Arterial Blood Gas Sampling

Simon Giles
Consultant Nurse
Critical Care
Aims and Objectives

- Identify the indications for blood gas sampling
- Discuss the process of arterial puncture
- Highlight complications of blood gas sampling
- Discuss arterial blood gas values and their implications to patient management
Forewarning

- Arterial Blood Gases are a diagnostic adjunct and should not blinker clinical judgement

- You may not be able to interpret some results – don’t get too concerned!
Indications for sampling

Clinical Scenario's

- Any unexpected deterioration in an ill pt
- Acute exacerbation of a chronic chest condition / Impaired respiratory effort (consider when SpO$_2$<92%)
- Impaired conscious level
- Systemic sepsis (Acid/base status and Lactate)
- Metabolic / electrolyte problem (DKA / Status epilepticus/ severe D&V)

Signs and Symptoms

- Bounding pulse
- Drowsy
- Tremor (Flapping)  CO2 Retention
- Headache
- Pink palms
- Papilloedema
- Cyanosis
- Confusion
- Visual hallucinations

CO2 Retention
Hypoxaemia
Indications for sampling

Monitoring of the Critically ill patient

- Monitoring treatment of known respiratory failure
- Anyone ventilated invasively or non-invasively
- Peri-arrest / post-arrest assessment
- Any major trauma
Equipment

- Approved syringe – does it self fill?
- Skin preparation / asepsis
- Personal protective equipment
- Gauze / tape / plaster
- IV fluid bag / towel
- Sterile field
- Local anaesthetic

**Lightowler et al (1997)**
Surveyed junior doctors – 84% found not using LA made procedure more difficult and painful

**Good**
- Patient comfort
- Allows you to ‘dig-around’
- More compliant patient
- Repeat if un-successful

**Bad**
- Masks the artery
- PGD / prescribing issues
- Iatrogenic issues (anaphylaxis / arrhythmia)

**Bottom Line**
- Users discretion – debateable for isolated sampling / essential for multiple samples and insertion of line.
Procedure

- Identification of patient - is there a clinical need?
- Obtain consent
  written / verbal & document
- Access to sampler
- Correct medium to transit sample
- Identify site
- Aseptic procedure
- Oxygen therapy (Consider removal NOT if pt in extremis!)
Puncture Sites

ARterial Sampling Sites

The illustration to the left shows the location of the most commonly used arterial sampling sites. These include the radial artery, brachial artery, and femoral artery. Of these three arteries, the radial artery (lying in the wrist area on the thumb side) is the preferred sampling site owing to 3 primary factors: 1) it is easy to access, 2) it is a superficial artery (it is easier to palpate, stabilize, and puncture a superficial artery rather than a deeper one), and 3) it has collateral blood flow.

If damage to the radial artery occurs or if it becomes obstructed, the ulnar artery will supply blood to the tissues normally supplied by the radial artery.
Preferred Sites

Radial

- Easily accessible
- Easily compressible
- Post sampling can be observed easily
Preferred Sites

**Femoral**
Larger artery - collapsed patient loses radial pulse

**Disadvantages**
More structures
‘Dirty area’
Accessibility
Femoral Artery

- Clean area with a suitable antiseptic
- Needle at 90 degrees to skin
- NAVY
- Pressure for 5 mins minimum
Radial - Modified Allen’s Test

1) Elevate hand and make a tight fist for 30 seconds.

2) Apply firm pressure to ulnar and radial arteries to occlude them.

3) Still elevated, open the hand. It should appear blanched (pallor can be observed at the finger nails).

4) Ulnar pressure is released and the colour should return in 7 seconds.

Inference: Ulnar artery supply to the hand is sufficient and it is safe to cannulate/prick the radial.

If colour does not return or returns after 7–10 seconds, then the ulnar artery supply to the hand is not sufficient and the radial artery therefore cannot be safely stabbed.

Anatomical basis
The hand is normally supplied by blood from the ulnar and radial arteries. The arteries undergo anastomosis in the hand. Thus, if the blood supply from one of the arteries is cut off, the other artery can supply adequate blood to the hand. A minority of people lack this dual blood supply.
2. Using your fingers, apply occlusive pressure to both the ulnar and radial arteries.
3. The syringe should be held at a 45° angle or less in your opposite hand, much like you would hold a pencil or a dart. This near-parallel insertion of the needle will minimize trauma to the artery and allow the smooth muscle fibers to seal the puncture hole after you withdraw the needle.
Procedure

- Position patient
  - Radial, slight wrist extension (IV bag / towel)
  - Femoral, abduct legs (genitals and abdomen)

- Palpate artery

- Palpate and clean skin

- Prepare syringe - small amount of air
Procedure

- Position fingers distally and proximally to needle insertion site / roll finger over artery
- Advance needle
  - Radial - 45 degrees to skin
  - Femoral - 90 degrees to skin
- When in artery blood should pulsate into syringe / may need to aspirate
- Remove and apply immediate pressure for 5 mins
Sample Transit

- Room temperature samples should be analysed within 10 – 15 mins
- Store in iced water - samples should be analysed within one hour
- Storing directly on ice can haemolyse sample (lower pH and PaO\textsubscript{2} / increase PaCO\textsubscript{2} and K\textsuperscript{+})
- Possible elevation of potassium levels by prolonged chilling
- Don’t shake the samples – affects potassium calibration and causes haemolysis
- Gentle rolling of the syringe will reduce chance of clot formation
- Remove air from the sample
- Use approved syringes in machine – under-calculated heparin volumes can affect accuracy
Post procedure

- Record in notes and ensure therapy is adjusted as required

- Recheck patient
  - further bleeding
  - Sensory deficit
Caution!

- Negative Allen’s test (collateral circulation test)

- Should not be taken through or distally to a surgical shunt (Fistula) or through a bypass graft (groin)

- Should not be taken through areas of infection or via a limb with evidence of peripheral vascular disease (Raynaud’s Disease)

- Caution with groin if evidence of thrush

- Bleeding diathesis / coagulopathy (relative contraindication post thrombolysis)

- When you haven’t done the basics!
Hazards / Complications

- Haematoma
- Arteriospasm
- Emboli
- Infection
- Haemorrhage
- Vessel trauma
- Arterial occlusion
- Nerve damage
- Pain
- Anaphylaxis (L.A.)
- Needlestick injury to clinician
- Vaso-vagal episode
Arteriospasm / Embolism
Haematoma
Pathological Allen’s Test
Trust Policy for non-medical practitioners to sample?

Appropriate training and assessment criteria

Need to maintain competence

Record of competency
  - trust audit
  - Individual audit – record / case records
Blood Gas Analysis

The 5 step approach....
The Easy 5 Step Approach
5-Step approach to arterial blood gas interpretation

1. **Assess oxygenation**
   - Is the patient hypoxic?
   - Is there a significant alveolar-arterial gradient?

2. **Determine status of the pH or H⁺ concentration**
   - \( \text{pH} > 7.45 (H^+ < 35 \text{ nmol l}^{-1}) \) – alkalaemia
   - \( \text{pH} < 7.35 (H^+ > 45 \text{ nmol l}^{-1}) \) – acidaemia

3. **Determine respiratory component**
   - \( \text{PaCO}_2 > 6.0 \text{ kPa (45 mmHg)} \) – respiratory acidosis
   - \( \text{PaCO}_2 < 4.7 \text{ kPa (35 mmHg)} \) – respiratory alkalosis

4. **Determine metabolic component**
   - \( \text{HCO}_3^- < 22 \text{ mmol l}^{-1} \) – metabolic acidosis
   - \( \text{HCO}_3^- > 26 \text{ mmol l}^{-1} \) – metabolic alkalosis

0.1333kPa is 1mmHg
mmHg /7.5 approximates to kPa
5. Combine the information from the pH, PaCO2 and the bicarbonate - determine the primary disturbance - is there any metabolic or respiratory compensation?

In the presence of a low pH (acidaemia): - a high PaCO2 implies a primary respiratory acidosis - a low PaCO2 implies respiratory compensation for a primary metabolic acidosis.

In the presence of a high pH (alkalaemia): - a low PaCO2 implies a primary respiratory alkalosis - a high PaCO2 implies respiratory compensation for a primary metabolic alkalosis.

It is also possible to have mixed acid base disorders, e.g. a combination of a respiratory and a metabolic acidosis creating an acidaemia, or a combination of a respiratory and metabolic alkalosis creating an alkalaemia.
For optimal cellular function / homeostasis, the body will naturally buffer itself in order to maintain an equilibrium.

Will buffer quickly by utilising the lungs to ‘blow-off’ or maintain CO2.

(CO2 is an acid)

The kidneys also act as a buffer by removing or keeping bicarbonate.

(Bicarbonate is an alkaline)
Mixed Picture

- Adjustments in both the respiratory and metabolic components

<table>
<thead>
<tr>
<th></th>
<th>Acidosis</th>
<th>Alkalosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory</td>
<td>$\text{CO}_2 \uparrow$</td>
<td>$\text{CO}_2 \downarrow$</td>
</tr>
<tr>
<td>Metabolic</td>
<td>$\text{HCO}_3^-$ or base excess $\downarrow$</td>
<td>$\text{HCO}_3^-$ or base excess $\uparrow$</td>
</tr>
</tbody>
</table>
## Respiratory Failure

<table>
<thead>
<tr>
<th>Type</th>
<th>Low O2</th>
<th>Normal / Low PaCO2</th>
<th>Elevated PaCO2</th>
<th>Elevated HCO3</th>
<th>COPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Summary of changes in pH, PaCO\textsubscript{2} and HCO\textsubscript{3}\textsuperscript{-} in acid-base disorders

<table>
<thead>
<tr>
<th>Acid-base disorder</th>
<th>pH</th>
<th>PaCO\textsubscript{2}</th>
<th>HCO\textsubscript{3}\textsuperscript{-}</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Respiratory acidosis (Asthma/COPD)</strong></td>
<td>↓</td>
<td>↑</td>
<td>N</td>
</tr>
<tr>
<td><strong>Metabolic acidosis (DKA)</strong></td>
<td>↓</td>
<td>N</td>
<td>↓</td>
</tr>
<tr>
<td>Respiratory alkalosis (PE / hypervent.)</td>
<td>↑</td>
<td>↓</td>
<td>N</td>
</tr>
<tr>
<td><strong>Metabolic alkalosis (Vomiting)</strong></td>
<td>↑</td>
<td>N</td>
<td>↑</td>
</tr>
<tr>
<td><strong>Respiratory acidosis with renal compensation</strong></td>
<td>↓*</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td><strong>Metabolic acidosis with respiratory compensation</strong></td>
<td>↓*</td>
<td>↓</td>
<td>↓</td>
</tr>
</tbody>
</table>

* If the compensation is virtually complete the pH may be in the normal range – over compensation does not occur.

Those marked in bold are particularly common after cardiac arrest.
### Summary of changes in pH, PaCO$_2$ and HCO$_3^-$ in acid-base disorders (continued)

<table>
<thead>
<tr>
<th>Acid-base disorder</th>
<th>pH</th>
<th>PaCO$_2$</th>
<th>HCO$_3^-$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory alkalosis with renal compensation</td>
<td>↑ *</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Metabolic alkalosis with respiratory compensation</td>
<td>↑ *</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td><strong>Mixed metabolic and respiratory acidosis</strong></td>
<td>↓</td>
<td>↑</td>
<td>↓</td>
</tr>
<tr>
<td>Mixed metabolic and respiratory alkalosis</td>
<td>↑</td>
<td>↓</td>
<td>↑</td>
</tr>
</tbody>
</table>

* If the compensation is virtually complete the pH may be in the normal range – over compensation does not occur.

**Those marked in bold are particularly common after cardiac arrest**
Scenario 1

Initial Information
A 69 year old lady is brought to the emergency department after a witnessed out-of-hospital VF cardiac arrest.

The paramedics arrived approximately 8 minutes post collapse, poor CPR had been given. The paramedics had successfully restored spontaneous circulation after 3 shocks.

On arrival to ED:
(GCS 3/15)
ETT in-situ ventilated with 60% oxygen via ventilator
HR 118 min      BP 140/100 mmHg.
Scenario 1 (continued)

Arterial blood gas analysis reveals:

<table>
<thead>
<tr>
<th></th>
<th>Normal Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>FiO(_2)</td>
<td>0.6 (60%)</td>
</tr>
<tr>
<td>pH</td>
<td>7.10</td>
</tr>
<tr>
<td>PaCO(_2)</td>
<td>6.2 kPa</td>
</tr>
<tr>
<td>PaO(_2)</td>
<td>7.5 kPa</td>
</tr>
<tr>
<td>HCO(_3^-)</td>
<td>14 mmol l(^{-1})</td>
</tr>
</tbody>
</table>

4.7 – 6.0 kPa

> 10 kPa on air

22 – 26 mmol l\(^{-1}\)
Scenario 1 Feedback

Mixed metabolic and respiratory acidosis

- Increase the FiO2 – this should increase the PaO2

- Increase the minute ventilation to reduce the PaCO2 this will quickly increase the pH

- Optimise the cardiac output – increased oxygen delivery to the tissues will restore aerobic metabolism, reduce the lactic acidosis, and slowly restore the pH toward normal

- Bicarbonate is not indicated, as restoration of cardiac output will restore the plasma bicarbonate toward normal
Scenario 2

Initial Information

A 65 year old man with severe COPD has just collapsed in the waiting room.

On initial assessment by the ED nurse he is apnoeic but has an easily palpable carotid pulse at 90 min$^{-1}$.

The nurse is attempting to ventilate his lungs with a bag-mask and supplemental oxygen (with reservoir) as the ED team are summoned.
Arterial blood gas analysis reveals:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Normal Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FiO₂</strong></td>
<td>0.85 (85%) estimated</td>
<td></td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>7.10</td>
<td>7.35 – 7.45</td>
</tr>
<tr>
<td><strong>PaCO₂</strong></td>
<td>18.0 kPa</td>
<td>4.7 – 6.0 kPa</td>
</tr>
<tr>
<td><strong>PaO₂</strong></td>
<td>19.5 kPa</td>
<td>&gt; 10 kPa on air</td>
</tr>
<tr>
<td><strong>HCO₃⁻</strong></td>
<td>36 mmol l⁻¹</td>
<td>22 – 26 mmol l⁻¹</td>
</tr>
</tbody>
</table>
Severe respiratory acidosis

- The patient’s arterial blood is well oxygenated

- There is a compensatory increase in bicarbonate, which reflects a chronically raised PaCO2 – this is consistent with severe COPD

- The significant acidaemia (low pH) and very high PaCO2 indicate an additional acute respiratory acidosis (occurring around the time of the respiratory arrest) – in the presence of a fully compensated chronic respiratory acidosis the pH would be near normal.

- If considered appropriate, the active treatment of this patient would include:
  - Tracheal intubation and positive pressure ventilation
Scenario 3

A 23yr old female is brought to the ED by her parents she has experienced some emotional upheaval (‘boyfriend dumped her’). She is upset, hyperventilating and complains of her fingers feeling tingly.

A junior doctor has asked you to comment on the results……..

RR 28  HR 116  BP 128/60
### Scenario 3

**Arterial blood gas analysis reveals:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Normal Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>FiO₂</td>
<td>0.21 (21%)</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>7.51</td>
<td>7.35 – 7.45</td>
</tr>
<tr>
<td>PaCO₂</td>
<td>2.65 kPa</td>
<td>4.7 – 6.0 kPa</td>
</tr>
<tr>
<td>PaO₂</td>
<td>13.4 kPa</td>
<td>&gt; 10 kPa on air</td>
</tr>
<tr>
<td>HCO₃⁻</td>
<td>23 mmol l⁻¹</td>
<td>22 – 26 mmol l⁻¹</td>
</tr>
</tbody>
</table>
Respiratory Alkalosis

- Was an ABG indicated?
- Paper Bag
- Close curtains and lecture!!
- Encourage deep slow breaths
- Observe
Scenario 4

Initial Information

An 23 year old insulin dependent diabetic is brought to the Emergency Department.

He has been unwell with the ‘man-flu’ for 3/7, has vomited several times and not taken his insulin.

On arrival:

- HR 130 min\(^{-1}\)
- BP 90/65 mmHg
- Spontaneous breathing, RR 35 min\(^{-1}\)
- Oxygen 4 l min\(^{-1}\) via Hudson mask
- GCS 14 (E3, M6, V5)
Scenario 4 (continued)

Arterial blood gas analysis reveals:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Normal Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>FiO₂</td>
<td>0.28 (28%)</td>
<td>7.35 – 7.45</td>
</tr>
<tr>
<td>pH</td>
<td>7.15</td>
<td>4.7 – 6.0 kPa</td>
</tr>
<tr>
<td>PaCO₂</td>
<td>2.48 kPa</td>
<td>&gt; 10 kPa on air</td>
</tr>
<tr>
<td>PaO₂</td>
<td>22.0 kPa</td>
<td>22 – 26 mmol l⁻¹</td>
</tr>
<tr>
<td>HCO₃⁻</td>
<td>6.1 mmol l⁻¹</td>
<td></td>
</tr>
</tbody>
</table>

The blood glucose is 30 mmol l⁻¹ and there are ketones+++ in the urine.
Metabolic acidosis with partial compensation provided by a respiratory alkalosis

- These blood gas values are consistent with severe diabetic ketoacidosis.

The treatment would include:

- Fluid resuscitation – initially, with normal saline
- Insulin
- The use of bicarbonate is controversial but many clinicians would give it in the presence of an acidaemia of this severity, particularly if it did not improve quickly after starting insulin and fluid resuscitation
A 75 year old man is on the surgical ward 2 days after a laparotomy for a perforated sigmoid colon secondary to diverticular disease. He has become hypotensive over the last 6 hours. His vital signs are:

- **Heart rate**: 120 min\(^{-1}\) – sinus tachycardia
- **Blood pressure**: 70/40 mmHg
- **Respiratory rate**: 35 breaths min\(^{-1}\)
- **SpO\(_2\) on oxygen**: 92%
- **Urine output**: 50 ml in the last 6 hours
- **GCS**: 13 (E3, M6, V4)
Scenario 5 (continued)

Arterial blood gas analysis reveals:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Normal Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>FiO₂</td>
<td>0.4 (40%) approx</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>7.12</td>
<td>7.35 – 7.45</td>
</tr>
<tr>
<td>PaCO₂</td>
<td>4.5 kPa</td>
<td>4.7 – 6.0 kPa (35–45 mmHg)</td>
</tr>
<tr>
<td>PaO₂</td>
<td>8.2 kPa</td>
<td>&gt; 10 kPa (75 mmHg) on air</td>
</tr>
<tr>
<td>HCO₃⁻</td>
<td>12 mmol l⁻¹</td>
<td>22 – 26 mmol l⁻¹</td>
</tr>
<tr>
<td>BE</td>
<td>- 15 mmol l⁻¹</td>
<td>+/- 2 mmol l⁻¹</td>
</tr>
</tbody>
</table>
Questions?
By reading this article and writing a practice profile, you can gain a certificate of learning. You have up to a year to send in your practice profile. Guidelines on how to write and submit a profile are featured at the end of this article.

Arterial blood gas analysis


Aim and intended learning outcomes

This article aims to give nurses an understanding of the main gas and acid base measurements derived and how to interpret the main ABG results. It does not discuss how to take samples, errors that can occur when taking samples, or care of arterial lines.

In brief

Author

Philio Woodrow MA, RGN
References

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- www.en.wikipedia.org/wiki/Main_Page
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- NICE (2007) *Acutely Ill Patients in Hospital: Recognition of and Response to Acute Illness in Adults in Hospital*. www.nice.org.uk


Oxygenation

- Normal Range 10 - 14 kPa
- Is the PaO₂ less than 8kPa (hypoxic)?
- Is the patient on O₂?

Ensure the FiO₂ / delivered O₂ is documented on the gas sampler.

- Is there a significant alveolar-arterial gradient?

1% O₂ is approximately 1kPa.
Normal drop inspired to alveolar is approximately 10.0 kPa
Thus on an inspired oxygen concentration of 50% should give an approximate PaO₂ of 40 kPa

\[
\begin{align*}
\text{FiO₂} & \quad 0.21 \quad \text{(Air 21\%)} \\
& \quad 0.4 \quad \text{(40\%)}
\end{align*}
\]
The normal Range is 7.35 – 7.45

What is the pH doing?

A range less than 7.35 is acidaemia (acidosis)

A range greater than 7.45 is alkaleamia (alkalosis)

> 7.45 (H+ < 35 nmol l-1) alkalaemia
< 7.35 (H+ > 45 nmol l-1) acidaemia
Carbon dioxide is an acidic gas and is responsible for the respiratory component of the blood gas. PaCO2 levels can fluctuate quickly by increasing / decreasing respiratory rates.

**Normal Range is 4.7 - 6.0 kPa**

Does the pH reflect changes associated with PaCO2 levels?

- PaCO2 >6.0 kPa *Respiratory acidosis* (Hypercapnia)
- PaCO2 <4.7 kPa *Respiratory alkalosis* (Hypocapnia)
Bicarbonate is an alkaline and acts as a buffer, Bicarbonate takes several hours to adjust therefore elevated or lowered levels normally indicate sub-acute / chronic changes.

Determine metabolic component

<table>
<thead>
<tr>
<th>HCO3</th>
<th>&lt; 22 mmol l-1 – metabolic acidosis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&gt; 26 mmol l-1 – metabolic alkalosis</td>
</tr>
</tbody>
</table>
Venous versus arterial results

- What parameters stay the same?
  - PH
  - Hb / electrolytes / COHb

- Lactate – slightly higher on venous sample
  - Normal range less than 1mmol/l