ABG

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Indications for ABG

- Severe respiratory or metabolic disorders
- Clinical features of hypoxia or hypercarbia
- Shock
- Sepsis
- Decreased cardiac output

Indications for ABG

- Renal failure
- Ideally any baby on oxygen therapy
- Inborn errors of metabolism
- ventilated infant
- CPR
- ……………………

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What are the Indications for Sticking an ABG?

- To assess the patient's response to treatment, such as mechanical ventilation
- To determine a patient's oxygen-carrying capacity
- To determine the need for supplemental oxygen
- For the diagnosis of respiratory, metabolic, and mixed acid-base disorders
- To monitor the patient's acid-base status
- To collect a blood sample in emergency situations when access to the vein is not possible
- For the quantification of hemoglobin levels

What are the Contraindications for Sticking an ABG?

- An abnormal Modified Allen Test
- Blood clotting problems
- Local infection or damage at the injection site
- Patients who are receiving anticoagulation therapy
- Patients who are taking thrombolytic agents
- The presence of a disease that affects the blood vessels
- The presence of arteriovenous fistulas or vascular grafts

INTRODUCTION

An arterial blood gas (ABG) is a test that measures the

- oxygen tension (PaO2),
- carbon dioxide tension (PaCO2),
- acidity (pH)
- oxyhemoglobin saturation (SaO2)
- bicarbonate (HCO3)

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INTRODUCTION

Some blood gas analyzers also measure the

- methemoglobin,
- carboxyhemoglobin
- hemoglobin levels.

Such information is vital when caring for patients with critical illness or respiratory disease.

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ARTERIAL SAMPLING

Arterial blood is required for an ABG.

It can be obtained by percutaneous needle puncture or from an indwelling arterial catheter.

A) Needle puncture – Percutaneous needle puncture refers to the withdrawal of arterial blood via a needle stick. It needs to be repeated every time an ABG is performed, since an indwelling catheter is not inserted.

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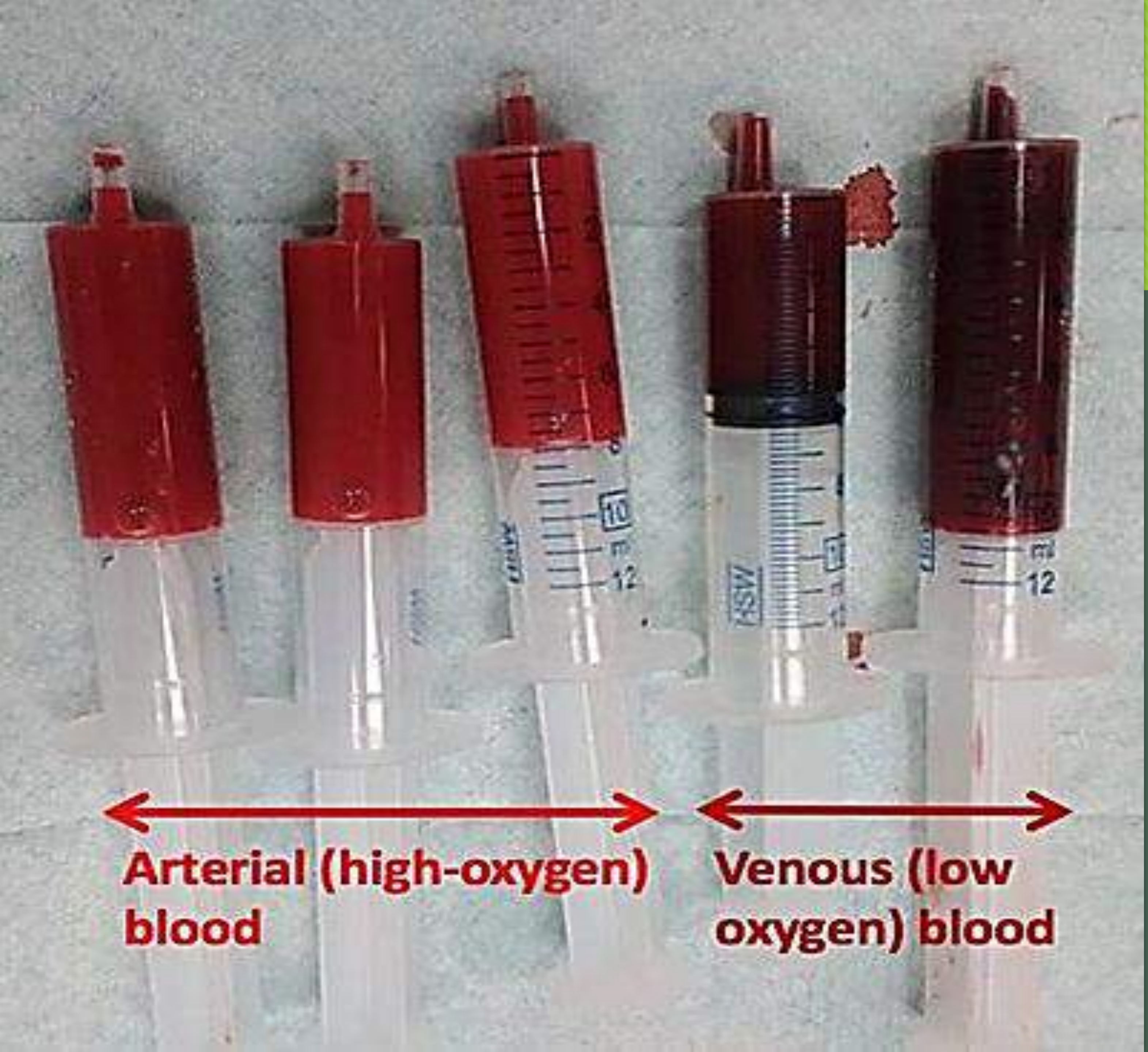
Arterial (high-oxygen) blood
Venous (low oxygen) blood

Site selection

The initial step in percutaneous needle puncture is locating a palpable artery.

Common sites include the radial, femoral, brachial, dorsalis pedis, or axillary artery.

There is no evidence that any site is superior to the others. However, the radial artery is used most often because it is accessible, easily positioned, and more comfortable for the patient than the alternative sites.

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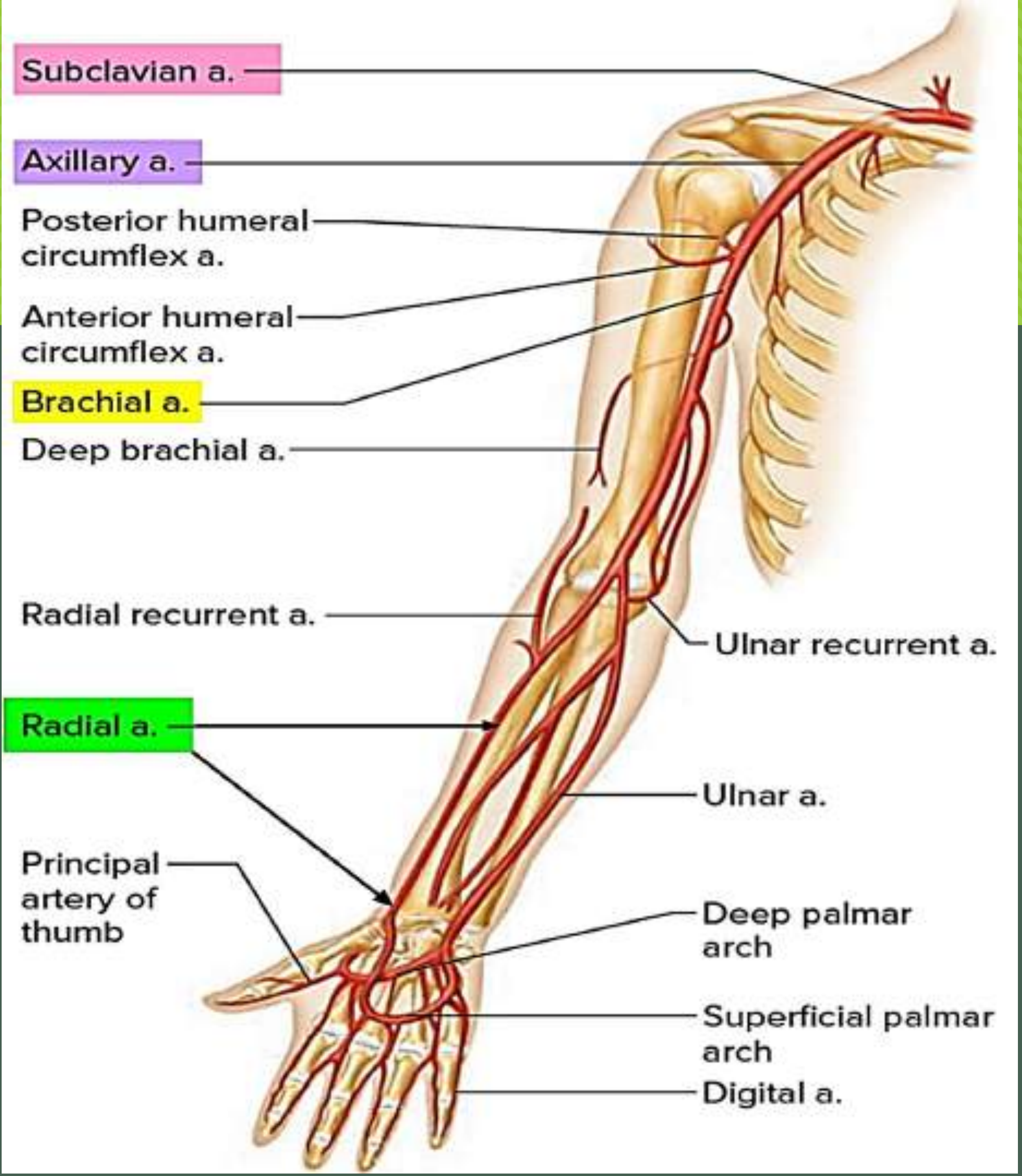
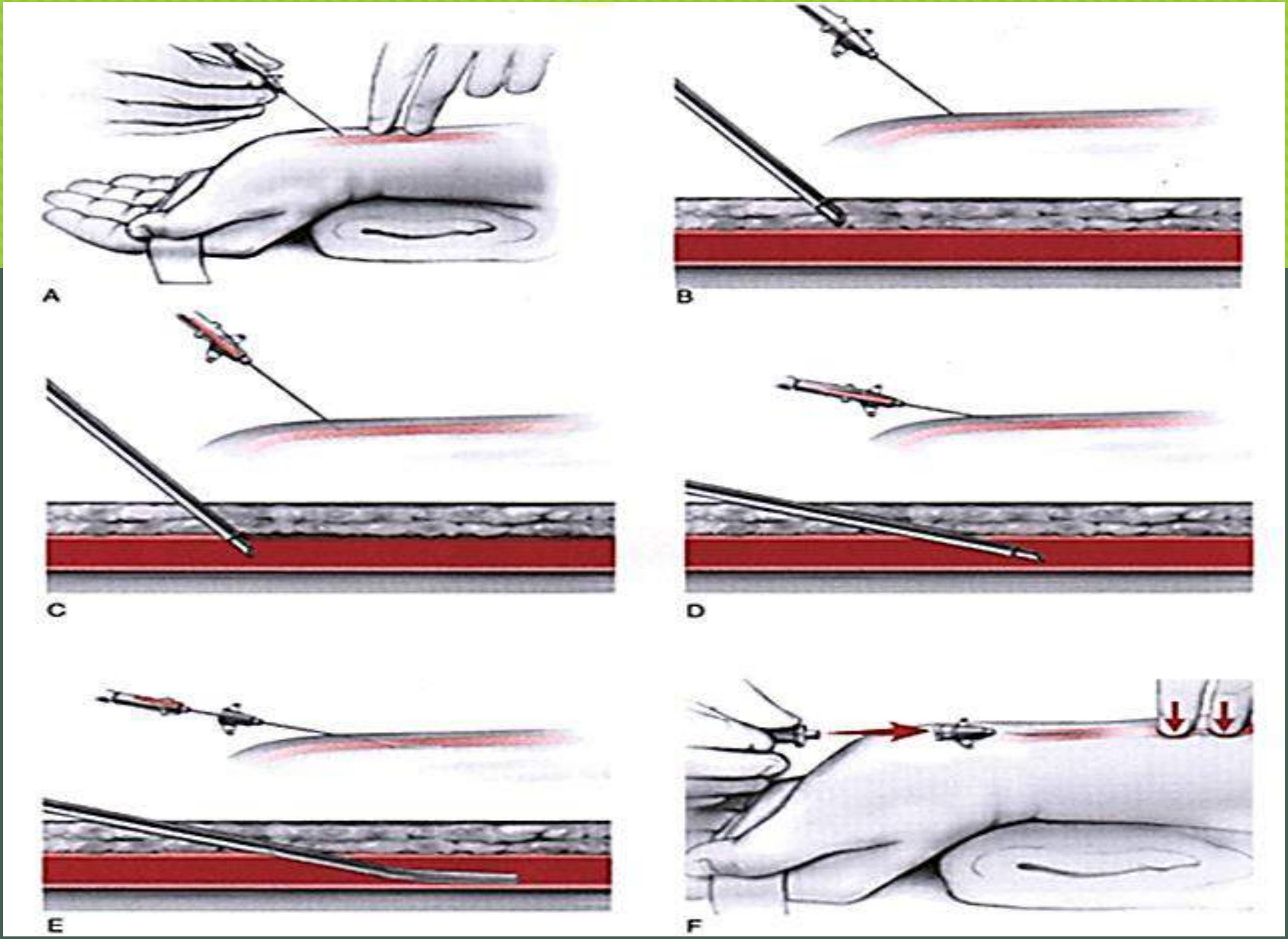

Subclavian a.
Axillary a.
Posterior humeral circumflex a.
Anterior humeral circumflex a.
Brachial a.
Deep brachial a.
Radial recurrent a.
Ulnar recurrent a.
Radial a.
Ulnar a.
Principal artery of thumb
Deep palmar arch
Superficial palmar arch
Digital a.

Radial artery

The radial artery is best palpated between the distal radius and the tendon of the flexor carpi radialis when the wrist is extended.

To get the wrist into this position, the arm should be positioned on an arm-board with the palm facing upward and a large roll of gauze should be placed between the wrist and the arm-board in a position that extends the wrist. Taping the forearm and palm to the arm-board helps maintain the position.



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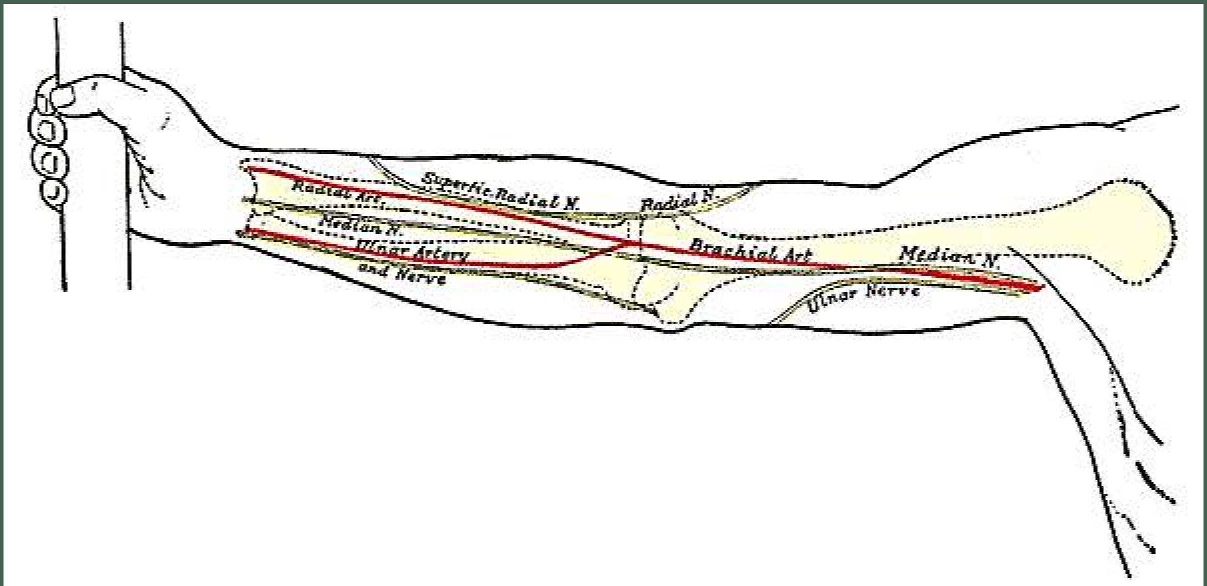
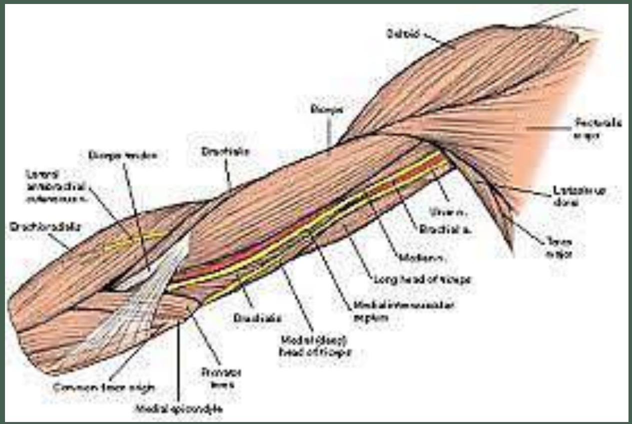
brachial artery

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. The needle should be inserted just above the elbow crease.

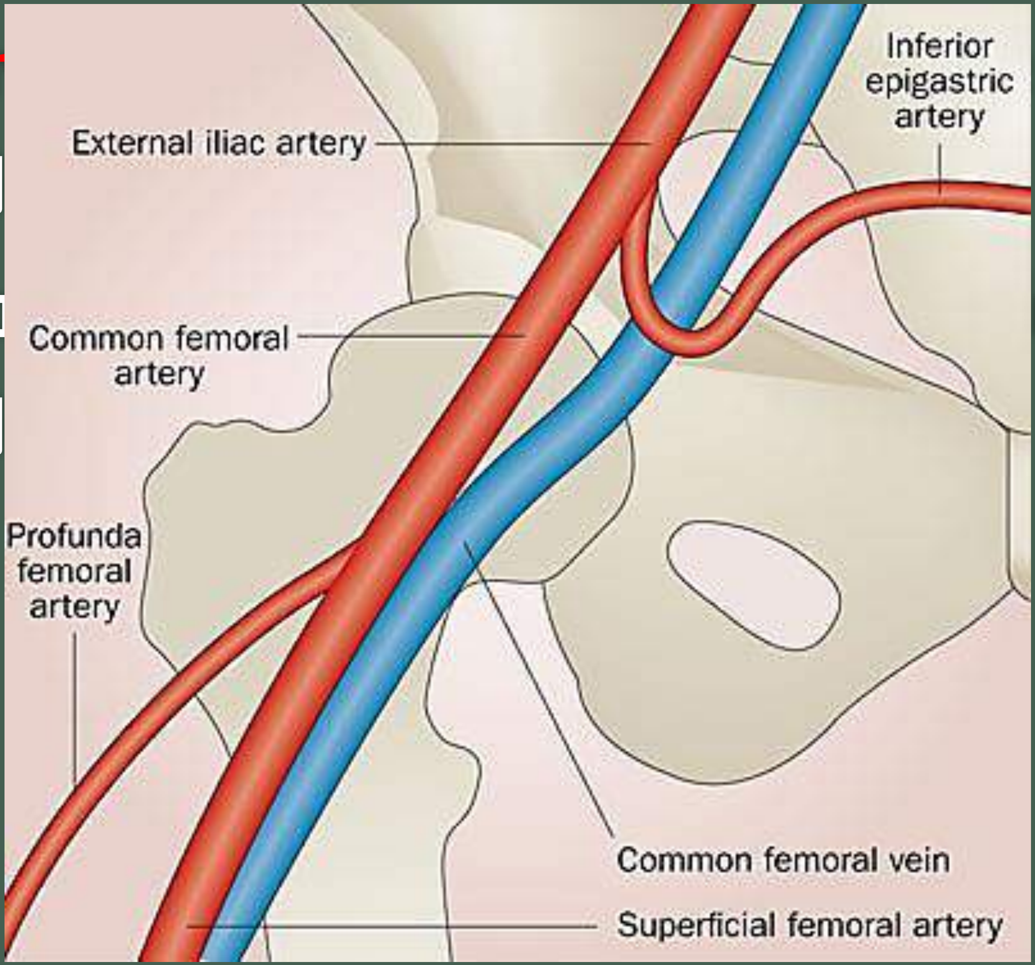




femoral artery

The femoral ar midpoint of the inguinal lig extended.

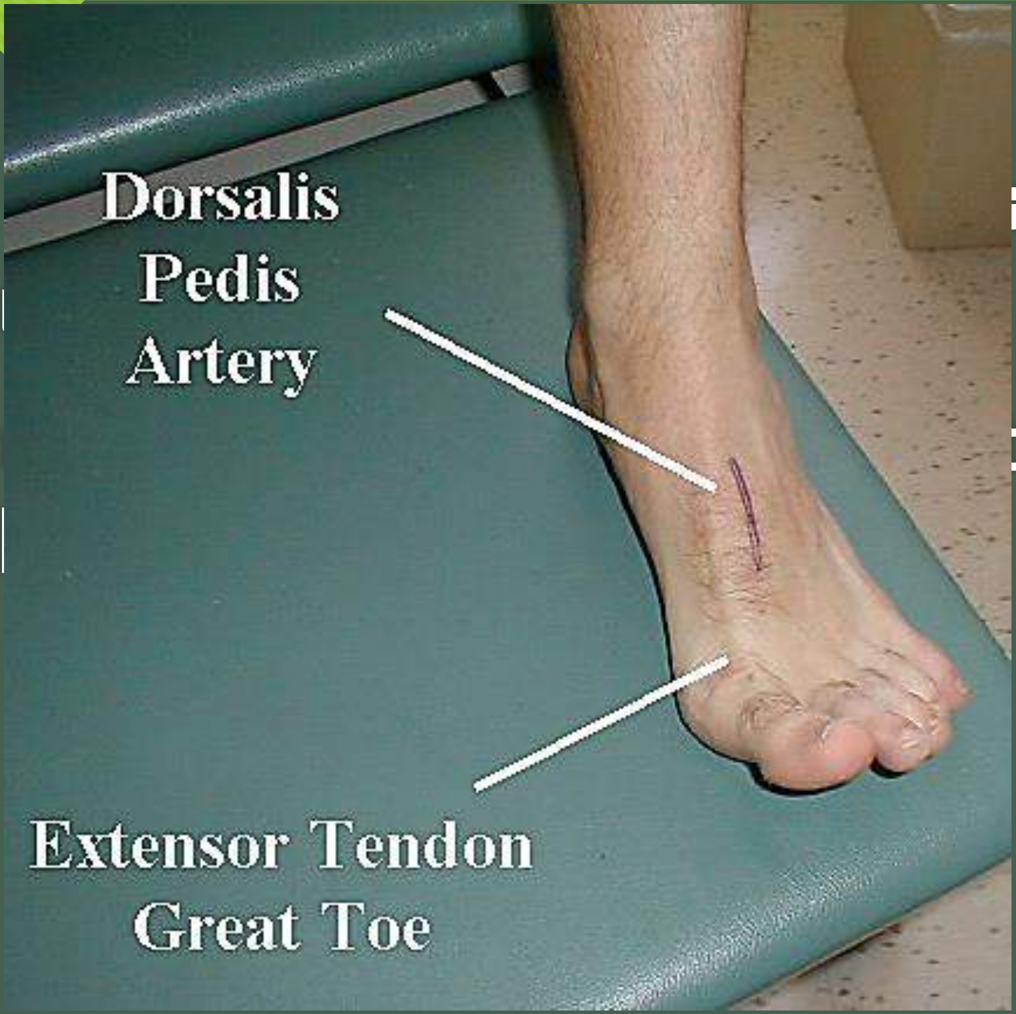
The needle sho e just below the inguinal lig



Dorsalis pedis artery

The dorsalis … al to the extensor hallucis long…

It receives c… tar artery through an arch simil…



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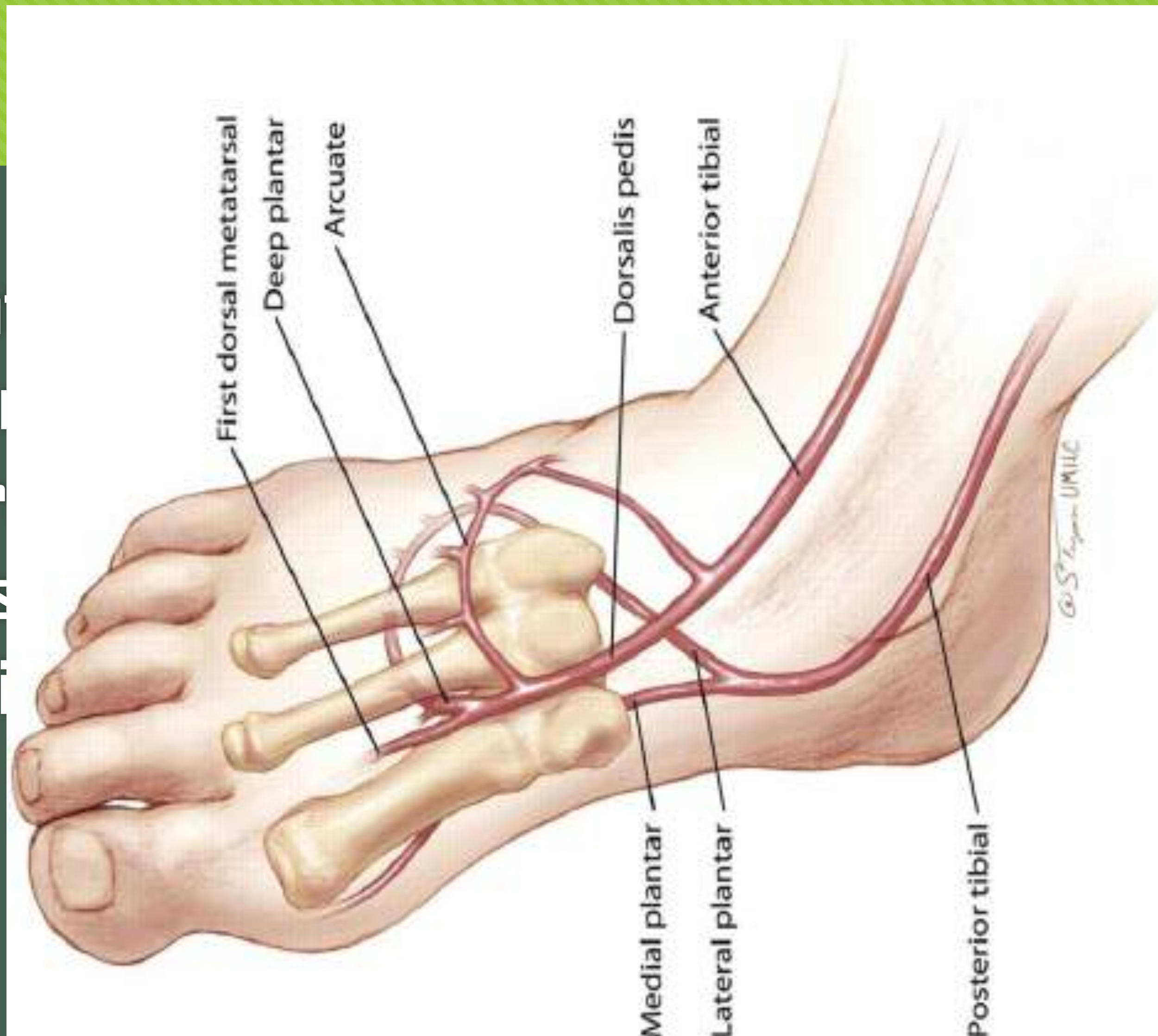

Axillary artery

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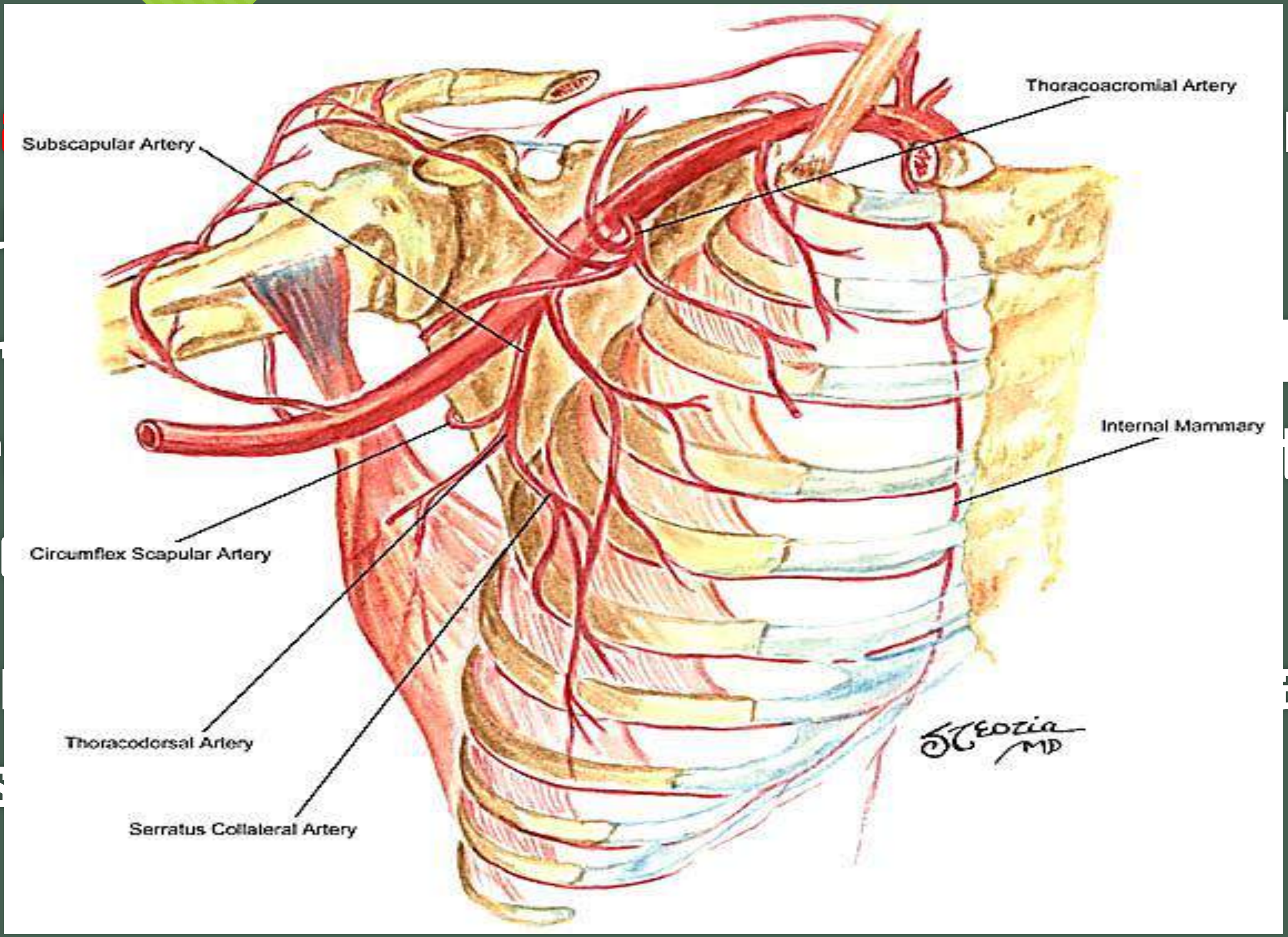

Collateral circulation

We believe that patients undergoing radial or dorsalis pedis artery puncture should have the collateral flow to those vessels evaluated prior to puncture, even though studies have found variable accuracy associated with such evaluations.

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Collateral circulation

Our belief is based upon the notion that the evaluation can be performed quickly at the bedside at no cost and with little risk for harm, but has substantial potential for benefit

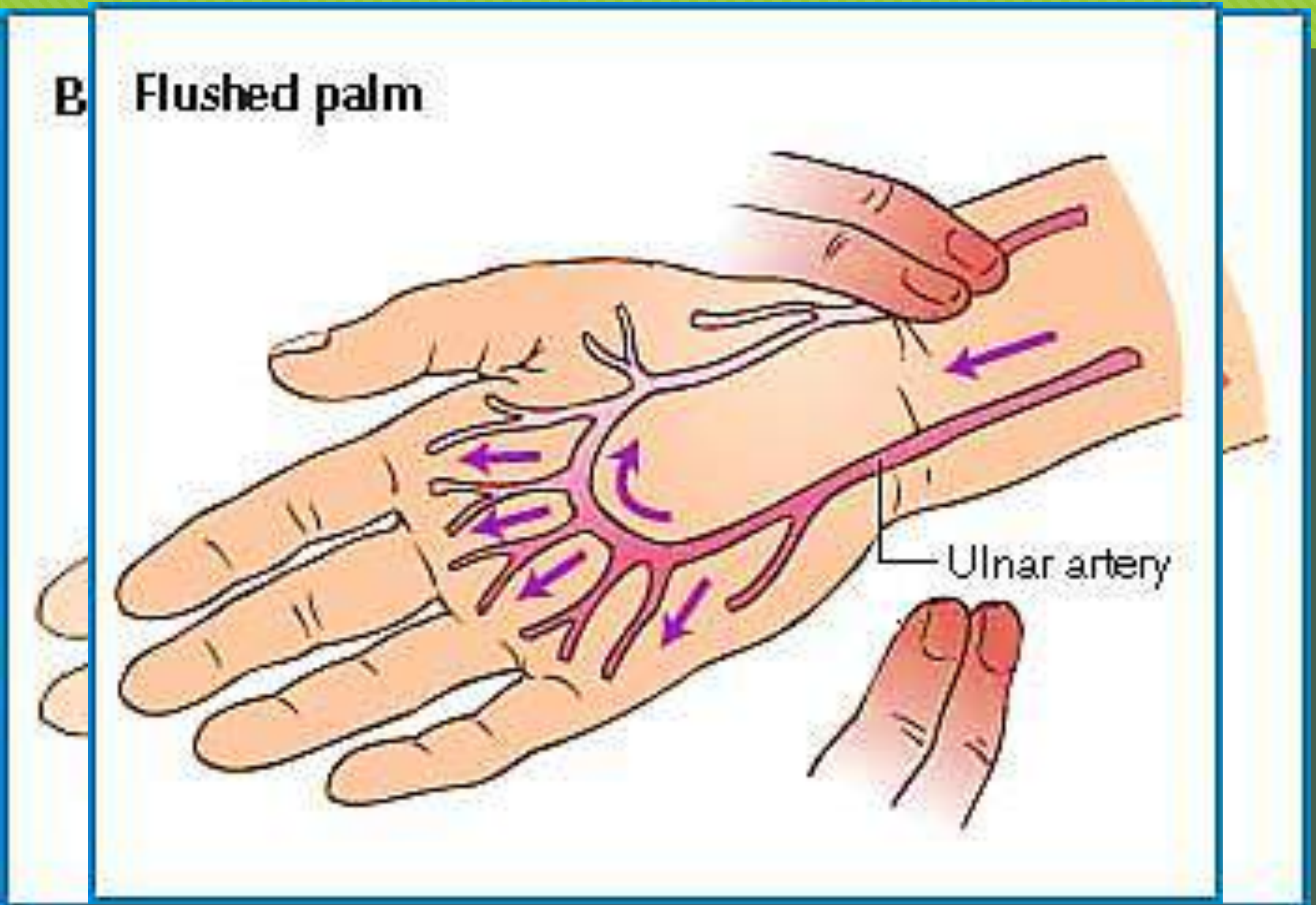
(ie, to identify patients who have impaired collateral circulation and, therefore, may be at increased risk of an ischemic complication).

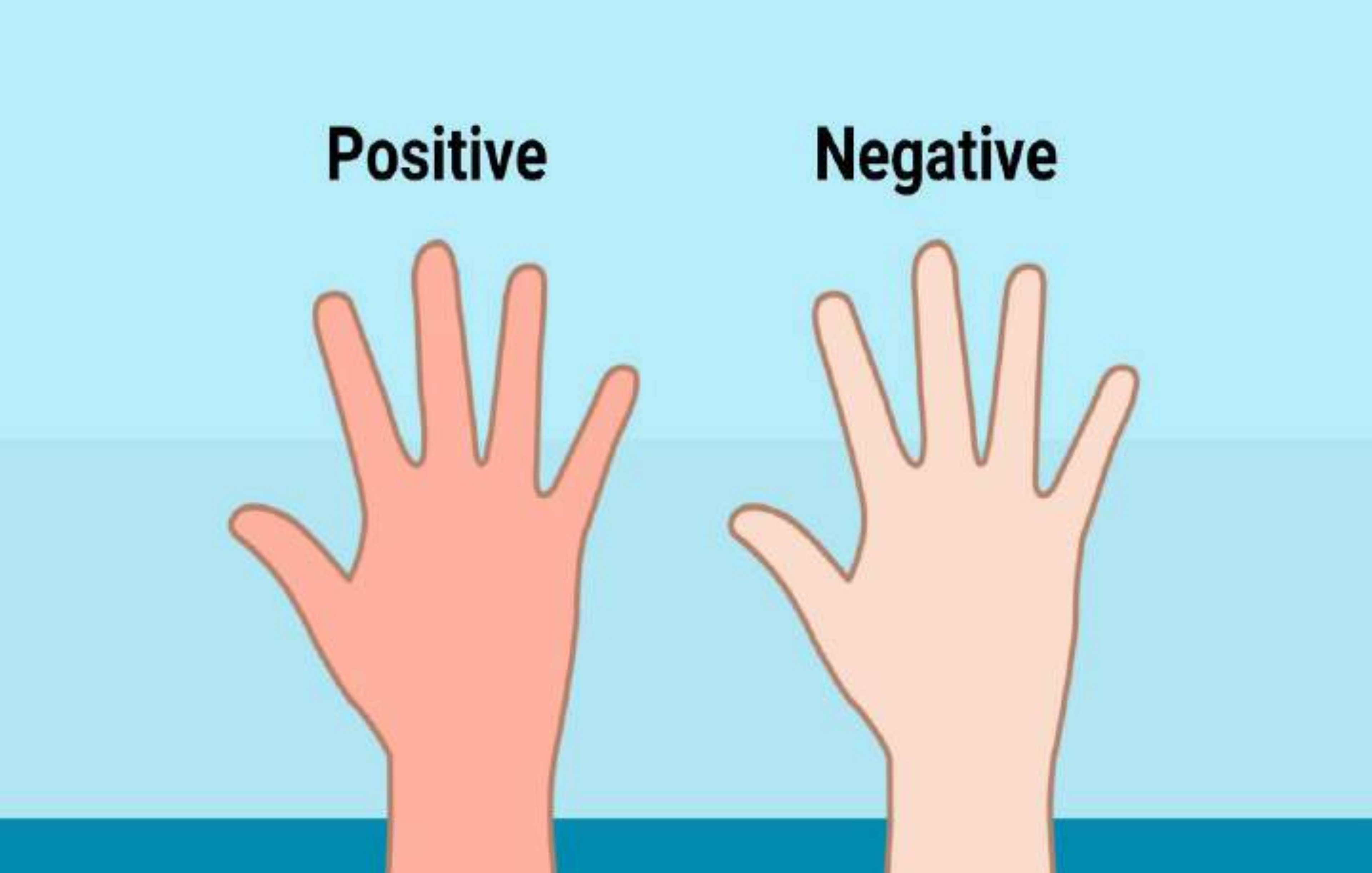
Allen test

The Allen test or modified Allen test can be performed in patients undergoing radial artery puncture.

These are bedside tests that demonstrate collateral flow through the superficial palmar arch.

Allen test




Positive
Negative

Allen test

Technique

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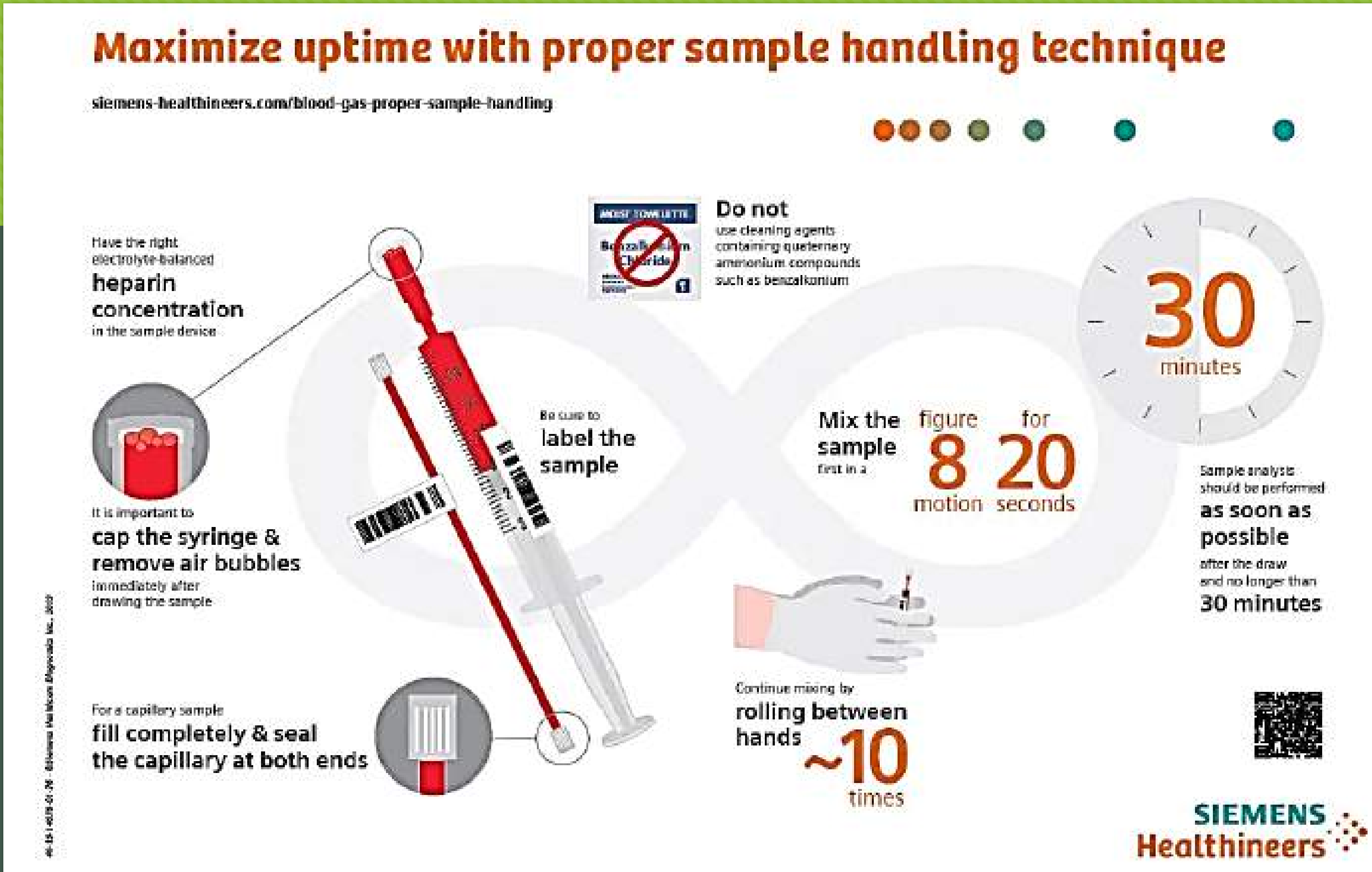
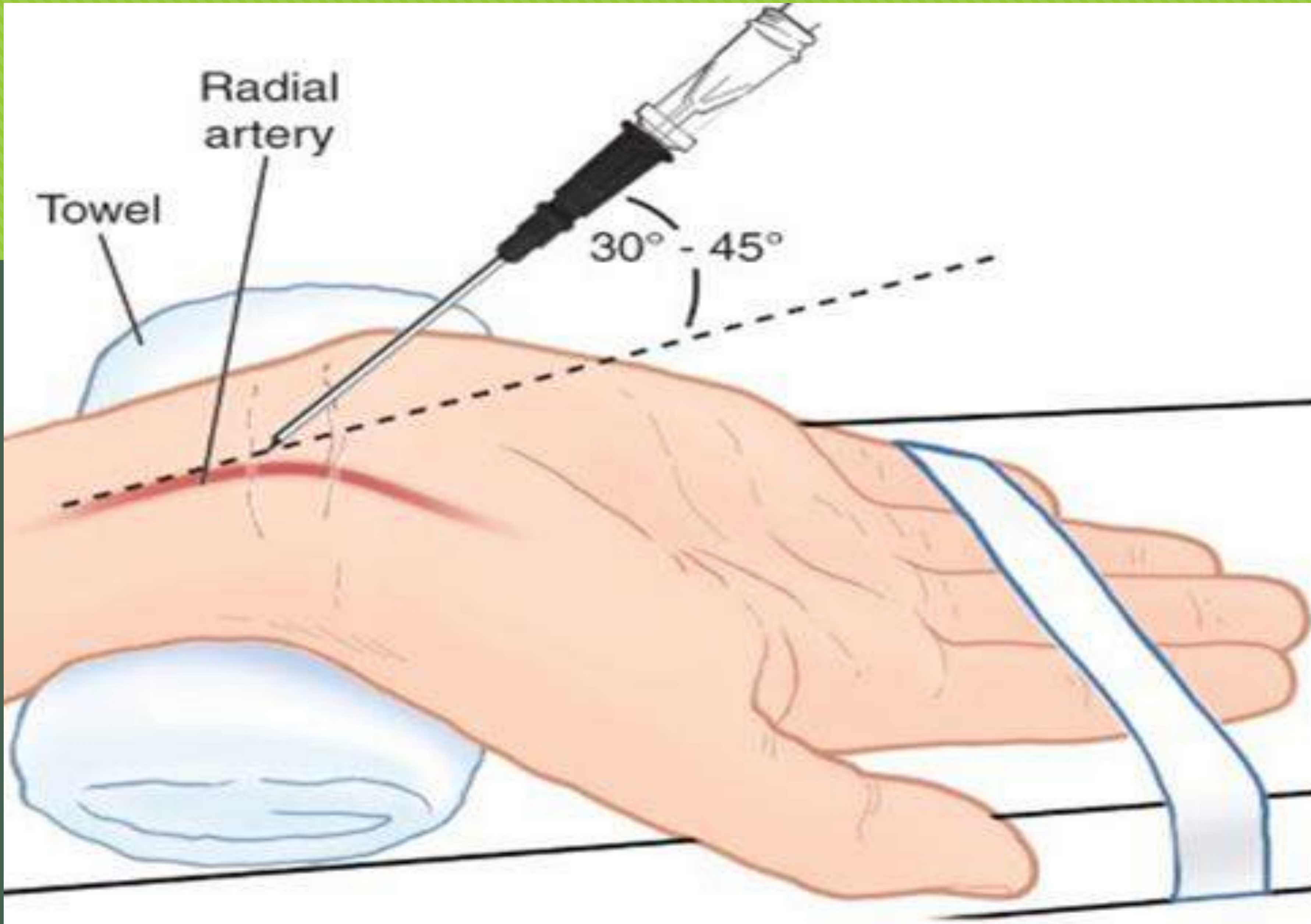

Maximize uptime with proper sample handling technique
siemens-healthineers.com/blood-gas-proper-sample-handling
Have the right electrolyte-balanced
heparin concentration
in the sample device
It is important to
cap the syringe & remove air bubbles
immediately after drawing the sample
For a capillary sample
fill completely & seal the capillary at both ends
Be sure to
label the sample
Do not
use cleaning agents containing quaternary ammonium compounds such as benzalkonium
Mix the sample
first in a
figure 8 motion
for 20 seconds
Continue mixing by
rolling between hands
~10 times
30 minutes
Sample analysis should be performed
as soon as possible
after the draw and no longer than
30 minutes
SIEMENS Healthineers



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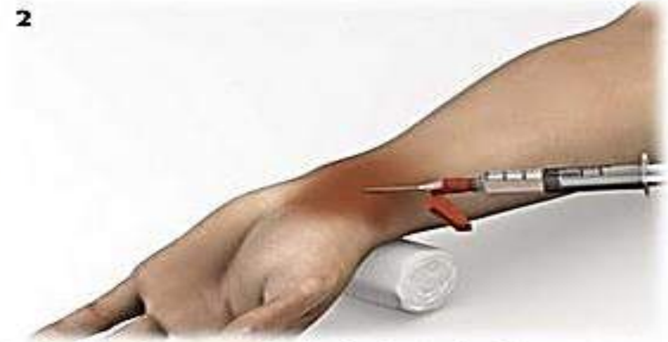
ARTERIAL PUNCTURE (RADIAL ARTERY)

Position the wrist in slight dorsiflexion, cleanse the skin with antiseptic solution, and palpate the radial pulse.

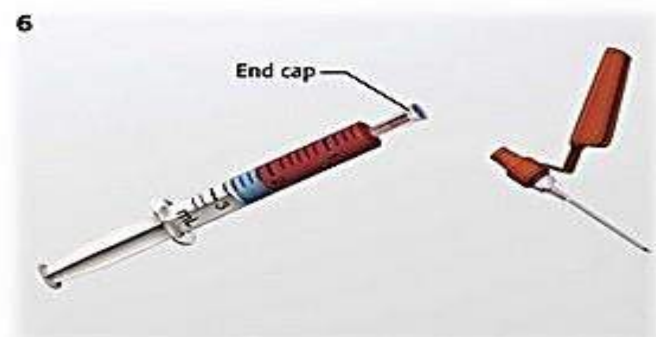


Optionally, place a small wheal of local anesthetic (e.g., 1% lidocaine without epinephrine) over the entry site. Avoid placing too large of a wheal, which may obscure the artery.

Hold the syringe in your hand like a dart, with the bevel up. Palpate the artery with the index and middle fingers of your other hand. Puncture the skin distal to your finger, and slowly advance the needle at a 30° angle toward the pulsating vessel.

As soon as blood flows, stop advancing the needle. Allow the syringe to fill on its own. If bone is encountered, withdraw slowly because both vessel walls may have been penetrated and the lumen may be entered as the needle is withdrawn.

Remove the needle from the artery after the syringe has filled. Apply a bandage and firm pressure to the puncture site for a minimum of 3 to 5 minutes.



Remove all air from the syringe by holding it upward, gently tapping it, and depressing the plunger. Attach the end cap to the syringe to maintain anaerobic conditions, and submit the sample to the laboratory.

Complications

Needle puncture

They include:

Persistent bleeding

Bruising

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.

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Complications

Indwelling catheters

Arterial blood can also be obtained via an indwelling arterial catheter.

Indwelling catheters provide continuous access to arterial blood, which is helpful when frequent blood gases are needed (eg, respiratory failure).

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SPECIMEN CARE

1. 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.

Using a glass syringe will also prevent this error.

SPECIMEN CARE

The heparin that is added to the syringe as an anticoagulant can decrease in the pH if acidic heparin is used.

It can also dilute the $PaCO2$, resulting in a falsely low value.

Thus, the amount of heparin solution should be minimized and at least 2 mL of blood should be obtained.

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SPECIMEN CARE

Air bubbles that exceed 1 to 2 percent of the blood volume can cause a falsely high PaO_2 and a falsely low $PaCO_2$.

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.

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SPECIMEN CARE

This reduces oxygen consumption by leukocytes

(ie, leukocyte larceny), which can cause a factitiously low PaO2.

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.

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TRANSPORT

The arterial blood should be placed on ice during transport to the lab and then analyzed as quickly as possible.

Table II: Changes in ABG every 10 minutes in vitro

	37°C	4°C
pH	0.01	0.001
pCO_2	0.1 mm Hg	0.01 mm Hg
pO_2	0.1 mm Hg	0.01 mm Hg

* It is obvious that blood sample should be stored at 4°C, if it cannot be processed immediately for minimal error.

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The effect of temperature on blood gas measurements

Arterial blood gas measurements are effected by temperature. Specifically, pH increases and both PaO2 and PaCO2 decrease as temperature declines.

Temperature		pH	PCO2	PO2
ºC	ºF			
20	68	7.65	19	27
30	86	7.50	30	51
35	95	7.43	37	70
36	97	7.41	38	75
37	98	7.40	40	80
38	100	7.39	42	85
40	104	7.36	45	97

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ABG Normal Value Ranges

- pH: 7.35-7.45
- Partial Pressure of Oxygen (PaO2): 75-100 mmHg
- Partial Pressure of Carbon Dioxide (PaCO2): 35-45 mmHg
- Bicarbonate (HCO3-): 22-26 mEq/L
- Oxygen Saturation (SpO2): 94-100%

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ABG Normal Value Ranges

- pH – refers to the acid-base balance of the blood.
- Partial Pressure of Oxygen (PaO2) – refers to the amount of oxygen in arterial blood.
- Partial Pressure of Carbon Dioxide (PaCO2) – refers to the amount of carbon dioxide in arterial blood.
- Bicarbonate (HCO3-) – refers to the total amount of CO2 that is transported in the blood.
- Oxygen Saturation (SpO2) – refers to the amount of hemoglobin in the blood that is saturated with oxygen.

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Normal Neonatal ABG values

PH: 7.35 – 7.45

pCO2: 35 – 45 mm Hg

pO2: 50 – 70 mm Hg

HCO3: 20 – 24 mEq/L

BE: +/- 5

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ABG vs VBG?

	ARTERIAL	VENOUS
pH	7.35-7.45	7.30-7.40
pCO2	35-45	41-45
pO2	85-105	25-45
O2	95-100	70-75
tCO2	22-26	22-26

ABG vs VBG?

Comparison of blood gas analysis at different sites

Variables	Arterial	Venous
pH	Same	Lower
$PaCO_2$	Lower	Higher
PaO_2	Higher	Lower
HCO_3	Same	Same

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Correlation with arterial blood gases

- Central venous
- The central venous pH is usually 0.03 to 0.05 pH units lower than the arterial pH
- The PCO_2 is usually 4 to 5 mmHg higher
- little or no increase in serum HCO_3.
- Mixed venous blood gives results similar to central venous blood.

Correlation with arterial blood gases

peripheral venous

- The pH is approximately 0.02 to 0.04 pH units lower than the arterial pH
- The venous serum HCO3 concentration is approximately 1 to 2 meq/L higher
- The venous PCO2 is approximately 3 to 8 mmHg higher.

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The Terms

ACIDS

- Acidemia
- Acidosis
- Respiratory
  - ↑CO_2
- Metabolic
  - ↓HCO_3

BASES

- Alkalemia
- Alkalosis
  - Respiratory
    - ↓CO_2
  - Metabolic
    - ↑HCO_3

Terminology of ABG

- **Acidemia** – An arterial pH below the normal range (less than 7.36).
- **Alkalemia** – An arterial pH above the normal range (greater than 7.44).

Terminology of ABG

- Acidosis — A process that tends to lower the extracellular fluid pH (hydrogen ion concentration increases).
- This can be caused by a fall in the serum bicarbonate (HCO_3) concentration and/or an elevation in PCO_2.
- Alkalosis — A process that tends to raise the extracellular fluid pH (hydrogen ion concentration decreases).
- This can be caused by an elevation in the serum HCO_3 concentration and/or a fall in PCO_2.

Terminology of ABG

- Metabolic acidosis — A disorder that causes reductions in the serum HCO_3 concentration and pH.

- Metabolic alkalosis — A disorder that causes elevations in the serum HCO_3 concentration and pH.

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Terminology of ABG

- **Respiratory acidosis** — A disorder that causes an elevation in arterial PCO_2 and a reduction in pH.

- **Respiratory alkalosis** — A disorder that causes a reduction in arterial PCO_2 and an increase in pH.

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Simple acid-base disorder

- The presence of one of the above four disorders with the appropriate respiratory or renal compensation for that disorder.

Mixed acid-base disorder

Mixed acid-base disorders can be suspected from the patient's history, from a lesser- or greater-than-expected compensatory respiratory or renal response, and from analysis of the serum electrolytes and anion gap.

As an example, a patient with severe vomiting would be expected to develop

a metabolic alkalosis due to the loss of acidic gastric fluid. If, however,

the patient developed hypovolemic shock from the fluid loss, the ensuing lactic acidosis would lower the elevated serum HCO3 possibly to below normal values, resulting in acidemia

INTERPRETATION

- Acid-Base & ventilation Information
  - pH
  - PCO2
  - HCO3 [calculated vs measured]

INTERPRETATION

- Oxygenation Information
  - PO2 [oxygen tension]
  - SO2 [oxygen saturation]

General principles in ABG interpretation

The Henderson-Hasselbalch equation shows that the pH is determined by the ratio of the serum bicarbonate (HCO3) concentration and the PCO2, not by the value of either one alone.

Each of the simple acid-base disorders is associated with a compensatory respiratory or renal response that limits the change in ratio and therefore in PH.

$$pH = 6.10 + \log ([HCO_3^-] \div [0.03 \times PCO_2])$$

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Hydrogen Ions

- H+ is produced as a by-product of metabolism.
- [H+] is maintained in a narrow range.
- Normal arterial pH is around 7.4.
- A pH under 7.0 or over 7.8 is compatible with life for only short periods.

PH and [H+]

A normal [H+] of 40 nEq/L corresponds to a pH of 7.40.

Because the pH is a negative logarithm of the [H+], changes in pH are inversely related to changes in [H+] (e.g., a decrease in pH is associated with an increase in [H+]).

Basic Steps for ABG Interpretation

- Step 1 – Obtain and Run the ABG Sample
- Step 2 – Determine if the pH is Alkalosis or Acidosis
- Step 3 – Determine if the Issue is Respiratory or Metabolic
- Step 4 – Determine if it's Compensated or Uncompensated

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Step 1: Obtain and Run the ABG Sample

- First things first, to be able to interpret an ABG, you must collect the actual arterial blood sample from the patient.
- We discuss how to stick an ABG below, but let's focus on interpretation for now.
- After you have collected and analyzed the sample, we can now assess the results to see what's going on with the patient.

Step 2: Determine if the pH is Alkalosis or Acidosis

- We first need to determine if the pH is acidotic or alkalotic.
- To do so, again, you needed to know that the normal value for pH is 7.35-7.45.

- Acidosis = pH < 7.35
- Alkalosis = pH > 7.45

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Examples of pH Interpretation:

- If the pH is 7.26, this is less than 7.35, so the pH is . Acidosis
- If the pH is 7.49, this is greater than 7.45, so the pH is . Alkalosis
- If the pH is 7.39, this falls within the normal range, so the pH is Normal.

Step 3: Determine if the Issue is Respiratory or Metabolic

- In this step, we will look at the $PaCO_2$ (carbon dioxide) and the HCO_3^- (bicarb) to determine if it is a respiratory or metabolic issue.
- Carbon Dioxide ($PaCO_2$) is being regulated by the lungs.
- Bicarb (HCO_3^-) is being regulated by the kidneys.

Step 3: Determine if the Issue is Respiratory or Metabolic

- If the PaCO2 value is abnormal, meaning that it falls outside of the normal range (35-45 mmHg),
- while the Bicarb value is normal, this would mean that a Respiratory issue is present.

- Carbon Dioxide (PaCO2) = Acid
- Bicarb (HCO3-) = Base

Step 3: Determine if the Issue is Respiratory or Metabolic

- If the $PaCO_2$ value is normal, meaning that it is within the normal range (35-45 mmHg),
- while the Bicarb value is abnormal, this would mean that a Metabolic issue is present.

- Carbon Dioxide ($PaCO_2$) = Acid
- Bicarb (HCO_3^-) = Base

Example

- pH: 7.26
- PaCO2: 51
- HCO3-: 25

- Looking at the pH, we can interpret it as **Acidosis** since 7.26 is less than 7.35.
- Looking at the PaCO2, we can see that it is increased above the normal range, which is abnormal.
- This indicates that there is a **Respiratory** issue.
- Looking at the HCO3-, we can see that it falls within the normal range.
- This also helps confirm that there is a **Respiratory** issue.

Now we have confirmed that the pH is Acidosis.
we looked a the PaCO2 and HCO3- to determine :Respiratory issue

Interpretation: Respiratory Acidosis

Example

pH:	7.26
PaCO2:	38
HCO3:	19

- **Looking** at the **pH**, we can interpret it as **Acidosis** since 7.26 is less than 7.35.
- **Looking** at the **PaCO2**, we can see that it falls within the normal range.
- This indicates that it is not a **Respiratory** issue.
- **Looking** at the **HCO3**, we can see that it falls below the normal range.
- This indicates that a **Metabolic** issue is present.

Now we have confirmed that the pH is Acidosis.
Also, we looked a the PaCO2 and HCO3- to determine :Metabolic issue.

Interpretation: Metabolic Acidosis

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Step 4: Determine if it's Compensated or Uncompensated

- After identifying whether the blood gas is Acidosis or Alkalosis and whether it's a Respiratory or Metabolic issue,
- we must now observe the compensatory component of the ABG results.
- Here are two things that you should remember:
- When there is a Respiratory Problem ($PaCO_2$), our body will compensate with Bicarbonate.
- When there is a Metabolic Problem (HCO_3^-), our body will compensate with Carbon Dioxide.

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Metabolic Compensation

- For example, when we have Respiratory Acidosis the body will try to compensate by increasing the amount of Bicarb in our system.
- Bicarbonate is a base, so one of its functions is to neutralize the acid that is causing the problem.
- When we have Respiratory Alkalosis, it will to do the opposite by decreasing the amount of Bicarb.

Metabolic Compensation

- To conclude that there is compensation, the increase or decrease in HCO_3^- has to go outside the normal range.
- In other words, it has to be lower than 22 or higher than 26.
- If the Bicarb value is still within normal limits, you can conclude that there is no compensation

Example

pH:	7.29
PaCO2	51
HCO3:	47

- we can conclude that the pH is Acidosis because it is less than 7.35.
- Now we need to identify if there is a Respiratory or Metabolic problem.
- The PaCO2 is <u>increased</u> above the normal range, which indicates that there is a Respiratory issue.

Interpretation: Respiratory Acidosis

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Is this a Full Compensation or Partial Compensation?

- Next, we need to look at the Bicarb to determine if it's compensated or uncompensated.
- The Bicarb value is 47, which means that the body detected acidosis, so it tried to compensate by increasing the amount of base in the system.
- This tells us that there is definitely is some compensation going on.

To answer this question, we need to look back at the pH.
Since the pH of 7.29 is outside of the normal range, this means that the compensation was not enough to bring the pH back to normal.
For there to be full compensation, the pH would need to be within the normal range

Interpretation: Partially Compensated Respiratory Acidosis

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Respiratory Compensation

- When we have a metabolic problem, always remember that our respiratory system will compensate by regulating the amount of carbon dioxide in the blood.
- For example, when we have Metabolic Acidosis the body will compensate by decreasing the amount of carbon dioxide.
- Carbon Dioxide is associated with acidity, so when the body detects acidosis, it will try to compensate by decreasing the amount of carbon dioxide in our system.

Respiratory Compensation

- When we have Metabolic Alkalosis, our body will do the opposite.
- It will try to compensate by increasing the amount of carbon dioxide in our system.
- To conclude that there is compensation, the increase or decrease of carbon dioxide has to go outside the normal range. In other words, it has to be lower than 35 or higher than 45.
- If the carbon dioxide level is still within the normal range, you can conclude that there is no compensation.

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Example

pH:	7.51
PaCO2:	51
HCO3:	42

- we can conclude that the pH is Alkalosis because it is greater than 7.45.
- Now we need to identify if there is a Respiratory or Metabolic problem.
- The PaCO2 is increased above the normal range, which would typically indicate that there is a Respiratory issue. However, the HCO3- value is also increased.
- Remember that the PaCO2 value represents acidity and the HCO3- represents a base.
- We've already decided that the pH is Alkalotic which indicates that there are more bases (HCO3-) in the blood.

Interpretation: Metabolic Alkalosis

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Is this a Full Compensation or Partial Compensation?

- Since we have a Metabolic problem, the next step is to look at the respiratory system.
- In this case, we see that the carbon dioxide ($PaCO_2$) is <u>increased</u> above the normal range, which tells us that there is some compensation going on.

To answer this question, we need to look back at the pH. Was the compensation enough to bring the pH back to normal?
The answer is no, so this indicates that there is only partial compensation.
If the pH had been within the normal range, then it would be considered full compensation.

Interpretation: Partially Compensated Metabolic Alkalosis

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Oxygen Saturation and Hypoxemia Levels

- The final step of ABG Interpretation is to determine if hypoxemia is present by looking at the patient's oxygenation status. To do so, you will be looking at the Partial Pressure of Arterial Oxygen (PaO2).
- Here are the levels of hypoxemia when classified into categories:

	PaO2	SaO2
Normal Oxygenation	80 – 100 mmHg	> 95%
Mild Hypoxemia	60 – 79 mmHg	90 – 94%
Moderate Hypoxemia	40 – 59 mmHg	75 – 89%
Severe Hypoxemia	< 40 mmHg	< 75%

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Respiratory Acidosis

↓ph, ↑CO2, ↓Ventilation

Causes

- CNS depression
- Pleural disease
- COPD/ARDS
- Musculoskeletal disorders
- Compensation for metabolic alkalosis

Respiratory Alkalosis

- ↑pH, ↓CO_2, ↑Ventilation
- Causes CHAMPS
  - C – CNS Disease e.g. Intracerebral hemorrhage/ Cirrhosis
  - H – Hypoxia
  - A – Anxiety
  - M – Over ventilation
  - P – Progesterone
  - S – Salicylate/Sepsis

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Metabolic Acidosis

- ↓pH, ↓HCO_3
- 12-24 hours for complete activation of respiratory compensation
- ↓PCO_2 by 0.15 kPa for every 1 mEq/L ↓HCO_3
- The degree of compensation is assessed via the Winter's Formula

  □ $PCO_2 = \{1.5(HCO_3) + 8 \pm 2\} \times 0.133$ [converts to kPa]

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The Causes

- Metabolic Gap Acidosis
  - M - Methanol
  - U - Uremia
  - D – DKA - AKA
  - P - Paraldehyde
  - I – Isoniazid / Iron
  - L - Lactic Acidosis
  - E - Ethylene Glycol
  - R- Rhabdomyolysis
  - S - Salicylate
- Non Gap Metabolic Acidosis
  - H - Hyperalimentation
  - A - Acetazolamide
  - R - RTA
  - D - Diarrhoea
  - U - Uretero-pelvic shunt
  - P - Pancreatic Fistula
  - S – Spironolactone

Anion Gap

Anion Gap Metabolic Acidosis

Normal pH = 7.35 - 7.45

Acidosis = Low pH 7.35

Anion Gap = (Na + K) - (HCO3 + Cl)

Anion Gap = < 12

Metabolic = Low pH, Low Bicarb
Respiratory = Low pH, High CO2

Metabolic Alkalosis

- ↑pH, ↑HCO_3
- ↑PCO_2 by 0.1 for every 1mEq/L ↑ in HCO_3
- Causes – CLEVER PD
- C- Contraction
- L - Liquorice
- E - Endocrine: Conn's / Cushing's / Bartter's
- V - Vomiting / NG Suction
- E - Excess Alkali
- R - Refeeding Alkalosis
- P - Post Hyper-capnoea
- D - Diuretics and Chronic diarrhoea

Mixed Acid-Base Disorders

- Patients may have two or more acid-base disorders at one time

- Corrected Bicarbonate = AG – 12 + Serum HCO3-
- If > 30 then there is also underlying metabolic alkalosis
- If < 23 then there is an underlying non-AG metabolic acidocis

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Respiratory Acidosis

- Acute vs Chronic
- Acute - little kidney involvement. Buffering via titration via Hb for example
- pH ↓by 0.1 for 1.25 kPa ↑ in CO_2
- Chronic - Renal compensation via synthesis and retention of HCO_3 (↓Cl to balance charges □ hypochloremia)
- pH ↓by approx 0.05 for 1 kPa ↑in CO_2

Respiratory Alkalosis

- Acute vs. Chronic
  - Acute - ↓HCO_3 by 1.5 mEq/L for every 1 kPa ↓ in PCO_2
  - Chronic - Ratio increases to 3 mEq/L of HCO_3 for every 1 kPa ↓ in PCO_2
  - Decreased renal bicarb reabsorption and decreased ammonium excretion to normalize pH

Expected Compensation in Acid-Base Disorders

Respiratory	ΔPco_2		ΔHCO_3^-
Acute acidosis	1 mm Hg ↑	→	↑ 0.1 mEq/L
Acute alkalosis	1 mm Hg ↓	→	↓ 0.25 mEq/L
Chronic acidosis	1 mm Hg ↑	→	↑ 0.5 mEq/L
Chronic alkalosis	1 mm Hg ↓	→	↓ 0.5 mEq/L
Metabolic	ΔHCO_3^-		ΔPco_2
Acidosis	1 mEq/L ↓	→	↓ 1.25 mm Hg
Alkalosis	1 mEq/L ↑	→	↑ 0.2-0.9 mm Hg

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PRIMARY AND SECONDARY ACID-BASE DERANGEMENTS

Acid-Base Disorder	Primary Change	Compensatory Change
Respiratory acidosis	PCO_2 up(10)	HCO_3 up(1),(5)
Respiratory alkalosis	PCO_2 down(10)	HCO_3 down(2),(4-5)
Metabolic acidosis	HCO_3 down(1)	PCO_2 down(1.2)
Metabolic alkalosis	HCO_3 up(1)	PCO_2 up(0.7)

ABG values vary with age of neonate

	Pre-birth (Scalp)	5 min after birth	1-7 days after birth
pH	>7.20	7.20-7.34	7.35-7.45
pCO_2	<50	35-45	35-45
pO_2	25-40	49-73	70-75
Sat%	>50	>80	>90
HCO_3	>15	16-19	20

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ABG values vary with gestational age

	<28 wks	28-40 wks	Term infant with PFC	Infant with BPD
PaO_2	45-65	50-70	80-100	60-80
$PaCO_2$	40-50	40-60	35-45	45-70
PH	>7.25	>7.25	7.50-7.60	7.35-7.45

What are the Potential Errors When Running an ABG?

- Drawing a blood sample from the incorrect patient
- Failure to obtain a blood sample from an artery or vein
- Blood clotting
- Obtaining a blood sample on incorrect settings or support
- Air contamination of the blood sample
- Contamination caused by too much heparin
- Inappropriate mixing of the blood sample
- Prolonged delays in blood sample analysis

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What are the Potential Errors When Running an ABG?

Sample

35-year-old mother, just getting off the night shift.

She reports to the ED in the early morning with shortness of breath. She has cyanosis of the lips. She has had a productive cough for 2 weeks.

Her temperature is 39 , blood pressure 110/76, heart rate 108, respirations 32, rapid and shallow.

Breath sounds are diminished in both bases, with coarse rhonchi in the upper lobes. Chest X-ray indicates bilateral pneumonia.

ABG results are:

pH= 7.44 / $PaCO_2$= 28 / HCO_3= 24 / PaO_2=54

Problems

- $PaCO_2$ is low.
- pH is on the high side of normal, therefore

  compensated respiratory alkalosis.
- Also, PaO_2 is low, probably due to mucous displacing air in the alveoli affected by the pneumonia

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Solutions

- most likely has ARDS along with her pneumonia.
- The alkalosis need not be treated directly.
- She is hyperventilating to increase oxygenation, which is incidentally blowing off CO_2. Improve PaO_2 and a normal respiratory rate should normalize the pH.
- High FiO_2 can help, but if she has interstitial lung fluid, she may need intubation and PEEP, or a BiPAP to raise her PaO_2.
- Expect orders for antibiotics, and possibly steroidal anti-inflammatory agents.
- Chest physiotherapy and vigorous coughing or suctioning will help the patient clear her airways of excess mucous and increase the number of functioning alveoli.

Sample

52-year-old widow. He is retired and living alone.

He enters the ED complaining of shortness of breath and tingling in fingers.

His breathing is shallow and rapid. He denies diabetes; blood sugar is normal.

There are no EKG changes. He has no significant respiratory or cardiac history. He takes several antianxiety medications. He says he has had anxiety attacks before. While being worked up for chest pain an ABG is done:

- ABG results are:
  - pH= 7.48 /$PaCO_2$= 28
  - HCO_3= 22 /PaO_2= 85

Problems

- pH is high,
- $PaCO_2$ is low
  - respiratory alkalosis.

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Solutions

- If he is hyperventilating from an anxiety attack, the simplest solution is to have him breathe into a paper bag.

- He will rebreathe some exhaled CO_2.This will increase $PaCO_2$ and trigger his normal respiratory drive to take over breathing control.

- * Please note this will not work on a person with chronic CO_2 retention, such as a COPD patient. These people develop a hypoxic drive, and do not respond to CO_2 changes.

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Sample

You are the critical care nurse about to receive, a 24-year-old DKA (diabetic ketoacidosis) patient from the ED. The medical diagnosis tells you to expect acidosis. In report you learn that his blood glucose on arrival was 780. He has been started on an insulin drip and has received one amp of bicarb. You will be doing finger stick blood sugars every hour.

- ABG results are:
- pH= 7.33 /HCO3=12
- PaO2= 89 /PaCO2= 25

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Problem

The pH is acidotic,

$PaCO_2$ is 25 (low) which should create alkalosis.

This is a respiratory compensation for the metabolic acidosis.

The underlying problem is, of course, a metabolic acidosis.

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Solutions

- Insulin, so the body can use the sugar in the blood and stop making ketones, which are an acidic by-product of protein metabolism.
- In the mean time, pH should be maintained near normal so that oxygenation is not compromised

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Sample

75 year old gentleman living in the community is being assessed for home oxygen. His ABG is as follows:

- pH: 7.36 (7.35-7.45)
- pO2: 8.0 (10–14)
- pCO2: 7.6 (4.5–6.0)
- HCO3: 31 (22-26)
- BE: +5 (-2 to +2)
- Other values within normal range

compensated respiratory acidosis

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Sample Problem

A 21 year-old woman presents feeling acutely lightheaded and short of breath. She has her final university exams next week.

- pH: 7.48 (7.35-7.45)
- pO2: 13.9 (10–14)
- pCO2: 3.5 (4.5–6.0)
- HCO3: 22 (22-26)
- BE: +2 (-2 to +2)
- Other values within normal rang

respiratory alkalosis

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Sample Problem

A 32 year-old man presents to the emergency department having been found collapsed by his girlfriend.

pH: 7.25 (7.35-7.45)

pO2: 11.1 (10–14)

pCO2: 3.2 (4.5–6.0)

HCO3: 11 (22-26)

BE: -15 (-2 to +2)

Potassium: 4.5

Sodium: 135

Chloride: 100

Other values within normal range

Anion gap = ([Na+] + [K+]) − ([Cl−] + [HCO3−])=28.5

= Normal range is 7 – 16.

metabolic acidosis with raised anion gap

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causes of a metabolic acidosis with raised anion gap is ‘MUDPILES

- Methanol
- Uraemia
- Diabetic ketoacidosis (and alcoholic/starvation ketoacidosis)
- Propylene glycol
- Isoniazid
- Lactate
- Ethylene glycol
- Salicylates

Sample Problem

A 62 year-old woman with a history of diabetes and a long smoking history presents to the emergency department with worsening shortness of breath. On auscultation of the chest there are widespread crackles and you notice moderate ankle oedema. ABG shows:

- pH: 7.20 (7.35-7.45)
- pO2: 8.9 (10–14)
- pCO2: 6.3 (4.5–6.0)
- HCO3: 17 (22-26)
- BE: -8 (-2 to +2)
- Other values within normal range

Note that despite the low pH the pCO2 is also high.

mixed respiratory and metabolic acidosis.

Winters' Formula

$$\text{Expected } PaCO_2 = (1.5 \times HCO_3^-) + 8 \pm 2$$

- Then you can compare the estimated $PaCO_2$ value to the patient's actual measured $PaCO_2$. This can result in three possible scenarios:
- Measured $PaCO_2$ = Estimated $PaCO_2$
- Measured $PaCO_2$ > Estimated $PaCO_2$
- Measured $PaCO_2$ < Estimated $PaCO_2$

Measured PaCO2 = Estimated PaCO2

- If the patient's PaCO2 is within the expected PaCO2 range, it indicates that respiratory compensation is taking place.
- This is considered to be pure metabolic acidosis.
- However, if the patient's PaCO2 is not within the expected range, it means that a mixed disorder is present.

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Measured $PaCO_2$ > Estimated $PaCO_2$

- If the patient's measured $PaCO_2$ is greater than the estimated $PaCO_2$, it indicates that the patient has respiratory acidosis in addition to metabolic acidosis.
- This is because the patient's respiratory system is not compensating enough for the metabolic acidosis, resulting in an increase in $PaCO_2$.

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Measured $PaCO_2$ < Estimated $PaCO_2$

- If the patient's measured $PaCO_2$ is less than the estimated $PaCO_2$, it indicates that the patient has respiratory alkalosis in addition to metabolic acidosis.
- This is because the patient's respiratory system is overcompensating for the metabolic acidosis, resulting in a decrease in $PaCO_2$.

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Example

- A patient has the following arterial blood gas results:
- pH = 7.34
- $PaCO_2$ = 28 mmHg
- HCO_3^- = 14 mEq/L

- The pH is slightly decreased and falls outside of the normal range.
- The $PaCO_2$ and HCO_3^- are both decreased as well.
- Therefore, this ABG can be interpreted as partially compensated metabolic acidosis.
- In other words, the patient has a metabolic issue, which is causing the lungs to work harder in order to compensate and raise the pH back to normal.

Now, let's calculate the expected $PaCO_2$ using Winters' formula:

- Expected $PaCO_2 = (1.5 \times HCO_3^-) + 8 \pm 2$
- Expected $PaCO_2 = (1.5 \times 14) + 8 \pm 2$
- Expected $PaCO_2 = 29 \pm 2$
- Expected $PaCO_2$ Range = 27–31 mmHg
- As you can see, the patient's measured $PaCO_2$ of 28 mmHg falls within the expected $PaCO_2$ range.
- Therefore, by using Winters' formula, you can confirm that this patient has pure metabolic acidosis with appropriate respiratory compensation and no primary lung disorders.

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Example

- A patient has the following arterial blood gas results:
- pH = 7.30
- $PaCO_2$ = 43 mmHg
- HCO_3^- = 18 mEq/L

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The pH is low and outside of the normal range. The $PaCO_2$ normal, while the HCO_3^- is decreased.
Therefore, this ABG can be interpreted as acute or uncompensated metabolic acidosis.

In other words, the patient has a metabolic issue, but the lungs have not yet had a chance to compensate and raise the pH back to normal.

Now, let's calculate the expected PaCO2 using Winters' formula:

Expected PaCO2 = (1.5 x HCO3-) + 8 ± 2

Expected PaCO2 = (1.5 x 18) + 8 ± 2

Expected PaCO2 = 35 ± 2

Expected PaCO2 Range = 33–37 mmHg

In this case, the patient's measured PaCO2 of 42 mmHg is higher than the expected PaCO2 range.

Therefore, this indicates that the patient has primary respiratory acidosis in addition to metabolic acidosis

Example

A patient has the following arterial blood gas results:

pH = 7.32

$PaCO_2$ = 27 mmHg

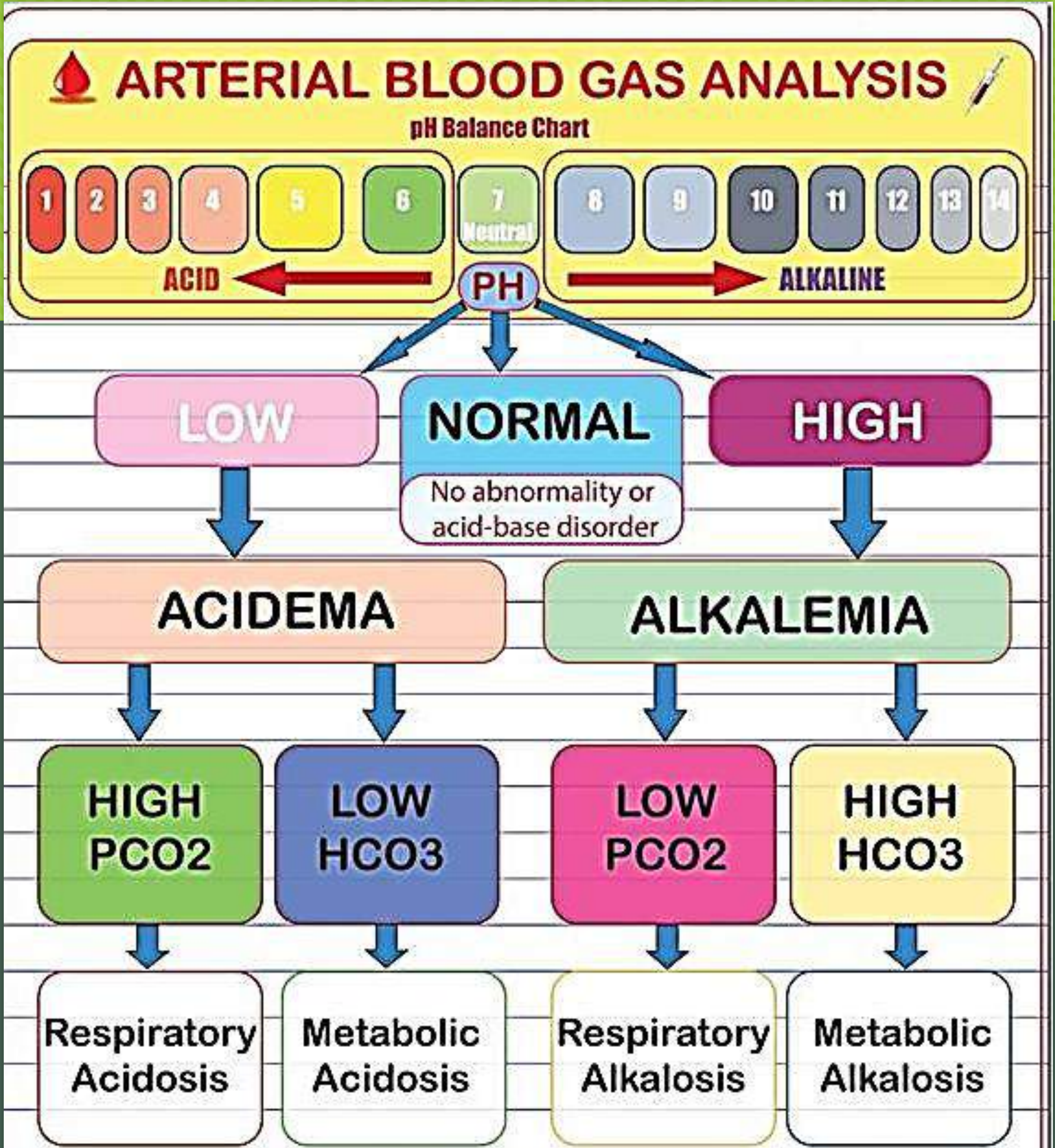
HCO_3^- = 16 mEq/L

Again, the pH is low and outside of the normal range, while the $PaCO_2$ and HCO_3^- are both decreased.
This ABG can be interpreted as partially compensated metabolic acidosis.

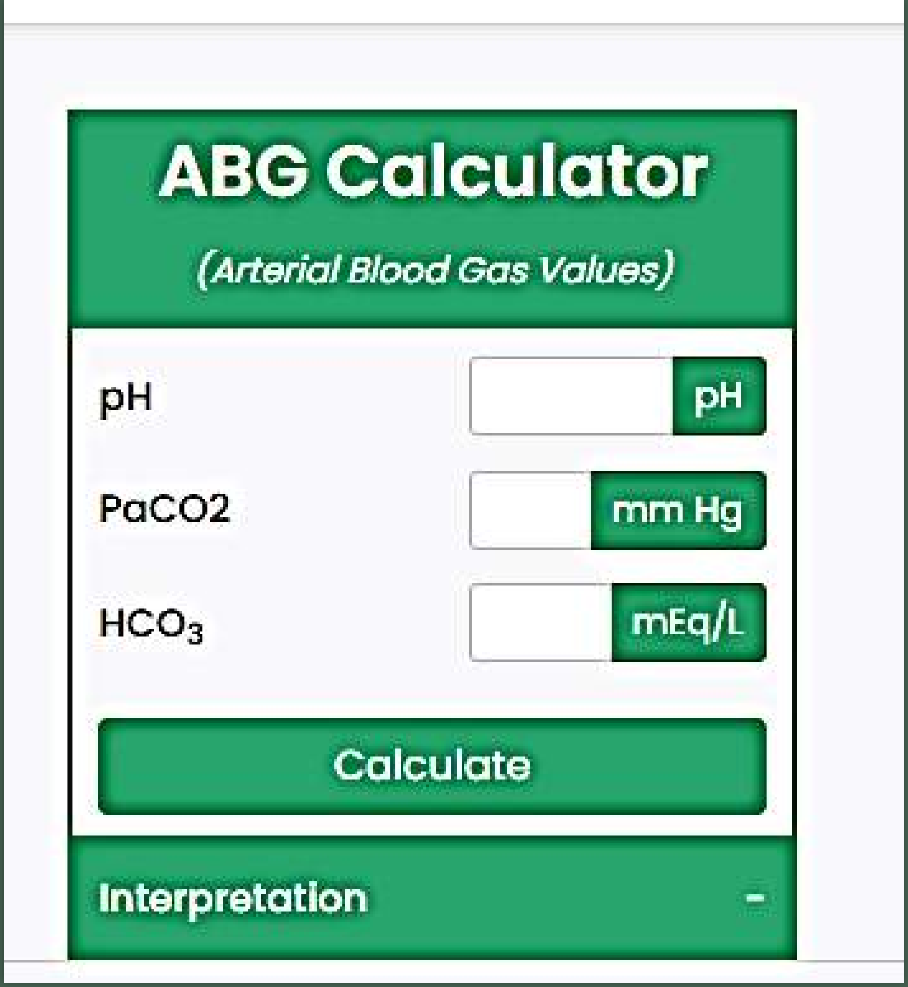
Now, let's calculate the expected PaCO2 using Winters' formula:

- Expected PaCO2 = (1.5 x HCO3-) + 8 ± 2
- Expected PaCO2 = (1.5 x 16) + 8 ± 2
- Expected PaCO2 = 32 ± 2
- Expected PaCO2 Range = 30–34 mmHg
- In this case, the patient's measured PaCO2 of 27 mmHg is lower than the expected PaCO2 range.

Therefore, this indicates that the patient has primary respiratory alkalosis in addition to metabolic acidosis.


ARTERIAL BLOOD GAS ANALYSIS
pH Balance Chart
1
2
3
4
5
6
7
Neutral
8
9
10
11
12
13
14
ACID
PH
ALKALINE
LOW
NORMAL
No abnormality or acid-base disorder
HIGH
ACIDEMA
ALKALEMIA
HIGH PCO2
LOW HCO3
LOW PCO2
HIGH HCO3
Respiratory Acidosis
Metabolic Acidosis
Respiratory Alkalosis
Metabolic Alkalosis

ABG Interpretation Calculator Tool



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Modified Allen

برای دریافت اپلیکیشن و جزوات اسکن کنید

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Thanks For Attention

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