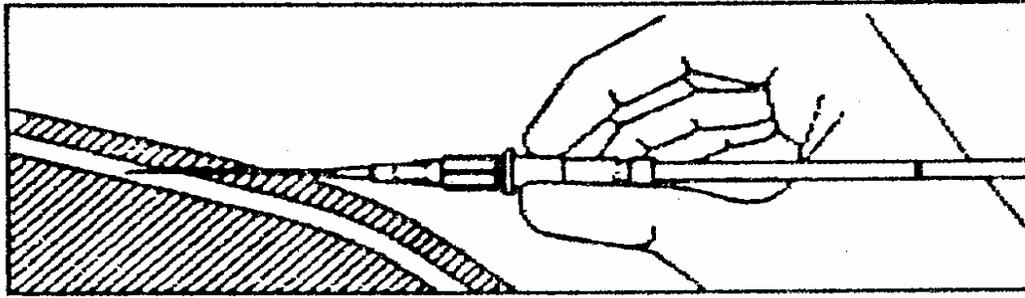


Figure 1. Arterial Insertion

- (6) Advance the needle under the skin, aiming for the artery just under the finger. When the artery is entered, blood will enter the flashback chamber spontaneously unless a needle smaller than 23-gauge is used. A very gentle and slow pull on the plunger may be necessary in order for blood to flow into the syringe.

If a glass syringe is used, the blood pressure will push the plunger back. Apply gentle pressure on the end of the plunger to prevent it from being pushed out.

- (7) After the required amount of blood has been obtained, place a dry gauze sponge over the puncture site, while simultaneously quickly withdrawing the attached needle and collection device.
- (8) Immediately, manually compress the artery at the puncture site with firm pressure for a minimum of three to five minutes.^{10,32,33} While applying pressure to the artery with one hand, immediately check the syringe or other device for air bubbles and carefully expel any trapped bubbles, following the manufacturer's recommended procedure. In order to prevent potential worker exposure, the needle safety feature should be activated immediately after specimen collection and discarded, without disassembly, into a sharps container.³⁴ Mix thoroughly by rotating or *inverting specimen several times* ensuring adequate anticoagulation, in order to prevent clots from being introduced into the specimen. Pressure dressings are not an acceptable substitute. If the patient is under anticoagulant therapy or has a prolonged clotting time, hold pressure on the site for a longer time period. After relieving pressure, immediately assess the puncture site. If hemostasis has not occurred or a hematoma is developing, reapply pressure for a period of two minutes. Continue with this process until hemostasis has occurred. If hemostasis has not occurred within a reasonable time, obtain medical assistance. Ambulatory patients should remain in the area until the test results have been assessed.

6.5.2.1.2 Brachial Artery Puncture

- (1) The patient's arm is fully extended and the wrist rotated until the maximum pulse is palpated with the index finger just above the skin crease in the antecubital fossa. If necessary, use a rolled towel to facilitate positioning of the extremity. The arterial pulse is then followed proximally by palpation with the middle finger for 2 to 3 cm (see [Appendix A](#)).
- (2) Skill in performing the puncture is required to avoid hitting the median nerve which carries sensory fibers and lies very close to the brachial artery.³⁵
- (3) Cleanse the site [see [Section 6.5.2.1.1\(4\)](#)].
- (4) Spread two fingers along the course of the artery which may be located by palpating the pulsations. Enter the skin just below the distal (index) finger and aim the needle along a line connecting the two

fingers using a 45° angle of insertion with the bevel up. The artery lies deep in the tissues, especially in obese individuals.

- (5) After puncture, it may be necessary to compress the artery against the humerus, if possible, for a minimum of five minutes or longer, in order to stop bleeding. Effective compression of the brachial artery is often difficult, but important [see [Section 6.5.2.1.1\(8\)](#)].

6.5.2.1.3 Femoral Artery Puncture

- (1) The femoral artery is located quite superficially in the inguinal triangle, just below the inguinal ligament. The patient should lie flat with both legs extended. The pulsating vessel should be palpated with two fingers.
- (2) Cleansing of the puncture site [see [Section 6.5.2.1.1\(4\)](#)] should be very thorough because of the often heavy contamination of this area. The area around the puncture site should be shaved, if necessary.
- (3) The palpating fingers are spread 2 to 3 cm apart along the course of the artery to anchor the vessel. The needle puncture is made perpendicular to the skin surface, or at an angle against the blood stream, between the two fingers.
- (4) Compression of the artery after the puncture is required as in [Section 6.5.2.1.1\(8\)](#).

6.5.2.1.4 Umbilical Arteries

These arteries, which are accessible within the first few hours of life, should not be punctured with a needle but must be cannulated with a catheter (see [Appendix D](#)).

6.5.3 Capillary Collection Procedures

6.5.3.1 Blood Flow

When blood is collected for pH and blood gas determinations, the site must be properly warmed prior to puncture. A warm moist towel (or other warming device) at a temperature **no higher than 42 °C** may be used to cover the site for three to five minutes.³⁶ This technique increases arterial blood flow to the site up to sevenfold³⁷ reducing the difference between the arterial and venous gas pressures, does not burn the skin, and except for Po₂ does not result in significant changes for routinely tested analytes.³⁸ Increasing the temperature at the site also produces vasodilation and aids in providing a free-flowing blood specimen after the puncture is performed. The inadequate warming of the site prior to the puncture will result in unreliable values.¹²

6.5.3.2 Procedure³⁹

For general capillary puncture procedure standards and guidelines, refer to the most current version of NCCLS document [H4—Procedures and Devices for the Collection of Diagnostic Capillary Blood Specimens](#) and the American Association for Respiratory Care (AARC) *Clinical Practice Guideline: Capillary Blood Gas Sampling for Neonatal & Pediatric Patients*.⁴⁰

NOTE: It is very difficult to obtain arterial specimens that have not been somewhat contaminated with room air or with interstitial fluid, even when these procedures are followed correctly. Room air will affect the blood gases and interstitial fluid will modify the electrolyte values.

6.5.3.3 Puncture Site

Blood may be obtained from the palmar surfaces of fingers ([Appendix E](#)), the plantar surface of the heel, and the plantar surface of a big toe. Heel puncture is generally performed in infants less than one year old. Heel puncture sites should be restricted to those areas indicated in [Appendix F](#). The puncture must not be made through a previous puncture site, the posterior curvature of the heel, or the central area of the foot.

6.5.3.4 Depth of Puncture

To obtain sufficient blood flow, the heel should be punctured with a sterile lancet, or with an automated lancet device, to a depth of approximately 2 mm. Puncturing deeper than 2 mm on the plantar surface of the heel of small infants may risk bone damage. (See the most current version of NCCLS document [LA4—Blood Collection on Filter Paper for Newborn Screening Programs](#).)

6.5.3.5 Collection

The specimen should be collected in heparinized capillary tubes and *must not* contain air bubbles. (See [Appendix G](#) for a detailed description of blood gas microcollection devices.) Exposure of blood to air even for short periods (10 to 30 seconds) can result in significant changes in the specimen. The presence of air bubbles has little effect on P_{O_2} until the surface area is increased by mixing.⁴¹ However, since whole blood is mixed before pH and blood gas analyses, great care must be taken to avoid air bubbles at the time the specimen is obtained. The specimen is to be kept anaerobic (capillary ends sealed) at all times.

After collecting a specimen, perform the following steps:

- (1) Immediately seal one end of the capillary tube with a cap or sealant putty.

NOTE: Trays of sealant putty become contaminated with blood and small fragments of glass. They should not be recycled; that is, the clay slabs should not be removed to extend their life. Rather, they should be replaced at appropriate intervals. (Refer to the most current version of NCCLS document [M29—Protection of Laboratory Workers from Occupationally Acquired Infections](#).)

- (2) Place a small magnetic stirring bar (also called a flea) into the bore of the tube.
- (3) Quickly seal the opposite end.

With the mixing bar in the tube, the blood can be mixed by moving a magnet back and forth along the entire length of the outside of the tube.

6.5.4 Arterial Cannulation for Sampling and Monitoring

6.5.4.1 Special Consideration

The placement of an indwelling catheter primarily in either the radial or brachial artery (i.e., preferred sites for cannulation) provides an effective mechanism for obtaining serial blood gas samples from a single arterial puncture. Although invasive and not without some untoward risks (e.g., obstruction of blood flow), arterial catheterization has been demonstrated to be relatively safe when performed by competent personnel.⁴² (Please refer to the most current version of NCCLS document [GP21—Training and Competence Assessment](#) for additional information on training and competence.) Exercise evaluation, shunt calculation, and oxygen therapy assessment can be determined in the laboratory setting with minimal discomfort to the patient. Arterial cannulation also plays a vital role in the monitoring of both blood pressure and partial pressure of respiratory gases in the critically ill patient. However, the danger

of obstruction of the blood flow—either by the needle cannula or catheter itself in a relatively narrow artery or by a thrombus—and of thrombosis followed by emboli, demands additional precautions besides those required for single arterial punctures.⁴³

A pliable needle cannula or a flexible catheter is inserted and fixed in the artery. The external part of the catheter ends in a standard adapter which fits a three-way luer-lock stopcock connected to an infusion system, as well as to an outlet for a sampling syringe and a pressure-monitoring device, if required (see Figure 2).

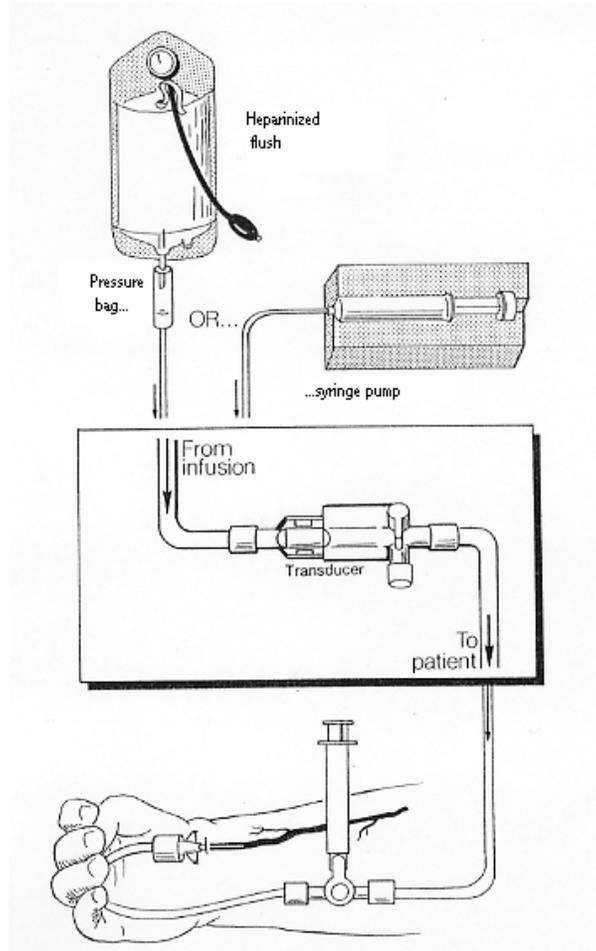


Figure 2. Pressure Transducer Setup for Continuous Arterial Monitoring. (Reprinted from *Nursing Care of the Critically Ill Child*, 2nd ed., Hazinski MF, Bioinstrumentation: Principles and techniques, pg. 944, Copyright 1999, with permission from Elsevier.)

6.5.4.2 Equipment and Supplies

- (1) Personal protective equipment to include gloves, gown, and face protection.
- (2) Arm board, rolled towel, or pad for positioning of the extremity.
- (3) Tape for securing both the arm board and the catheter.
- (4) Suitable antiseptic solution (e.g., povidone-iodine) for skin preparation.
- (5) Sterile, disposable 16-, 18-, or 20-gauge intravascular catheter with luer-lock hub. Length of catheter varies with manufacturer. In selecting the diameter and length of the catheter, a compromise must

be made between a lumen that does not offer excessive resistance to blood flow and outer dimensions that prevent friction and obstruction to flow in the artery.

- (6) Sterile, disposable 3-way stopcock and connector tubing as needed.
- (7) A 1-mL syringe filled with 1% lidocaine without epinephrine attached to a 25- to 26-gauge needle. (Local anesthetic is optional, but recommended for arterial line insertion.)⁴⁴
- (8) Preheparinized syringes for sampling.
- (9) 5- to 10-mL syringes for waste removal.
- (10) Flush solution (e.g., normal saline).
- (11) Tincture of benzoin spray, antibiotic ointment (optional).
- (12) Sterile 2x2 gauze sponge to dress.
- (13) Clean 4x4 gauze sponges.
- (14) Pressure transducer set up for arterial monitoring, if needed.
- (15) Puncture-resistant disposal container for used needles and syringes.

6.5.4.3 Patient Preparation

- (1) Includes patient identification, assessment, and explanation, as in [Section 6.2](#).
- (2) Obtain informed, written consent per institutional policy.
- (3) Ascertain patient allergy to lidocaine or its derivatives, iodine preparations, latex (if in use), and adhesives.
- (4) Ascertain if patient is on anticoagulant therapy or has a known history of serious coagulopathy.

6.5.4.4 Procedure for Cannulation

- (1) Have the patient sit in a straight chair with his or her arm resting on a table or have him or her lie on a bed.
- (2) Secure the arm to a board with tape or nonconstrictive bandage. A towel or padding may be placed under the wrist to maintain hyperextension. The site of the puncture should be visible and easily accessible.
- (3) Don personal protective equipment and observe standard precautions.
- (4) Inspect the wrist for anatomical abnormalities and/or surgical scars in or near the puncture site, which may indicate an increased risk for injury, especially nerve injury.
- (5) Palpate the radial or brachial artery to locate the site of strongest pulsation and determine the course of the artery. If using the brachial artery, the puncture site should be below the antecubital fossa to reduce the possibility of damage to surrounding nerves.

- (6) Perform the Allen test.
- (7) Prepare the puncture site antiseptically with an iodine preparation.
- (8) Anesthetize the site as described in [Appendix C](#).

6.5.4.4.1 Over-the-Needle Catheter Placement Technique

- (1) Remove the plug from the end of the catheter hub before insertion.
- (2) While palpating the artery with a finger, insert the catheter into the initial puncture site at an angle of 10 to 15 degrees with the skin along the course of the artery.¹⁰ (Refer to [Figure 1](#).) Direct the catheter toward the pulsating artery using a slow, continuous, controlled, forward motion. Blood flashback in the catheter appears when the artery is punctured.
- (3) Hold the needle hub in place with one hand while grasping the catheter adapter hub with the other. Slowly advance the catheter forward along the needle into the artery. If resistance is encountered, do not attempt to force the catheter. Withdraw the unit and attempt a new puncture. Never pull the catheter back over the needle once the catheter has been advanced.
- (4) Hold the catheter adapter hub in place while withdrawing the needle. Attach a three-way, luer-lock stopcock to the catheter hub.
- (5) Secure the catheter with tape. Clean the area of blood and spray with tincture of benzoin. Antibiotic ointment may be applied to the site and the area covered with a sterile gauze sponge.
- (6) Discard the needle assembly in a puncture-resistant container.
- (7) Assess the skin color, temperature, and quality of distal pulses in the affected extremity. Capillary refill may be assessed by pinching the skin distal to the catheter, which will cause the area to be pale. Upon release of pressure, color will return to the area in about three seconds in a person with adequate capillary flow. This assessment should be made at least every eight hours.

6.5.4.4.2 Over-the-Needle Catheter with Spring Wire Assembly Technique

- (1) Remove the catheter from the package and attach the spring wire tube assembly to the hub of the needle if not previously done by the manufacturer.
- (2) Trial advance and retract the spring wire guide through the needle via the actuating lever to ensure proper feeding. The actuating lever must be fully retracted in the tube assembly proximally as far as possible before insertion to clear the catheter of the spiral wire guide and allow immediate blood flow upon entering the vessel.
- (3) Perform the puncture.
- (4) Stabilize the position of the introducer needle and slowly advance the spring wire guide distally as far as required into the artery. If resistance is encountered, do not force-feed or attempt to retract the spring wire guide. Withdraw the catheter and attempt a new puncture. Do not advance the wire guide unless there is free blood flashback.
- (5) Holding the introducer needle hub in position, advance the catheter forward.
- (6) Hold the catheter in place and remove the introducer needle and wire guide feed assembly.

- (7) Attach a three-way luer-lock stopcock or other appropriate connecting device.

6.5.4.4.3 Through-the-Needle Catheter Placement Technique

- (1) Perform puncture with a 17-, 18-, 19-, or 20-gauge needle device by gently inserting the needle into the artery [see [Section 6.5.2.1.1\(6\)](#)]. Blood flashback in a flexible catheter will verify entry into the artery.
- (2) Advance the catheter into the artery by grasping the needle hub assembly with one hand and the catheter (through the catheter protective sleeve) with the other hand, approximately one inch behind the needle hub; then push the catheter forward into the artery. Repeat the procedure until the catheter is placed at the desired distance into the artery.

CAUTION: If the catheter placement is not successful, remove the needle and catheter together. Do not remove the catheter first as the needle bevel may cut the catheter as it is being withdrawn.

- (3) Remove the needle assembly from the artery and the skin, leaving the catheter in place.

6.5.5 Arterial Lines

6.5.5.1 Flushing the Arterial Line

- (1) Open the stopcock to flush the solution and clear the system by pulling the induction flush device.
- (2) To ensure complete removal of blood from the stopcock, turn the stopcock hand toward the patient, hold a sterile sponge at the open stopcock port by pulling the infuser, and return the stopcock hand to maintain an open flush system to the patient.
- (3) Cap the port with a sealed cap.
- (4) A pressure bag should be inflated and maintained at 300 mmHg at all times. The flush system should deliver 1 to 3 mL/hr to ensure catheter patency.

6.5.5.2 Obtaining Arterial Specimens from an Indwelling Catheter

Any invasive catheter is a potential source of infection either at the site of insertion or by contaminated fluids, tubing, or connectors. Organisms passed through the catheter can enter the bloodstream and lead to a life-threatening bacteremia.⁴⁵

6.5.5.2.1 Sampling When No Infusion Fluid is Used

First, precautions must be taken to:

- Prevent introducing any air into the system.
- Ensure that all connections are secure.
- Completely remove “dead-space” contents of the catheter and connectors prior to withdrawing the specimen.
- Avoid getting air into the syringe or collection device after blood collection.

- (1) Place a 4x4 gauze sponge under the three-way stopcock or the end of the connecting tube. Attach a 5- to 10-mL waste syringe to the syringe port of the stopcock. Open the stopcock to the syringe and aspirate a volume of flush/blood six times the volume of the catheter and connectors.⁴⁶
- (2) Close the stopcock. Remove the waste syringe and replace with a preheparinized arterial blood gas syringe.

NOTE: Use only a self-filling device and allow the device to fill with fresh arterial blood.

Open the stopcock to the syringe and slowly obtain the desired sample. Turn the stopcock off to the syringe.

- (3) Once the sample is obtained, the catheter, stopcock, and connectors must be flushed with saline to maintain patency. The exact volume of flush necessary to clear the system varies with different catheters and should be determined prior to catheter insertion.
- (4) Warn the patient that they will feel a warming sensation in the extremity as the flush solution is introduced.
- (5) Attach a syringe with the appropriate amount of normal saline to the syringe port. Open the stopcock to the syringe and slowly but steadily push the fluid through the stopcock. Turn the stopcock off to the syringe.

6.5.5.2.2 Sampling When Infusion Fluid is Used

When continuous monitoring of arterial pressure is required, a flush solution must be infused through the catheter to maintain patency and to prevent the formation of clots. A 500-mL bag of normal saline with 1000 units of heparin has been commonly used throughout the medical industry to ensure catheter patency. However, an increasing awareness of heparin-induced thrombocytopenia with its manifestations of hemorrhage and thromboembolic events has raised serious concerns about the safety of this practice. Hospitals which opt to use heparin in the flush solution should be aware of the potential risks and must monitor the patient closely. If the platelet count falls to less than 100,000/mm³ or if recurrent thrombosis develops, the drug should be discontinued.⁴⁷

- (1) When using an open system, a waste syringe (5- to 10-mL) is connected to the stopcock closest to the patient.

NOTE: Closed systems are available. Users should consult manufacturer's instructions for use.

- (2) The hand of the stopcock is turned toward the pressure bag and an amount of fluid/blood five to six times the volume between the stopcock and the cannula is aspirated (3 mL).

NOTE: Because this length of tubing is variable, each institution should determine the volume of fluid/blood to be aspirated.

- (3) Turn the stopcock to 45 degrees and point it between the open port and the patient, remove and discard the fluid/blood mixture. However, in specific populations where blood loss is an issue, this fluid/blood may be reinfused after samples have been obtained as long as there are no obvious signs of clots.
- (4) Attach the preheparinized syringe, turn the stopcock hand toward the pressure bag, and allow the syringe to fill with blood.

- (5) Return the stopcock hand to 45 degrees between the open port and the patient.
- (6) Cap the sample and label it appropriately.
- (7) Flush the line per institutional policy.

6.5.5.2.3 Care of the Arterial Catheter During Continuous Monitoring

When an arterial catheter is used for continuous monitoring, special precautions must be taken to maintain the integrity of the catheter and to prevent infection both locally and systemically. In order to meet accreditation standards, intensive care units must have written policies and procedures for the maintenance of an indwelling catheter and must vigilantly practice these safeguards. The American Association of Critical Care Nurses *Procedure Manual for Critical Care* presents specific guidelines on catheter care and is a recommended resource for authorizing and editing institutional policy.⁴⁵

6.5.5.2.4 Removal of the Arterial Catheter

- (1) Gently loosen the adhesive from around the insertion site.
- (2) With one hand, hold a dry gauze sponge over the insertion site ready to apply pressure once the catheter is removed. Grasp the stopcock with the thumb and index finger of the other hand.
- (3) Firmly pull the stopcock and connecting catheter toward you in a continuous motion until the entire catheter is withdrawn.
- (4) Immediately compress the artery at the puncture site for a minimum of 10 to 15 minutes. Pressure dressings are not an acceptable substitute for firm manual pressure at the site. (See Section 6.5.2.1.1(8).)
- (5) Assess the site after relieving pressure. When hemostasis has occurred, place a gauze pad over the site and secure with tape or apply a pressure bandage. Leave covered a minimum of four hours.
- (6) Document visual observations of the site and the presence or absence of palpable pulses in the extremity. Notify the appropriate medical personnel if additional assessment or intervention is required.
- (7) Advise the patient to use the extremity normally, but to avoid heavy lifting and/or strenuous activity for 24 hours. Ambulatory patients should be given written instructions for the care of their cannulation site over a minimum of 24 hours.

6.6 Handling and Transport of Arterial Blood Specimen

6.6.1 Initial Handling

Properly identify and label the specimen according to institutional guidelines. If the specimen is to be immersed in coolant, the label must remain legible after immersion.

6.6.1.1 Coolant

If it is necessary to cool the specimen, a container with a mixture of crushed ice and water or other suitable coolant, large enough to permit immersion of the entire barrel of the syringe or collection device, should be prepared before the specimen is obtained. As soon as the syringe or collection device has been securely closed and labeled, it should be immersed in coolant.

6.6.2 Samples for Blood Gas and pH Analysis

6.6.2.1 Prompt Analyses (within 30 minutes of collection)

If the sample will be analyzed within 30 minutes, use of a plastic syringe is recommended. If other analytes are included in the specimen analysis, time may need to be adjusted. Transport the specimen to the laboratory at room temperature. Do not cool the specimen.

6.6.2.2 Delayed Analysis (more than 30 minutes after collection)

Glass syringes should be used if analysis will be delayed. The specimen should be immersed in coolant as soon as possible after collection. (For laboratories with combination blood gas systems, refer to the most current version of NCCLS document [C46—Blood Gas and pH Analysis and Related Measurements](#), since cooling may affect other analytes.)

NOTE: Cooling effects on other analytes are more prominent if the specimen is immersed in ice.

6.7 Specimen Receipt/Processing

6.7.1 Transportation to the Laboratory

Regardless of the method of delivery, the entire container (including the coolant when used) and the specimen should be taken to the laboratory and analyzed as soon as possible.

6.7.2 Specimen Receipt

A test request form must accompany the specimen and include a unique specimen identification, date and time of specimen collection, and additional information as referred to in [Section 5.3.2](#). Record the date and time the specimen is received in the laboratory. A specimen may be rejected for analysis when improperly labeled, transported, or stored. Institutional policies should address specimen rejection criteria.⁴⁸

References

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Appendix A. Arterial Specimen Collection Sites

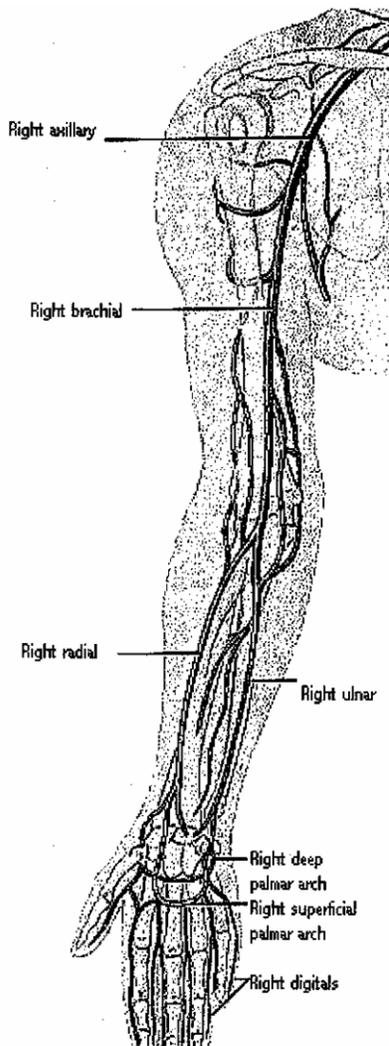


Figure A1. Arm and Hand

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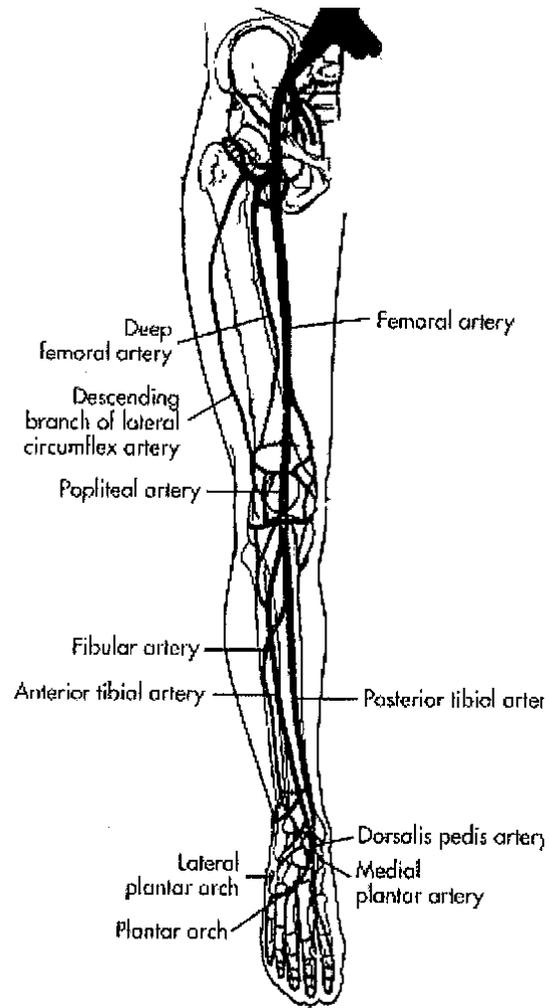


Figure A2. Groin

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Appendix B. Preparation of a Nonheparinized Syringe

NOTE: Glass syringes must be lubricated before drawing an arterial blood specimen.

- (1) Using a sterile cotton-tipped applicator and observing aseptic technique, coat the plunger of a sterile glass syringe with sterile mineral oil.
- (2) Insert the plunger into the syringe, rotating the plunger along the length of the syringe to distribute the oil evenly.
- (3) Attach an 18- or 20-gauge needle to the hub of a glass or plastic syringe.
- (4) Aseptically prepare the top of the anticoagulant vial.
- (5) Aspirate 0.5 mL of heparin (1000 u/mL) into the syringe. Remove the needle and syringe from the vial. Thoroughly wet the inside of the syringe by extending the plunger down the length of the syringe.
- (6) Holding the syringe with the tip upward, expel the air. Invert the syringe and expel the remaining heparin. Remove the needle from the syringe.
- (7) Cap the syringe or attach a sterile needle.

Appendix C. Local Anesthesia

The use of local anesthesia is optional. Local anesthesia has several advantages: 1) it relieves patient discomfort/apprehension and therefore, may minimize changes in ventilation; and 2) it may prevent arterial vasoconstriction. If used, 1% lidocaine without epinephrine is recommended.

CAUTION: Ascertain and document the absence of patient allergy to lidocaine or its derivatives prior to administration.

C1. Procedure

- (1) After positioning and cleansing the puncture site, raise a skin wheal above the artery.
- (2) Inject the local anesthetic subcutaneously and then infiltrate the tissue periarterially. Using a small 1-mL syringe and a 25- to 26-gauge needle, withdraw the plunger slightly before injecting the lidocaine to ensure that a blood vessel has not been punctured. A total amount of 0.25 to 0.50 mL of lidocaine should suffice for most applications.
- (3) Wait two to three minutes after injecting the local anesthetic before continuing to allow for the full anesthetic effect to take place. The anesthesia begins to wear off in about 15 to 20 minutes.

CAUTION: Anaphylaxis is a hazard with local anesthesia for any purpose; however, no such incident has been reported among many thousands of arterial punctures.^{1,2}

References to Appendix C

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2. Lindesmith LA, et al. Arterial punctures by inhalation therapy personnel. *Chest*. 1972;61:83.

Appendix D. Technique for Umbilical Artery Cannulation¹

This procedure is performed by physicians, nurse practitioners, or specially trained nurses and respiratory therapists only, due to the risk of the procedure.

- (1) The infant must be restrained in the supine position on a suitable work surface, with adequate provision for maintenance of body temperature during the procedure. A radiant warming table is well suited for this purpose.
- (2) The vertical distance from shoulder to umbilicus is measured. Based upon this measurement, the distance of the catheter insertion is determined from Dunn's graph² correlating these variables (see [Figure D1](#)).
- (3) A sterile catheterization tray should be available, containing the following items:
 - 2 curved smooth mosquito forceps
 - 3 to 4 mosquito clamps
 - 1 pair of straight iris scissors
 - scalpel and #11 blade
 - blunt probe (optional)
 - towel clamps
 - 4 small towels
 - 4 inch x 4 inch (10 x 10 cm) gauze sponges
 - umbilical catheter*
 - 3-way stopcock with luer lock*
 - umbilical tape tie [6 to 8 inch length (15 to 20 cm length)]
 - medicine cup
 - 2 to 3 syringes (5 to 10 mL).

*For specifications for umbilical catheter and stopcock, see No. (7) below.

- (4) The operator dons a surgical cap and mask; scrubs as for a surgical procedure; then dons a sterile gown and gloves.
- (5) The skin of the abdomen is scrubbed with povidone-iodine solution, paying special attention to the area of the umbilical cord. This is followed with an alcohol rinse.
- (6) The abdomen is draped with sterile towels, allowing a small opening around the umbilical cord. The infant's face should remain visible at all times, so that any color change during the procedure may be promptly noted.
- (7) Using the sterile catheterization tray, the catheter is prepared for insertion. A size 5 French catheter is generally suitable for infants over 1200 g and a size 3.5 French catheter is suitable for those under 1200 g birthweight. The catheter is attached to a three-way disposable stopcock, and the system is then filled with isotonic saline or other suitable flush solution. The syringe containing flush solution is left connected to the stopcock, and the stopcock is turned off to the catheter.

NOTE: Use only catheters specifically designed for this purpose.³

- (8) A single tie is placed around the base of the umbilical cord, using the umbilical tape. This tie should encircle the cord only once, and should be surrounding the Wharton's jelly of the cord (and not constricting any of the adjacent skin). This tie may be tightened if necessary to prevent bleeding later in the procedure.

Appendix D. (Continued)

- (9) A horizontal cut is made across the umbilical cord approximately 1.0 to 1.5 cm above the abdominal wall, using the scalpel blade.
- (10) The umbilical vein and the two umbilical arteries are identified. The arteries will be identified by the thicker walls and the pinpoint lumen.

The side walls of one of the arteries are gently dilated with the smooth curved mosquito forceps. This is accomplished by carefully inserting the closed forceps into the cut end of the artery, and then allowing the tips to gently spring apart. Toothed forceps should be avoided, as they will tear the walls of the artery. If necessary, a blunt probe may be advanced carefully 1 to 2 mm into the cut end of the artery to further dilate the lumen. While holding the side walls apart with forceps, the catheter is gently inserted and slowly advanced the desired distance into the artery (see No. (2) above). It may be necessary to use a gentle twisting motion, rotating the catheter between thumb and index finger, while advancing into the artery. This motion may help to negotiate the tortuous course of some arteries.

Resistance may be encountered at the 1- to 3-cm level, due to arterial spasm as the artery crosses the abdominal wall, or at the 5- to 6-cm level, where the umbilical artery curves to join the iliac artery. When this occurs, 30 to 60 seconds of steady gentle pressure will often overcome the spasm. If this fails, 0.2 to 0.5 mL of 1 % lidocaine (without epinephrine) may be injected through the catheter in an effort to relieve the spasm.

However, excessive pressure while advancing the catheter may lead to perforation of the walls of the artery, with the consequent production of “false channels” through the Wharton’s jelly or in the subcutaneous space. It is, therefore, unwise to forcibly advance a catheter which is meeting resistance.

- (11) The catheter is advanced to the premeasured distance and fixed in place with a suture ligature to prevent slippage. The umbilical cord stump should not be covered with a dressing as this may prevent early detection of bleeding or signs of infection. An antibiotic ointment may be applied to the moist base of the cord.
- (12) The catheter position should be confirmed with an x-ray. It can be either in the high position, T 7-11, or low position, L3.⁴

NOTE: Minor variations from the above described procedure may be appropriate.

References to Appendix D

1. Symansky MR, Fox HA. Umbilical vessel catheterization: Indications, management and evaluation of the technique. *J Pediat.* 1972;80:820-826.
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Appendix D. (Continued)

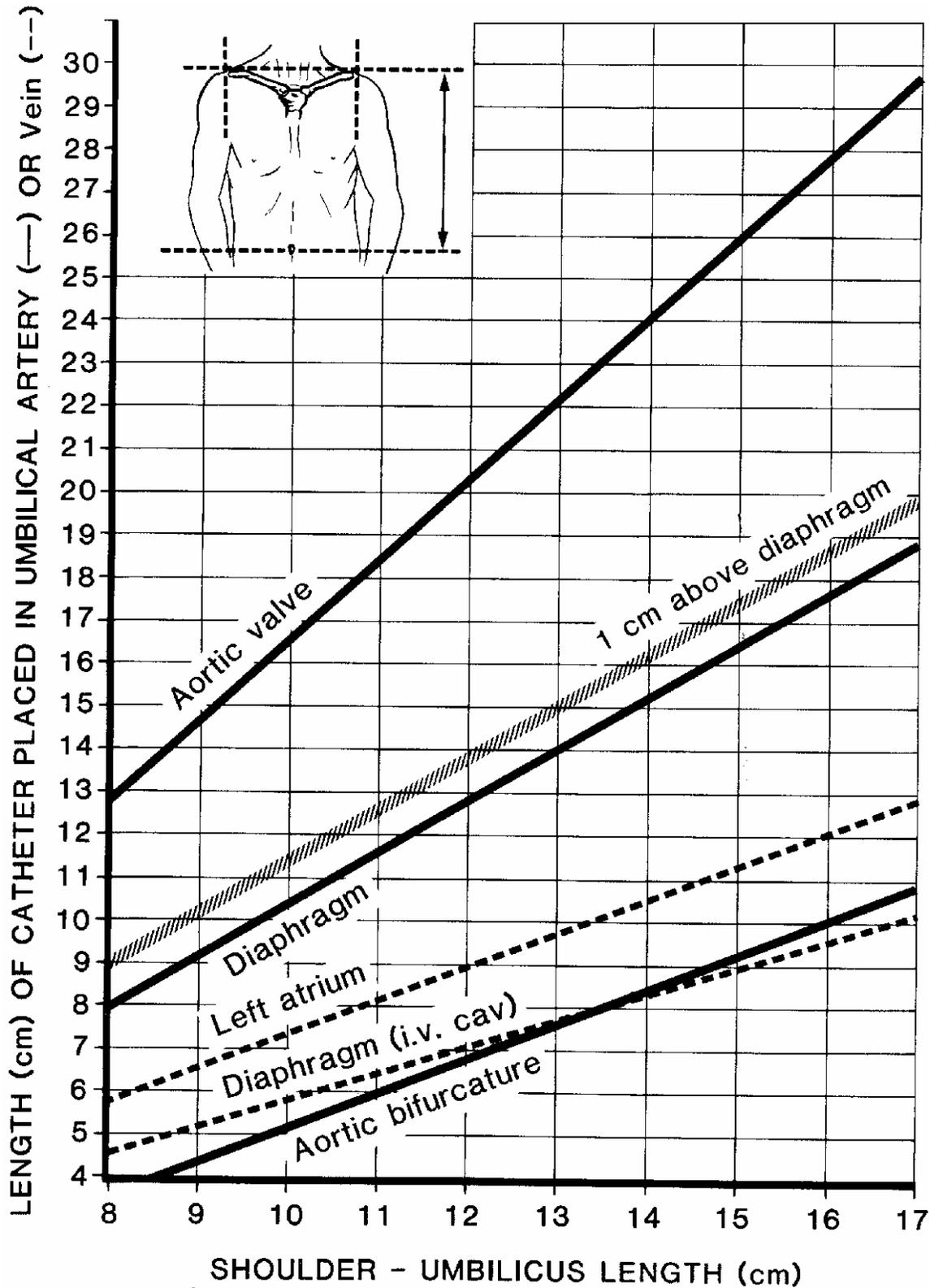
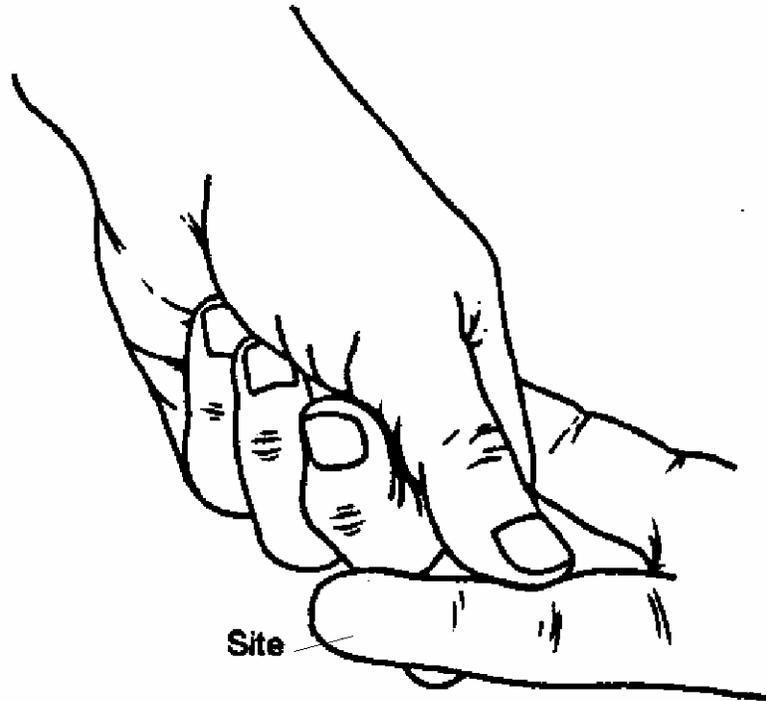


Figure D1. Correlation Graph of the Vertical Distance from the Shoulder to the Umbilicus and the Distance of the Catheter Insertion. (Reproduced from Dunn PM, *The Archives of Diseases in Childhood* (1966;41:69-75) with kind permission from the BMJ Publishing Group.)

Appendix E. Recommended Skin Puncture Sites in Adults and Older Children



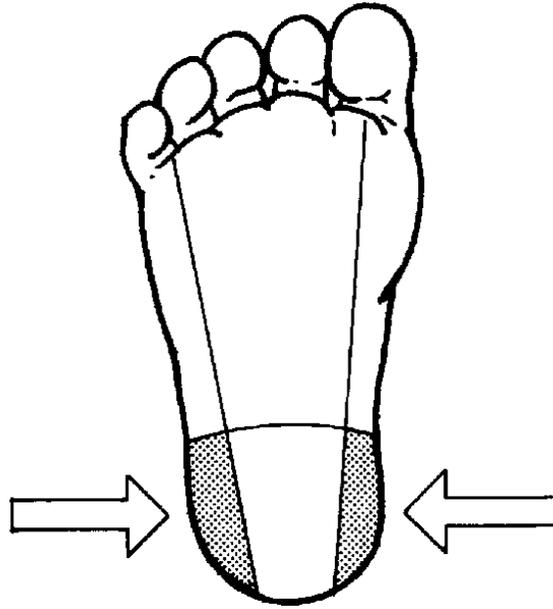
Modified with permission. From McCall RE, Tankersley CM. *Phlebotomy Essentials*. Lippincott Williams & Wilkins. © 1993.

When skin punctures are performed on the fingers of adults or older children (over one year old), the following guidelines must be observed:

- The puncture must be on the palmar surface of the distal phalanx and not at the side or tip of the finger because the tissue on the side and tip of the finger is about half as thick as the tissue in the center of the finger.
- The middle finger and ring finger are the preferred sites because the thumb has a pulse and the index finger may be more sensitive or callused. The fifth finger *must not* be punctured because the skin is too thin.
- Skin punctures *must not* be performed on the fingers of newborns.

For more information regarding skin punctures, see the most current version of NCCLS document [H4](#)—*Procedures and Devices for the Collection of Diagnostic Capillary Blood Specimens*.

NOTE: Gloves must be worn when performing skin punctures. (See the most current version of NCCLS document [M29](#)—*Protection of Laboratory Workers from Occupationally Acquired Infections*.)

Appendix F. Recommended Skin Puncture Sites in Newborn Infants

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Shaded areas indicated by arrows represent recommended areas for infant heel puncture. See Sections [6.5.3.3](#) and [6.5.3.4](#) in the text.

Appendix G. Blood Gas Microcollection Devices

G1 Product Description and Applications

Blood gas collection tubes are used to collect skin puncture blood specimens for blood gas determinations by both manual and automated procedures. Specific instructions should be followed as indicated by methodology and instrumentation. Caution must be used when comparing blood gas results on skin puncture specimens with those on arterial blood specimens. For detailed specifications related to microcollection devices, see the most current edition of NCCLS document [H4—Procedures and Devices for the Collection of Diagnostic Capillary Blood Specimens](#).

G2 Material

Blood gas collection tubes have been made from soda lime, or borosilicate glass.

NOTE: To reduce the risk of injury due to breakage, regulatory agencies (e.g., in the U.S., the FDA, NIOSH, OSHA) recommend that users consider collection devices less prone to accidental breakage. These include:

- nonglass capillary tubes;
- glass capillary tubes wrapped in puncture-resistant film; or
- products that use a method of sealing that does not require manually pushing one end of the tube into putty to form a plug.

Collection devices with these characteristics are currently available, and their use may reduce the risk of injury and blood exposure.¹

G3 Dimensions

G3.1 Size

Tubes vary in length and diameter as appropriate to provide adequate sample volume for testing and to fit specific instrumentation. Tubes generally are 100 to 150 mm in length with 1 to 2 mm inside diameter (i.d.).

G3.2 Taper

Tubes generally are not tapered except for larger I.D. tubes that may have a tapered tip to aid capillary filling.

G4 Volumes and Markings

Tubes are noncalibrated. Variable approximate volumes are available ranging from 50 to 250 μL . The individual instruments draw as much specimen as required. Surplus specimen should be present.

G5 Coding

Tubes may have a colored band denoting the presence and type of anticoagulant coating. This band also identifies the top end of the tube for reference in specimen handling. Generally, red denotes “ammonium heparin” and green denotes “sodium heparin.”

Appendix G. (Continued)

G6 Workmanship

Tubes should have smooth ends and be clean and free of contaminants such as dust, dirt, embedded lint, chips that affect their bore, films, or stains when viewed under normal room light.

G7 Surface Coatings, Treatments, Stability Dating

Tubes for blood gas analysis should contain sufficient heparin to prevent clotting of whole blood samples between the time of collection and presentation to the instrument. Blood gas tubes containing sodium, lithium, or ammonium salts of heparin have been used. Because ammonium ion in sufficient quantity can change the pH, sodium heparin or lithium heparin is preferred.^{2,3} The type and activity of heparin should be stated on the label. The product may have a stated expiration date based on the claimed anticoagulant activity. Store unused material at room temperature with minimal exposure to ambient conditions above 25 °C.

G8 Packaging

Tubes should be packaged in a protective overpack to minimize breakage and dust contamination. Generally, tubes are packaged 50 to 200 per vial or cylinder.

G9 Accessories

G9.1 Closures and Sealants

Sealant putty or caps should be used to contain the sample and to maintain anaerobic conditions. Proper mixing of anticoagulant and sealing of tube ends is required to maintain the sample under anaerobic conditions.

G9.2 Adapters

Adapters are required to allow the insertion of the sample into various instruments. Manufacturer's directions are to be followed.

G9.3 Magnets and Stirrers

Magnetic stirrer "fleas" and a ring-shaped permanent magnet are usually included with blood gas tube kits or are available separately. Proper mixing promotes heparin dissolution, prevents clot formation, and suspends blood cells more uniformly for accurate hemoglobin readings.

G9.4 Files and Scorers

Metal files may be required to reopen the tube for sample removal when sealant putty is used. Precautions should be taken to avoid accidental injury when scoring and breaking the tubes. There is a potential hazard for broken glass when opening the ends of the sealant. Many kits now contain the plastic caps. (Capillary tubes shrouded in plastic may be an option to prevent stick injuries.)

G10 Speed and Ease of Fill

With adequate blood supply, the tube should normally fill in less than 30 seconds when collected horizontally.

Appendix G. (Continued)

G11 Centrifugation and/or Processing

Because instrumentation is designed for use with whole blood, these specimens are not centrifuged. Closures and tubes may not be designed to function under high relative centrifugal force (RCF) conditions.

G12 Blood Gas Collection Tubes

Blood gas collection tubes are labeled for minimum capacity or sufficient capacity for a specific instrument. Before using, the volume must be checked to make sure it is adequate for proper operation of the instrument in use.

G13 Directions for Presenting Blood Gas Samples to Instruments

When inserting the tube into the instrument and analyzing a microsample, it is necessary to follow the manufacturer's instructions for each instrument.

In general, the following steps are suggested:

- (1) Mix the contents of the tube with a stirrer by moving the magnet back and forth over the length of the tube, until blood components are uniformly distributed.
- (2) Open the end of the tube and then remove stirrer fleas by pulling a magnet slowly over the tube, being careful not to spill blood or admit air.

NOTE: Be sure that the stirrer flea is removed before introducing sample into the instrument.

- (3) Open the opposite end of the tube and allow the sample to flow to the end to remove any trapped air, and then insert the end of the tube into the instrument nozzle, adapter, or aspirator tip. Attach the microsample aspirator tubing to the end of the tube (if appropriate).
- (4) Initiate instrument operation per instrument instructions.

References to Appendix G

1. *Glass Capillary Tubes: Joint Safety Advisory About Potential Risks*. Rockville, MD: Food and Drug Administration, Department of Health and Human Services; 1999.
2. Van Kessel AL. The blood gas laboratory: An update. *Lab Med*. 1979;10:419.
3. Shapiro BA. *Clinical Application of Blood Gas*. New York: Yearbook Medical Publishers. 1973:167.

Additional References

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3. Kilpatrick F, Niles A, Wilson WB. Arterial and capillary blood gas analysis. In: Barnhart SL, Czervinske MP, eds. *Perinatal and Pediatric Respiratory Care*. Philadelphia: WB Saunders. 1995:115.

NCCLS consensus procedures include an appeals process that is described in detail in Section 8 of the Administrative Procedures. For further information, contact the Executive Offices or visit our website at www.nccls.org.

Summary of Delegate Comments and Working Group Responses

H11-A4: *Procedures for the Collection of Arterial Blood Specimens; Approved Standard—Fourth Edition*

Section 6.3, Selection of the Site for Arterial Puncture (Formerly Section 5.3)

1. Selection of site for specimen collection—clarify why the lack of collateral circulation is important.
 - **Ensuring the presence of collateral circulation prior to arterial puncture is an integral part of good clinical practice. The text has been modified to clarify this recommendation.**

Section 6.4, Equipment (Formerly Section 5.4)

2. Clarify the different type of arterial blood collection kits that are available. Specifically, the ones that fill on their own and are premixed with heparin versus those that do not or are not. Discuss how excess heparin can affect the measurements on an ABG. Mention the length of time arterial blood specimens can be stored in ice water prior to measurement.
 - **A variety of arterial blood collection kits are currently available; however, use of trade names (i.e., reference to specific products) has been avoided per NCCLS policy.**

Table 1 provides examples of substances that may interfere with blood gas measurements. The cited reference provides additional information on the effects of excess heparin in blood gas analyses.

Arterial blood gases are dynamic measurements and should be analyzed as soon as possible after collection. However, if an extended period of time between collection and testing is anticipated, collection of arterial blood via glass syringe and transport in an ice slurry are preferable. Multiple references have been provided (in Section 6.4 on Equipment) for additional information on time and temperature issues related to arterial blood collection.

3. When more than 30 minutes are anticipated prior to measurement, are both ice and a glass syringe recommended, or just one?
 - **See response to Comment 2.**

Section 6.5.1, Hazards/Complications of Arterial Puncture (Formerly Section 5.5.1)

4. Replace “hazard” with “complication.”

The heading of this section has been modified to address the commenter’s concern.

Section 6.5.2.1.1(5), Radial Artery (Formerly Section 5.5.2(5))

5. Single arterial puncture. Clarify whether the needle bevel should be up or down during this procedure. Mention not to redirect the needle until it is withdrawn from the skin. In reference to the Allen test, the fist is clenched and opened in repeated fashion to exsanguinate the hand of blood. Avoid overextending and abducting the hand and fingers because this can compress the arteries to yield a false positive Allen test. If the patient cannot cooperate to perform an Allen test, an Esmarch or rubber wrap can be used to exsanguinate the hand.
 - **The bevel of the needle should be facing up during arterial puncture. The commenter’s statement regarding redirecting the needle is not commonly accepted practice; therefore, no modification to the text**

has been made. Section 6.5.2.1.1 discusses use of the *Modified Allen Test* for assessing the patient and the information supplied is supported by a reference. Note that the use of a rubber wrap is not supported in the literature.

6. Single arterial puncture. Radial artery. Because this is a very common site to collect specimens from, a picture of the wrist position and needle approach would benefit the reader of this document.
 - **Users are referred to Figure 1 for a diagrammatic representation of arterial insertion.**
7. Single arterial puncture. Brachial artery. Clarify the anatomic location of the median nerve in relation to the brachial artery.
 - **Additional text has been added to Section 6.3.2.2 to clarify the anatomic location of the median nerve.**
8. Single arterial puncture. Femoral artery. Clarify if the groin area is to be shaved or cropped of pubic hair.
 - **Cropping/shaving of pubic hair prior to arterial puncture procedures is determined by institutional policy.**
9. Single arterial puncture. Femoral artery. Clarify the anatomic location of the femoral nerve, artery, and vein.
 - **Additional text has been added to Section 6.3.2.3 to clarify the anatomic location of the femoral artery, nerve, and vein.**

Section 6.4. Equipment (Formerly Section 5.4)

10. Arterial cannulation and monitoring. In general, the radial artery is preferred, and then the femoral artery.
 - **The commenter's observation is noted.**
11. Arterial cannulation and monitoring. Can this cannula site be used to obtain blood specimens for other laboratory analyses?
 - **Site selection for specific tests/analyses is determined by institutional policy and is not within the scope of this document.**
12. Arterial cannulation and monitoring. Clarify if sterile technique (e.g., gloves, gowns) is to be used for this procedure.
 - **Adoption of sterile technique for arterial cannulation is determined by local/institutional policy and is not within the scope of this document.**
13. Arterial cannulation and monitoring. Clarify to be aware of arterial blood flashback upon removal of the needle assembly from the catheter. The placement of gauze under the hub of the catheter, as suggested in Section 6.5.5.2.1, is appropriate and serves as an example.
 - **As suggested by the commenter, the placement of gauze under the hub of the catheter, as suggested in Section 6.5.5.2.1, is appropriate and serves as an example of a method that can be used to avoid flashback when removing the needle assembly from the catheter.**
14. Arterial cannulation and monitoring. Suture material and equipment are needed to adequately secure these arterial catheters.
 - **Use of sutures following arterial cannulation procedures is determined by institutional policy and is not within the scope of this document.**
15. Arterial cannulation and monitoring. Add notation to refer to the figures of the various types of cannulation kits/catheter over a needle, catheter through a needle, use of a guide wire.

- **Figures B1 through B4 have been deleted. Users should consult manufacturers of catheter/collection devices for information on specific products.**

Appendix A, Arterial Specimen Collection Sites

16. Clarify for the reader the preferred location for arterial blood sampling in the figure. This is unclear in the diagram demonstrating the entire extremity.

- **Preferred sites for arterial blood sampling are described in Section 6.3, “Selection of the Site for Arterial Puncture.”**

Appendix C, Local Anesthesia (Formerly Appendix D)

17. Clarify the sentence regarding lidocaine and bleeding. Statement made that lidocaine prolongs bleeding in patients receiving anticoagulation therapy. Is this because of a drug interaction? Lidocaine causes a transient vasodilation, which can increase bleeding, but this effect is not specific to patients on anticoagulation therapy. Also, ensure the patient has no sensitivities to lidocaine prior to administering this drug.

- **The sentence has been deleted.**

Appendix G, Blood Gas Microcollection Devices (Formerly Appendix H)

18. Typo, change “the” to “then.”

- **This editorial correction has been made.**

NOTES

The Quality System Approach

NCCLS subscribes to a quality system approach in the development of standards and guidelines, which facilitates project management; defines a document structure via a template; and provides a process to identify needed documents through a gap analysis. The approach is based on the model presented in the most current edition of NCCLS document [HS1—A Quality System Model for Health Care](#). The quality system approach applies a core set of “quality system essentials” (QSEs), basic to any organization, to all operations in any healthcare service’s path of workflow. The QSEs provide the framework for delivery of any type of product or service, serving as a manager’s guide. The QSEs are:

| | | | |
|--|--|---|--|
| Documents & Records Organization Personnel | Equipment Purchasing & Inventory Process Control | Information Management Occurrence Management Assessment | Process Improvement Service & Satisfaction Facilities & Safety |
|--|--|---|--|

H11-A4 addresses the following quality system essentials (QSEs):

| Documents & Records | Organization | Personnel | Equipment | Purchasing & Inventory | Process Control | Information Management | Occurrence Management | Assessment | Process Improvement | Service & Satisfaction | Facilities & Safety |
|---------------------|--------------|------------------|-----------|------------------------|-----------------|------------------------|-----------------------|------------|---------------------|------------------------|-----------------------|
| X HS4 | HS4 | X GP21 HS4 | X HS4 | HS4 | X HS4 | HS4 | HS4 | HS4 | X HS4 | HS4 | X HS4 M29 X3 |

Adapted from NCCLS document [HS1—A Quality System Model for Health Care](#).

Path of Workflow

A path of workflow is the description of the necessary steps to deliver the particular product or service that the organization or entity provides. For example, [GP26](#) defines a clinical laboratory path of workflow which consists of three sequential processes: preanalytic, analytic, and postanalytic. All clinical laboratories follow these processes to deliver the laboratory’s services, namely quality laboratory information.

H11-A4 addresses the following steps within the clinical laboratory path of workflow:

| Preanalytic | | | | | Analytic | | Postanalytic | |
|--------------------|--------------|----------------------|--------------------|------------------|----------------|---------------------------|----------------|-------------------------------|
| Patient Assessment | Test Request | Specimen Collection | Specimen Transport | Specimen Receipt | Testing Review | Laboratory Interpretation | Results Report | Post-test Specimen Management |
| X | X | X H3 H4 LA4 | X | X | C46 | C46 | | |

Adapted from NCCLS document [HS1—A Quality System Model for Health Care](#).

Related NCCLS Publications*

- C46-A** **Blood Gas and pH Analysis and Related Measurements; Approved Guideline (2001).** This document provides clear definitions of the quantities in current use, and provides a single source of information on appropriate specimen collection, preanalytical variables, calibration, and quality control for blood pH and gas analysis and related measurements.
- GP21-A2** **Training and Competence Assessment; Approved Guideline—Second Edition (2004).** This document provides background and recommended processes for the development of training and competence assessment programs that meet quality/regulatory objectives.
- GP26-A2** **Application of a Quality System Model for Laboratory Services; Approved Guideline—Second Edition (2003).** This guideline describes the clinical laboratory's path of workflow and provides information for laboratory operations that will assist the laboratory in improving its processes and meeting government and accreditation requirements.
- H3-A5** **Procedures for the Collection of Diagnostic Blood Specimens by Venipuncture; Approved Standard—Fifth Edition (2003).** This document provides procedures for the collection of diagnostic specimens by venipuncture, including line draws, blood culture collection, and venipuncture in children.
- H4-A5** **Procedures and Devices for the Collection of Diagnostic Capillary Blood Specimens; Approved Standard—Fifth Edition (2004).** This document provides a technique for the collection of diagnostic capillary blood specimens, including recommendations for collection sites and specimen handling and identification. Specifications for disposable devices used to collect, process, and transfer diagnostic capillary blood specimens are also included.
- HS1-A** **A Quality System Model for Health Care; Approved Guideline (2002).** This document provides a model for healthcare service providers that will assist with implementation and maintenance of effective quality systems.
- HS4-A** **Application of a Quality System Model for Respiratory Services; Approved Guideline (2002).** This document provides a model for providers of respiratory services that will assist with implementation and maintenance of an effective quality system.
- LA4-A4** **Blood Collection on Filter Paper for Neonatal Screening Programs; Approved Standard—Fourth Edition (2003).** This document addresses the issues associated with specimen collection, the filter paper collection device, and the transfer of blood onto filter paper, and provides uniform techniques for collecting the best possible specimen for use in newborn screening programs.
- M29-A2** **Protection of Laboratory Workers from Occupationally Acquired Infections; Approved Guideline—Second Edition (2001).** This document provides guidance on the risk of transmission of hepatitis viruses and human immunodeficiency viruses in any laboratory setting; specific precautions for preventing the laboratory transmission of blood-borne infection from laboratory instruments and materials; and recommendations for the management of blood-borne exposure.
- X3-R** **Implementing a Needlestick and Sharps Injury Prevention Program in the Clinical Laboratory; A Report (2002).** This document provides guidance for implementing safer medical devices that reduce or eliminate sharps injuries to laboratory personnel.

* Proposed- and tentative-level documents are being advanced through the NCCLS consensus process; therefore, readers should refer to the most recent editions.

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