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Arterial blood gases

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INTRODUCTION — An arterial blood gas (ABG) is a test that measures the arterial oxygen tension (PaO₂), carbon dioxide tension (PaCO₂), and acidity (pH). In addition, arterial oxyhemoglobin saturation (SaO₂) can be determined. Such information is vital when caring for patients with critical illness or respiratory disease. As a result, the ABG is one of the most common tests performed on patients in intensive care units (ICUs).

The sites, technique, and complications of arterial sampling are discussed in this topic review. Transport and analysis of the arterial blood are also reviewed. Finally, an alternative method of obtaining similar information — pulse oximetry plus transcutaneous carbon dioxide measurement — is discussed. Interpretation of ABG data is reviewed separately. (See "Oxygenation and mechanisms of hypoxemia", see "Oxygen delivery and consumption", and see "Simple and mixed acid-base disorders").

ARTERIAL SAMPLING — Arterial blood is required for an ABG. It can be obtained by percutaneous needle puncture or from an indwelling arterial catheter.

Needle puncture — Percutaneous needle puncture refers to the withdrawal of arterial blood via a needle stick. An indwelling catheter is not inserted; therefore, this procedure needs repeated every time an ABG is performed.

Site selection — The initial step in percutaneous needle puncture is locating a palpable artery. Data do not support a particular site, but common sites include the radial, femoral, brachial, dorsalis pedis, or axillary artery. The radial artery is used most often because it is more

accessible, easily positioned, and more comfortable for the patient than the alternative sites.

- Radial artery puncture — The radial artery is best palpated between the distal radius and the tendon of the flexor carpi radialis when the wrist is extended ([show figure 1](#) and [show figure 2](#)). To hold the wrist in this position:
 - Position the arm on an armboard with the palm facing upward
 - Place a large roll of gauze between the wrist and the armboard
 - Adjust the position of the gauze so that the wrist is extended
 - Tape the forearm and palm to the armboard

Prior to percutaneous needle puncture, the Allen test or modified Allen test should be used to demonstrate collateral flow through the superficial palmar arch [1]. Its purpose is to identify patients who have impaired collateral circulation in the hand and, therefore, may be at increased risk of an ischemic complication.

To perform the modified Allen test, the patient's hand is initially held high with the fist clenched and both the radial and ulnar arteries compressed ([show figure 3](#)). This allows the blood to drain from the hand. The hand is then lowered, the fist is opened, and pressure is released from the ulnar artery. Color should return to the hand within six seconds, indicating that the ulnar artery is patent and the superficial palmar arch is intact. The test is considered abnormal if ten seconds or more elapses before color returns to the hand ([show figure 4](#)). The Allen test (from which the modified Allen test evolved) is performed identically, except these steps are executed twice — once with release of pressure from the ulnar artery and once with release of pressure from the radial artery.

- Brachial artery puncture — The brachial artery is best palpated medial to the biceps tendon in the antecubital fossa, when the arm is extended and the palm is facing up ([show figure 5](#)). The needle should be inserted just above the elbow crease ([show figure 6](#)).
- Femoral artery puncture — The femoral artery is best palpated just below the midpoint of the inguinal ligament, when the lower extremity is extended ([show figure 7](#)). The needle should be inserted at a 90 degree angle just below the inguinal ligament ([show figure 8](#)).

- Dorsalis pedis artery puncture — The dorsalis pedis artery is best palpated lateral to the extensor hallucis longus tendon ([show figure 9](#)). It receives collateral flow from the lateral plantar artery through an arch similar to that in the hand, which should be checked prior to percutaneous needle puncture. This is done by occluding the dorsalis pedis artery and compressing the nailbed of the great toe. Color should return to the nailbed rapidly when pressure on the toe is released ([show figure 10](#)).
- Axillary artery puncture — The axillary artery is best palpated in the axilla, when the arm is abducted and externally rotated ([show figure 11](#)). There is good collateral flow to the arm through the thyrocervical trunk and subscapular artery; thus, the risk of ischemic complications to the arm is low. The needle should be inserted as high into the axilla as possible ([show figure 12](#)).

Technique — Once a palpable artery has been located, blood is withdrawn using the following steps.

- The planned puncture site should be sterilely prepped.
- Local analgesia prior to arterial puncture should be considered because it appears to prevent pain without adversely impacting the success of the procedure [2]. This was illustrated by a trial that randomly assigned 101 patients undergoing arterial puncture to receive local 2 percent lidocaine, local normal saline, or no local agent prior to the procedure [3]. Local lidocaine decreased pain without increasing the difficulty of the procedure (ie, the number of attempts), compared to the other groups.
- The seal of a heparinized syringe should be broken by pulling its plunger. The plunger can then be pushed back into the syringe, leaving a small empty volume (eg, less than 1 mL) in the syringe. A small needle (eg, 22 to 25 gauge) should then be attached.
- Using one hand to gently palpate the artery and the other to manipulate the syringe and needle, the artery should be punctured. The syringe will fill on its own (ie, pulling the plunger is unnecessary). Approximately 2 to 3 mL of blood should be removed.

- After withdrawing a sufficient volume of blood, the needle should be removed and pressure should be applied to the puncture site for five to ten minutes to achieve hemostasis.

Complications — Complications due to percutaneous needle puncture are rare, but include persistent bleeding, bruising, and injury to the blood vessel. Circulation distal to the puncture site may also be impaired following percutaneous needle puncture, presumably due to thrombosis at the puncture site.

Indwelling catheters — Arterial blood can also be obtained with an indwelling arterial catheter. Compared to percutaneous needle punctures, advantages of an indwelling catheter include continuous access to arterial blood and the ability to measure the blood pressure continuously. This may be helpful when frequent blood gases or close monitoring of the blood pressure are needed, such as during respiratory failure, shock, major surgery, or a hypertensive emergency.

Indwelling arterial catheters should be preferentially placed in an artery that has collateral flow and allows easy maintenance of aseptic care. Options include the radial, dorsalis pedis, femoral, axillary, or brachial artery.

Complications of indwelling arterial catheters include local and systemic infection, bleeding, hematoma, bruising, and vascular complications such as blood vessel injury, pseudoaneurysm, thromboembolism, and vasospasm. The frequency of these complications is related to the insertion technique, duration of catheterization, and site.

Arterial catheterization is discussed in greater detail separately. (See "Arterial catheterization").

Specimen care — Regardless of the method used to withdraw the arterial blood, several things should be considered prior to sending the specimen to the laboratory:

- Gas diffusion through the plastic syringe is a potential source of error. However, it appears that the clinical significance of the error is minimal if the sample is placed on ice and analyzed within 15 minutes [4-7] . Using a glass syringe will also prevent this error.

- The heparin that is added to the syringe as an anticoagulant can cause a decrease in the pH (if acidic heparin is used) and dilute the PaCO₂, resulting in a falsely low value [4,8] . Therefore, the amount of heparin solution should be minimized and at least 2 mL of blood should be obtained.

- Air bubbles that exceed 1 to 2 percent of the blood volume can cause a falsely high PaO₂ and a falsely low PaCO₂ [9] . The magnitude of this error depends upon the difference in gas tensions between blood and air, the exposure surface area (which is increased by agitation), and the time from specimen collection to analysis. The clinical significance of this error can be decreased by gently removing the bubbles without agitation and analyzing the sample as soon as possible [5,10] .

TRANSPORT — The arterial blood should be placed on ice during transport to the lab and then analyzed as quickly as possible. This reduces oxygen consumption by leukocytes, which can cause a factitiously low PaO₂ [11] . This effect is most pronounced in patients whose leukocytosis is profound. In addition, it reduces the likelihood that error due to gas diffusion through the plastic syringe or air bubbles will be clinically significant.

ANALYSIS — Analysis of arterial blood is usually performed by automated blood gas analyzers, which automatically transport the specimen to electrochemical sensors to measure pH, PaCO₂, and PaO₂:

- The PaCO₂ is measured using a chemical reaction that consumes CO₂ and produces a hydrogen ion, which is sensed as a change in pH [9] .
- The PaO₂ is measured using oxidation-reduction reactions that generate measurable electric currents [9] .

In addition, automated blood gas analyzers rinse the system, calibrate the sensors, and report the results. Rigorous quality control by the laboratory is essential for accurate results.

Arterial blood gas measurements are effected by temperature. Specifically, pH increases and both PaO₂ and PaCO₂ decrease as temperature declines ([show table 1](#)) [12,13] . Modern automated blood gas analyzers can report the pH, PaO₂, and PaCO₂ at either 37°C (the temperature at which the values are measured by the blood

gas analyzer) or at the patient's body temperature. Most centers report the values of pH, PCO₂, and PO₂ at 37°C, even if the patient's body temperature is different. However, this practice is controversial [12-15] .

ALTERNATIVES — ABGs are performed frequently in critically ill patients because they are the best guide to a patient's oxygenation (measured as PaO₂) and ventilation (measured as PaCO₂ and pH). However, they are invasive and require repeated collection of arterial blood. Alternative methods that do not require arterial blood but obtain similar information are desirable, especially if they are noninvasive or minimally invasive.

Pulse oximetry is a widely accepted method of evaluating oxygenation noninvasively, but it does not provide data about ventilation. Thus, pulse oximetry is an inadequate substitute for ABGs, unless it is combined with another technique, such as transcutaneous pCO₂ (ptcCO₂) monitoring.

Systems exist that combine pulse oximetry and ptcCO₂ monitoring. Such combination systems usually have a heating element that raises the skin temperature to 42 to 45°C to increase local perfusion, an electrode to measure ptcCO₂, and a light emitter and sensor to measure arterial oxyhemoglobin saturation (SaO₂) [16] . Previous studies suggested that ptcCO₂ measurements are accurate in neonates, but not critically ill adults because of poor peripheral perfusion (peripheral artery disease, hypotension, vasopressors). Devices have since improved and several more recent observational studies suggest that such systems are accurate in most critically ill patients, although accuracy diminishes when the PaCO₂ is greater than 56 mmHg [17-21] . Despite the promising observational data, clinical trials are necessary before combined pulse oximetry and ptcCO₂ monitoring can be recommended as routine care.

Such combination systems have limitations. They may be difficult to keep calibrated, may be difficult to mount in a way that prevents air trapping, and may take up to an hour to sufficiently warm the skin [21] . In addition, the devices must be attached to an ear, which may be difficult in agitated patients or in those who had neurosurgery. Given the limitations of noninvasive monitoring, any persistent or unexpected change in SaO₂ or ptcCO₂ should be confirmed with an ABG.

Measurement of end tidal CO₂ (PetCO₂) is another way of non-invasively measuring the PaCO₂. This technique requires a closed system of gas collection, either with a tight fitting mask or a ventilator circuit. A sample of expired gas is analyzed by infrared or mass spectrometry, and then displayed as a numerical value or a graph. The PetCO₂ is usually within 1 mm of the PaCO₂ in healthy adults, but is far less accurate in critically ill adults [22]. Thus, routine use of PetCO₂ exists primarily in newborn ICUs, operating rooms, and emergency rooms, to provide early warning of tube complications. PetCO₂ has not been validated by clinical trials in adult ICUs.

SUMMARY AND RECOMMENDATIONS

- An arterial blood gas (ABG) is a test that measures the arterial oxygen tension (PaO₂), carbon dioxide tension (PaCO₂), and acidity (pH). In addition, arterial oxyhemoglobin saturation (SaO₂) can be determined. (See "Introduction" above).
- Percutaneous needle puncture is one method of obtaining the arterial blood necessary for an ABG. (See "Arterial sampling" above).

- Data do not support a particular site, but common sites include the radial, femoral, brachial, dorsalis pedis, or axillary artery. The radial artery is used most often because it is more accessible, easily positioned, and more comfortable for the patient than the alternative sites. (See "Site selection" above).

- For patients undergoing radial or dorsalis pedis artery puncture, we suggest evaluating the collateral flow to those vessels prior to puncture (**Grade 2C**). The Allen test or modified Allen test can be performed in patients undergoing radial artery puncture. For patients undergoing dorsalis pedis artery puncture, the dorsalis pedis artery can be occluded, followed by compression of the nailbed of the great toe and assessment of the rapidity with which color returns to the nailbed after pressure is released from the great toe. (See "Site selection" above).

- Once the target artery has been identified, the planned puncture site should be sterilely prepped, the artery should be punctured with a small needle and syringe, 2 to 3 mL of blood should be withdrawn, the needle should be removed, and, finally, pressure should be applied to the puncture site for five to ten minutes. (See "Technique" above).

- We recommend the administration of local analgesia prior to arterial puncture ([Grade 1B](#)). Local analgesia prevents pain without adversely impacting the success of the procedure. (See "Technique" above).

- Complications due to percutaneous needle puncture are rare, but include persistent bleeding, bruising, and injury to the blood vessel. Circulation distal to the puncture site may also be impaired. (See "Complications" above).

- Alternatively, an indwelling arterial catheter can be used to obtain arterial blood for an ABG. Advantages of an indwelling catheter include continuous access to arterial blood and the ability to measure the blood pressure continuously. Arterial catheterization is discussed in greater detail separately. (See "Indwelling catheters" above and see "Arterial catheterization").
- Regardless of the method used to withdraw the arterial blood, the amount of heparin solution should be minimized, at least 2 mL of blood should be obtained, air bubbles should be removed, and the specimen should immediately be placed on ice and analyzed as quickly as possible. (See "Specimen care" above and see "Transport" above).
- Systems exist that combine pulse oximetry and transcutaneous carbon dioxide monitoring may be a noninvasive substitute for ABGs. However, such systems have important limitations and clinical trials are necessary before their use become routine. (See "Alternatives" above).

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