Preanalytical errors in blood gas testing

Ana-Maria Simundic
Zagreb, Croatia

Clinical Institute of Chemistry, Clinical unit for Medical Biochemistry and Toxicology, University Hospital Center "Sestre milosrdnice"

Faculty of Pharmacy and Biochemistry, Zagreb University

Biochemia Medica

EFLM WG-Preanalytical Phase
I will talk about...

- Errors in medicine
- Laboratory responsibility
- Blood gas testing
  - Patient condition
  - ID errors
  - Sampling procedure / errors
  - Sample type
  - Transport
  - Anticoagulants
  - Safety
Case # 1

8:00 a.m.
lab receives arterial blood sample, for blood gas testing for an ICU patient. Sample has been delivered to the lab in a plastic syringe, on ice. Sampling time was 6:30 a.m. Sample is visibly sedimented. What would you do?

a) Sample is acceptable. I would thoroughly mix the sample and perform the analysis.
b) Sample is not perfect, but I would accept it for analysis after thoroughly mixing it. I would report the result with a comment.
c) Sample is not acceptable. I would reject the sample and request repeated sampling.
d) I would call a physician and ask him to decide what to do.
Healthcare system

- Healthcare is a system that frequently harms and routinely fails to deliver the appropriate standard of care.

98,000 people die annually in USA as a result of preventable medical errors (268/day)

- proposal for error reducing strategy
- government, health care providers, industry, and consumers should be involved
- a minimum goal a 50 percent reduction in errors over the next 5 yrs

published on November 1, 1999
Healthcare errors are not rare

WHO acknowledges that patient safety is of global concern.

10 facts on patient safety

Patient safety is a serious global public health issue. Estimates show that in developed countries as many as one in 10 patients is harmed while receiving hospital care.

In developing countries, the probability of patients being harmed in hospitals is higher than in industrialized nations. The risk of health care-associated infection in some developing countries is as much as 20 times higher than in developed countries.
Patient safety is defined as freedom for a patient from unnecessary harm or potential harm associated with healthcare. It is a serious concern in the European Union. Recent studies consistently show, in an increasing number of countries, that healthcare errors occur in around 10% of hospitalisations, although adverse events take place in all settings where healthcare is delivered, including in primary care, secondary care, community care, social care and private care, in acute and chronic care.
Key factors contributing to this problem:

- the failure of health care providers to:
  - define the safe practice standards
  - consistently enforce compliance
Do we need to worry?

Large laboratory contribution to the decision/diagnosis (70%)

Laboratory errors can lead to:
- **mis**diagnosis
- **missed** diagnosis
- **delayed** diagnosis

Graber, M. L. et al. Diagnostic error in internal medicine. Archives of internal medicine. 2005;165
### Figure Legend:

Classification of diagnostic errors in 583 physician-reported cases using the Diagnostic Error Evaluation and Research project tool to localize where in the diagnostic process error occurred.

#### Table: Classification of Diagnostic Errors

<table>
<thead>
<tr>
<th>Process</th>
<th>Error Description</th>
<th>No. of Cases (N=583)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Access/Presentation</td>
<td>A. Failure/delay in presentation</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>B. Failure/delay in eliciting critical piece of history data</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>C. Failure in weighing</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>D. Failure/delay to follow-up</td>
<td>10</td>
</tr>
<tr>
<td>2. History</td>
<td>A. Failure/delay in eliciting critical physical exam finding</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>B. Inaccurate/missinterpreted</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>C. Failure in weighing</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>D. Failure/delay to follow-up</td>
<td>20</td>
</tr>
<tr>
<td>3. Physical Exam</td>
<td>A. Failure/delay in ordering needed test(s)</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>B. Failure/delay in performing ordered test(s)</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>C. Error in test sequencing</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>D. Ordering of wrong test(s)</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>E. Test ordered wrong way</td>
<td>5</td>
</tr>
<tr>
<td>4. Tests (Lab/Radiology)</td>
<td>A. Sample mix/mislabeled (eg, wrong patient/test)</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>B. Technical errors/poor processing of specimen/test</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>C. Failed/delayed reporting of result to clinician</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>D. Failed/delayed follow-up of (abnormal) test result</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>E. Error in clinician interpretation of test</td>
<td>5</td>
</tr>
<tr>
<td>5. Assessment</td>
<td>A. Failure/delay in considering the diagnosis</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>B. Suboptimal Weighting/Prioritizing</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>C. Too much weight on competing/coexisting diagnosis</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>D. Recognizing Urgency/Complications</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>E. Failure/delay to recognize/weight urgency</td>
<td>10</td>
</tr>
<tr>
<td>6. Referral/Consultation</td>
<td>A. Failure/delay in ordering referral</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>B. Failure/delay obtaining/scheduling ordered referral</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>C. Error in diagnostic consultation performance</td>
<td>20</td>
</tr>
<tr>
<td>7. Follow-up</td>
<td>A. Failure to refer patient to close/safe setting/monitoring</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>B. Failure/delay in timely follow-up/rechecking of patient</td>
<td>40</td>
</tr>
</tbody>
</table>

44% of all cases were due to radiology and laboratory errors.
Preanalytical phase

- Preanalytical phase: 68%
- Analytical phase: 19%
- Postanalytical phase: 13%

Case #2

Lab receives arterial blood sample from emergency department. Blood gas testing is requested. Sample was transported by pneumatic tube within 10 minutes from sampling. You notice an air bubble in the syringe.

What would you do?

a) Sample is acceptable. I would expel the bubble and perform the analysis.

b) Sample is not perfect, I would expel the bubble and perform the analysis. I would report the result with a comment.

c) Sample is not acceptable. I would reject the sample and request repeated sampling.

d) I would call a physician and ask him to decide what to do.
Why is preanalytical phase so vulnerable?
Brain-to-brain cycle

TOTAL TESTING CYCLE

Clinical decision/action

Clinical question

Selecting the right test

Test ordering

Patient identification

Sample handling

Sample transport

Sampling

Analysis

Results reporting

Results interpretation

most relevant for blood gas analysis

Lundberg GD. JAMA 1981;245:1762-3
Brain-to-brain cycle

TOTAL TESTING CYCLE

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Results interpretation

Hemolysis?

Clotted sample?

Sample mixed?

Adequate container?

Adequate adjuvants?

Patient identification

Is it the patient prepared?

Is it the right patient?

Is the transport temperature OK?

Is the sample delivered on time?

Most relevant for blood gas analysis

Lundberg GD. JAMA 1981;245:1762-3
It is our responsibility

- ISO 15189 recognises **lab responsibility** for monitoring and improving the preanalytical phase:

  pre-examination processes include “*all steps starting in chronological order from the clinician’s request, including the examination requisition, preparation of the patient, collection of the primary sample, transportation to and within the laboratory and ending when the analytical examination starts*”.
How?

- define safe practice standards
- consistently enforce compliance
Blood gas testing is unique in many ways

- patient condition
- urgent action needed
- invasive procedure
- limited sample stability
- low biological variability
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Desirable specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemoglobin, g/L</td>
<td>±1.8%</td>
</tr>
<tr>
<td>pH</td>
<td>±1.0%</td>
</tr>
<tr>
<td>pO₂, mm Hg</td>
<td>±1.8%</td>
</tr>
<tr>
<td>pCO₂, mm Hg</td>
<td>±1.8%</td>
</tr>
<tr>
<td>HCO³⁻, mmol/L</td>
<td>±1.6%</td>
</tr>
<tr>
<td>p50, mm Hg</td>
<td>-</td>
</tr>
<tr>
<td>sO₂, %</td>
<td>-</td>
</tr>
<tr>
<td>ABE, mmol/L</td>
<td>-</td>
</tr>
<tr>
<td>COHb, %</td>
<td>-</td>
</tr>
<tr>
<td>MetHb, %</td>
<td>-</td>
</tr>
<tr>
<td>Ca²⁺, mmol/L</td>
<td>±0.6%</td>
</tr>
<tr>
<td>Potassium, mmol/L</td>
<td>±1.8%</td>
</tr>
<tr>
<td>Cell free hemoglobin, g/L</td>
<td>-</td>
</tr>
</tbody>
</table>
### Case #3

<table>
<thead>
<tr>
<th>parameter</th>
<th>value</th>
<th>unit</th>
<th>Ref range</th>
<th>Repeated sample - OK</th>
</tr>
</thead>
<tbody>
<tr>
<td>pO₂</td>
<td>14.6</td>
<td>kPa</td>
<td>11 - 14.4</td>
<td>13.1</td>
</tr>
<tr>
<td>pCO₂</td>
<td>3.70</td>
<td>kPa</td>
<td>4.7 - 6.4</td>
<td>4.8</td>
</tr>
<tr>
<td>K</td>
<td>3.2</td>
<td>mmol/L</td>
<td>3.5 – 5.0</td>
<td>4.3</td>
</tr>
<tr>
<td>Na</td>
<td>148</td>
<td>mmol/L</td>
<td>136 – 146</td>
<td>139</td>
</tr>
<tr>
<td>Cl</td>
<td>111</td>
<td>mmol/L</td>
<td>98 – 106</td>
<td>102</td>
</tr>
<tr>
<td>Glu</td>
<td>2.8</td>
<td>mmol/L</td>
<td>3.9 – 5.8</td>
<td>5.6</td>
</tr>
</tbody>
</table>

- a) Sample hemolyzed.
- b) Sample dilution.
- c) Air bubble.
- d) Clotted sample.
Brain-to-brain cycle

TOTAL TESTING CYCLE

Clinical question

Selecting the right test

Test ordering

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Results interpretation

Results reporting

Analysis

Sample handling

Patient identification

Sample transport

Sampling

most relevant for blood gas analysis

Lundberg GD. JAMA 1981;245:1762-3
Patient identification errors

- ID error frequency:
  - 0.1-1% in laboratory medicine
  - 0.05% in transfusion medicine
- underreported (most go undetected)
- major healthcare issue
- potentially associated with serious adverse consequences
- zero tolerance!

Any potentially mislabeled or misidentified specimen should be rejected.

CLSI GP33-A Accuracy in Patient and Sample Identification

- **at least two** acceptable unique patient identifiers
  - full name
  - assigned ID number
  - date of birth
  - photo ID on government issued ID card (driver’s licence)
  - any other person specific identifier

- **active** ID (engaging the patient)

- **open ended question** (and check with sample label and request form):
  - what is your name?
  - what is your date of birth?
CLSI GP33-A Accuracy in Patient and Sample Identification

- if any discrepancies are identified, do not collect samples until issues are resolved
- if patient is not able to identify himself, ask a nurse, a friend or a relative to do that and record their names.
- to minimize the error risk:
  - use ID bracelets with barcodes or radiofrequency identifier devices (RFID) are recommended
  - use barcoded sample identifiers
  - generate labels at the time and site of collection
  - label the sample in the presence of the patient
Brain-to-brain cycle

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Sampling

most relevant for blood gas analysis

Lundberg GD. JAMA 1981;245:1762-3
Sampling

- patient condition
- sample type
- sampling site
- anticoagulant
Patient condition

- **CLSI 46-A2**: *sampling should be done in the steady state*
- Patient condition **determinants** should be carefully considered and records kept for:
  - patient status (resting, exercising, crying, anxious),
  - change in the ventilatory setting (spontaneous breathing or assisted mechanical ventilation)
  - change in oxygen delivery settings (fraction of inspired oxygen (FiO2) through nasal cannula or Ventourni mask)
  - respiratory rate,
  - body temperature.
Relation between temperature and PCO2 (upper) and pH (lower)


©2009 by American Academy of Pediatrics
Steady state?

- 3-5 minutes are usually enough for patients without pulmonary disease to stabilize
- 20-30 minutes for COPD patients

- CLSI 46-A2: *a stable ventilatory status for 20-30 minutes is adequate for most patients following ventilatory changes.*

- recent evidence* shows that oxygen equilibration relevant for clinical interpretation in patients with COPD receiving long-term oxygen therapy requires:
  - **10 minutes** following an increase in oxygen delivery
  - **16 minutes** following a decrease in oxygen delivery

Time and site of sampling

- **Exact time** of the blood collection and the **site** of sampling should always be recorded and reported on the test report.
- **difficulties** during blood collection

### Table III: ABG values based on neonatal age

<table>
<thead>
<tr>
<th></th>
<th>Pre-birth (Scalp)</th>
<th>5 min after birth</th>
<th>1-7 days after birth</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>&gt;7.20</td>
<td>7.20-7.34</td>
<td>7.35-7.45</td>
</tr>
<tr>
<td>pCO₂</td>
<td>&lt;6.65</td>
<td>4.6-5.9</td>
<td>4.6-5.9</td>
</tr>
<tr>
<td>pO₂</td>
<td>3.3-5.3</td>
<td>6.5-9.7</td>
<td>9.3-9.9</td>
</tr>
<tr>
<td>Sat%</td>
<td>&gt;50</td>
<td>&gt;80</td>
<td>&gt;90</td>
</tr>
<tr>
<td>HCO₃</td>
<td>&gt;15</td>
<td>16-19</td>
<td>20</td>
</tr>
</tbody>
</table>

Ashok Deorari. Blood gas analysis. All India Institute of Medical Sciences. 2008
Difficulties with blood sampling

- Male patient, 82 years, chest pain, admitted to ED
- 1. sample – capillary - difficulties during blood collection
- 2. sample – arterial blood, after 10 minutes

<table>
<thead>
<tr>
<th></th>
<th>Rezultat</th>
<th>Jedinica</th>
<th>Rezultat</th>
<th>Referentni interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7,28</td>
<td>L</td>
<td>7,45</td>
<td>7,35 do 7,45</td>
</tr>
<tr>
<td>pCO2</td>
<td>6,89</td>
<td>H</td>
<td>4,70</td>
<td>4,66 do 6,38</td>
</tr>
<tr>
<td>BE</td>
<td>-3,4</td>
<td>L</td>
<td>0,8</td>
<td>-2 do +3</td>
</tr>
<tr>
<td>HCO3-</td>
<td>23,9</td>
<td>H</td>
<td>24,1</td>
<td>18 do 23</td>
</tr>
<tr>
<td>tCO2</td>
<td>25,5</td>
<td>H</td>
<td>25,2</td>
<td>22 do 29</td>
</tr>
<tr>
<td>pO2</td>
<td>4,4</td>
<td>L</td>
<td>10,27</td>
<td>11 do 14,4</td>
</tr>
<tr>
<td>sat O2</td>
<td>55</td>
<td>L</td>
<td>94,9</td>
<td>95 do 98</td>
</tr>
</tbody>
</table>
Sample type

- CLSI 46-A2 guideline state:

  “Blood gas measurement for the purpose of evaluating the gass exchange function of the lungs (pO2 and pCO2) should be performed on **arterial blood only**. ...
  
The blood should be collected under **anaerobic** conditions, mixed immediately to dissolve heparin anticoagulant and promptly analysed.”
Alternative?

- CLSI 46-A2 guideline state:
  
  "if arterial blood can not be collected directly, peripheral capillary blood may be collected using an arterialization technique (warming the skin to 40-45 °C with a warm towel or vasodilating cream).

  ...blood gas results may differ, especially those for pO2, sO2, FO2Hb and ctO2."

- earlobe is better than a fingertip

- there is really no substitute for arterial blood if accuracy of pO2 measurement is important (oxygen therapy)
Arterial vs. capillary sample?

- large debate over the years...
- Zavorsky et al. (2007) in their meta analysis showed that:
  - earlobe is preferred over the fingertip
  - capillary sampling accurately reflects arterial pCO(2) and pH over a wide range of values.
  - capillary blood is not an adequate substitute for arterial blood for accurate pO2 measurement

- many subsequent recent studies have confirmed this
- capillary sample acceptable alternative only during medical transport and pre-hospital critical care.

Arterial vs. capillary sample?

Figure 1: Capillary network

<table>
<thead>
<tr>
<th>Arterial blood</th>
<th>AV Difference</th>
<th>Venous Blood</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.40</td>
<td>pH</td>
</tr>
<tr>
<td>$pCO_2$</td>
<td>5.3 kPa</td>
<td>$pCO_2$</td>
</tr>
<tr>
<td>$pO_2$</td>
<td>13.0 kPa</td>
<td>$pO_2$</td>
</tr>
</tbody>
</table>

Higgins C. Capillary-blood gases: To arterialize or not. MLO. November 2008:42-47
Arterial sample vs. arterialized earlobe?

Results:
Poor PO2 concordance (CCC = 0.45; CI 95% = 0.26 to 0.6) of arterialized earlobe with arterial blood.

Mean PO2 difference was 12 mmHg (P < 0.001) (Figure 1).

The higher the arterial PO2, the greater the difference (slope = 0.54).

Arterial blood sampling


Sampling:
- from radial artery
- indwelling arterial catheters

- discomfort and pain
- possible complications
  - bleeding,
  - bruising,
  - arterial thrombosis,
  - infection.

http://www.gla.ac.uk/media/media_168894_en.pdf

ABG SAMPLING TECHNIQUE. University of Glasgow.
Sample contamination with flush solution

- during sampling from arterial catheters, there is a risk of diluting the sample with flush solution.

To avoid errors:

- discard at least 3 times the dead space when sampling from catheter
- check catheter package for the exact volume of dead space

↑ pO2 ↓ pCO2
↓ K+ ↑ Na+ ↑ Cl– ↓ Ca2+
↓ cGlu ↓ cLac ↓ ctHb
Case #3 - results
Sample contamination with venous blood

- during sampling from arterial catheters, there is a risk of accidentally puncturing the vein and contaminating the sample with venous blood.

- use self-filling syringes – they fill readily when puncturing an artery but not when hitting a vein
- use short-bevelled needles – easier to position inside the artery
- make the puncture at an angle of 45°

To avoid errors:

\( \downarrow pO_2 \downarrow sO_2 \uparrow pCO_2 \)
## Sample filling time


<table>
<thead>
<tr>
<th>Table. P_{aO_2} and Sampler Filling Times in Arterial and Venous Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Filling time, s/mL                           Arterial (n = 22)</td>
</tr>
<tr>
<td>15 ± 4</td>
</tr>
<tr>
<td>P_{aO_2}, mm Hg</td>
</tr>
</tbody>
</table>

Values are mean ± SD.
Sample contamination by air bubbles

- even bubble as small as 1% of the sample volume is significant

To avoid errors:

- visually inspect the sample immediately after sampling
- expel bubbles by gently tapping the syringe, immediately after sampling and before mixing!
- use syringes with vented tip caps that will allow you to expel air and seal the sampler without getting in contact with blood

↑pH  ↑pO2  ↑sO2  ↓pCO2
Case #2 - results
Sample mixing

- Blood samples will coagulate if not mixed properly immediately after sampling.

To avoid errors:

- mix by inverting the syringe several times and rolling it between the palms
- syringes with a metal ball

↑K, clotted sample analyzer malfunction
Capillary sampling

- anaerobic???
- excessive repetitive pressure (milking) causes hemolysis and sample contamination with tissue fluid

<table>
<thead>
<tr>
<th>ELECTROLYTES</th>
<th>WITHOUT MILKING</th>
<th>WITHOUT MILKING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na&lt;sup&gt;+&lt;/sup&gt;</td>
<td>140.1</td>
<td>137.1</td>
</tr>
<tr>
<td>K&lt;sup&gt;+&lt;/sup&gt;</td>
<td>3.76</td>
<td>4.12</td>
</tr>
<tr>
<td>Ca&lt;sup&gt;++&lt;/sup&gt;</td>
<td>0.97↓</td>
<td>0.70↓</td>
</tr>
<tr>
<td>Ca&lt;sup&gt;++&lt;/sup&gt; (7.4)</td>
<td>0.99</td>
<td>0.71</td>
</tr>
<tr>
<td>Cl&lt;sup&gt;-&lt;/sup&gt;</td>
<td>104</td>
<td>101</td>
</tr>
</tbody>
</table>

same patient, 2 minutes time difference, resting

To avoid errors:

- avoid milking, arterialization, take preferably arterial samples
Hemolysis – significant source of errors


<table>
<thead>
<tr>
<th>Parameter</th>
<th>Desirable specifications</th>
<th>Non-hemolized blood</th>
<th>Hemolyzed blood</th>
<th>p-Value</th>
<th>Bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemoglobin, g/L</td>
<td>±1.8%</td>
<td>147±7</td>
<td>148±7</td>
<td>0.13</td>
<td>0.7% (-0.6% to 2.0%)</td>
</tr>
<tr>
<td>pH</td>
<td>±1.0%</td>
<td>7.39±0.01</td>
<td>7.38±0.01</td>
<td>0.01</td>
<td>-0.2% (-0.3% to -0.0%)</td>
</tr>
<tr>
<td>pO₂, mm Hg</td>
<td>±1.8%</td>
<td>34.6±3.2</td>
<td>32.9±3.0</td>
<td>0.04</td>
<td>-4.9% (-9.6% to -0.2%)</td>
</tr>
<tr>
<td>pCO₂, mm Hg</td>
<td>±1.8%</td>
<td>45.6±1.0</td>
<td>47.5±1.1</td>
<td>&lt;0.01</td>
<td>4.1% (1.7% to 6.6%)</td>
</tr>
<tr>
<td>HCO³⁻, mmol/L</td>
<td>±1.6%</td>
<td>27.1±0.6</td>
<td>27.5±0.6</td>
<td>&lt;0.01</td>
<td>1.4% (0.4% to 2.4%)</td>
</tr>
<tr>
<td>p50, mm Hg</td>
<td>—</td>
<td>27.9±0.4</td>
<td>27.5±0.4</td>
<td>&lt;0.01</td>
<td>-1.5% (-2.5% to -0.4%)</td>
</tr>
<tr>
<td>sO₂, %</td>
<td>—</td>
<td>61.7±6.0</td>
<td>58.9±5.9</td>
<td>&lt;0.01</td>
<td>-4.9% (-8.0% to -1.9%)</td>
</tr>
<tr>
<td>ABE, mmol/L</td>
<td>—</td>
<td>2.1±0.5</td>
<td>2.2±0.6</td>
<td>0.23</td>
<td>-14% (-69% to 40%)</td>
</tr>
<tr>
<td>COHb, %</td>
<td>—</td>
<td>1.2±0.1</td>
<td>1.0±0.1</td>
<td>&lt;0.01</td>
<td>-11% (-14% to -8%)</td>
</tr>
<tr>
<td>MetHb, %</td>
<td>—</td>
<td>0.6±0.01</td>
<td>0.6±0.1</td>
<td>0.50</td>
<td>0.0% (-9.2% to 9.2%)</td>
</tr>
<tr>
<td>Ca²⁺, mmol/L</td>
<td>±0.6%</td>
<td>1.06±0.01</td>
<td>0.99±0.02</td>
<td>&lt;0.01</td>
<td>-7.0% (-11.3% to -2.8%)</td>
</tr>
<tr>
<td>Potassium, mmol/L</td>
<td>±1.8%</td>
<td>3.7±0.1</td>
<td>6.6±0.8</td>
<td>&lt;0.01</td>
<td>152% (150% to 155%)</td>
</tr>
<tr>
<td>Cell free hemoglobin, g/L</td>
<td>—</td>
<td>0</td>
<td>8.9±1.5</td>
<td>&lt;0.01</td>
<td>—</td>
</tr>
</tbody>
</table>

To avoid errors:

- Do not store the sample directly on ice cubes
- Avoid vigorous mixing, sample turbulence caused by narrow needles, high vacuum and older pneumatic tube systems
Anticoagulant

- lyophilized balanced Li-heparin is recommended
- caution!
  - **dilution** of electrolytes, HCO3-, pCO2 by liquid heparin
  - liquid heparin has atmospheric pO2 (150 mmHg/20 kPa) and affects pO2 results
  - Na-heparin falsely elevates sodium
  - heparin **binds cations** (Ca++, Na+, K+)
  - CLSI 46-A2 states that final sample heparin concentration should be **20 IU/mL** blood (flushing with therapeutic heparin is not recommended – it contains high heparin concentration and my alter sample pH and electrolytes)
  - **mix** as soon as possible to ensure proper anticoagulation and avoid clot formation

Dilution by liquid sodium heparin – 2/4

Dilution by liquid sodium heparin – 3/4

Brain-to-brain cycle

TOTAL TESTING CYCLE

- Clinical question
- Selecting the right test
- Test ordering
- Patient identification
- Sample handling
- Sample transport
- Sampling
- Analysis
- Results reporting
- Results interpretation
- Clinical decision/action

most relevant for blood gas analysis

Lundberg GD. JAMA 1981;245:1762-3
Time is the key to sample quality
Sample transport

- CLSI H11-A4 defines transport condition:
  - analyse the sample within **30 minutes** of collection in a plastic syringe, at **room temperature**
  - if expected delivery time is longer than 30 minutes, use glass syringes, cool the sample

- CLSI 46-A2: samples should be **delivered by hand**, **vigorous movement** should be avoided

- **exposure to air** should be avoided (↑ pO2, ↓ pCO2, ↑ ↓ pH – *mixed effect due to↓ pCO2 and cell metabolism*)

- **pneumatic tube transport** introduces bias in pO2 due to vigorous sample shaking
Case #1 - results
Brain-to-brain cycle

TOTAL TESTING CYCLE

Clinical decision/action
Clinical question
Selecting the right test
Test ordering
Results reporting
Analysis

Sample handling
Sample transport
Patient identification
Sampling

most relevant for blood gas analysis

Lundberg GD. JAMA 1981;245:1762-3
Sample handling

- Proper sample **mixing** prior to analysis to obtain a homogeneous sample

  - mix by inverting the syringe several times and rolling it between the palms
  - have a written policy and procedure for mixing
  - mix gentle to avoid hemolysis!
Safety issues

- Needle-stick injury and unwanted contact with patient blood are everyday daily risks
- in 2000 occupational HCWs exposure has led to:
  - 16,000 HCV,
  - 66,000 HBV,
  - 1,000 HIV infections *

To avoid risks:
- Use a **safety devices** (contact with patient blood is limited)
- Use a protection device for the **safe removal** of needles
- Lab has a **procedure for operator safety** and lab staff is **compliant** with the procedure

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• measure must be taken to specify and implement safe procedures for using and disposing of sharp medical instruments and contaminated waste.

• ... providing medical devices incorporating safety-engineered protection mechanisms.
Tips for safer blood gas testing:

- patient properly identified
- patient is in a steady state
- proper sampling site
- self-filling plastic syringes with short-beveled needles, vented caps and balanced dry heparine
- 45° aspiration
- visually inspect the sample,
- expel any bubbles,
- mix the sample,
- deliver on room temperature,
- analyse within 30 minutes
- if visibly sedimemented, mix >5’
Quality management

- standardize procedures
- provide written instructions
- enforce compliance
- educate yourself and educate others
- monitor the quality
- continuous improvement

lab responsibility!