Turkish Biochemical Society

Guidelines for Preanalytical Phase in Blood Gas, pH and Other Related Measurements

Prepared by the Turkish Biochemical Society Preanalytical Phase Working Group
2020-ANKARA
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CONTENT

Abbreviations

AG: Anion gap

BE: Base excess

Cl: Chloride

CLSI: Clinical Laboratory Standards Institute

COHb: Carboxyhemoglobin

ctO_2: Total arterial oxygen concentration

HCO_3: Bicarbonate concentration

Hb: Hemoglobin

K^+: Potassium

IFCC: International Federation of Clinical Chemistry and Laboratory Medicine

iCa^{+2}: Ionised calcium

iMg^{+2}: Ionised magnesium

IVC: Intravenous catheter

MetHb: Methemoglobin

Na^+: Sodium

p(A-a) O_2: Alveolar-arterial oxygen gradient

pCO_2: Partial arterial carbondioxyde pressure

pO_2: Partial arterial oxygen pressure

pH: Negative logarithm of H+ ion concentration

sO_2: Arterial oxygen saturation

TBS: Turkish Biochemical Society

WHO: World Health Organization

1. INTRODUCTION

Preanalytical phase in a clinical laboratory is one of the critical stages for quality of patient care. If sampling is not correct, then the value of the laboratory results decreases (1).

Arterial blood sample is one of the specimens which is the most responsive ones to preanalytical effects. Inappropriate preparation of the patient from whom arterial blood sample will be drawn, incorrect test order, inaccurate sample collection or inaccurate handling of the sample can change the values of the blood gas measurements. Current enhanced devices have the ability of carrying out measurements of other significant analytes (e.g. sodium, potassium, chloride, ionized calcium, glucose, hematocrit, hemoglobin) along with pH and blood gas analysis. This guideline has been produced in order to describe preanalytical phase practice and management with a holistic view to get accurate and reliable results associated with blood gas and stated metabolites.

As this guideline was compiled, it was made benefit of the Clinical Laboratory Standards Institute (CLSI) (2), American Association for Respiratory Care (AARC) (1) and World Health Organisation (WHO) (3) blood collection guidelines. WHO Guidelines on Drawing Blood indicates that arterial blood collection should be performed by healthcare workers who have qualified through a formal training. However, in our country, although no guidance which is described and arranged for healthcare workers who collects arterial blood specimen is available, sample collection is performed by clinicians. Arterial blood collection is technically a difficult procedure and it may be painful and hazardous for the patient. Therefore, healthcare workers who perform arterial intervention have to know convenient techniques, risks of the procedure and precautions that has to be taken against the complications (1).

In our country, as we were arranging these guidelines, we have seen fit to portray doctor as a target with the perspective that it is the doctor's responsibility; in this point of view we have given particular importance to complication management proficiency and competence of the staff. As for the venous blood collection, all healthcare workers who have been trained for blood collection procedures are seen fit.

The main targets of these guidelines are to decrease possible risks that may be encountered by patients and healthcare workers, to keep the integrity of blood sample and to manage preanalytical variables which are to occur during blood collection for the good of patients. Analytical phase and device-based issues are out of the scope of these guidelines.

Arterial blood is the blood type delivered to all organs for their metabolic needs; its composition is the same and equal all over the body. Composition of the venous blood reflects metabolic activity of the tissue that it discharges and therefore it varies among different parts of the body and among different times (e.g. due to muscular activity). Despite the evidences associated with the comparability of arterial and venous blood gases with respect to their pHs, partial arterial carbon dioxide pressures (pCO_2) and bicarbonate concentrations (HCO_3) in some clinical cases, venous blood gas should be accepted as an alternative to the arterial blood gas sample in only some cases that display full-featured clinical conditions (1).

The main difference between arterial and venous blood is the oxygen content. However, it has been reported that pH, carbon dioxide content, cellular volume and the concentration of lactic acid, plasma chloride, glucose, ammonium, and other metabolites can change (2). Venous blood is not a satisfying alternative of arterial blood for routine blood gas analysis (4). With this point of view, this guideline approaches venous blood sample in such a way which is supported by various references: Venous blood sample is convenient if it is collected in proper conditions for the assessment of dishemoglobin levels such as pH, pCO_2, electrolytes, carboxyhemoglobin (COHb) and methemoglobin (MetHb) (4). Venous samples collected in heparin containing evacuated tubes are not appropriate for measuring pO2, oxygen content or oxygen saturation / fractional hemoglobin analysis (3).

Capillary blood gas samples can be used as substitute for arterial interventions or samples collected from indwelling arterial catheters for measuring acid-base balance (pH) and ventilation efficiency ($PaCO_2$). The value of capillary pO_2 measurement is a bit low in the assessment of arterial oxygenation (5).

In this guideline, in addition to radial, brachial, femoral arterial sample collection, procedures for venous arterialized capillary blood collection and sample collection through indwelling arterial catheter will be included.

All healthcare workers who practice arterial access must know intentional precautions that are planned to manage the risks of the procedure, complications and risks for the patient or laboratory workers as well as effects of those on laboratory test results. Details should be paid attention before and after arterial blood collection procedures in order to ensure the reliability of test results (1). From this point of view, another subject which will be mentioned in the guideline is the considerations to be taken into account while collecting blood sample in order to ensure safety for patients and healthcare workers.

With respect to preanalytical phase of blood gas analysis, for quality control requirements and country specific accreditation needs, in the section of Technical Requirements included in ISO 15189:2012, there exists the expression "Quality indicators are to be constituted for monitoring and evaluating the performance in the critical points of processes before, during and after the laboratory examinations" (6). In this context, ISO 15189 Accreditation Standard considers medical laboratories responsible for preanalytical process controls related to the blood gas analyzers taking place within the scope of point-of-care testing devices. However, a multidisciplinary teamwork is also recommended under the coordination of the laboratory in practice.

Quality Standards in National Health stated that the responsibility for the management of blood gas systems used with the intent of point-of-care testing.

2. DEFINITIONS

2.1. Blood Gas and Blood Gas Content

Blood gas analysis is a valuable laboratory practice which gives information about metabolic and respiratory physiology of patients. In blood, partial pressures of physiologically active gases (oxygen and carbon dioxide), pH and hemoglobin oxygen saturation measurements are made. Blood gas analyses, unlike routine laboratory tests, are performed in patients who have critical or acute pathology and generally in intensive care units. When all other routine analyses are performed in venous blood sample, blood gas analyses are carried out in arterial whole blood sample as a golden standard. Nevertheless, in recent years, also venous whole blood samples take part in guidelines (1,2,4).

Blood gas analyses involve essentially the amount of unbounded dissolved oxygen and carbon dioxide in blood and blood acid/base analysis. As the amounts of oxygen and carbon dioxide are measured and reported as partial pressures (pO_2 and PCO_2), blood acidity is measured and reported as pH. As to the blood HCO_3 levels, it is calculated by "Henderson-Hasselbach" equation using pCO_2 and pH values.

With developing technology, hemoglobin and electrolyte measurements have been added to the blood gas parameters. Thus, many different parameters can be calculated. While hemoglobin (Hb), sodium (Na^+), potassium (K^+), chloride (Cl), ionized calcium ($iCa+^2$), lactate, glucose are measured directly, parameters such as oxygen saturation (sO_2), anion gap (AG), base excess (BE), alveolar-arterial oxygen gradient ($p(A-a)O_2$), total arterial oxygen concentration (ctO_2) are calculated. In addition, in some blood gas analyzers, concurrent co-oximetry measurements along with hemoglobin derivatives dishemoglobin levels such as methemoglobin (MetHb), carboxyhemoglobin (COHb) measurement can also be made.

2.2. Arterial Blood

Arterial blood is blood sample that is free of many metabolites and has high hemoglobin oxygen saturation as a result of high oxygen pressure coming from alveoli. Arterial blood completely reflects gas exchange particularly from lungs. In the blood gas analyses, it is considered as the most reliable sample for evaluating respiratory function with arterial oxygen pressure (pO_2). During the evaluations of respiratory and metabolic acidosis, the golden standard is arterial blood analyses. Blood sample should be collected under anaerobic conditions, mixed in order to make it homogenized with anticoagulant agent and analyzed without delay.

pO_2, pCO_2 and pH values of arterial blood are given in Table 1 (Appendix-A).

2.3. Venous Blood

Venous blood is the blood that has plenty of hydrogen ions resulting from the metabolism in peripheral tissues, concurrently having high amount of COHb. Due to difficulties in collecting arterial blood gas sample and need for staff with special training, recently blood gases might be studied in venous blood samples (7). If venous blood sample is collected under anaerobic conditions, then pH and pCO_2 measurements can reliably be evaluated. However, in various studies, the opinion stating that, except for pH, venous blood samples cannot be used instead of arterial samples in pO_2 and pCO_2 analyses dominates the discussion (8,9). Particularly in patients who are hemodynamically unstable and with congestive heart failure, inconsistencies between venous and arterial blood gas analyses increase more (7). Besides, there are also suggestions reporting that venous sample type can be substituted arterial blood type for the measurements of pH, pCO_2 and HCO_3 in some diseases such as respiratory distress syndrome, neonatal sepsis, renal failure, pneumonia, diabetic ketoacidosis and epilepsy (1).

CAUTION: It is necessary to make arterial blood gas measurements and to measure oxygen partial pressure and oxygen saturation for demonstrating oxygenation (8,10).

pO_2, pCO_2 and pH values in venous blood are given in Table 2 (Appendix-A).

2.4. Mixed Venous Blood

Similar to the arterial blood, mixed venous blood sample provides information about oxygenation, ventilation and acid-base status of the patient (1). Venous blood sample is the sample type which should be used together with arterial blood sample for the evaluation of cardiac output. It can be used also

in evaluating the degree of intrapulmonary shunt (11). Measuring mixed venous oxygen saturation helps to determine if cardiac output and oxygen delivery is sufficient for metabolic needs or not (9). Mixed venous blood is a mixture of all venous blood coming from coronary veins to the right atrium of the heart through vena cava superior, inferior and coronary sinuses. It forms during the blood flow from the right atrium into the right ventricle before reaching pulmonary artery (11). Briefly, mixed venous blood reaching pulmonary artery has not been reoxygenized yet in pulmonary capillaries. This type of blood which is not oxygenized buy the lungs reflects remaining amount of oxygen existing in the circulation after the tissues take the oxygen they need for themselves. Mixed venous blood sample is the golden standard in evaluating oxygen usage of the tissues (12).

2.5. Central Venous Blood

SCentral venous blood is obtained via central venous catheters. In general, it is not suitable for determining oxygenation status of patients (13). However, central venous blood gas analysis is recommended for determining oxygen consumption in target-specific early treatment practices. In addition, central venous oxygen saturation and mixed venous oxygen saturation can reflect the relation between oxygen delivery and oxygen consumption. Peripheral venous sample is preferred for evaluating acid-base status. Central venous samples can be sufficient for evaluating pH and pCO_2 in patients who are hemodynamically stable (1).

2.6. Capillary Blood

Capillary blood is the blood existing in the meeting points of arterioles and venules which are as thin as 1-8 μm in diameter and where oxygen and nutrients are released to the tissues from arteriolar blood as well as plenty of metabolites and carbon dioxide are absorbed from the tissue (Figure 1).

As mentioned above, although the golden standard in blood gas analyses is arterial blood collection, blood gas evaluations can be done by collecting capillary blood samples in patients in whom arterial sample cannot be taken or in pediatric patients. In these cases, preferred method is the capillary arterializations.

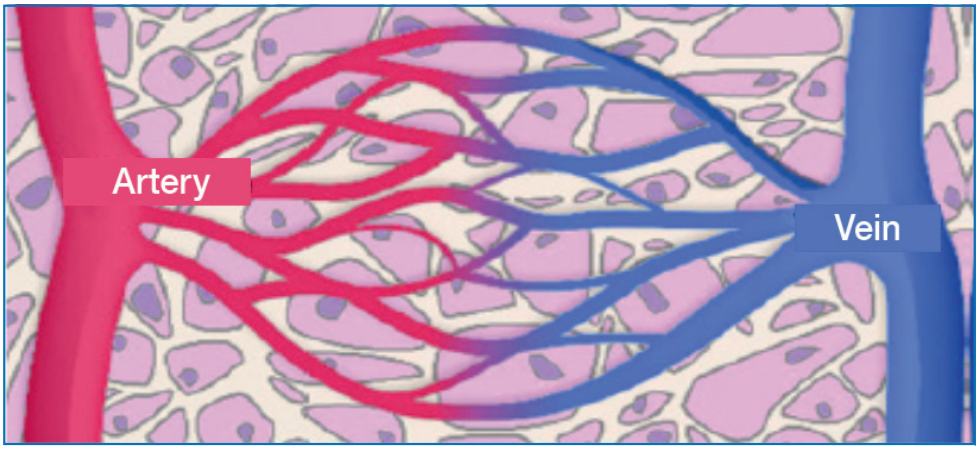


Figure 1: Capillary bed where arterioles and venules meet.
(https://acutecaretesting.org/en/articles/capillary-blood-gases--to-arterialize-or-not)

2.7. Staff

In our country, although there is not any instruction or guidelines described and issued legally for the staff who draws arterial blood sample, sample collection is realized by clinicians in general (1). This liability is for clinical physician due to the priority of suitability and competency sufficient enough for the management of complications in arterial blood collection.

Where the circumstances of arterial blood collection are as stated, in case venous blood collection is preferred, all healthcare workers who have been trained are considered to be suitable for the procedure of blood collection.

Staff member who draws blood sample for blood gas analysis must behave in accordance with the "Rules for patient and employee safety and infection control" arranged by Infection Control Committees and Hospital Infection Control Committee. Also, laboratory staff who performs blood gas analysis must work in compliance with standard protocols and procedures for precautions against contamination (14,15).

RECOMMENDATION: Due the particulars in blood gas sampling, with respect to providing staff safety and for preventing needle stick injuries, it is recommended to use safety needles possessing a locking or knockback system after the use (11).

Blood gas analyses can be carried out by trained staff in various fields:

- Hospital emergency unit
- Intensive care unit
- Patient care unit
- Clinical laboratory
- Pulmonary intervention laboratory
- Operating theater
- Cardiac catheterization laboratory

3. EQUIPMENT

3.1. Antiseptic Agents

The usage of appropriate antiseptic agents (e.g. isopropanol foam rubbers) is necessary for cleaning and disinfecting vascular access site.

CAUTION: In blood, which is contaminated with providone iodine, test results might be deceptively high for potassium levels (3).

3.2. Gauze Pads

Gauze dressing (e.g. 5 x 5cm) is appropriate for usage.

3.3. Cooler

In case where blood gas analysis shall not be performed within 30 minutes after the sample collection, the sample should be kept and transferred to the laboratory in a 1-5 oC cooler boxes or in containers in the size that is sufficient for holding the sample collection equipment and containing ice-water mix.

3.4. Safety Engineered Sharp Devices

Along with the safety engineered sharp devices preventing needle stick injuries and providing to retract the syringe needle with a single hand, “Luer” tip or other appropriate caps or covers that can prevent the syringe or blood collection equipment to let the air in should be kept available.

3. 5. Sharps Bin

Puncture proof sharps bins should be made ready to use to get rid of used sharp objects, syringes, or needles. Sharps bins should be made of rigid plastic, metal or compressed carton, and there should be a hole on the box and should be labeled as biohazardous waste.

3. 6. Hypodermic Needle

In general, needles of which the beveled end is short, size number is 20-25 (Gauge, G) and length is 16 – 25.4 cm according to the access site comply with arterial access.

CAUTION: It is needed to use shorter needles for drawing blood from the radial arteries and longer needles for drawing blood from brachial or femoral arteries.

Needles with smaller gauges (25 Gauge) require more critical aspiration to provide blood flow into the syringe (16).

3.7. Blood Collection Equipment

Usually, appropriate blood collection equipment for arterial access includes a plastic, single use 1, 3 or 5 mL syringe with automatic filling feature which contains accurate amount of lyophilized heparin salt or any other appropriate anticoagulant agent. Heparin type depends on the analytes to be measured and analysis method.

CAUTION: Liquid heparin use may cause dilution of the sample specimen. For this reason, it is recommended to use sprayed dry heparin or heparin in dry form (4). Analytes affected by dilution are; pCO_2, Na^+, K^+, iCa^+_2, Hb (17). While using dry form “lyophilized” heparin, easy dissolution of heparin preparation is important as it is mixed with blood. Otherwise, it might cause blood to clot.

CAUTION: Standard heparin which is not ion-balanced, bounds electrolytes and may cause significant decrease in iCa+2 results (4,18). Other analytes which are affected less are iMg^+_2, Na^+, K^+.

10-20 IU/mL heparin concentrations can be used to reduce heparin bias effect (2,4), but low concentration heparin, increases the risk of clotting in the specimen. Instead, use of ion-balanced modified heparin is important. Binding sites of ion-balanced heparin are saturated with electrolytes, thus there is no additional risk of clotting. For plastic syringes, heparin amount recommended by the International Federation of Clinical Chemistry and Laboratory Medicine (IFCC) is 50 IU/mL (10).

CAUTION: Sodium heparin, due to including sodium salt, increases Na+ values putting 1-3 mmol/L on during analysis.

NOTE: Unlike glass syringes, blood gas sample specimens obtained using plastic syringes should be kept in room temperature and should be analyzed within 30 minutes following sample collection. Blood oxygen and carbon dioxide levels in samples kept in room temperature for 30 minutes or lower duration are influenced minimally, except for cases with increased leukocyte or platelet count (4).

Sample specimens obtained for special examinations (alveolar-arterial gradient ($P(A\text{-}a)O_2$) or "shunt" examinations) should be analyzed immediately or within five minutes just after sample collection. If a long delay (more than 30 minutes) will take place before analyzing, it is recommended to use glass syringe and to keep the syringe in iced water (4).

NOTE: Syringes kept in iced water cause to unreliable potassium results due to the diffusion effect of temperature on erythrocytes, so these syringes cannot be used for electrolyte measurements. Keeping in iced water is only applied to the blood gas measurements (4).

Capillary tubes can be used for capillary blood sample specimens. Magnetic bars can help blood mixing.

CAUTION: Because it is more effective in small volumes, air bubbles should be evacuated attentively from the sample specimen (4).

3. 8. Other

Required materials for sample specification and registry.

Additional equipment and supplies for drawing blood gas sample specimen from the arterial cannula:

- Armboard for extremity positioning, roll towel or pad
- Bandage to fix both armboard and catheter
- 5 or 10 mL syringe needed for drawing the blood which is to be discarded before
- collecting sample specimen for analyses
- Irrigation solution (0.9% saline, etc.)
- Clean 5x5 gauze patch chlorhexidine
- 2% chlorhexidine pad containing 70% isopropyl alcohol

4. WORK-FLOW FOR SPECIMEN COLLECTION

4.1. Test Order

Blood gas analyses are requested particularly in pathologies which lead to disorders in gas exchange or acid-base balance and such patients are usually critical patients hospitalized in wards and intensive care units. However, blood gas analyses are also requested in some outpatients, but this kind of patient number is limited.

In addition, also in monitoring the patients who are connected to mechanic ventilation system in intensive care units, ventilation and regulation of oxygen amount is determined according to the results of blood gas analyses.

In hospitalized patients who are not in mechanical ventilation or have no metabolic pathology, continuous monitorization with pulse-oxymetry can be used instead of blood gas analyses.

Blood gas analyses are ordered by the physician who has evaluated the patient and following the results is carried out by the clinic.

4.1.1. Order Forms and Records

Accurate sampling process begins with accurate identification of the patient. These patients are usually emergency and critically ill patients. Thus, accurate patient identification during blood gas sampling becomes a more difficult procedure.

Depending on the general status of the patient, clinical condition (medical ventilation, body temperature, breathing pattern, etc.) of the patient should be specified and recorded (19).

After identity confirmation in compliance with the order and compliance with blood sampling are assessed, capillary tube and/or syringe are to be labeled which is going to be used in sampling process. During identification, at least 2 delineative information must be matched.

In the patient barcode label information, at least the following ones are to be appeared:

- Patient's first name and surname,
- Patient's gender
- Patient's protocol number
- Sample number.

In addition to below information, the following information should be included in the information processing records, if not included on the barcode label:

- Date of birth
- TR identity number
- Sampling date and time
- Information about the phlebotomist who draw the sample (20).

4.2. Preparing the Patient

Arterial blood gas sampling is more difficult compared to other blood collection methods. In addition, it is highly affected by the patient's breathing rate and depth. For this reason, preparing the patient for blood collection is very important.

- Patient is kept waiting for 5 minutes or until his/her breathing reforms.
- Then, in position changing, the patient is kept waiting at least 15 minutes in lying or sitting position (21)
- In case of changing the mechanical ventilation, it is recommended to wait for 30 minutes (21)
- If needed, local anesthesia can be applied for arterial access (Appendix-B).

Above mentioned details are equally important for arterial, capillary, and venous samplings.

4.2.1. Patient Evaluation and Necessary Conditions

If the patient is conscious and can receive instructions, identification is confirmed, he or she is informed about the process to be done, necessary preparations are realized, and sampling is performed.

If the patient is unconscious and has indwelling catheter, identity confirmation is done bed side using wristband and with the responsible nurse/healthcare worker, then sampling is performed.

4.2.2. Documentation

Before sampling, information during the process about the patient should be recorded. These records can be kept in digital media or in written form.

Besides the patient's identity information, following points should be recorded:

- Age, gender
- Ward where the sampling is performed
- Patient's body temperature
- Time of sampling
- Body site of sampling
- Respiration type and rate (spontaneous/ventilation support)
- If the sampling is carried out in a patient who is under respiratory support/mechanical ventilation; the amount of oxygen administered should be recorded.

4.2.3. Clarifying the Procedure

For patients, arterial blood gas sample collection is a more difficult and painful process compared to the other blood collection methods. Therefore, the action to be done should be explained to the patients and the patient should be informed. It should be considered if local anesthesia is needed or not.

4.3. Selection of the Puncture Site

The most frequently preferred site for arterial blood gas sampling is peripheral arteries. Among peripheral arteries, the easiest and safest access, and near surface artery is the radial arteries in wrist sites. Alternative sites are brachial artery in forearms and femoral arteries in groins.

As for venous samples, the most frequently preferred site is again antecubital fossa region veins. For detailed information about venous blood collection, you can see the Guidelines for Venous Blood Collection (Phlebotomy) of the Turkish Biochemical Society (20).

Blood gas sampling needs to be carried out under completely aseptic conditions and by trained staff and considering the patient and worker safety.

4.3.1. Criteria for Site Selection

If the sampling for blood gas analyses will be done, arterial blood sample should be the first choice. In case of skipping over arterial blood, also the capillary and venous blood samples can be used in blood gas measurements, but in these cases concentration difference of some analytes between these two

kinds of samples must be taken into consideration. Sampling can be carried out according to the patient's general status, age, type, and position of the indwelling catheter.

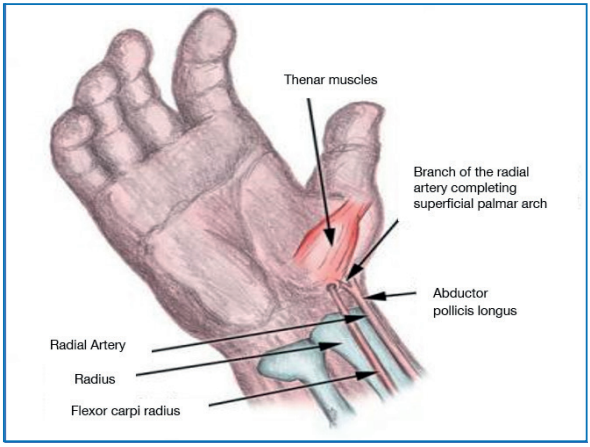
When it is intended to sample arterial blood specimen, first of all healthy blood flow should be inspected, then the collateral circulation should be inspected by pressing down on the intended artery (See Allen test; Appendix-C). Arterial pulsations and traces should be checked and be sure that the skin integrity is intact and there is no lesion on the region.

Patient's age and weight is important while selecting the capillary sampling site. While heels are almost always the site to choose for sampling within the first 6 months of infants, in adults and in children who are more than 10 kg, capillary sampling is drawn from finger vessels.

Antecubital fossa veins are superficial enough and preferred site for venous samplings.

4.3.2. Arterial Access Sites

Radial Artery

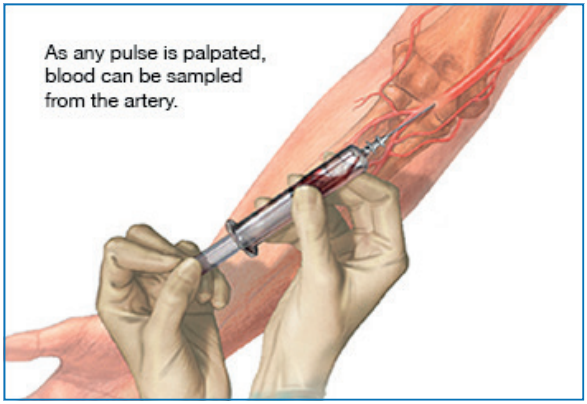


Radial artery which is found internal side of the wrist is the peripheral artery that is selected most frequently for arterial blood gas analyses (Figure 2). If it is found to be suitable by Allen test (Appendix-C), then sampling can be performed.

Figure 2: Radial Artery.

(https://www.medscape.com/answers/1999586-90970/what-is-the-anatomy-of-the-radial-artery-relative-to-arterial-line-placement.)

Brachial Artery

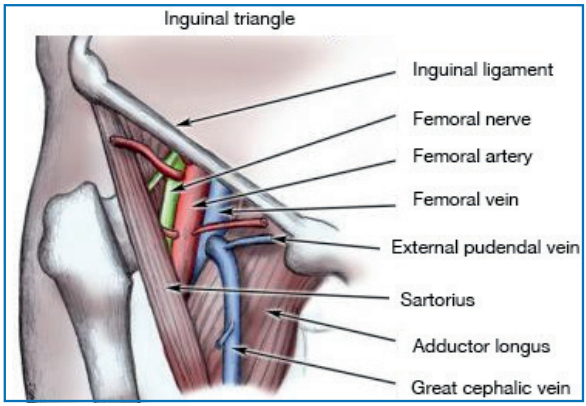


Brachial artery which is found in the internal side of the upper arms is used as the second chose of sampling site for arterial blood gas measurements (Figure 3). However, as it is located deeper than radial artery, it might be more difficult to detect its location; collateral circulation should be observed attentively, and there are neural neighborhoods around the artery that can be damaged easily.

Figure 3: Brachial artery

(http://printer-friendly.adam.com/content.aspx?productId=117&pid=1&gid=003422&c_custid=758)

Femoral Artery



It is one of the maximum size arteries in diameter in the body (Figure 4) and located in a depth more than radial and brachial arteries' locations, but detection of this artery is easier. In case of failure in radial arterial sampling, it is the second choice of sampling site.

Figure 4: Femoral artery

(https://www.medscape.com/answers/1999586-90970/what-is-the-anatomy-of-the-radial-artery-relative-to-arterial-line-placement.)

4.3.3. Venous Access Sites

Although arterial blood sampling is the golden standard in blood gas analyses, in recent years, venous blood sampling is also used in blood gas analyses. Venous sampling can be used for ventilation and pH evaluations particularly in hospitalized and venous catheter patients. You can reach detailed information about venous blood sampling in the Guidelines for Venous Blood Collection (Phlebotomy) of the TBS (20).

If the patient has central venous catheter, blood gas sampling can be drawn from the catheter under anaerobic conditions. In other patients, the veins used in routine blood collection can be used in a manner that allows anaerobic sampling.

While arterial and mixed venous blood gas analyses provide information about oxygenation, ventilation and acid-base status of the patient, analysis results of sample types obtained from peripheral vein samplings provides more limited information (1).

Although it is improper most of the time, as compared to arterial blood sampling for blood gas analyses, venous blood sampling frequency has been increasing due to that it causes less pain and leads less complications. Besides that, venous blood samples particularly obtained from the central and peripheral catheters in intensive care unit patients are frequently used.

As summary, recognizing how to interpret the results of venous blood gas analyses and their limitations will benefit to using these results more proper and more effective in clinical practices.

4.3.4. Capillary Access Sites

In pediatric patients, sampling is made particularly from lateral sides of the heel (Figure 5) by warming up the tissue if possible (3-5 minutes, capillary arterializations).

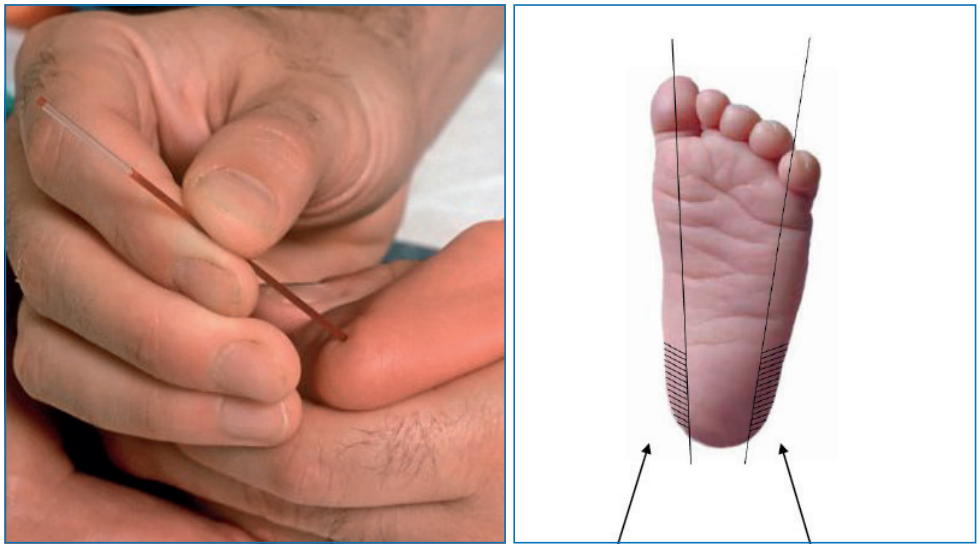


Figure 5: Vascular access sites for capillary blood sampling on the heels.
(http://www.newbornbabyzone.com/health-safety/the-newborn-heel-prick-is-it-going-to-be-history/ https://www.bsuh.nhs.uk/wp-content/uploads/sites/5/2016/09/Heel-prick-protocol.pdf)

CAUTION: Squeezing should not be administered, and it must be disallowed air bubbles to reach capillary tubes (Figure 6). Blood should be drawn attentively preventing to contact with air.

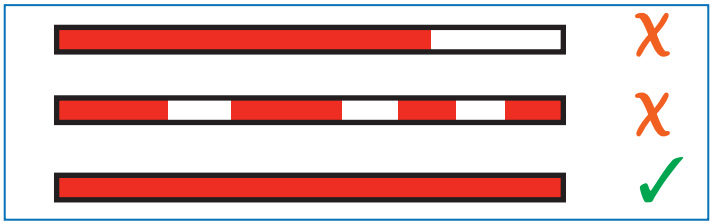


Figure 6: Proper blood sampling into the capillary tubes

In adult patients and in children whose body weight is over 10 kg, capillary blood sampling can be made from a fingertip (Figure 7). If the blood sampling will be performed from a fingertip, 3rd or 4th finger of the inactive hand is selected. Fingertip might be warmed up (capillary arterializations) for a while (3-5 minutes). After puncturing or making an incision with a lancet, the first blood drop is cleaned and then blood sample is drawn into the capillary tube disallowing air bubbles to come into the tube (Figure 6). Immediately after the sampling procedure is completed, both end of the tube must be sealed with a paste or with the tube's own caps. Also, in fingertip samplings, squeezing should be avoided.

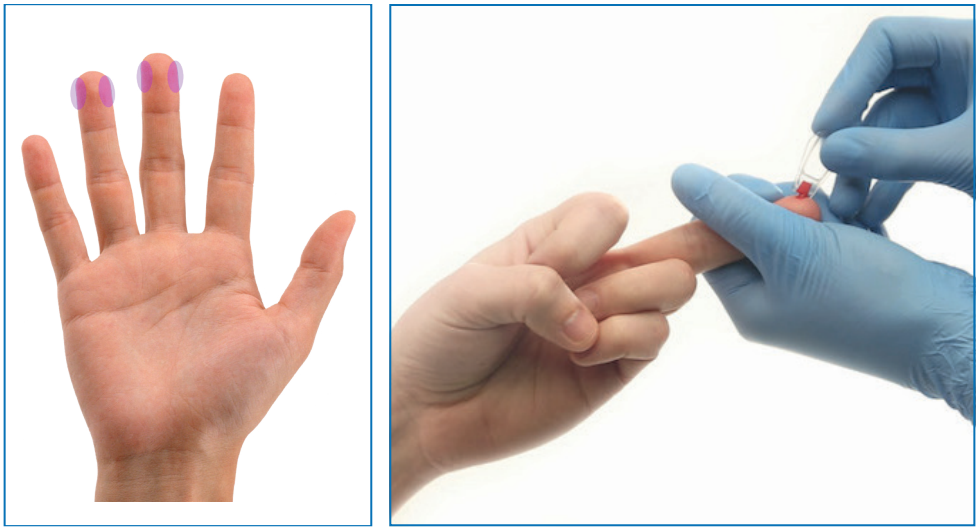


Figure 7: Fingertip vascular access sites for capillary blood sampling.
(http://www.clpmag.com/2017/11/best-practices-fingerstick-capillary-sampling/)

Capillary blood can be drawn from the earlobes (Figure 8). A meta-analysis suggested that arterial gasometrical values can be estimated from the capillary blood samples obtained from earlobes and are useful in clinical practices. However, at the same time, the same meta-analysis drew attention on the lack of standard procedures of sampling as well as the limited precision attributed to arteriovenous capillary gas differences (22).

It is suggested that, in medical scenarios where gasometrical evaluation using less proper but easier and faster techniques can be useful or in cases where it is not easy to reach blood gas analytical techniques, arterialized capillary sample obtained from earlobes has particular advantages compared to conventional methods using specifically designed sampling equipment and procedures (23).

In patients in whom tight periodical pO2 monitoring is not required, blood gas analyses sampling from earlobe capillaries with arterializations estimates arterial pH, pCO_2, BE and HCO_3 values accurately (24).

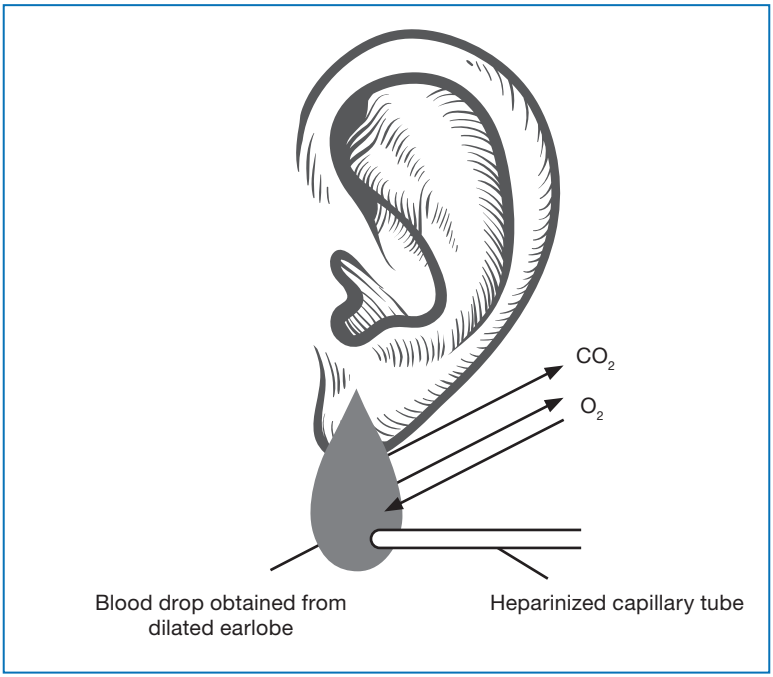


Figure 8: Earlobe puncture site for capillary blood sampling.

4.4. Blood Sampling Procedures

4.4.1. Arterial Blood Gas Sampling Procedures

Procedures

The practice is realized as described in the following after preparing all necessary equipment and selecting the puncture site.

Radial Artery Access. Prior to selecting this site, availability of sufficient collateral circulation by ulnar artery is explored using Modified Allen test (Appendix-C) or Doppler ultrasound flow indicators (25) or both.

1. Modified Allen Test is performed. (Appendix-C) If the test result is negative, that is if ulnar artery does not feed the hand good enough, radial artery should not be used as the vascular access site. An alternative artery should be selected.

2. If the result of the Allen test is positive, radial artery can be used for vascular access. The arm is positioned in abduction with the wrist in extension of 30^0 ɵ and the palm in supine position in order to make the soft tissue stretch and fix on the ligament and the bone. If necessary, for positioning the extremity, roll towel or pad can be used.

3. Radial artery is located on the continuation line of the thumb, lateral of the wrist. Transillumination of the wrist using a fiberoptic light source can help to find the radial artery and to draw the trunk line of palmar arch in infants.

4. Vascular access site is prepared aseptically. It is to be ensured not to touch vascular access site except for the gloved hands after cleaning.

5. Blood gas syringe is held with one hand as holding a dart arrow and the finger of the other hand is placed on the point, on the artery, where the needle is to be driven (not into the skin). The skin is punctured on the 5-10 mm of the distal side of the finger angled about 30-45° against the blood flow placing the bevel of the needle towardsupwards (Figure 9).

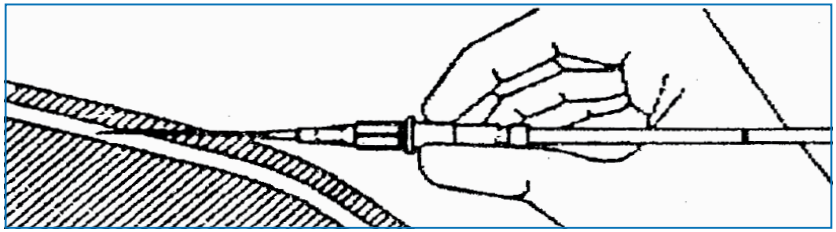


Figure 9: Accessing the artery (2).

6. Needle is driven towards subcutaneously and targeted the artery palpated under the finger. As artery access is maintained, blood will extravasate spontaneously into the syringe in case any needle which is smaller than 23G is not used. It might be needed to draw the plunger back gently and slowly in order to let blood draw into the syringe. If glass syringe is used, blood pressure pushes the plunger back. Avoiding this pushing back, slight compression onto the end of the plunger should be applied.

7. As required amount of blood is collected, dry and sterile gauze is placed onto the puncture site and the needle is retracted quickly.

8. Immediately, the artery in the access site is manually compressed with a sharp pressure at least for three to five minutes (26-28).

9. As pressure is applied with single hand on the artery, blood gas syringe is immediately checked regarding air bubbles; in case existence of air bubbles, should be removed attentively following the procedures recommended by the manufacturer. In order to prevent potential healthcare worker exposure, needle safety mechanism is to be activated as the sampling is completed and equipment is to be wasted in the sharps bin without being disintegrated (10,29).

10. In order to ensure sufficient anticoagulation and to prevent clotting, the sample is to be mixed well enough by rotating a few times or by making it upside down. Tight cloths that may apply pressure are not recommended. If the patient is receiving anticoagulation therapy or having a long clotting time, pressure is exerted for a longer time on the access site.

11. After completing the pressure application, access site is evaluated immediately. If hemostasis is not occurring or hematoma is appearing, pressure is exerted one more time for 1-2 minutes. This procedure is proceeded with until hemostasis is constituted. If hemostasis is not constituted in a reasonable time, medical consultancy is needed. Outpatients should stay in the practice area until their test results are evaluated.

CAUTION: In order to prevent post-procedure bleeding risk, a sufficient time of pressure application is a must-do step.

Brachial Artery Access. Vascular access must be performed according to the following procedures.

1. Patient's arm is stretched completely, and the wrist is rotated till the maximum pulse just over the wrinkle in the antecubital fossa is palpated by

the index finger. If needed, a roll towel is used in order to ease to position the extremity. After palpating the first arterial pulse, middle (third) finger continues to palpate the pulse 2-3 cm proximally.

2. In order not to damage median nerve sustaining sensorial fibers and stretching very near to the brachial artery, it must be very careful during the vascular access (30).

3. The site is cleaned.

4. Palpating the pulse, two fingers of the hand other than the hand which is holding the syringe is placed uncoupled on the arterial trace. The skin is punctured distally, just below the (index) finger and the needle is driven along the line binding the two fingers in a manner that its bevel to face upward and with 45° puncture angle. The artery goes on deeply particularly in obese people.

5. After vascular access, in order to stop bleeding, if possible, the artery may need to be compressed against the humerus. It is difficult to compress brachial artery effectively, but it is important.

Femoral Artery Access. Arterial access is to be performed according to the following procedure.

1. Femoral artery is located highly superficial within the inguinal triangle and just below the inguinal ligament. Patient should lie down extending both of his/her legs. Arterial pulsation is to be palpated with two fingers.

2. Cleaning of the arterial access site (see radial artery 4th step) must be sweeping due to frequent intervals of contamination in this site. If needed, the area around the site should be shaved.

3. Palpating fingers are placed along the artery with on and off 2 to 3 cm spaces in order to fix the vessel. Needle punctuation is done with a right angle against the skin surface or between two fingers against the blood flow.

4. Pressure on the artery after the arterial access is similar as described in the radial artery.

Procedures for Blood Gas Sampling from Arterial Catheter. It is a practical way of regular blood sampling without disturbing the patients. It is preferred in patients who have sepsis and hypotension or who display blood

pressure fluctuations due to the use of vasoactive drugs and under permanent blood pressure control. Therefore, the use of arterial cannulation is usually limited to the patients who are hospitalized in intensive care units and in situations where the patient must be under close monitorization.

Special Considerations

Arterial cannulation provides an opportunity to multi arterial blood sampling after a single vascular access. Arterial cannulation plays an important role in following up respiratory gas partial pressures as well as following up blood pressure. Radial artery is frequently preferred for arterial cannulation because it has an ease of use, is accessible and has a less complication risk compared to larger vessels such as the femoral artery. In addition, due to the collateral circulation provided by the ulnar artery in the hand region it is a safe site for cannulation (Figure 10). Nevertheless, radial cannulation procedure may cause nerve damage due to the neighborhood between radial artery and median nerve.

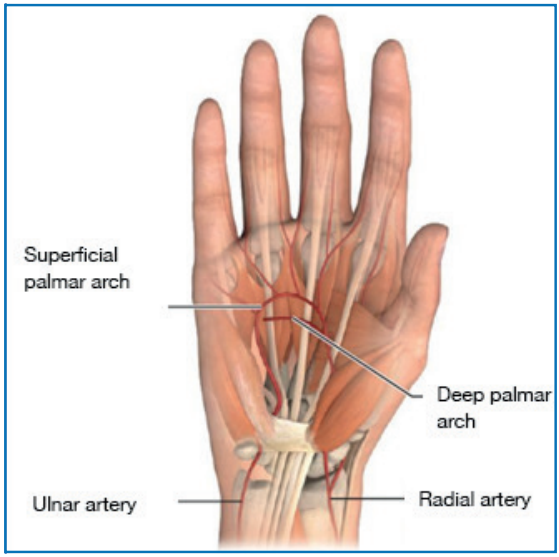


Figure 10: Radial and ulnar arteries
(source: https://slideplayer.biz.tr/slide/9274629/)

Particularly in critical patients, the reasons of frequent selection of radial artery for cannulation are as in the following:

- If vascular occlusion happens to be due to cannulation, ischemic complications are seen less depending on the good condition of collateral circulation in relevant site.

- Cannulation process is easy depending on the ease of accessing and superficiality of the radial artery.
- Location of this site is in anatomical balance, because the radius plays a natural splint role for stabilizing the radial artery.

Brachial and dorsalis pedis arteries are also used in inserting arterial cannula, but these sites are never the first choice. Dorsalis pedis artery should never be used for cannulation particularly in case of peripheral vascular diseases and advanced diabetes. Although it is easy to place cannula or catheter into the femoral artery, it creates difficulty regarding caring to patient confidentiality during follow up with respect to comfort and due to its location. Sampling from the arterial cannula, compared to the arterial vascular access other than catheterization, may rise the risk of preventing the blood flow resulting from obstruction. Therefore, additional precautions are to be taken (2, 31).

Procedure

Any interventional catheterization is a source of potential infection by the way of the location area or contaminated fluids, tubes or connections.

CAUTION: Microorganisms passing through the catheter can enter into the blood circulation and cause life threatening bacteriemia.

First of all, following precautions are to be taken:

- Air ingress into the system must be prevented,
- Safety of all connections must be ensured,
- Prior to sampling, “dead space” content in the catheter and its connections must be completely removed,
- After collecting the blood, air ingress into the syringe or blood collection devices must be prevented (2)

Sampling in Patients Not Receiving Infusion Fluid.

Regarding this method, infusion fluid bag is not connected to the arterial catheter of the patient (Figure 11).

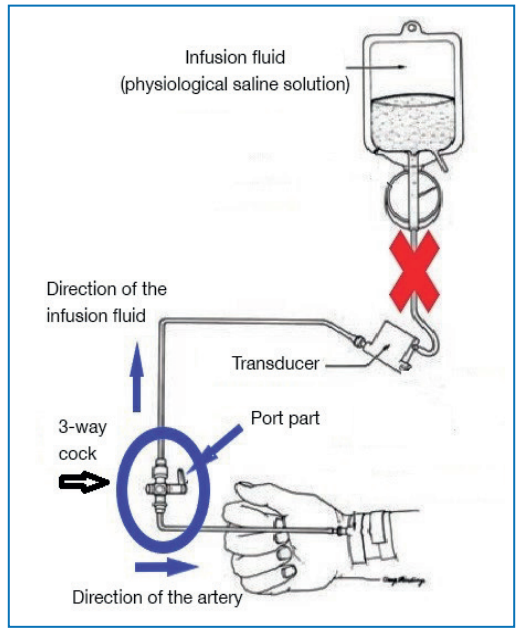


Figure 11: Radial arterial catheter which is not connected to any infusion fluid (2).

After taking the necessary precautions, blood collection process should be performed as in the following:

- Blood collection equipment is prepared, and it is ensured that there is no lacking piece.
- In order to decrease the risk of cross-infection, hands are washed with a bactericidal soap and water or with an alcohol-based antiseptic solution.
- In order to prevent the blood to flow into the cannula from the artery and blood spill, three-way stopcock is checked if it is closed towards the port part. Therefore, when blood collection is not performed, three-way stopcock is positioned as infusion and arterial direction is non-closed and port direction is closed (the position of the three-way stopcock is in a manner that the direction of the infusion fluid is non-closed, but any infusion fluid is not connected to the patient) (Figure 12a).
- Because hands are contaminated as touching the three-way stopcock, they must be cleaned again using an alcohol- based hand disinfectant.

- Gloves are worn avoiding the hands be contaminated with blood.
- The cap on the port part of the three-way stopcock is removed and port part is cleaned with 2% chlorhexidine pad containing 70% isopropyl alcohol.
- 4x4 gauze is placed under the three-way stopcock or the end of the connection line.
- A 5-10 mL discard syringe for collecting the blood to be disposed prior to sampling for analyses is attached to the syringe port of the cock.
- Three-way stopcock is turned in a manner that artery and port part to which the syringe connected is non-closed (Figure 12b) and a sum of irrigation fluid – blood mixture as much as six times of the volume of the catheter and its connections is aspirated in order to remove infusion fluid from the cannula.
- In order to prevent the blood to flow backward, to be contaminated with the infusion fluid and to spill, three-way stopcock is turned diagonally and the port part which is connected to the artery and the syringe is made closed (Figure 12c).
- Syringe to be discarded is to be removed and wasted.
- For collecting the necessary amount of blood to be used in blood gas analyses, a preconditioned arterial blood gas syringe is connected. Three-way stopcock is turned in such a manner that flow line in the artery and the port part become non-closed (Figure 12b) and required amount of blood is drawn into the syringe.

CAUTION: Only blood collection syringes which fill automatically should be used and the syringe should be allowed to fill with new arterial blood (2).

CAUTION: Necessary amount of blood is drawn gently in order to prevent any vascular spasm and provide sufficient mixture with heparin.

- For preventing the blood flow backward from the artery and blood spill, three-way stopcock is made closed by rotating it diagonally (Figure 12c) and the syringe is removed.
- After sampling, for avoiding the catheter line obstruction, catheter, cock and connections are washed preferably with normal saline. Accurate flushing volume required for cleaning the system varies depending on the catheters and this should be specified before catheterization.

CAUTION: In some catheter lines, flushing solution is not connected to the catheter line (Figure 12) and for avoiding the catheter line obstruction due to the reasons such as clot formation catheter, cock and connections are washed preferably with normal saline.

RECOMMENDATION: Patient should be warned about the heating sensation in the extremities as flashing solution is administered.

- For the process of catheter line irrigation, a syringe containing necessary amount of normal saline is connected to the syringe port. Port part of the cock is put into non-cleat position (Figure 12d) and the solution is given slowly but permanently from the syringe port of the cock. Following the process is completed, syringe port of the cock is again put into closed position (Figure 12a) (2, 31).

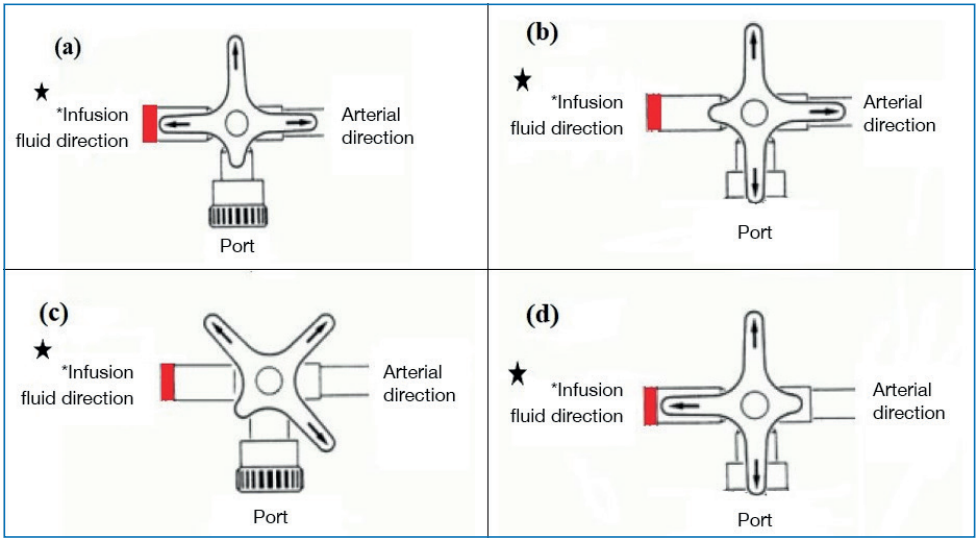


Figure 12: Model showing three-way stopcock positions in arterial catheters which are not connected infusion fluid (33)

★ As infusion fluid for flushing the line is not connected to the patients' catheters, infusion direction in the three-way stopcock is closed in all four figures.

NOTE: The arrows on the figures indicate the non-closed ends of the three-way cock (gaining access). The end without an arrow mark has no connection, because it is closed (dead end).

Sampling in Patients Receiving Infusion Fluid.

In cases of continues monitoring of the arterial pressure, irrigation solution must be infused in order to sustain cannulation and to prevent clotting within the line. Commercially available bags of 500 mL normal saline containing 1000 IU heparin is used prevalently for sustaining cannulation (Figure 13).

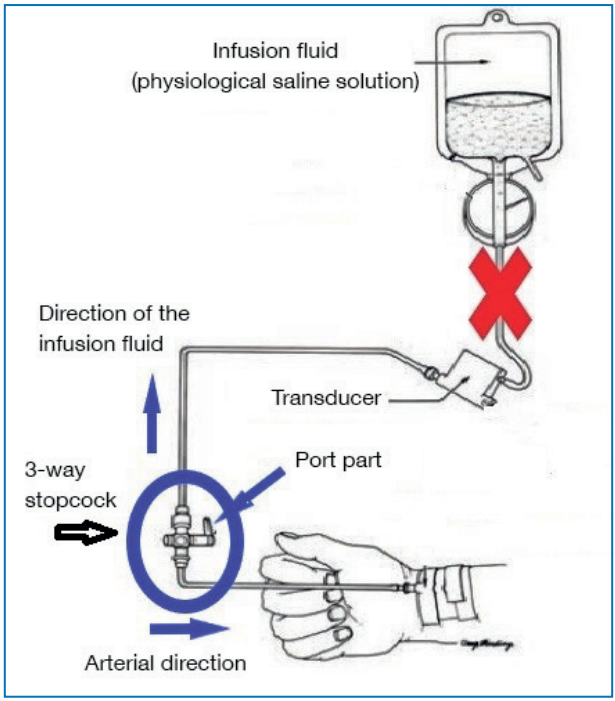


Figure 13: Radial arterial catheter connected infusion fluid (2).

However, appearance of hemorrhagic and thromboembolic incidents has created an increasing awareness about thrombocytopenia related to heparin and worried about safety of this practice. Hospitals preferring heparin in the irrigation fluid must be conscious of potential risks and monitor patients closely.

CAUTION: In case the platelet count decreases under 100.000/mm3 or recurring thrombocytopenia develops, this practice must be discontinued (2).

- When an open system is used, a waste syringe (5-10 mL) is connected to the nearest-patient part of the cock (Open system means the system using three-way cock) (Figure 14A).

CAUTION: Close systems are available. Users should refer to instructions of use of the manufacturer. (Closed system means the systems where there is a needleless access (vein valve) device instead of three-way cock in the ends of every port) (Figure 14B). During blood collection, disinfection and irrigation procedures in these systems are similar to the stages of closed systems if infusion fluid is connected. The only difference is that the infection risk is reduced in closed systems, compared to open systems (32,33).

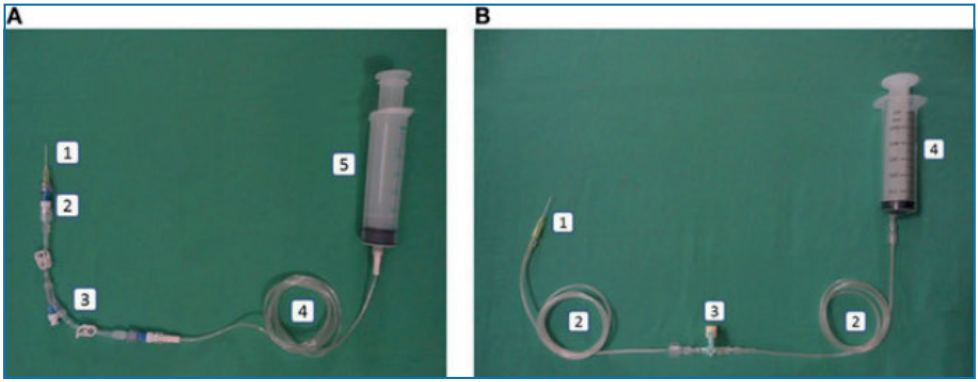


Figure 14: A. Open system B. Closed system

A. Open system peripheral catheterization. 1. Intravascular cannula, 2. Single needleless access device, 3. Double lumen luer lock needleless access device, 4. Luer lock extension tube, 5. Luer lock syringe,

12. Closed system peripheral catheterization. 1. Intravascular cannula, 2. Slip tip extension tube, 3. Three-way stopcock, 4. Slip tip syringe (https://www.researchgate.net/publication/274728231_Closed_Catheter_Access_System_Implementation_in_Reducing_the_Bloodstream_Infection_Rate_in_Low_Birth_Weight_Preterm_Infants/figures?lo=1)

- Stopcock is turned towards infusion direction. In this position, the direction which is connected to the flushing solution and port direction is non-closed, artery direction is closed (Figure 15a). In this position, fluid-blood mixture as much as five or six times of the volume between stopcock and the catheter is aspirated (3 mL).

CAUTION: For tubing lengths in the catheter system are variable, each institution should specify the volume of the fluid-blood mixture which is to be aspirated by itself.

- By turning the stopcock, make it all closed in every three direction (Figure 15b). While the stopcock is in this position, remove the fluid-blood mixture and discard it.

RECOMMENDATION: In cases when the patient has blood loss and it is necessary to keep the blood volume as possible as it can be, this fluid-blood mixture can be reinfused after sampling if there is no clotting.

CAUTION: If blood collection process prolongs or if healthcare worker forgets to reinfuse the collected blood, thus the blood collected and kept for reinfusion is administered to the patient in a longer time, some complications may be observed (34). This is open to contamination, clotting, and accordingly to infection and embolism. For this reason, it should not be preferred as possible as it can be.

Pre-heparinized blood gas syringe is connected, artery and port directions of the stopcock is non-closed (Figure 15c) and let the syringe fill with blood. Syringe is disconnected from the port sufficient volume of sampling is completed.

- Stopcock is positioned as its infusion fluid and the artery direction are non-closed, and port part is closed (Figure 15d).
- Tip of the blood gas syringe is closed and labeled as it is appropriate.
- Catheter line is irrigated with flushing solution containing 15-20mL normal saline (2, 34).

CAUTION: Sufficient amount of flushing solution should be used in order to clean the catheter completely from residual blood (35).

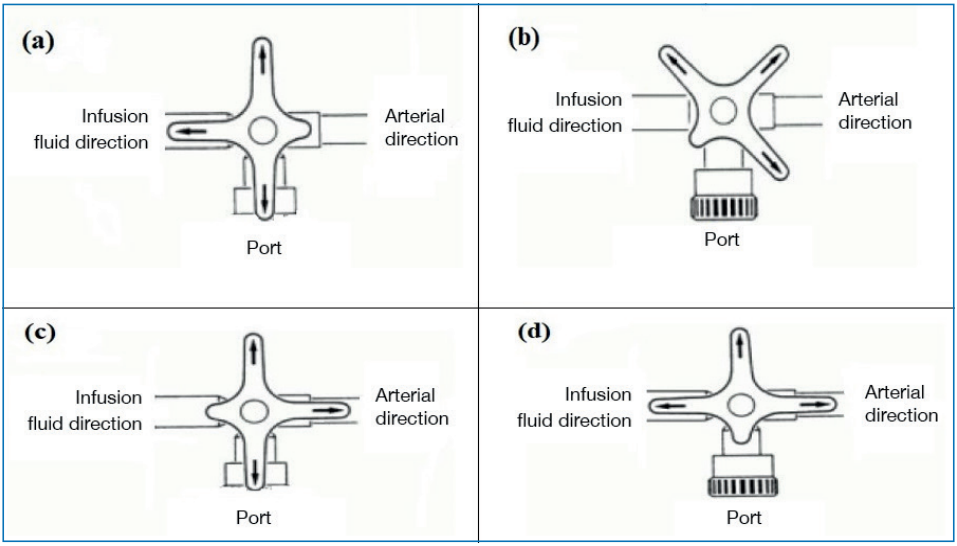


Figure 15: Model illustrating the positions of three-way stopcock in arterial catheter connected infusion fluid. (33)

NOTE: Arrows on the figure show non-closed tips (accessible) of the three-way stopcock. The tip without arrow does not have any connection because it is closed (dead-end).

Importance of Arterial Catheterization in Continuous Monitoring

If the arterial catheter is used for continuous monitorisation, special precautions should be taken in order to keep the integrity of the catheter and to prevent both local and systemic infections. With the purpose of meeting accreditation standards, intensive care units should develop written policies and procedures for maintaining catheterizations and employ these precautions attentively. For instance, in the USA, Guidelines for Critical Care prepared by the American Intensive Care Nurses Society suggests particular instructions regarding catheter maintenance and it is a recommended source for specifying and regulating institutional policies (2).

Complications

The incidence of complications developing during blood sampling from the arterial catheters is lower than blood collections by direct arterial access. For instance, complications such as vasovagal reaction, arteriospasm and hematoma seen during arterial access are not observed in blood collection from catheterization. In addition, not related to the sampling directly from the catheterization, complications such as arteriospasm developing during catheterization or during removing the catheter or hematoma developing as a result of blood leakage due to improper catheterization or dislocation are not observed during sampling from the catheter.

Using Improper Infusion Fluid. Normal saline should be used in catheter flushing. If 5% glucose solution or a mixture of both and a sufficient amount of blood is not removed during the sampling process instead of using normal saline, false results might be obtained (36). For example, erroneously high glucose results can be obtained after analyses performed in a contaminated arterial blood specimen with the infusion fluid in a patient whose arterial catheter is flushed with 5% glucose solution (36). In addition, normal saline solution with heparin used prevalently with this purpose also causes complications such as bleeding associated with thrombocytopenia and thromboembolism (2).

CAUTION: Solutions used in flushing the arterial lines should be kept separately from the other intravenous solutions.

RECOMMENDATION: Availability of written procedures and continuing training of the staff about this issue can lower the mistakes.

RECOMMENDATION: Order of infusion solution used in arterial line flushing by the doctor and administration after double check by two staff prior to arterial flushing can lower erroneous results.

Thrombus and Embolism. If needle or the catheter indwelling time prolongs, probability of complication development may increase. One of the complications is thrombus associated with damage on internal wall of the vessel and, in an advanced stage, embolism associated with the enlargement of the thrombus and vascular obstruction. While the incident of arterial obstruction by a thrombus is directly related to the size of the artery and indwelling time of the catheter, it is inversely proportional to arterial diameter and blood flow in the artery.

CAUTION: Thrombus can develop both in arteries and veins. Unlike arteries, most superficial veins used for vascular access have collateral vasculature that can provide sufficient circulation. For this reason, arterial thrombus leads to more serious consequences (2).

Besides, the blood which is getting to reinfuse to the patient can cause contamination and sample clotting due to possible prolongation of blood sampling procedures or a delay in the reinfusion of the blood to the patient as a result of forgetting of the phlebotomist, thus it can cause infection and embolism (34).

Blood Leakage in the Catheter. During blood sampling, blood leakage can occur as a result of the misplacing the three-way stopcock following the procedure or displacing the catheter by accident (36). This circumstance is an important problem as it can cause iatrogenic anemia.

Infection. Infection can develop as a result of catheter line contamination due to using weak aseptic techniques during catheter maintenance (36). Therefore, it is critically important to comply with the institutional procedures in applying aseptic technique.

Vasovagal Reaction. Vasovagal reaction can develop in patients that can cause loss of consciousness (37). Following procedures are applied as treating the patients who are fainting or who are not responding stimuli:

1. Staff who has first aid training is informed.
2. If the patient is in sitting position, if possible, he/she is made lie flat or his/her head and arms are lowered.
3. Tight clothing is loosened.

Arteriospasm. Arteiospasm is reflexive narrowing of the artery as a response to pain or other stimuli; sometimes it can be triggered with anxiety. However, it is temporary, even if the needle is placed properly in the lumen, it can make blood collection impossible.

Hematoma. As blood pressure is higher in arteries than in veins, in arterial access, tendency of blood leakage is higher in arterial access site. On the other hand, elastic tissue in arterial walls provides the access site wound close more rapidly, but elastic tissue decreases by aging and some disorders; therefore, hematoma risk is higher in elderly. Probability of blood leakage in the vascular access site increases as the diameter of the needle increases. Hematoma or external bleeding risk increases in patients who are receiving anticoagulant therapy or in individuals who have a serious coagulopathy (e.g. last stage hepatic disorder, oncology patients).

4.4.2. Procedures of Arterial Blood Gas Sampling

Procedure

Proper application of venous blood collection procedures contributes in decreasing the errors in measurements of venous blood gas (except for pO2) and other metabolites (7). Venous blood samples can be collected from different sites and with different methods. Venous sampling procedures vary according to the sampling sites and method. For this reason, when results of a venous blood gas analysis, sampling site and method should be taken into account.

CAUTION: Here, the point that is important and should not be forgotten is to ensure venous sampling is performed under anaerobic conditions.

CAUTION: If venous sampling is needed to be performed for divergent tests, blood gas analysis should be done with a second venous sampling different from the first vascular access.

CAUTION: It is definitely inappropriate to transfer blood to the blood gas syringe from any evacuated tube or vacuum syringe during venous blood sampling.

Procedures of Peripheral Venous Blood Gas Sampling. Proper application of venous sampling procedures contributes in decreasing the errors in blood gas measurements. Venous blood gas samples can be obtained from different sites and with different methods. For venous blood varies according to the vascular access site and method, while reading the results of blood

gas analysis sampling site and method should be taken into account. Overall, principles of venous sampling are applied to the venous blood sampling. For venous sampling, please refer to the detailed information included in the Guidelines of Venous Sampling (Phlebotomy) of the TBS (20). Pre-analytical requirements such as getting the sample under anaerobic conditions, transfer conditions and rapid analyzing are similar to the procedures of arterial sampling (see. Procedures of Arterial Sampling).

CAUTION: Venous blood collected in heparinised evacuated tubes is improper for evaluating pO2, oxygen content and oxygen saturation/fractional hemoglobin.

CAUTION: Oxygen existing in evacuated tubes can change the results of pO2 substantially.

CAUTION: Venous stasis resulting from forearm exercise depending on clenching can lead to substantial changes in K+ values reaching 3 mmol/L.

RECOMMENDATION: Tourniquet application must be performed venous sampling and it must be untied just before the needle is retracted from the vessel (4, 20).

CAUTION: Sampling must be done under anaerobic conditions. For this reason, syringes that have self closing tip caps following blood collection must be selected. pH, pO_2 and pCO_2 values change in samples which come into contact with air. Overall, for pCO_2 is low in atmospheric air, pCO_2 in blood also decreases more and pH increases. If the patient does not receive additional oxygen therapy, pO_2 increases (11).

Procedures of Mixed Venous Blood Gas Sampling. True mixed venous blood is obtained from pulmonary artery through pulmonary artery catheterization. Procedure resembles sampling from the arterial catheter (see. Sampling from Arterial Catheter) (Figure 16).

In mixed venous blood collection, the sample should be obtained from the most distal port of the pulmonary artery catheterization (pulmonary artery port) (9).

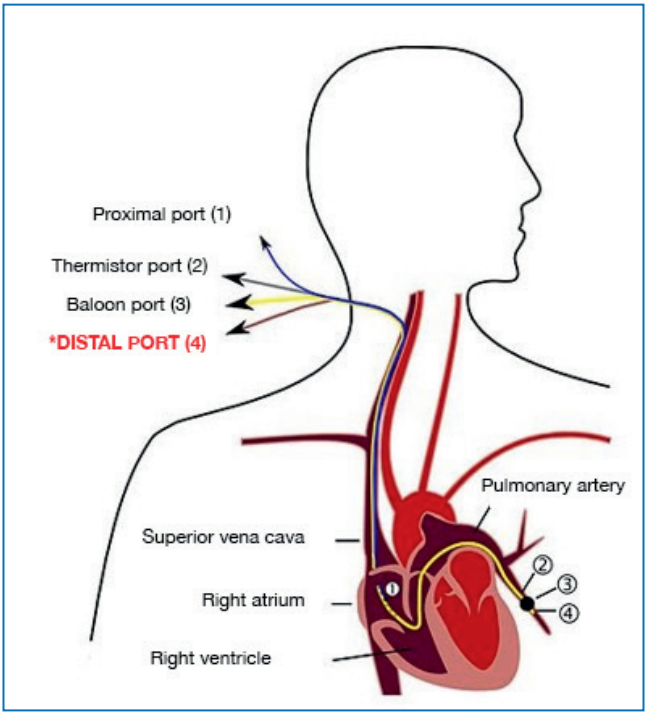


Figure 16: Pulmonary artery catheterization

https://en.wikipedia.org/wiki/Pulmonary_artery_catheter

*It shows the port from which the blood must be collected to ensure a complete mixed blood sampling.

CAUTION: Prior to blood collection, infusion solution in the catheter must be removed completely (10).

CAUTION: Tip of the pulmonary artery catheterization should be positioned in the pulmonary artery tree without clamping (4,10).

CAUTION: In order to prevent backward blood leakage based arterialised blood to mix, blood should be drawn slowly from the catheter. In this context, recommended blood drawing rate is 1 mL per 5 seconds (4,10). In different publications, it is recommended to draw 1-5 mL of blood in 1-2 minutes from the distal port of pulmonary arterial catheterization (9).

Procedures of Central Venous Blood Gas Sampling. Central venous blood is collected through a catheter placed percutaneously into the internal jugular vein in the neck or subclavian vein which is found on the lower part of the chest. These catheters are included in the class of central venous cath-

eters. They are called vascular access devices in general. Vascular access devices are used to access to the blood circulation of the patient in order to give a wide range of treatments including vascular access for infusion therapy, parenteral nutrition and medication besides blood collection. Central venous catheter is placed from a point which is near the site where vena cava superior opens to the right atrium. For this reason, it has the venous blood content related to the upper part of the body (13, 38).

CAUTION: Blood obtained from central venous catheter does not have complete content of mixed venous blood because it does not contain the blood circulated by vena cava inferior (13).

Special Considerations

Catheter access includes medication administration, flushing and locking the catheter, inserting or changing infusion set or needleless intravascular catheter (IVC) system besides blood sampling (34).

For blood sampling from the catheter increases the count of catheter access, it is an infection source. If flushing is not performed after sampling, the risk of catheter obstruction increases (34).

CAUTION: Particularly catheter hub (catheter junction) or needleless IVC system is a gateway for microorganisms to enter intraluminal surface of the catheter. Microorganisms colonized here can cause central venous catheter related bloodstream infections (34).

CAUTION: In each catheter access, disinfection must be done. In disinfection, the method which is known as “scrubbing the hub” must be used. Surfaces that must be disinfected are catheter hub and needleless IVC system surfaces (34, 39-41).

In blood sampling, the largest lumen is to be selected; if the catheter is a multiple-lumen catheter, one lumen should be kept for blood sampling (34).

The method is employed as in the following:

- After cleaning the hub, a 10 mL injector containing 5-10 mL normal saline (0.9% sodium chloride solution) is connected to the central catheter junction site.
- Following catheter flushing, a new empty injector is connected to the junction site for the blood-fluid mixture which is to be discarded then.
- Blood at least threefold of the volume used to flush catheter line is drawn with an injector just about to be discarded.

Methods of Blood Sampling

While blood can be collected from central venous catheter directly with a vacuum system or syringe by using discard system, it can be performed from the catheter with a syringe by using push-pull method (35). Reinfusion method can be used as another method.

Discard Method: It is the technique where the first sample is discarded. In this technique, a certain volume of sample is collected, and it is discarded. Then, needed sample for blood gas analysis is collected with a new syringe. It is collected using catheter "hub" or needleless DIC system.

The method is employed as in the following:

- After cleaning the hub, a 10 mL injector containing 5-10 mL normal saline (0.9% sodium chloride solution) is connected to the central catheter junction site.
- Following catheter flushing, a new empty injector is connected to the junction site for the blood-fluid mixture which is to be discarded then.
- Blood at least threefold of the volume used to flush catheter line is drawn with an injector just about to be discarded.

CAUTION: This blood-fluid mixture drawn to be discarded should be discarded into an appropriate waste bin in order not to mistake it for the other.

- Then, a new blood gas syringe is connected for drawing required amount of blood sample to be used in blood gas analysis.
- Catheter line is flushed with normal saline which is selected as flushing solution.
- Finally, the hub is closed with a sterile stopper (35).

Push-Pull Method: This method is based on the homogenization of blood.

- First of all, catheter is flushed. 5 mL normal saline is used in flushing.
- Using the same syringe, 6 mL of blood is drawn from the catheter. Prior to retracting the syringe from the hub, the blood drawn into the syringe is reinjected into the catheter.
- Drawing blood sample and reinjecting it into the catheter procedures described above are repeated at least three times.
- After completing the process, syringe is retracted from the catheter and discarded in an appropriate waste bin.

- Blood gas syringe is connected to the catheter for drawing required blood for blood gas analysis.
- Following sampling, blood gas syringe is disconnected, and it is labeled.
- Catheter is flushed with flushing solution containing 10-20 mL normal saline (34).

CAUTION: Sufficient amount of flushing solution should be used for cleaning the catheter from residual blood completely (35).

Method of Reinfusion: In the reinfusion technique, 6 mL of sample is drawn and the tip of the syringe is sealed with a sterile cap. The procedures of drawing required sample with a new syringe are similar to the other two methods. Different from the other methods, the sample drawn into the first syringe is reinfused (34).

CAUTION: This method is a method which is open to contamination and clotting of the drawn blood. For this reason, it should not be selected as possible as it can be (See. Complications: Embolism or Infection).

Complications

Some complications developing during sampling from central venous blood catheter are similar to the complications developing in phlebotomy from peripheral veins. You can reach detailed information about the complications of venous blood collection in the Guidelines of Venous Blood Sampling of the TBS (20). And some complications are in common with the complications observed in blood sampling from arterial catheters (see. Complications observed in blood sampling from arterial catheters)

Bloodstream Infection. It develops due to underutilizing aseptic techniques during blood sampling from catheter. Catheter hub or IVC system is a gateway for microorganisms to enter the intraluminal surface of the catheter. Microorganisms colonized in these parts can cause central venous catheter related bloodstream infections (CVCR-BSI) (34,39) Any approach decreasing the risk of contamination should be pursued. In each of the catheter access, disinfection should be done. During disinfecting, the method which is known as “scrubbing the hub” should be used. Surfaces that must be disinfected are surfaces of catheter hub and needleless IVC system (34, 39-41).

RECOMMENDATION: ≥0,5% chlorhexidine gluconate (CHG) containing 70% alcohol is highly effective in decreasing colonization. In addition, using providone iodine and 70% alcohol is recommended by the guidelines. For this reason, in case ≥0,5% CHG containing 70% alcohol is not available, providone iodine and 70% alcohol can be used (34).

CAUTION: Hand hygiene must be ensured after all types of intervention related to catheterization. Aseptic technique must be used in vascular catheter access.

Sample Contaminated with Flushing Solution. Erroneous test results can be observed after contamination of blood samples collected for analysis with flushing solutions used in catheter cleaning and fluids infused via catheter with the purpose of treatment. Also, reasons such as hemolysis resulting from improper blood sampling techniques can lead to errors in test results (35).

RECOMMENDATION: It is recommended to use normal saline while flushing cannulation.

CAUTION: Using solutions such as 5% glucose for flushing can cause erroneous results associated with contamination.

RECOMMENDATION: Any lumen which is not used, or which is used at intervals should be selected. It should be paid attention that the lumen is not used for medication administrations (34).

RECOMMENDATION: Infusion administered in the patient should be paused as far as possible prior to the process of blood sampling (34). Depending on the clinical status of the patient, the time of infusion pause lasts for 1 minute (41) or 3-5 minutes (42) before blood sampling.

Nosocomial Blood Loss. Nosocomial blood loss is frequently seen when blood sampling is performed with discard method (34).

RECOMMENDATION: In the guidelines, there are various recommendations related to discarded blood sample. As all recommendations are taken into account, appropriate volume is 5-10 mL (34, 41, 43, 44).

Confusing Discard Syringes and Syringes to Be Analyzed. It is seen frequently in the technique of reinfusion. In this technique, the blood sample drawn and kept to be reinfused into the catheter upon completion of sampling may be confused with the sample drawn by a new syringe for analysis. Also, in discard method where the first sample drawn is discarded, syringes maybe confused. In this method, a certain volume of blood sample is drawn and discarded. Then, required sample for blood gas analysis is drawn with a new syringe. If the syringe containing the blood drawn to be discarded is not

wasted immediately in an appropriate waste bin, there is a risk of confusing the two syringes (34).

Hemolysis. Mechanical hemolysis can be seen during drawing from the catheter and reinfusing the blood in the push-pull technique due to misimplementation of the technique (34).

RECOMMENDATION: Performing the procedures of drawing the blood from the catheter and reinfusing as slow as it can be preventing mechanical disintegration of erythrocytes.

Embolism or Infection. It is observed in reinfusion method as a result of a delay in reinfusing the blood to the patient as a result of prolongation of the procedures or forgetfulness of the phlebotomist to reinfuse the blood drawn from the catheter to be reinfused to the patient (34). Because of this situation, contamination and clotting of the blood which is collected can occur, thus infection and embolism can appear.

RECOMMENDATION: Sampling from the catheter by at least two phlebotomists can decrease delays related to forgetting.

4.4.3. Procedures of Capillary Sampling

Procedure

When sampling is performed for pH and blood gas analysis, selected site of capillary sampling should be warmed up before accessing. A warm and damp towel (or another heating device) which is not more than 42°C can be used to cover the site for three to five minutes (45). As this technique enhances arterial blood flow to the site, it lowers the difference between arterial and venous blood pressures, does not burn the skin and does not cause any significant variability for analytes tested in routine other than pO_2 (46,47).

Warming up the sampling site also leads to vasodilatation and helps obtaining a blood sample with free flow after accessing the site. Prior to accessing, insufficient warming of the site will cause unreliable results (48).

CAUTION: Even if these procedures are applied properly, obtaining arterial samples not contaminated with room air or interstitial fluid is very difficult. Room air affects blood gases, and interstitial fluid alters electrolyte values.

Site of Access

Capillary blood can be obtained in the plantar surface of the heels or hallux (Figure 5), palmar surfaces of the fingers (Figure 7) or from the earlobes (Figure 8).

Access from the heels is usually performed in infants younger than 1 year. Heel access sites should be limited to the sites shown in Figure 5. Access should not be performed from any prior access site, posterior curvature or in the midst of the foot.

Depth of Penetration

In order to get sufficient blood flow, the heel should be penetrated 2 mm in depth with a sterile manual or automatic lancet device. A penetration depth which is more than 2 mm in the plantar surface of the infant's heel can cause bone damage (2).

The sample should be collected in heparinized capillary tubes and should not contain air bubbles. Air exposure of the blood even for short time (10-30 seconds) can lead to significant changes in the sample. Existence of air bubbles of a volume which is smaller than 10% of the sample container has a small impact on pO_2 (49). However, for complete blood is mixed before pH an blood gas analyses, it should be paid strict attention in order to avoid air bubbles in sampling. Sample should be always kept in anaerobic conditions (capillary ends closed).

After sampling, following steps are to be taken:

1. One end of the capillary tube must be immediately closed with a cap or filler.

CAUTION: Filler containers get contaminated with blood and small glass pieces. For this reason, they should be changed at appropriate intervals.

2. A small magnetic stirring bar (also called pyrex) is placed into the hole of the tube.

3. Opposing end of the tube is closed rapidly. Blood can be stirred by a magnet moving back and forth outside the tube along the whole length of the stirring bar within the tube.

Complications (3)

Complications that can develop during capillary sampling are as in the following:

Venous Collapse. It is collapsing of veins due to the laceration of tibial artery associated with puncture of the heel from a medial site. Vascular access should be done in the posterior curvature of the heel or in the midst of the foot. Access sites in heels should not be limited to the sites marked in Figure 5. Plantar surface of heels and plantar surface of toes are appropriate for blood

sampling.

Osteomyelitis. A penetration depth which is more than 2 mm in the plantar surface of the infant's heel can cause calcaneus bone damage and risk of osteomyelitis development (2,50). In order to prevent this, it is recommended to use automatic lancets of which penetration depth is adjusted and not to press the lancet more than required.

Nerve Injury. For the tissue in fingertips of newborns is pretty thin, the risk of the lancet to cause nerve damage is high (51). For this reason, capillary sampling should be performed from heels.

Therefore, it is recommended to use automatic lancets of which penetration depth and width are adjusted and not to press the lancet more than needed and to select appropriate lancet size according to the patient.

Hematoma. Risk of hematoma development increases with uncontrolled capillary accesses and with penetration depths more than adequate.

In patients receiving anticoagulant therapy or having a serious clotting disorder, the risk of hematoma or external bleeding increases. Bleeding control should be performed after sampling.

Scar Formation. Risk of scar formation increases with uncontrolled capillary access, deeper and wider penetration than needed.

Therefore, it is recommended to use automatic lancets of which penetration depth and width are adjusted and not to press the lancet more than needed and to select appropriate lancet size according to the patient.

Laceration. Skin injury associated with repetitious application of tapes after sampling (particularly in very young and elderly patients) may appear. One must be careful in tape selection and application duration. Tapes should have antiallergic specifications and be removed after the bleeding is over.

4.5. Blood Sampling Safety

Staff related to blood gas laboratory should comply with the "Procedures for Isolation Precautions in Hospitals" developed by the Infection Control Committee.

Laboratory management should develop and apply standard and contamination-based protocol and procedures for precautions during blood gas analysis (14,15).

Regarding healthcare workers' safety related to the difficulties in blood gas sampling, it is recommended to use safety needles that have locking or automatic self-retraction specifications at the moment of withdrawing from the skin and to activate safety mechanism just after the end of sampling process with the purpose of preventing needle stick injuries (11).

For patient safety, please refer to the "Complications" items.

4.6. Blood Gas Sample Processing and Transportation

4.6.1. Mixing

Blood specimen must be stirred after sampling to make it mix with additive that prevents clotting and also to ensure resuspension and homogenization of the blood (Figure 17) (4,10,52). It should not be forgotten that the blood sample is to be stirred once more before entering into the device (Figure 18).

Mixing should be performed by moving towards both directions upside down and rolling between the hands. Manufacturer's instructions of use regarding blood collection equipment used should be taken into account (11,52). Stirring the sample for resuspension is critically important for testing particularly hemoglobin, hematocrit or oximetry (17, 52).

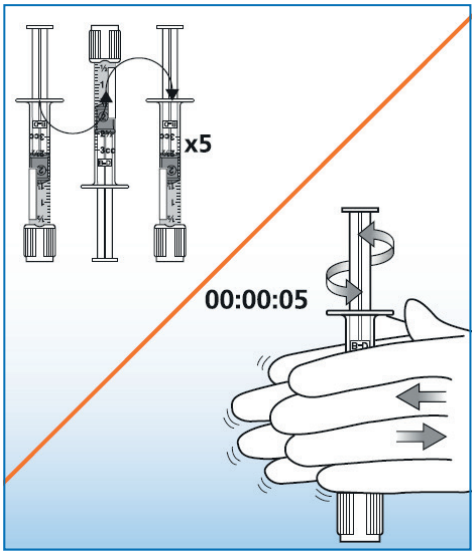


Figure 17: Stirring the sample immediately after blood collection

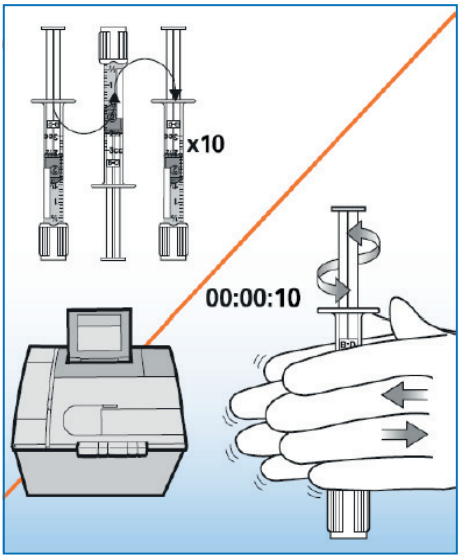


Figure 18: Stirring the sample prior to entering the device before analysis

Figures are retrived from the BD Posters; 2013: 2710, 2711

CAUTION: Since hemolyzed samples affect the results, procedures which can lead to hemolysis should be avoided. Sampling traumatically and severe shaking after sampling may cause hemolysis. With erythrocyte damage, 23-fold more K^+ is released to the plasma than normally found in plasma (53). This causes deceptively high results for K^+.

4.6.2. Removal of Air Bubbles

Air bubbles can be seen with a rate of 13% in syringe tip, and 25% in plunger tip (54). For the pO_2 and pCO_2 measurement stability, it is critical to remove the air bubbles following the sampling (Figure 19).

Figure 19: Air bubbles within the syringe.
https://www.scienceabc.com/humans/how-do-doctors-prevent-air-bubbles-during-surgical-procedures.html

Before capping the syringe, all the air bubbles should be removed by tapping on the syringe gently. Pneumatic system transportation can also lead air bubbles go into the syringe (55). For this reason, if possible, blood gas samples should be transferred to the unit where analysis shall be done by carrier/courier staff.

4.6.3. Patient Identification and Labeling

Exact blood collection procedure begins with the correct identification of the patient. In emergency services and in critical patients, exact patient identification may be more difficult to get during sampling for blood gas.

Depending on the patient status, clinical indications of the patient (medical ventilation, body temperature, breathing pattern, etc.) should also be specified and recorded (19).

The tube/syringe should be labeled after identity authentication in accordance with the order and blood collection compliance evaluation. During identification, at least two descriptive information should be compared.

At least the following should take place in patient barcode label information:

- Patient's name and surname
- Gender
- Patient number
- Laboratory number

Apart from all these should also take place;

- Date of birth
- TR Identity number
- Sampling date and time
- Phlebotomist who collected the sample should take place in records, if not in the barcode label.

4.6.4. Sample Transportation

Sample should be transferred to the laboratory and analyzed as soon as it is collected (2).

When possible, blood gas samples are preferred to be transferred manually without strong motion (4).

Temperature has an impact on analyte results. Any delay in ice application leads to glycolysis (56), also potassium may increase (57). It is recommended to transfer lactate samples as soon as they are collected and with ice water (0°C) (58) and analyzed within 15 minutes (10).

CAUTION: In patients with leukocytosis and high hematocrit, oxygen consumption will increase due to increased cell count. For this reason, it is important to perform analysis within the first 5 minutes (2).

If necessary, prior to sampling, a mixture of ice chips and water that can contain the sample should be prepared or another appropriate refrigerant should be used. Immediately after blood collection procedure is completed and after ensuring that the sample container is closed tightly and its barcode is adhered to the container, the sample should be immersed into the refrigerant. Barcode label should be waterproof (2).

CAUTION: Ice water application should be used only for glass syringes, not be used for plastic syringes.

a) Rapid analysis (within 15-30 minutes following blood collection)

If the sample shall be analyzed within 30 minutes, it is recommended to use plastic syringe. If analytes other than blood gas and pH shall be included in the measurements, timing can be adjusted. Samples should be transferred to the laboratory under room temperature. The sample should not be cooled (2, 10).

b) Delayed analysis (more than 30 minutes after blood collection)

If the analysis will delay, glass syringe should be used. The sample should be immersed into the refrigerant media immediately after it is collected. If $P(A\text{-}a)O^2$ or shunt study will be performed, the sample should be analyzed within 5 minutes. If there will be delay in the analysis, it is recommended to cool the glass syringe in ice water (2).

NOTE: Other analytes will also be analyzed besides blood gas and pH, cooling may have an impact on these analytes. It is not recommended to test electrolytes (especially potassium) in cooled samples (2).

CAUTION: If the sample is transported by a pneumatic system, the blood sample in the syringe exposes to strong swashes. While this condition has a small effect on pH, pCO_2 and several biochemical tests, it has a significant effect on pO_2 (4).

4.6.5. Accessioning the Sample in Laboratory

The date and the time when the sample is received by the laboratory should be recorded. Samples waited for a longer time than an acceptable duration according to the analyte should be rejected by the laboratory and a new sample should be obtained.

Samples that are not labeled properly, if its label cannot be read, if the sample is not held or kept properly are to be rejected. Rejection criteria should be included in institutional procedures (59).

Samples which are collected in inappropriate sample containers (non-heparinized syringe or capillary tube, syringes or capillary tube without ion-balanced heparin) or blood samples that are not collected in the sufficient amount to provide correct blood to additive ratio should be rejected.

4.6.6. Introducing the Sample to the Device

It should be insured that the device has been calibrated and its control results are appropriate before beginning analysis.

It is important to mix the blood again in order that precipitated blood is homogenized before putting into the device for analysis.

APPENDIX

APPENDIX – A Reference Ranges (13)

Parameter	Reference Range
pH	7.35-7.45
pCO_2 (mmHg)	35-45
pO_2 (mmHg)	90-100
sO_2 (%)	>95
HCO_3 (mmol/L)	22-26

Table 1: pO_2, pCO_2 and pH values in arterial blood

Parameter	Reference Range
pH	7.31-7.41
pCO_2 (mmHg)	40-50
pO_2 (mmHg)	30-40
sO_2 (%)	75
HCO_3 (mmol/L)	23-29

Table 2: pO_2, pCO_2 and pH values in arterial blood

APPENDIX – B Local Anesthesia

Local anesthesia can be used for relaxing patient, thus stabilizing patient's ventilation, or preventing arterial vasoconstriction, but using local anesthesia should be evaluated by the physician.

CAUTION: Allergy state of the patient regarding lidocaine and its derivatives should be evaluated and documented.

CAUTION: Whatever the purpose is, anaphylaxis is a hazard associated with local anesthesia. However, up to the present, there is no reporting about anaphylactic reaction related to local anesthesia administered before arterial access (60, 61).

Pain resulting from a second intervention and hyperventilation can also influence the results. Decision for local anesthesia depends on the decision of the clinician or healthcare worker in accordance with the institutional procedures.

APPENDIX – C Modified Allen Test

Patient clenches tightfisted. Pressure is applied over the ulnar and radial arteries by pressuring over the wrist. The hand is then opened (but not completely), fading in the palm and fingers is observed. Then, only pressure over ulnar artery is released, and thumb, palm and fingers are observed. As blood coming from the ulnar artery is filling the capillary bed, the color should return (flushing) within 15 seconds. If ulnar artery blood supply to the hand is not sufficient (negative Allen test), radial artery site should not be used for vascular access. An alternative artery should be selected.

If the Allen test is positive, radial artery can be used for vascular access (2, 26).

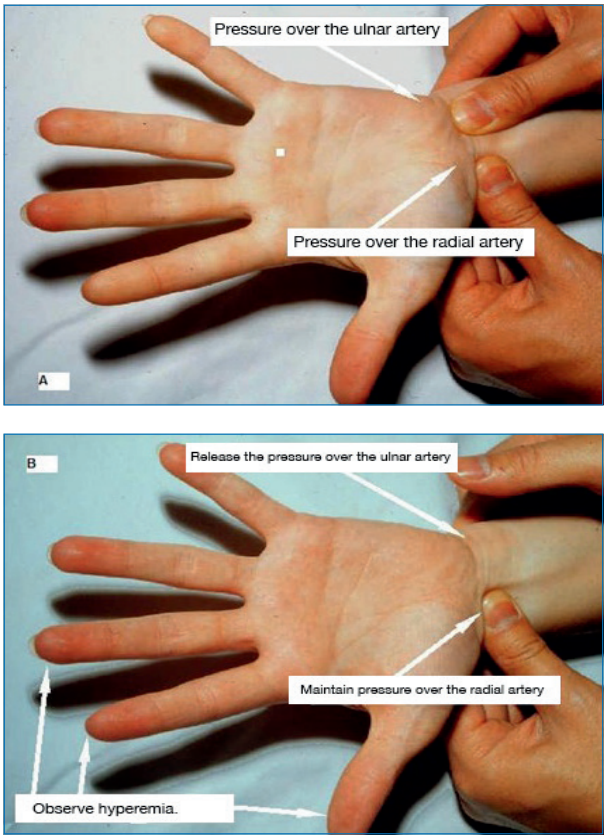


Figure A: Allen Test Practice

(https://tip.ebyu.edu.tr/?p=2411&lang=tr)

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