# Blood Gas Interpretation in NICU

**Sites where Local Guideline applies**: Neonatal Intensive Care Unit, JHCH

- **This Local Guideline applies to:**
  - **1. Adults**: No
  - **2. Children up to 16 years**: No
  - **3. Neonates – less than 29 days**: Yes Approval gained from the Children Young People and Families Network on 26/06/2017

**Target audience**: NICU Clinical staff

**Description**: Information for clinicians to guide practice in collecting blood samples for blood gas analysis

## Keywords
- Acidosis, alkalosis, blood gas analysis, compensation, metabolic, pH, respiratory

## Document registration number
- JHCH_NICU_12.10

## Replaces existing document?
- No

**Related Legislation, Australian Standard, NSW Ministry of Health Policy Directive or Guideline, National Safety and Quality Health Service Standard (NSQHSS) and/or other, HNE Health Document, Professional Guideline, Code of Practice or Ethics**:

- Clinical Procedure Safety NSW Ministry of Health Policy PD2014_036

## Prerequisites (if required)
- Nil

**Local Guideline note**: This document reflects what is currently regarded as safe and appropriate practice. The guideline section does not replace the need for the application of clinical judgment in respect to each individual patient but the procedure/s **require mandatory compliance**. If staff believe that the procedure/s should not apply in a particular clinical situation they must seek advice from their unit manager/delegate and document the variance in the patients’ health record.

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**This document contains advice on therapeutics**: No

**Issue date**: 26/06/2017

**Review date**: 26/06/2020

RISK STATEMENT

This local guideline has been developed to provide guidance to clinical staff in NICU to analyse and interpret blood gas results in the neonate to assist in management of clinical condition. It ensures that the risks of harm to the infant are identified and managed.

Any unplanned event resulting in, or with the potential for injury, damage or other loss to infants/staff/family as a result of this management must be reported through the Incident Information management System and managed in accordance with the Ministry of Health Policy Directive: Incident management PD2007_061. This would include unintended injury that results in disability, death or prolonged hospital stay.

Risk Category: Clinical Care & Patient Safety

GLOSSARY

<table>
<thead>
<tr>
<th>Acronym or Term</th>
<th>Definition</th>
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<tr>
<td>CO₂</td>
<td>Carbon Dioxide</td>
</tr>
<tr>
<td>pH</td>
<td>Measure of acidity or alkalinity and refers to hydrogen ion concentration</td>
</tr>
<tr>
<td>Hb</td>
<td>Haemoglobin</td>
</tr>
<tr>
<td>H+</td>
<td>Hydrogen ions</td>
</tr>
<tr>
<td>HCO₃</td>
<td>Bicarbonate</td>
</tr>
<tr>
<td>OH⁻</td>
<td>Hydroxyl ions</td>
</tr>
</tbody>
</table>

GUIDELINE

This Guideline does not replace the need for the application of clinical judgment in respect to each individual patient.

Note: Over time links in this document may cease working. Where this occurs please source the document in the PPG Directory at: http://ppg.hne.health.nsw.gov.au/

OUTCOMES

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<thead>
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<th></th>
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<td>1</td>
<td>Blood gas collection will be according to guidelines related to umbilical and peripheral arterial sampling</td>
</tr>
<tr>
<td>2</td>
<td>Interpretation of blood gas data should follow a logical pattern</td>
</tr>
<tr>
<td>3</td>
<td>The classification and interpretation of blood gases will be based on a set of normal values.</td>
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<td>4</td>
<td>Blood gases will be collected and evaluated with an understanding of appropriate technique and potential sources of error.</td>
</tr>
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<td>5</td>
<td>Respiratory support interventions and corrections will be based on an analysis that includes blood gas information</td>
</tr>
<tr>
<td>6</td>
<td>Blood gas collection will be performed using universal precautions</td>
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**Rationale**

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**Guideline**

This Guideline does not replace the need for the application of clinical judgment in respect to each individual patient.

**Rationale**

An adjunct to clinical assessment of wellbeing is chemical assessment via blood gas analysis. The purpose of obtaining blood gases in a neonate is to determine if the baby is ventilating adequately, the acid-base status that reflects kidney function, fluid and electrolyte therapy and potentially adequacy of tissue perfusion and oxygenation. While blood oxygen level is measured continuous saturation monitoring is the preferred method for assessing adequate oxygenation clinically in most neonates. The latest blood gas machines also measure a number of other parameters that should not be ignored in interpreting a ‘blood gas’ printout.

**Definitions**

**pH**  
Is a measure of the acidity or alkalinity of a solution. The H in ph refers to the concentration of hydrogen ions (H+) dissolved in a solution. Many organic acids are produced during normal metabolism. Sometimes they can accumulate in the blood (e.g. lactic acid). The hydrogen ion (H+) may be “mopped up” by buffers including bicarbonate (HCO$_3$), plasma proteins and haemoglobin. As the H+ concentration increases, the pH decreases (acidosis); as the H+ decreases, the pH increases (alkalosis).
Acid – a chemical compound that when dissolved in water can donate H+ to another compound. Excess acid causes decreased pH (<7.25)

Base (Alkali) – a chemical compound which forms hydroxyl ions (OH⁻) when dissolved in solution and is capable of accepting H+. The more basic a solution; a decrease of H+ causes increased pH (>7.45)

Lungs – controls pH by varying the amount of CO₂ that is exchanged. Changing pH by changing pCO₂ can be very rapid.

Kidneys – control pH by generating HCO₃ or excretion of HCO₃⁻. Changing pH by altering HCO₃ is a slow process.

Acidotic. If the pH is low the blood is said to be acidotic.

Alkalotic. If the pH is high the blood is said to be alkalotic.

Acidosis – a physiologic process where an accumulation of acid or depletion of the alkali reserve in the blood and body tissues is characterized by an increase in hydrogen ion concentration (Decrease in pH).

Respiratory Acidosis – a process when the lungs do not promptly vent carbon dioxide (poor alveolar ventilation) and carbon dioxide levels increase. Carbon dioxide combines with bicarbonate to form carbonic acid. Carbonic acid then dissociates into H+ and HCO₃⁻ ions

Metabolic Acidosis – a process that occurs when a disorder adds acid (apart from carbonic acid) to the body or causes alkali to be lost faster than it can be regenerated.

Alkalosis – a physiologic process where a loss of acid or increase of the alkali reserve in the blood and body tissues is characterized by an decrease in hydrogen ion concentration (Increase in pH).

Respiratory Alkalosis – occurs when the lungs excrete excessive amounts of carbon dioxide to lower than normal levels.
**Metabolic Alkalosis** – occurs whenever acid is excessively lost or alkali is excessively retained

**Compensation** – the secondary physiologic process occurring in response to a primary disturbance in the acid-base balance, lessening the deviation of pH from normal. The secondary compensation process will never over compensate to reverse the primary acidosis or alkalosis process.

**Correction** – is a change in the system originally affected by the primary disturbance by some intervention using available therapy.

**Normal**

The classification and interpretation of blood gases are based on a set of normal values. Acceptable values not requiring intervention will vary from patient to patient, over time in an individual and from unit to unit. Using one set of normal values simplifies analysis. Analysis should then be followed by clinical decision making as to whether any action is required i.e. acceptability of the numbers.

The print out of results from the blood gas machine provides a range of values including blood gas values, oximetry values, electrolyte values, metabolic values, temperature corrected values, oxygen status and acid base status. See table below for normal values most commonly assessed from a blood gas printout.

**Normal Arterial Blood Gas Values**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Normal Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.35 - 7.45</td>
</tr>
<tr>
<td>PaCO₂</td>
<td>35 - 45 mm Hg</td>
</tr>
<tr>
<td>PaO₂</td>
<td>50 - 70 mm Hg (term infant)</td>
</tr>
<tr>
<td></td>
<td>45 - 65 mm Hg (preterm infant)</td>
</tr>
<tr>
<td>Base Excess</td>
<td>-2 - +2 mEq/litre</td>
</tr>
<tr>
<td>HCO₃</td>
<td>22 - 26 mEq/litre</td>
</tr>
<tr>
<td>O₂ saturation (sO₂)</td>
<td>86-94%</td>
</tr>
</tbody>
</table>

**Other useful values**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Normal Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hb</td>
<td>120-160g/L</td>
</tr>
<tr>
<td>Hct</td>
<td>0.39-0.63</td>
</tr>
<tr>
<td>K⁺</td>
<td>3.2-5.6mmol/L</td>
</tr>
<tr>
<td>Na⁺</td>
<td>135-145 mmol/L</td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>2.1-2.6 mmol/L</td>
</tr>
<tr>
<td>Glu</td>
<td>Maintain ≥2.6mmol/L</td>
</tr>
<tr>
<td>Lac</td>
<td>0.5-1.6 mmol/L</td>
</tr>
<tr>
<td></td>
<td>Mild 2-4mmol/L</td>
</tr>
<tr>
<td></td>
<td>Severe &gt;5mmol/L</td>
</tr>
</tbody>
</table>
Haemoglobin/Haematocrit

If infant appears anaemic on evaluation of blood gas—↓ HB and ↓ Haematocrit then 3 general causes need to be considered

- Blood loss - may be prior to delivery-cord/placental abruption, trauma during delivery e.g. sub galeal haemorrhage or post-delivery e.g. Intraventricular haemorrhage (IVH)
- ↑ RBC destruction-e.g. G6PD, Rh incompatibility or infection
- ↓RBC production-e.g. anaemia of prematurity

Electrolytes/Glucose

Fluid, electrolyte, and nutrition management is important for infants in a neonatal intensive care unit (NICU). Infants often require intravenous fluids and may have shifts of fluids between intracellular, extracellular, and vascular compartments. Therefore, careful attention to fluid and electrolyte balance for potassium, sodium, calcium and glucose is essential.

Lactate

Blood lactate concentrations can be a useful measurement in newborns and neonates to assess tissue perfusion. When an infant is asphyxiated prior to or during delivery there is a critical reduction in oxygen and substrate delivery. This affects the sustainability of aerobic metabolism, a more efficient form of energy production via the Kreb’s cycle.

This then leads to the tissues requiring anaerobic metabolism to meet their energy needs and results in an increased production and accumulation of blood lactate, (Deshpande & Ward Platt, 1997).

Assessment of Oxygenation

Blood gas measurement and non-invasive estimations provide important information about oxygenation. Oxygen delivery to the tissues is the product of cardiac output and blood oxygen content. When insufficient oxygen is provided to the tissues, hypoxia leads to metabolic acidosis.

Optimal oxygenation will result in different Pao2/Sao2 goals for different types of Neonatal patients. Most commonly, premature infants in respiratory failure should have PaO2 values of between 45-65 mm Hg. These goals minimize the chances of retinopathy and bronchopulmonary dysplasia (BPD). The term Neonate with PPHN may require PaO2 values of 80-100 mm Hg to maintain stability minimize pulmonary resistance and avoid worsening pulmonary hypertension.

P (A-a) o2 is the Alveolar- arterial difference in partial pressure of oxygen. It results from the concentration gradient required to facilitate diffusion across the alveolar-capillary membrane. PAO2 (alveolar) is always calculated based on FiO2, PaCO2, and barometric pressure. PaO2 (arterial) is always measured on an arterial blood sample in a blood gas machine. Except in an unsteady state, alveolar PO2 is always higher than arterial PO2.
Virtually all lung disease lowers PaO$_2$ via an abnormal degree of ventilation/perfusion (V-Q) imbalance or decreased permeability of the alveolar-capillary membrane.

SaO$_2$ (known as oxygen saturation) is the percentage of oxygen binding sites on Hb that are occupied by oxygen. There are four binding sites on the Hb molecule that can each take one molecule of oxygen.

Oxygen diffuses into the blood where it is predominantly bound to hemoglobin in red blood cells, with a small proportion being dissolved in plasma. The relationship between PaO2 and hemoglobin is described by the curvilinear oxyhemoglobin dissociation curve. At a PaO2 above 90 mmHg, the curve is nearly flat, and hemoglobin is almost completely saturated. At lower values of PaO2, the curve falls steeply, promoting release of oxygen to the tissues (UpToDate,2016)

Oxygen affinity, which refers to the ability of hemoglobin to bind or release oxygen, is modulated by pH, CO2 (in part independent of pH), 2,3-diphosphoglycerate (DPG), temperature, and fetal hemoglobin (figure 1). Lower pH, higher CO2, increased temperature, and a decreased proportion of fetal hemoglobin reduce oxygen affinity. These shifts in affinity promote oxygen uptake in the pulmonary capillaries and release into the tissues.

When there is a right shift in the curve there is a resulting weak affinity of O$_2$ for Hb. In this situation the maximum possible amount of O$_2$ does not attach to Hb at lung level, but what is carried unloads easily at tissue level. Overall however, O$_2$ delivery is reduced.

When there is a left shift in the curve a strong affinity between O$_2$ and Hb results. O$_2$ attaches strongly to Hb at lung levels but is reluctant to unload at tissue level (UpToDate,2016)
<table>
<thead>
<tr>
<th>Causes of Right shift in the curve</th>
<th>Causes of Left shift in the curve</th>
</tr>
</thead>
<tbody>
<tr>
<td>acidosis,</td>
<td>alkalosis</td>
</tr>
<tr>
<td>high temperature</td>
<td>hypothermia</td>
</tr>
<tr>
<td>elevated CO₂</td>
<td>low CO₂</td>
</tr>
</tbody>
</table>

Any alterations in acid/base balance can have a significant effect on tissue oxygenation.

**Blood gas sampling**

Analysis of blood gases provides the clinician the basis for determining the adequacy of alveolar ventilation, acid-base status and oxygenation.

Regardless of the type of sample obtained attention should be given to the following factors:

*Infection control or universal precautions:* All types of blood gas sampling carry the risk of transmission of infection to the infant through the introduction of organisms into the blood stream. In addition, the risk of exposing the clinician to the infant’s blood makes it necessary to take appropriate precautions

*Bleeding disorders:* The potential for bruising and excessive bleeding should be evaluated. Particularly if an arterial puncture is being considered.

It is crucial that this test be collected and evaluated with an understanding of appropriate technique and potential sources of error.

**Before Sampling**

Steady state: Ideally, blood gases should measure the infant’s condition in a state of equilibrium. Usually oxygenation stabilizes in 2 to 3 minutes after a change but ventilation (as measured by carbon dioxide levels) will take 20 min or more.

**Look at the baby**

- Is the chest moving?
- What's the air-entry like?
- Is the respiratory support optimally placed?
- Is the baby struggling on the ventilator?
- Is the baby very tachypnoeic or is the baby apnoeic?

**Look at the nursing flow chart.**

- How stable has the baby been over the past few hours or days?
- Are there lots of secretions?
- How is the baby handling?
Errors in Blood Gas Measurement

During collection and analysis of blood gases, the clinician should be aware of the following potential sources of error:

- **Temperature** – blood gas machines report results for 37°C. Hypo or hyperthermia can alter true arterial gas values.

- **Haemoglobin** – calculated oxygen saturations are based on adult haemoglobin, not on fetal or mixed hemoglobin’s.

- **Dilution** – heparin in a gas sample will lower the PCO\textsubscript{2} and increase the base deficit without altering the pH.

- **Air bubbles** – room air has a PCO\textsubscript{2} close to 0 and a partial pressure of oxygen of 150. Therefore, air bubbles in the sample will decrease the PCO\textsubscript{2} and increase the PO\textsubscript{2} unless the PO\textsubscript{2} is greater than 150. Decreasing pCO\textsubscript{2} will artificially raise pH.

Site for Sampling

**Arterial Sampling** - can be obtained either from an indwelling line or through intermittent sampling of a peripheral artery. The choice of sample site will depend on the clinical situation. An indwelling arterial catheter should be placed when it is anticipated that the neonate will require frequent arterial blood sampling. Several criteria are used to determine the need for an indwelling line. The criteria include gestational age, disease process, and the amount of oxygen required. Common sites for indwelling arterial lines are the umbilical, radial, and posterior tibial.

**Capillary Sampling**- blood can be “arterialized” by warming the skin to increase local blood flow. Feet should only be warmed with booties, warm hands, or after a warm bath. Do not use cloths moistened with hot water or apply direct heat to infant (Janes et al., 2002). Samples can be obtained from the outer aspects of the heel or from the side of a finger or toe. When perfusion is normal, it has been shown that capillary pH and PCO\textsubscript{2} correlate well with arterial values. PO\textsubscript{2} correlates if the partial pressure of oxygen in arterial blood is < 60, but not at higher levels.

Blood Gas Interpretation

Interpretation of blood gas data should follow a logical pattern. The following steps can be used as a systematic way of evaluating parameters in neonatal blood gases:

1. Assess pH. Is the pH normal, acidic or alkalotic?
2. Assess respiratory component- pCO\textsubscript{2}.
   Is the pCO\textsubscript{2} normal or is there a respiratory acidosis (pCO\textsubscript{2} above normal value) or a respiratory alkalosis, (pCO\textsubscript{2} below normal).
3. Assess metabolic component- HCO₃.
   Is the HCO₃ normal, or is there a metabolic acidosis (HCO₃ below normal values) or a metabolic alkalosis (HCO₃ above normal values).

4. Assess compensation status-
   Use the pH to determine the primary process, i.e. acidosis or alkalosis. This is determined by the pH being acidotic or alkalotic i.e. above or below 7.4. A compensatory process will never over compensate. If the pH is in the normal range (7.35-7.45) then there is full compensation by the opposing process. If the opposing process has normal values then there is no compensation happening. If the opposing process values are abnormal but the pH hasn’t returned to normal range there is said to be partial compensation.

5. Assess base deficit. This provides a better indication of metabolic status than HCO₃ alone.

6. Assess oxygenation on blood gas and other parameters (electrolytes, hemoglobin, and blood glucose level) for variations from normal.

7. Combine information with clinical assessment of infant

8. Formulate a plan.
   This integrates findings from the blood gas, changes over time, current therapy and clinical status to develop a plan of management from that point in time.

9. Review with Dr/NP and formulate plan of management

**Evaluation of blood gas**

- Evaluate whether the result matches the clinical condition of the baby and the expected course for the baby, (e.g. improving compliance after surfactant for RDS).
- If it is vastly different than you expect, troubleshoot for a cause of the abnormality:
  - Was there an air bubble in the specimen?
  - If a capillary gas, is the perfusion awful? Did the baby bleed easily?

*A systematic approach to all blood gas analysis will help you interpret the result, understand what is happening at cellular level and anticipate appropriate medical/nursing management for the babies in your care.*

**Remember: a blood gas does not stand alone - adds information to the clinical picture**

**Repeat blood gases**

The decision to repeat a blood gas will be determined by the result, the condition of the infant and involve collaboration between medical and nursing staff.
How abnormal the gas is

- If it is really outside the normal range you are targeting, you probably want to check it quite soon to see whether your changes have had the effect you thought they would (that is, in 20-30 minutes).

How stable the baby is

- The neonatologist on duty should be able to give you some guidance on how often gases need to be done.
- If the baby is stable and you’re not doing too much with the ventilation, you don’t need to check it too soon after the change. Some babies who are chronically ventilated may only need a gas once a day.
- You can look at other things like the new tidal volume to see whether you think your changes have had any sort of effect.
- But if the baby is really unstable, you may wish to do gases often to see where they are heading.
- If you have given surfactant, you might want to check a gas within an hour to see what effect any change in compliance is having on gas exchange.

And if you are not sure what to do, ask someone!

It is important to approach blood gas interpretation systematically and to integrate physiology with the clinical history to provide optimal patient care and outcome. Monitoring a critically ill infant with a pulse oximeter will provide continuous information on his status by determining the pulse oxygen saturation. Intermittent assessment of the arterial blood gases will yield specific information on the acid-base balance.

Refer to the ‘Neonatal Blood Gas Interpretation’ Self Directed Learning package (June 2011) for further information and problem based scenarios.

References:


Travadi, J. (2008). Basic principles of ventilation


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