Agenda

- Introduction
- Why the preanalytical phase is important
- High Five for safe arterial blood gas sampling
- Additional educational resources
The preanalytical phase of arterial blood gas sampling

Preanalytical errors are said to be the reason for up to 62% of all errors in laboratory medicine [1].

“Several aspects of blood pH and gas analysis are unique among clinical and laboratory determinations, and, at the same time, no other test results have more immediate impact on patient care” [2]

Error rate

Preanalytical phase 62%

Analytical phase 15%

Post-analytical phase 23%

Safe arterial blood gas sampling:

Path of workflow [1,2]:

1. Patient preparation –  
   **FOCUS ON: patient safety**

2. Blood collection device  
   **FOCUS ON: sample integrity and operator safety**

3. Sample collection  
   **FOCUS ON: safety for patient and operator**

4. Sample handling  
   **FOCUS ON: sample integrity**

5. Sample transport  
   **FOCUS ON: time to patient results**


1. Patient preparation
Maximize patient safety

1. Patient preparation

Specimen labeling errors have significant consequences for patient care, for healthcare management and for increasing costs that are often unaccounted for [1]

Errors can be caused by:

- Lack of patient identification and/or sample labeling
- Transcription errors due to manual data entry
- Lack of a dedicated procedure for identifying patient and samples

Errors can lead to:

- Non-compliance
- Misdiagnosis
- Incorrect treatment
- Resampling
- Lost billing opportunities

Maximize patient safety

Accurate **patient identification** is fundamental for patient safety

- Use at least two patient identifiers [1]
- Always enter a patient ID into the analyzer before analysis

Proper sample labeling ensures the right result for the right patient

- Attach patient ID label to the syringe before leaving the patient
- Add additional patient characteristics and other relevant information

Tips!

Use **pre-barcoded** syringe

Use a barcode reader to **register at bedside**

Establish a **dedicated procedure** for identifying patient and sample

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2. Blood collection device
Greater sample integrity and operator safety

**Heparin amount and type is important:**

Too much heparin can bias electrolyte results - too little heparin may not be sufficient to prevent clotting

Non-compensated heparin may interfere with electrolyte results

**Facts:**

At some point in their career 48% of nurses had sustained an injury by a needle or sharp and 10% had been stuck in the last year [1]

The risk of infection by a contaminated needle is 1 in 3 for Hepatitis B, 1 in 30 for Hepatitis C, 1 in 300 for HIV [2]

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Greater sample integrity and operator safety

Heparin-induced bias can be caused by:

- Use of heparin that is not formulated to reduce bias on electrolytes
- The use of liquid heparin

This can lead to:

- Erroneous electrolytes and metabolites results
- Clots in the sample that may interfere with the analyzer and produce inaccurate value [1]
- Incorrect patient treatment [2]

Sharps injury can be caused by:

- Unavailability of sampling safety devices for operators
- Lack of a dedicated procedure for operator safety
- Dedicated procedures for operator safety are not followed

This can lead to:

- Operator concern over own safety
- Needlestick injury
- Infection by blood-borne pathogens

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Heparin

3 important points about heparin

1. Sufficient concentration of heparin is needed
2. Electrolyte-balanced heparin minimizes bias on positive ions like Ca$^{2+}$, Na$^+$ and K$^+$
3. Heparin needs to be provided in a dry format to avoid dilution errors

In depth on heparin

1. Heparin concentration

What is a sufficient concentration of heparin?

- The higher heparin concentration, the better anticoagulation
- Exact concentration for anticoagulation?
  - “10 IU/mL may not eliminate clotting and 150 IU/mL may also not be enough” [1]
  - “When below 200 IU/mL there is no effect on the blood gases but on electrolytes” [2]
- In 1960 the conventional heparin concentration adopted was 40 IU/mL [3]

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2. Heparin interference

- Heparin binds positively charged ions
- Avoided by using electrolyte-balanced heparin

Bias on ionized calcium with the use of non-balanced heparin

<table>
<thead>
<tr>
<th>IU/mL Heparin</th>
<th>Bias on ( cCa^{2+} )[1,2]</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>-0.03</td>
</tr>
<tr>
<td>50</td>
<td>-0.15</td>
</tr>
<tr>
<td>100</td>
<td>-0.19</td>
</tr>
</tbody>
</table>

2. Heparin interference

According to international guidelines:

- **CLSI C46-A2**
  - **5.2.1** “..special preparations of heparin are available, which virtually eliminate the interference from heparin binding of these electrolytes.”
  - **5.2.5** “Although a low concentration of ordinary heparin will reduce the error, it will not eliminate it, and the special heparin preparations discussed above (balanced or dispersed) are preferable”
  - **5.2.5** "Therapeutic heparin used for systemic anticoagulation should not be used....because of its very high concentration"

### 3 important points about heparin

- **Sufficient concentration of heparin is needed**
- **Electrolyte-balanced heparin minimizes bias on positive ions like Ca\(^{2+}\), Na\(^{+}\) and K\(^{+}\)**
- **Heparin needs to be provided in a dry format to avoid dilution errors**
The choice of device does make a difference

**3 important points about heparin**

- Sufficient concentration of heparin is needed
- Electrolyte-balanced heparin minimizes bias on positive ions like Ca$^{2+}$, Na$^+$ and K$^+$
- Heparin needs to be provided in a dry format to avoid dilution errors

“Taken together, two out of the three syringes tested here introduced a clinically significant negative bias” [1]

3. Heparin formulation

“Excess liquid heparin statistically exaggerated or produced false results consistent with metabolic acidosis with respiratory compensation” [3]

“The danger from nonstandardized blood collection into syringe washed with liquid heparin should be carefully assessed. For preventing serious medical errors due to nonstandardized blood gas sampling, electrolyte balanced dry heparin may be recommended.” [1]

3 important points about heparin

Sufficient concentration of heparin is needed

Electrolyte-balanced heparin minimizes bias on positive ions like Ca$^{2+}$, Na$^{+}$ and K$^{+}$

Heparin needs to be provided in a dry format to avoid dilution errors

3. Heparin formulation

3 important points about heparin

- Sufficient concentration of heparin is needed
- Electrolyte-balanced heparin minimizes bias on positive ions like Ca$^{2+}$, Na$^{+}$ and K$^{+}$
- Heparin needs to be provided in a dry format to avoid dilution errors

According to international guidelines:

- **IFCC [1]:**
  - “...a 5% dilution may be acceptable for the blood gases, but not for the electrolytes”

- **CLSI [2]:**
  - 5.2.1 “The ideal collection device for arterial blood sampling is....containing a small amount of anticoagulant such as lyophilized heparin”

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Greater sample integrity and operator safety

**Dry electrolyte-balanced heparin** is the foundation for a result you can trust

- Heparin is the only anti-coagulant recommended for blood gas analysis
- Use an anti-coagulant to reduce clotting of the sample
- Use an anti-coagulant which eliminates the interference from binding electrolytes
- Use dry anti-coagulant to prevent dilution effect

An ABG collection device with **sharps injury protection** prevents needlestick injuries

- Use one-hand operated sharps injury protection

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Tips!
Use a syringe with integrated needle shield device and tip cap

3. Sample collection
Sample contamination

When doing arterial punctures, there is a risk of accidentally puncturing a vein. Even a few drops of venous blood mixed with the arterial sample can cause bias on the patient results.

Example

Two samples are collected by arterial puncture. One is accidentally contaminated with a few drops of venous blood before the needle is correctly positioned in the artery. See below how this can affect patient results.

<table>
<thead>
<tr>
<th>Pure arterial sample</th>
<th>Contaminated arterial sample</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient results</strong></td>
<td><strong>Patient results</strong></td>
</tr>
<tr>
<td>$pO_2$</td>
<td>$pO_2$</td>
</tr>
<tr>
<td>100 mmHg (13.3 kPa)</td>
<td>90 mmHg (12.0 kPa)</td>
</tr>
<tr>
<td>$pCO_2$</td>
<td>$pCO_2$</td>
</tr>
<tr>
<td>41 mmHg (5.5 kPa)</td>
<td>41.5 mmHg (5.5 kPa)</td>
</tr>
<tr>
<td>$sO_2$</td>
<td>$sO_2$</td>
</tr>
<tr>
<td>98%</td>
<td>97.4%</td>
</tr>
</tbody>
</table>
Maximum safety for patient

Sample contamination can be caused by:

- Mixing venous blood with arterial blood
- Diluting the sample with flush solution if an insufficient amount of flush solution has been removed

This can lead to:

- Contaminating the sample with either venous blood or flush solution will alter the values of the sample so that it no longer represents the patient status
Maximum safety for patient and operator

A-puncture procedure

- Use of short-bevel needles eases the placement of needle in artery and minimizes the risk of puncturing opposite arterial wall.

- Self-filling syringes fill readily indicating an artery has been punctured and rapid appearance of the blood flash indicates an artery has been punctured.

- An ABG collection device with sharps injury protection prevents needle stick injuries.

- Use one-hand operated sharps injury protection.
4. Sample handling
Two samples are collected from the same patient and measured after 5 minutes. One sample is mixed and air bubbles expelled, the other is not. This may alter patient results as shown below.

<table>
<thead>
<tr>
<th>Sample without air bubbles</th>
<th>Sample containing air bubbles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient results</td>
<td>Patient results</td>
</tr>
<tr>
<td>$pO_2$</td>
<td>$pO_2$</td>
</tr>
<tr>
<td>70 mmHg (9.3 kPa)</td>
<td>90 mmHg (12.0 kPa)</td>
</tr>
<tr>
<td>$pCO_2$</td>
<td>$pCO_2$</td>
</tr>
<tr>
<td>45.6 mmHg (6.1 kPa)</td>
<td>45.4 mmHg (5.5 kPa)</td>
</tr>
<tr>
<td>$sO_2$</td>
<td>$sO_2$</td>
</tr>
<tr>
<td>94.0%</td>
<td>96.9%</td>
</tr>
</tbody>
</table>

0.2 mL of air is added to a blood gas sample and transported via pneumatic tube. The initial $pO_2$ value is 105 mmHg. After the pneumatic tube transport the $pO_2$ increases to 150 mmHg [2].
Key steps for greater sample integrity

Exposure to room air can lead to:
- Sample values no longer representative of patient status
- $pO_2$ will be most impacted – there will be minor effects on $pCO_2$ and pH [1]

An inhomogeneous sample can lead to:
- Erroneous hemoglobin and Hct values and bias on calculated parameters derived from ctHb

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Calculated and measured changes in blood $pO_2$ when 20 or 40 μL air (atmospheric $pO_2$) was added to blood. Data points are based on changes in $pO_2$ as measured on 19 blood specimens as air was sequentially introduced and equilibrated with the blood in a syringe.
Manual mixing (ABL700)

Automatic mixing (ABL800 FLEX)


Key steps for greater sample integrity

Thorough removal of air bubbles minimizes room air contamination of the sample

- Visually inspect the sample for air bubbles
- Expel any air bubbles before mixing

Proper mixing of the sample immediately post sample collection for a clot-free sample

- Mix immediately after air bubbles have been expelled
- Mix to dissolve the heparin to prevent clots to form

Mixing – again – prior to analysis to obtain a homogeneous sample

- Thoroughly mix the sample by inverting the syringe several times and rolling it between the palms of your hands
- Use automated mixing

Tips!

Use syringes with vented tip caps that seal the sample and remove air without getting in contact with blood

Establish a dedicated mixing procedure in your facility

Gentle mixing of the sample is required to avoid the risk of hemolysis

5. Sample transport
Biochemistry predicts the following changes caused by continued metabolism of heparinized arterial blood gas samples obtained anaerobically and stored at room temperature [1]:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Change</th>
<th>Because...</th>
</tr>
</thead>
<tbody>
<tr>
<td>$pO_2$</td>
<td>↓</td>
<td>The cells that utilize oxygen continue to do so</td>
</tr>
<tr>
<td>$pCO_2$</td>
<td>↑</td>
<td>$CO_2$ is a product of the metabolism</td>
</tr>
<tr>
<td>pH</td>
<td>↓</td>
<td>Combined effect: 1) Increase in $CO_2$ causes a decrease in pH 2) Increase in hydrogen-ion concentration due to continued glycolysis</td>
</tr>
<tr>
<td>Glucose</td>
<td>↓</td>
<td>Due to continued glycolysis</td>
</tr>
<tr>
<td>Lactate</td>
<td>↑</td>
<td>Due to continued glycolysis</td>
</tr>
</tbody>
</table>
Wrong storage temperature can lead to:

- Wrong storage temperature can alter the values in the sample so they no longer represent patient status

Prolonged storage time can lead to:

- Continuous metabolism alters values in the sample so they no longer represent patient status, for example: $pO_2$, $pCO_2$, pH, glucose and lactate are affected
Minimum time to patient results

Immediate analysis of sample for greater sample integrity and short TAT

- If storage is unavoidable, store the sample for maximum 30 minutes
- Glass syringes should be used if analysis will be delayed (more than 30 minutes after collection)

Store plastic sampling devices at room temperature to minimize any effect on sample values

- Glass sampling devices can be stored in ice slurry water or at room temperature

NB!
Analyze special samples within 5 minutes: high $pO_2$, high leucocyte count, shunt studies

Tips!
Use a blood gas analyzer that can keep track of sample age
Immediate analysis of sample for greater sample integrity and short TAT

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NB!
Analyze special samples within 5 minutes: high $pO_2$, high leucocyte count, shunt studies.

Tips!
Use a blood gas analyzer that can keep track of sample age.
High Five for

**safe arterial blood gas sampling:**

Path of workflow:

1. **Patient preparation** – patient assessment and correct data registration to maximize patient safety
2. **Blood collection device** – greater sample integrity and operator safety
3. **Sample collection** – maximum safety for patient and operator
4. **Sample handling** – key steps for greater sample integrity
5. **Sample transport** – minimum time to patient results

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**More educational resources**

Blood gas preanalytics app:
- Handbook with video demonstrations
- Skill test
- Interactive troubleshooting guide

Available for
- iPhone
- Android
- Windows Phone
In depth on heparin

Radiometer’s solution

First and only to market with fully balanced heparin

Dry electrolyte-balanced heparin

Radiometer facts:
First to market with high sensitive calcium measurement
First to market with balanced heparin

Bias on Ca^{2+} leading to low $c_{Ca^{2+}}$
No bias on Ca^{2+}
Radiometer’s dry electrolyte-balanced heparin – superiority confirmed by additional studies

References


Radiometer’s portfolio of arterial blood gas syringes
Arterial blood gas syringes

PICO
Arterial puncture and arterial line sampling

safePICO70
Arterial puncture sampling with integrated needle shield device

safePICO
Premium solution for arterial blood gas sampling

PICO70

PICO50

safePICO70

safePICO self-fill

safePICO aspirator
Radiometer’s **PICO line** – features

**PICO syringe**
- Available as **aspirator for arterial line** procedures and **vented for arterial puncture** procedure
- Pre-heparinized with **dry** electrolyte-balanced heparin coated on fiber disc
- TipCap to seal sample during transport
- Fill volume: PICO70 0.3-1.5 mL, PICO50 0.5-2 mL

**safePICO70 syringe**
- Arterial puncture draw
- Same features as PICO line
- Integrated needle shield device – single handed activation and audible “click” when activated correctly
- Fill volume: 0.3-1.5 mL

**Needle assortment**
For self-filling syringes:
Broad assortment of needles to suit puncture site and patient characteristics

<table>
<thead>
<tr>
<th>Length</th>
<th>25G Orange</th>
<th>23G Blue</th>
<th>22G Clear</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 mm</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>25 mm</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>32 mm</td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

Preferably short-bevel 20-25 gauge needles with a length of 16-38 mm are acceptable for arterial puncture [1]

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Radiometer’s **PICO line** – benefits

**Dry electrolyte-balanced heparin**
- Specially prepared heparin that minimizes bias on all electrolytes, $\text{Na}^+,$ $\text{K}^+,$ $\text{Ca}^{2+}$ as recommended by CLSI guidelines
- Minimal bias on electrolytes even at smaller sample volumes
- Heparin superiority proven by independent study

**Vented plunger system on self-filling syringe**
- Vented plunger designed to minimize bubbles in sample

**Needles with short bevel**
- Easy placement of needle in artery; prevent puncture of opposite arterial wall
- Minimize the risk of mixing venous blood with arterial blood

**Needles with super-thin needle wall**
- Larger inner diameter compared to regular needles
- Faster filling and reduced patient discomfort

**TipCap**
- Minimize room air: The special design of the Radiometer TipCap leaves no room for air in the luer tip
- Anaerobe sample: The TipCap is designed to expell air from the sample before sealing
Radiometer’s **needle safety mechanism**

**safePICO70 syringe**

Maximum operator safety

- Onboard safety mechanism → always where needed
- Single handed activation → allows operator to take care of patient while disposing of needle
- Audible “click” signals correct activation → ensure correct usage every time
- Full encapsulation of needle → safe disposal of needle and optimal prevention of stick injury
- Robust and irreversible once activated → maximum user safety
Radiometer’s premium safePICO line – features

**safePICO syringe**
Maximum safety and sample integrity
- *safePICO* aspirator for arterial line draw
- *safePICO* self-fill for arterial puncture draw
- Pre-heparinized with dry electrolyte-balanced heparin coated on fiber disc
- *safeTIPCAP* for safe and easy removal of air bubbles; seals the sample during transport
- Integrated mixing ball for easy and efficient mixing of sample
- Pre-barcoded to enable automatic match of patient ID and sample ID
- *safePICO* self-fill available with integrated needle shield device
- Fill volume: *safePICO* self-fill 0.7-1.5 mL, *safePICO* aspirator 0.7-1.7 mL

**Needle assortment** – for self-filling syringes
Broad assortment of needles to suit puncture site and patient characteristics

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</tr>
<tr>
<td>25 mm</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>32 mm</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>
Radiometer’s **premium safePICO line** – benefits

**safeTIPCAP**
Greater sample integrity and operator safety
- Allows for easy expelling of air while preventing exposure to blood
- Seals the sample during transport
- Stays on during measurement; forms a closed system once attached

**Mixing ball**
Greater sample integrity
- Gold plated metal mixing ball ensures easy, quick and efficient mixing
- Dissolves heparin to prevent clotting
- Ensures homogenous sample for correct hemoglobin results

**Pre-barcoded**
Maximum data accuracy
- Pre-attached barcode on syringe for automatic match of patient ID and sample ID