Arterial Line Sampling
Neonatal Clinical Guideline

V5.0

April 2019
Summary

This document provides guidance on Arterial line sampling for neonates, staff responsibilities, technique, and Aseptic Non-Touch Technique (ANTT) procedure. It also includes staff training blood gas workbook.
1. **Aim/Purpose of this Guideline**

1.1. This document is aimed at Health Care Professionals working in the neonatal unit who have studied the theory of caring for a neonate with an arterial line and interpretation of neonatal blood gas analysis Workbook see Appendix 3.

1.2. Practitioners sampling arterial lines are responsible for ensuring the results are recorded, interpreted and acted upon by a competent professional in Neonatal Intensive Care. In addition, practitioners must follow RCHT standards of Infection control and consider the indications for and complications associated with the use of arterial line sampling and use of the blood gas machine.

1.3. This version supersedes any previous versions of this document.

1.4. **Data Protection Act 2018 (General Data Protection Regulation – GDPR) Legislation**

The Trust has a duty under the DPA18 to ensure that there is a valid legal basis to process personal and sensitive data. The legal basis for processing must be identified and documented before the processing begins. In many cases we may need consent; this must be explicit, informed and documented. We can’t rely on Opt out, it must be Opt in.

The DPA18 covers how the Trust obtains, hold, record, use and store all personal and special category (e.g. Health) information in a secure and confidential manner. This Act covers all data and information whether held electronically or on paper and extends to databases, videos and other automated media about living individuals including but not limited to Human Resources and payroll records, medical records, other manual files, microfilm/fiche, pathology results, images and other sensitive data.

DPA18 is applicable to all staff; this includes those working as contractors and providers of services.

For more information about your obligations under the DPA18 please see the ‘information use framework policy’, or contact the Information Governance Team rch-tr.infogov@nhs.net

2. **The Guidance**

2.1. **Equipment Required**

- Dressing trolley
- Sterile dressing pack
- 2ml syringe for line fluid withdrawal and 2ml syringe for saline flush
- 1ml syringe for sample (use larger syringe only if other samples required total more than 1ml)
- Sterile needle
- 2% Chlorhexidine, 70% Alcohol wipe (Sanicloth)
- Appropriate requisition forms, labels and sample tubes
- Sodium Chloride 0.9% 5mL ampoule
2.2. **Procedure**

This procedure must be performed using an Aseptic Non-Touch Technique (ANTT):

1. Sanitise hands with alcohol gel/wash hands
2. Clean trolley with alcohol wipe and allow to dry
3. Gather equipment and identify patient, noting oxygen saturations, FiO2 requirement and any respiratory support settings
4. Explain procedure if parent present
5. Ensure the arterial line is in an accessible position
6. Open sterile pack onto trolley. Open sterile syringes x3, needle and 2% chlorhexidine Sanicloth wipe onto sterile field
7. Double check and open 0.9% saline ampoule and place in accessible position
8. Wash hands again and put on gloves
9. Prime one syringe, drawing from ampoule with sterile needle
10. Observe arterial trace quality and identify arterial line
11. Clean bionector thoroughly for 30 seconds with sanicloth wipe working away from the port and allow to dry
12. Place sterile towel beneath the 3 way tap. Using an ANTT, attach sterile syringe (2ml only) to bionector making sure connection is secure and elevated to avoid any air bubble entering line. Close stopcock to infusion line to prevent contamination of sample by infusion fluid
13. Withdraw fluid gently from line until blood is obtained and fills line and syringe with pure blood seen (usually 0.5ml) Aggressive sampling may damage the artery. Turn stopcock to 45° angle/off to patient side to close port and prevent blood loss from open line
14. Remove the syringe and place it on the sterile field. This fluid will be reinfused
15. Attach second sterile syringe and withdraw sample (0.1 ml adequate for blood gas unless more blood is required) Turn stopcock to 45° angle/off to patient side, remove syringe
16. Reattach the first syringe, primed, to reinfuse the initial sample. Hold the syringe elevated, aspirate any air from port and reinfuse fluid slowly over 10
seconds to avoid sudden change in arterial pressure. Turn 3 way tap 45° to remove syringe

17. Flush line with the 3rd syringe primed with 0.9% Saline to clear line of blood. Use the minimum amount necessary

18. Turn stopcock to close the port and check waveform has returned to normal trace on monitor

19. Ensure arterial line transducer is still positioned at the level of the baby’s heart to ensure accurate blood pressure monitoring

20. Put blood sample into gas tube/lab sample tubes for processing as soon as possible

21. Discard of waste as per RCHT waste management policy, remove personal protective equipment and wash hands with soap and water

22. Complete documentation in baby’s notes including date, time and for blood gases action taken as a result of the blood gas

3. Monitoring compliance and effectiveness

<table>
<thead>
<tr>
<th>Element to be monitored</th>
<th>Compliance with guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead</td>
<td>Neonatal Nurse Manager</td>
</tr>
<tr>
<td>Tool</td>
<td>ANNT monitoring, Staff education and training supervision</td>
</tr>
<tr>
<td>Frequency</td>
<td>Individual staff on biannual basis</td>
</tr>
<tr>
<td>Reporting arrangements</td>
<td>Report within current matrice returns. LMS training records</td>
</tr>
<tr>
<td>Acting on recommendations and Lead(s)</td>
<td>IPAC, Neonatal Consultants, Neonatal Sisters</td>
</tr>
<tr>
<td>Change in practice and lessons to be shared</td>
<td>Lessons will be shared with all the relevant stakeholders</td>
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</table>

4. Equality and Diversity

4.1. This document complies with the Royal Cornwall Hospitals NHS Trust service Equality and Diversity statement which can be found in the ‘Equality, Inclusion & Human Rights Policy’ or the Equality and Diversity website.

4.2. Equality Impact Assessment

The Initial Equality Impact Assessment Screening Form is at Appendix 2.
## Appendix 1. Governance Information

<table>
<thead>
<tr>
<th>Document Title</th>
<th>Arterial Line Sampling Neonatal Clinical Guideline V5.0</th>
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<tr>
<td>Date Issued/Approved:</td>
<td>Dec 2018</td>
</tr>
<tr>
<td>Date Valid From:</td>
<td>17 April 2019</td>
</tr>
<tr>
<td>Date Valid To:</td>
<td>17 April 2022</td>
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<tr>
<td>Directorate / Department responsible (author/owner):</td>
<td>Judith Clegg, ANNP, Neonatal Unit</td>
</tr>
<tr>
<td>Contact details:</td>
<td>01872 252667</td>
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<tr>
<td>Brief summary of contents</td>
<td>Arterial line sampling for neonates. Staff responsibilities. Technique. ANTT procedure</td>
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<tr>
<td>Suggested Keywords:</td>
<td>Neonate. Neonatal. Arterial. Blood gas. Sampling</td>
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<td>Target Audience</td>
<td>RCHT</td>
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<td>Medical Director</td>
</tr>
<tr>
<td>Date revised:</td>
<td>Dec 2018</td>
</tr>
<tr>
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<td>ARTERIAL LINE SAMPLING NEONATAL CLINICAL GUIDELINE V4.0</td>
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<td>Approval route (names of committees)/consultation:</td>
<td>Neonatal Guidelines group, Consultant led</td>
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<tr>
<td>Care Group General Manager confirming approval processes</td>
<td>Debra Shields</td>
</tr>
<tr>
<td>Name and Post Title of additional signatories</td>
<td>None required</td>
</tr>
<tr>
<td>Name and Signature of Care Group/Directorate Governance Lead confirming approval by specialty and care group management meetings</td>
<td>{Original Copy Signed} Name: Caroline Amukusana</td>
</tr>
<tr>
<td>Signature of Executive Director giving approval</td>
<td>{Original Copy Signed}</td>
</tr>
<tr>
<td>Publication Location (refer to Policy on Policies – Approvals and Ratification):</td>
<td>Internet &amp; Intranet</td>
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</table>
Related Documents:


Training Need Identified?

Yes. All staff need to be signed off/observed by professional staff competent in this procedure before performing this task independently

### Version Control Table

<table>
<thead>
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<th>Date</th>
<th>Version No</th>
<th>Summary of Changes</th>
<th>Changes Made by (Name and Job Title)</th>
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<td>V1.0</td>
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<td>J.Lane Sister NNU</td>
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<td>4/2009</td>
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<td>J.Clegg ANNP, Neonatal Unit</td>
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<td>Review, reformat, workbook update ‘question and answer’ documents included</td>
<td>Judith clegg ANNP, Neonatal Unit</td>
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**All or part of this document can be released under the Freedom of Information Act 2000**

**This document is to be retained for 10 years from the date of expiry.**

**This document is only valid on the day of printing**

**Controlled Document**

This document has been created following the Royal Cornwall Hospitals NHS Trust Policy for the Development and Management of Knowledge, Procedural and Web Documents (The Policy on Policies). It should not be altered in any way without the express permission of the author or their Line Manager.
### Appendix 2. Initial Equality Impact Assessment Form

**Name of the strategy / policy / proposal / service function to be assessed**
- Arterial Line Sampling Neonatal Clinical Guideline V5.0

<table>
<thead>
<tr>
<th>Directorate and service area:</th>
<th>Is this a new or existing Policy:</th>
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<tr>
<td>Child Health, Neonatal</td>
<td>Existing</td>
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</table>

<table>
<thead>
<tr>
<th>Name of individual completing assessment:</th>
<th>Telephone:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paul Munyard</td>
<td>01872 252667</td>
</tr>
</tbody>
</table>

1. **Policy Aim**
   - **Who is the strategy / policy / proposal / service function aimed at?**
     - To provide guidance on the sampling of neonatal arterial lines by experienced neonatal staff.

2. **Policy Objectives**
   - As above

3. **Policy – intended Outcomes**
   - Evidence based and standardised practice

4. **How will you measure the outcome?**
   - Audit

5. **Who is intended to benefit from the policy?**
   - Neonatal patients
   - Neonatal medical and nursing staff.

6a. **Who did you consult with**
   - Workforce | Patients | Local groups | External organisations | Other
   - x |

   b). Please identify the groups who have been consulted about this procedure.
   - Please record specific names of groups
     - Neonatal Guidelines group, Consultant led

What was the outcome of the consultation?
- Guideline approved
7. The Impact
Please complete the following table. If you are unsure/don’t know if there is a negative impact you need to repeat the consultation step.

Are there concerns that the policy could have differential impact on:

<table>
<thead>
<tr>
<th>Equality Strands:</th>
<th>Yes</th>
<th>No</th>
<th>Unsure</th>
<th>Rationale for Assessment / Existing Evidence</th>
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<tbody>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Sex (male, female, trans-gender / gender reassignment)</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Race / Ethnic communities /groups</td>
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<td></td>
<td>x</td>
<td>Any information provided should be in an accessible format for the parent/carer’s needs – i.e available in different languages if required/access to an interpreter if required</td>
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<tr>
<td>Disability - Learning disability, physical impairment, sensory impairment, mental health conditions and some long term health conditions.</td>
<td></td>
<td></td>
<td>x</td>
<td>Those parent/carer’s with any identified additional needs will be referred for additional support as appropriate - i.e to the Liaison team or for specialised equipment. Written information will be provided in a format to meet the family’s needs e.g. easy read, audio etc</td>
</tr>
<tr>
<td>Religion / other beliefs</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
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<tr>
<td>Marriage and Civil partnership</td>
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<td>Pregnancy and maternity</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Sexual Orientation, Bisexual, Gay, heterosexual, Lesbian</td>
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<td></td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>

You will need to continue to a full Equality Impact Assessment if the following have been highlighted:
- You have ticked “Yes” in any column above and
- No consultation or evidence of there being consultation- this excludes any policies which have been identified as not requiring consultation. or
- Major this relates to service redesign or development

8. Please indicate if a full equality analysis is recommended.  
- Yes  
- No  
- x

9. If you are not recommending a Full Impact assessment please explain why.

No areas indicated
Keep one copy and send a copy to the Human Rights, Equality and Inclusion Lead
c/o Royal Cornwall Hospitals NHS Trust, Human Resources Department, Knowledge Spa,
Truro, Cornwall, TR1 3HD

This EIA will not be uploaded to the Trust website without the signature of the
Human Rights, Equality & Inclusion Lead.

A summary of the results will be published on the Trust’s web site.

Signed __ Paul Munyard____________
Date ___25/03/2019____________
Appendix 3. Interpretation of neonatal blood gas analysis Workbook

Blood Gases

Introduction.

Acid/base balance is important for adequate control of all body functions. The enzymes which control these functions are affected by small environmental changes. Disturbances of acid/base can therefore be more dangerous than the primary disease. An understanding of acid/base balance is therefore essential in Neonatal care.

This package is designed to help you to interpret acid/base values in blood gas results and assess appropriate treatment.

Section 1 gives you the relevant information.

Section 2 sets clinical situations to assess your knowledge and understanding of acid/base balance.

Section 3 contains the answers to the clinical questions.

If you need further help to understand any portion, or have problems with the questions in section 2 please ask for assistance. Do not be afraid to keep asking until you get an answer that you can understand.

Space has been left in each section for your own notes and comments.
Acid/Base balance.

ACID- A substance which yields hydrogen ions (H+) in solution. A strong acid, e.g. hydrochloric acid, gives up hydrogen ions very rapidly. Other acids, e.g. carbonic acid, which do not yield hydrogen ions so readily are called weak acids.

BASE- An alkaline substance which accepts hydrogen ions. Adding an acid to a base in solution gives a weaker acid as the base accepts hydrogen ions given up by the acid.

pH- The hydrogen ion concentration in a solution will determine acidity or alkalinity. This concentration is expressed as a value called pH. It is inversely proportional to the hydrogen ion concentration. This means that a pH of 2.0 indicates a solution with more hydrogen ions than one with a pH of 3.0, and therefore has a higher acidity. pH is a logarithmic scale which means that a change of 1 unit in pH represents a 10 fold change in hydrogen ion concentration. This means that a small change in pH is significant.

BUFFER- A substance which minimises changes in pH when acid or base is added to a solution. This means a strong acid base will become weaker. There are normally sufficient buffers in the body to maintain pH within narrow limits. There are 3 important buffers in the body:

- Bicarbonate
- Haemoglobin
- Phosphate
Physiological Maintenance of Acid/Base Balance.

Acids are produced during normal metabolism. These must be neutralised before they can be excreted from the body.

Excretion of acids occurs in 3 main ways:

- **The Lungs**- the main route of excretion for carbonic acid which is converted to carbon dioxide and water. When pH falls the respiratory centre in the medulla of the brain detects the change and triggers an increase in the respiratory rate to blow off carbon dioxide.

- **The Kidneys**- the main route of excretion of hydrogen ions. Bicarbonate can also be conserved by the kidneys.

- **Haemoglobin**- contains a protein buffer which neutralises acid, especially carbonic acid. This is converted to bicarbonate and then released to the plasma as sodium bicarbonate.
Normal Blood Gas Values In Neonates.

Five values need to be considered in evaluating blood gases:

- pH
- Partial pressure of oxygen (pO²)
- Partial pressure of carbon dioxide (pCO²)
- Standard bicarbonate (St HCO³)
- Base excess (BE)

pH
This is a measure of the hydrogen ion concentration in the blood and indicates acidity or alkalinity.

**Normal pH of arterial blood is 7.35 – 7.44**
Values below 7.35 indicate increasing acidity, while values above 7.44 indicate alkalinity.
A pH below 7.25 may have many harmful effects including reduced cardiac contractility, periventricular haemorrhage, leucomalacia and increased vascular resistance.
A pH below 7.0 for prolonged periods is generally incompatible with life.

pO²
This is a measure of the partial pressure of oxygen dissolved in the blood.
The unit of measurement is the kilopascal (kPa).

**Arterial blood has a normal pO² of 7 – 12 kPa.**

pCO²
This is a measure of the partial pressure of carbon dioxide dissolved in the blood.
The unit of measurement is the kilopascal (kPa).

**Arterial blood has a normal pCO² of 4-6 kPa.**

Standard Bicarbonate (St HCO³)
This is a measure of the amount of bicarbonate (HCO³) in the blood.
The unit of measurement is millmoles/Litre (mml/L).

**Arterial blood has a normal value of 18-25 mml/L.**

Base Excess.
This is an indication of the amount of buffering agents available to mop up hydrogen ions.
The blood gas analyser performs a calculation and gives the base excess as a positive or negative value.

**Arterial blood has a normal base excess of +4 to -4.**
Disturbances of Acid/Base Balance.

Diminished or increased pH is the result of an alteration in the acid/base balance. Acidosis results from an accumulation of hydrogen ions. Accumulation of a base or loss of hydrogen ions results in alkalosis. If the changes are in response to a ventilation disorder they are termed respiratory acidosis or alkalosis. A general metabolic disturbance will result in metabolic acidosis or alkalosis.
**Metabolic Acidosis.**

**Causes.**
These include an accumulation of acids for example in anaerobic metabolism (as in hypoxia) metabolic disorders, and an infusion of acid e.g. parental nutrition. Other causes include hypoglycaemia, cold stress, sepsis and hypovolaemia. Renal immaturity in preterm babies can lead to a mild acidosis, especially when parental nutrition is necessary.

**Signs.**
- Fall in pH (due to increased H+)
- Negative base excess (when buffering agents are used up)
- Normal or low pCO²
- Normal or low pO²

**Treatment.**
It is very important to treat the cause of acidosis. The pO² may need to be increased to prevent anaerobic metabolism. If infusions of amino acids are in progress they may need to be stopped.

As sodium bicarbonate can lead to metabolic alkalosis and intraventricular haemorrhage it should only be used with extreme caution. Treatment with sodium bicarbonate usually takes the form of half correction, and is not be regarded as a cure of acidosis.

Base required in mmol = \( \text{B.E.} \times \text{wt} \times 0.3 \)

In extreme prematurity substitute 0.6 for 0.3 in the equation.
Metabolic Alkalosis.

Cause
Inappropriate treatment with sodium bicarbonate is the most common cause. Persistent vomiting or gastric suctioning with loss of gastric hydrochloric acid can also lead to metabolic alkalosis. Generation of bicarbonate by the kidney in response to low potassium levels.

Signs
- A rise in pH (because of increased alkalinity of the blood)
- A rise in St HCO³
- Normal pCO² and pO²

Treatment
The underlying cause must be treated.
Respiratory Acidosis

Causes
This is due to poor gas exchange. It is frequently seen in respiratory distress syndrome. Other causes include perinatal hypoxia.

Signs
- A fall in pH
- A rise in pCO²
- pCO², B.E. and St HCO³ may be normal.

Treatment
It may be necessary to commence Vapotherm, CPAP or mechanical ventilation. If the baby is already on mechanical ventilation then assess the adequacy of ventilation and consider the following actions:
- the rate may need to be increased
- peak pressure (PIP) may need to be increased
- the PEEP may need to be decreased
- longer expiratory time may allow CO² to be exhaled more efficiently
- Ensure adequate sedation/paralysis to aid compliance with ventilator
Respiratory Alkalosis.

Cause
Incorrect management of mechanical ventilation is the most common cause, allowing excessive elimination of CO₂. A very low pCO₂ under 4KPa leads to a fall in cardiac and cerebral blood flow so this situation can be dangerous.

Signs
- a high pH
- a low pCO₂

Treatment
The rate and or pressure must be reduced.
Mixed Acidosis

Cause
Poor gas exchange leading to anaerobic metabolism and an excess production of hydrogen is the usual cause of mixed acidosis.

Signs
- low pH because of general acidosis
- low pO² because of poor gas exchange
- high pCO² because of poor gas exchange
- low HCO³ because bicarbonate is used to buffer carbonic acid
- low B.E. because buffers are being used up.

Treatment
The respiratory acidosis will be corrected if gas exchange is improved. This may also help correct the metabolic acidosis. Sodium bicarbonate may be required if the metabolic acidosis is severe.

Summary
This table will provide a quick reference to distinguish the different types of acidosis:

<table>
<thead>
<tr>
<th>Acidosis</th>
<th>pH</th>
<th>pO²</th>
<th>pCO²</th>
<th>St HCO³</th>
<th>B.E.</th>
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</thead>
<tbody>
<tr>
<td>Metabolic</td>
<td>Low</td>
<td>Normal or</td>
<td>Normal or</td>
<td>Slightly low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>low</td>
<td>low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td>Mixed</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
</tr>
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</table>
Compensation

This is a physiological response to a disturbance in acid/base balance. The primary cause of the disturbance remains despite near normal blood gas values. Normal acid/base balance can only restored by treating the underlying cause of the disturbance.

Compensated Metabolic Alkalosis
Metabolic alkalosis is caused by an accumulation of bicarbonate. The body will attempt to retain CO$_2$ to compensate. This can result in hypoventilation.

**Signs**
- pCO$_2$ and HCO$_3$ will be raised
- pH will be normal.

Compensated Metabolic Acidosis
Accumulation of hydrogen ions is the primary cause of metabolic acidosis. The body will try to lower carbonic acid levels to compensate. This will result in hyperventilation.

**Signs**
- pCO$_2$ and St HCO$_3$ will be low
- pH will be near normal.

Compensated Respiratory Alkalosis
This is usually caused by hyperventilation with a resulting low pCO$_2$. Renal excretion of bicarbonate will be increased to restore the carbonic acid/bicarbonate ratio to normal.

**Signs**
- pCO$_2$ and St HCO$_3$ will be low
- pH will be normal.
**Compensated Respiratory Acidosis**
This is often found in chronic lung disease, with a persistently raised pCO² and decreased renal excretion of bicarbonate.

**Signs**
- pCO² and HCO³ will be raised
- pH will be normal.

This table is designed as a quick reference to distinguish different blood gas results. Work from the top downwards, establishing first whether there is acidosis or alkalosis, then whether it is respiratory or metabolic then moving on to determine whether it is mixed or partially compensated. Only pH, pCO² and B.E. are considered.

<table>
<thead>
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<th>Key</th>
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<tr>
<td>N</td>
<td>Normal value</td>
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<tr>
<td>-</td>
<td>Negative value</td>
</tr>
<tr>
<td>+</td>
<td>Positive value</td>
</tr>
<tr>
<td>M</td>
<td>Metabolic</td>
</tr>
<tr>
<td>R</td>
<td>Respiratory</td>
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<tr>
<td>PC</td>
<td>Partially compensated</td>
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<table>
<thead>
<tr>
<th></th>
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<th>Alkalosis</th>
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<tbody>
<tr>
<td>pH</td>
<td>&lt;7.36</td>
<td>&gt;7.44</td>
</tr>
<tr>
<td>pCO²</td>
<td>Metabolic Respiratory</td>
<td>Metabolic Respiratory</td>
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<tr>
<td>B.E.</td>
<td>-</td>
<td>N</td>
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<tr>
<td>pCO²</td>
<td>Combined Metabolic Respiratory</td>
<td>Combined Metabolic Respiratory</td>
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<tr>
<td>B.E.</td>
<td>-</td>
<td>-</td>
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<tr>
<td>pCO²</td>
<td>M</td>
<td>M</td>
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<td>B.E.</td>
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<tr>
<td>pCO²</td>
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<tr>
<td>B.E.</td>
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Once you are confident that you understand the material in this section work through the exercises in the next section to test your knowledge and understanding of blood gases.

If you need help with any part please ask any member of staff who is already certified to take blood gases.
Section 2

Exercise 1
Define what is meant by “acid”

Define what is meant by “base”

What does pH indicate?

What is the function of a buffer?

How does the body excrete acids?

Exercise 2
Fill in the upper and lower limits of normal arterial blood gases in neonates.

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
<th>pO²</th>
<th>pCO²</th>
<th>HCO³</th>
<th>B.E.</th>
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<tr>
<td>Upper Level</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Level</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Exercise 3
Which value in the table below is outside of the normal range?

<table>
<thead>
<tr>
<th>pH</th>
<th>pO²</th>
<th>pCO²</th>
<th>HCO³</th>
<th>B.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.34</td>
<td>8.4</td>
<td>4.8</td>
<td>16</td>
<td>+3</td>
</tr>
</tbody>
</table>

Exercise 4
Which value in the table below is outside of the normal range?

<table>
<thead>
<tr>
<th>pH</th>
<th>pO²</th>
<th>pCO²</th>
<th>HCO³</th>
<th>B.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.31</td>
<td>7.5</td>
<td>10</td>
<td>21</td>
<td>-2</td>
</tr>
</tbody>
</table>
Exercise 5
Here are 3 pH values:
1. 7.4
2. 7.5
3. 7.2

Which value is normal?

Which value indicates acidosis?

Which value indicates alkalosis?

Exercise 6
Here are 3 B.E. values:
1. +2
2. +10
3. -11

Which value is normal?

Which value indicates metabolic alkalosis?

Which value indicates metabolic acidosis?

Exercise 7
The following table represents a set of blood gas results from a neonate. What type of acid/base disturbance do they indicate?

<table>
<thead>
<tr>
<th>pH</th>
<th>pO²</th>
<th>pCO²</th>
<th>HCO³</th>
<th>B.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.25</td>
<td>7</td>
<td>9</td>
<td>24</td>
<td>0</td>
</tr>
</tbody>
</table>

What may have caused this disturbance?

How should it be corrected?
Exercise 8
Here is another set of blood gas results. What type of disturbance is indicated?

<table>
<thead>
<tr>
<th>pH</th>
<th>pO₂</th>
<th>pCO₂</th>
<th>HCO³</th>
<th>B.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.24</td>
<td>5</td>
<td>5</td>
<td>14</td>
<td>-8</td>
</tr>
</tbody>
</table>

Which values did you use to make your decision?

Exercise 9
This set of blood gas results indicates acidosis. What type?

<table>
<thead>
<tr>
<th>pH</th>
<th>pO₂</th>
<th>pCO₂</th>
<th>HCO³</th>
<th>B.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.22</td>
<td>5</td>
<td>8</td>
<td>16</td>
<td>-6</td>
</tr>
</tbody>
</table>

How might it have been caused?

Exercise 10
Which values in the blood gas results below are outside of the normal range?

<table>
<thead>
<tr>
<th>pH</th>
<th>pO₂</th>
<th>pCO₂</th>
<th>HCO³</th>
<th>B.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.22</td>
<td>5</td>
<td>6</td>
<td>12</td>
<td>-10</td>
</tr>
</tbody>
</table>

What type of acidosis is indicated?

Exercise 11
What kind of acidosis is present in the following results?

<table>
<thead>
<tr>
<th>pH</th>
<th>pO₂</th>
<th>pCO₂</th>
<th>HCO³</th>
<th>B.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.2</td>
<td>4</td>
<td>7</td>
<td>16</td>
<td>-8</td>
</tr>
</tbody>
</table>

Exercise 12
Which values are outside normal ranges in the following results?

<table>
<thead>
<tr>
<th>pH</th>
<th>pO₂</th>
<th>pCO₂</th>
<th>HCO³</th>
<th>B.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.24</td>
<td>8</td>
<td>9</td>
<td>21</td>
<td>-3</td>
</tr>
</tbody>
</table>

What type of acidosis is present?
Exercise 13
What kind of acidosis is present in the following blood gas results from a ventilated baby?

<table>
<thead>
<tr>
<th>pH</th>
<th>pO²</th>
<th>pCO²</th>
<th>HCO³</th>
<th>B.E.</th>
<th>FiO²</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.25</td>
<td>8</td>
<td>10</td>
<td>20</td>
<td>-3</td>
<td>40%</td>
</tr>
</tbody>
</table>

What would you do to correct it?

Exercise 14
What kind of acidosis is present in the following blood gas results?

<table>
<thead>
<tr>
<th>pH</th>
<th>pO²</th>
<th>pCO²</th>
<th>HCO³</th>
<th>B.E.</th>
<th>FiO²</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.28</td>
<td>4</td>
<td>9</td>
<td>18</td>
<td>-4</td>
<td>70%</td>
</tr>
</tbody>
</table>

What could you do to correct it?

Exercise 15
What kind of acidosis is present in the following blood gas results?

<table>
<thead>
<tr>
<th>pH</th>
<th>pO²</th>
<th>pCO²</th>
<th>HCO³</th>
<th>B.E.</th>
<th>FiO²</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.21</td>
<td>5</td>
<td>9.5</td>
<td>17</td>
<td>-6</td>
<td>60%</td>
</tr>
</tbody>
</table>

Is it severe or slight?

How would you correct it?

Exercise 16
What kind of acidosis is present in the following blood gas results?

<table>
<thead>
<tr>
<th>pH</th>
<th>pO²</th>
<th>pCO²</th>
<th>HCO³</th>
<th>B.E.</th>
<th>FiO²</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.2</td>
<td>6</td>
<td>10</td>
<td>22</td>
<td>-2</td>
<td>35%</td>
</tr>
</tbody>
</table>

Is it severe or slight?

How would you correct it?
Exercise 17
What kind of acidosis is present in the following blood gas results of a baby receiving parental nutrition?

<table>
<thead>
<tr>
<th>pH</th>
<th>pO²</th>
<th>pCO²</th>
<th>St HCO³</th>
<th>B.E.</th>
<th>FiO²</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.19</td>
<td>8</td>
<td>5</td>
<td>13</td>
<td>-11.5</td>
<td>air</td>
</tr>
</tbody>
</table>

Is it severe or slight?

What could you do to correct it?
APPENDIX 4. Answers to Blood gas analysis workbook

Exercise 1.

1.1 An acid is a substance which gives up hydrogen ions in solution.

1.2 A base is an alkaline substance which accepts hydrogen ions.

1.3 pH indicates acidity or alkalinity of a solution (hydrogen ion concentration).

1.4 A buffer is a substance which minimises the effect of an acid or base in a solution upon the pH, e.g. bicarbonate, Hb, Phosphate.

1.5 Lungs: main route for carbonic acid

Kidneys: main route for H+ ions

Haemoglobin: neutralises acid e.g. carbonic acid as it contains a protein buffer. Converted to bicarbonate and released to plasma as sodium bicarbonate.

Exercise 2.

<table>
<thead>
<tr>
<th>pH</th>
<th>pO²</th>
<th>pCO²</th>
<th>St HCO³</th>
<th>B.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Level</td>
<td>7.44</td>
<td>12kpa</td>
<td>6kpa</td>
<td>25mmol/l</td>
</tr>
<tr>
<td>Lower Level</td>
<td>7.35</td>
<td>7kpa</td>
<td>4kpa</td>
<td>18mmol/l</td>
</tr>
</tbody>
</table>

Exercise 3.

<table>
<thead>
<tr>
<th>pH</th>
<th>pO²</th>
<th>pCO²</th>
<th>St HCO³</th>
<th>B.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.34</td>
<td>8.4</td>
<td>4.8</td>
<td>16</td>
<td>+3</td>
</tr>
</tbody>
</table>

Low

Exercise 4.

<table>
<thead>
<tr>
<th>pH</th>
<th>pO²</th>
<th>pCO²</th>
<th>St HCO³</th>
<th>B.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.31</td>
<td>7.5</td>
<td>10</td>
<td>21</td>
<td>-2</td>
</tr>
</tbody>
</table>

Low High

Exercise 5.

Which value is normal? 7.4

Which value indicates acidosis? 7.2

Which value indicates alkalosis? 7.5

Exercise 6.

Which value is normal? +2
Which value indicates metabolic alkalosis? +10

Which value indicates metabolic acidosis? -11

Exercise 7.

<table>
<thead>
<tr>
<th>pH</th>
<th>pO²</th>
<th>pCO²</th>
<th>St HCO³</th>
<th>B.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.25</td>
<td>7</td>
<td>9</td>
<td>24</td>
<td>0</td>
</tr>
</tbody>
</table>

Acidosis = Raised

= Respiratory Acidosis

1.2. Inadequate ventilation- retaining CO2, O2, lower end of normal
   ? Respiratory Distress Syndrome
   Blocked Et tube, secretions, pneumothorax, equipment fault, check the
tube is in the correct position and patency.

1.3 If ventilated – suction ETT and oropharynx
   Increase rate to lower CO2
   Adjust rate or pressures, recheck gas within 1 hour.

Exercise 8

<table>
<thead>
<tr>
<th>pH</th>
<th>pO²</th>
<th>pCO²</th>
<th>St HCO³</th>
<th>B.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.24</td>
<td>6</td>
<td>5</td>
<td>14</td>
<td>-8</td>
</tr>
</tbody>
</table>

Acidosis = Low

= Metabolic Acidosis and Hypoxaemia

1.2 pH < 7.24
   st HCO₃ < 18
   Base excess greater than -4
   Low oxygen < 7kpa

Exercise 9

1.1 Mixed acidosis

1.2 Inadequate ventilation leading to exhaustion of compensation by buffers. Respiratory
   acidosis $\rightarrow$ mixed respiratory and metabolic acidosis.

Exercise 10.

<table>
<thead>
<tr>
<th>pH</th>
<th>pO²</th>
<th>pCO²</th>
<th>St HCO³</th>
<th>B.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.22</td>
<td>5</td>
<td>6</td>
<td>12</td>
<td>-10</td>
</tr>
</tbody>
</table>

Low = Low = Normal = Low = Low
1.3 Metabolic acidosis is indicated.

Exercise 11.

<table>
<thead>
<tr>
<th>pH</th>
<th>pO²</th>
<th>pCO²</th>
<th>St HCO³</th>
<th>B.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.2</td>
<td>4</td>
<td>7</td>
<td>16</td>
<td>-8</td>
</tr>
</tbody>
</table>

Low    Low     Raised   Low    Low

= Mixed Acidosis.

Exercise 12.

<table>
<thead>
<tr>
<th>pH</th>
<th>pO²</th>
<th>pCO²</th>
<th>St HCO³</th>
<th>B.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.24</td>
<td>8</td>
<td>9</td>
<td>21</td>
<td>-3</td>
</tr>
</tbody>
</table>

Low     High

1.2 Respiratory acidosis.

Exercise 13

<table>
<thead>
<tr>
<th>pH</th>
<th>pO²</th>
<th>pCO²</th>
<th>St HCO³</th>
<th>B.E.</th>
<th>FiO²</th>
<th>I:E ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.25</td>
<td>8</td>
<td>10</td>
<td>20</td>
<td>-3</td>
<td>40%</td>
<td>1:1</td>
</tr>
</tbody>
</table>

Low     High

= Respiratory Acidosis

1.2 Suction, ETT, increase rate, increase PIP, decrease PEEP for correction.

Exercise 14

<table>
<thead>
<tr>
<th>pH</th>
<th>pO²</th>
<th>pCO²</th>
<th>St HCO³</th>
<th>B.E.</th>
<th>FiO²</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.28</td>
<td>4</td>
<td>9</td>
<td>18</td>
<td>-4</td>
<td>70%</td>
</tr>
</tbody>
</table>

Low    Low     High

= Respiratory Acidosis

1.2 Increase rate, increase PIP, increase FiO2, check air entry and suction ETT for correction.

Exercise 15

<table>
<thead>
<tr>
<th>pH</th>
<th>pO²</th>
<th>pCO²</th>
<th>St HCO³</th>
<th>B.E.</th>
<th>FiO²</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.21</td>
<td>5</td>
<td>9.5</td>
<td>17</td>
<td>-6</td>
<td>60%</td>
</tr>
</tbody>
</table>

Low    Low     High    Low    Low

= Mixed Acidosis
1.2 Severe

1.3 Increase FiO2, increase rate, consider sodium bicarbonate if B.E. increasing for correction.

Exercise 16

<table>
<thead>
<tr>
<th>pH</th>
<th>pO²</th>
<th>pCO²</th>
<th>St HCO³</th>
<th>B.E.</th>
<th>FiO²</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.2</td>
<td>6</td>
<td>10</td>
<td>22</td>
<td>-2</td>
<td>35%</td>
</tr>
</tbody>
</table>

Low    Low    High

= Respiratory Acidosis

1.2 Severe

1.3 If ventilated, increase FiO2, increase rate, increase PIP, blow of CO2 and increase O2 for correction
If unventilated, N CPAP for correction.

Exercise 17

<table>
<thead>
<tr>
<th>pH</th>
<th>pO²</th>
<th>pCO²</th>
<th>St HCO³</th>
<th>B.E.</th>
<th>FiO²</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.19</td>
<td>8</td>
<td>5</td>
<td>13</td>
<td>-11.5</td>
<td>air</td>
</tr>
</tbody>
</table>

Low    Low    Low

= Metabolic Acidosis

1.2 Severe

1.3 Give volume e.g. N/Saline 10mls/kg, stop amino acids, consider ammonia and lactate measurement, check U’s and E’s, give bicarbonate/THAM, ventilate- extremely acidotic risk of collapse.