Reducing Preanalytical Errors
In Blood Gas Testing

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Outline

• Introduction

• Pre-analytical Variables:
  – Patient
  – Sampling
  – Transportation, Storage, and Mixing
  – Summary and Key Points

Safety
What is so special about blood gases?

- NOT like other blood samples
- Sample instability
- Invasiveness of collection
- Immediacy of impact and treatment decisions
- Critical nature of the patient
The Preanalytical Phase

- Processes that occur **before** a specimen is analyzed
- Up to 75% of all testing errors occur in the preanalytical phase
- Preanalytical errors can cause harm to patient
The Preanalytical Process

- Patient
  - Patient stability
  - Patient identification
- Sampling
  - Tube/syringe labeling
  - Site preparation
  - Sample collection
- Transport
- Processing
  - Specimen delivery to laboratory/storage
  - Specimen receipt
  - Order/requisition processing
  - Mixing
The Challenges of Preanalytical Variation

• Many people involved:
  – Physicians: writing orders, instructing patients
  – Nurses/Phlebotomists/RTs: patient ID, specimen collection
  – Runners: transport
  – Lab staff: receipt and processing

• Preanalytical variables are often unknown to lab personnel and the clinicians interpreting the results
Understanding Preanalytical Variation

• Most steps
• Most people
• High urgency & stress
• Most variation in work environment, technique, and training

% of Time Spent

- Pre-analysis: 60%
- Analysis: 25%
- Post-analysis: 15%
Poll- Where do you fit in?

- Nurse
- Laboratorian (MLT, MT etc)
- Respiratory Therapist
- Clinician
- Laboratory Director
- Lab supervisor
- POC coordinator
The steps of the preanalytical phase

- Patient Variation
- Sampling
- Transport
- Processing
THE PATIENT
Starting on the Right Foot: Identify the Patient

- Incorrect/missing patient and sample IDs are frequent and critical preanalytical errors
Consequences of Mislabling

- Failure to provide proper and immediate care to a patient
- Inappropriate care to a patient

Financial Implication of mislabeling:
- 250/month
- $500/incident
- Annual cost = USD 1.5 million

*Excluding medicolegal or liability costs
Avoiding Labeling Errors

• Positive Patient Identification x2
• Correlate Orders with Patient Name
• Identification on Sample Device at site of Collection
  • Patient ID label attached
  • Pre-barcoded arterial syringe
• Enter a patient ID into the analyzer before analysis
• Use barcode readers
Take Note: Patient Variables

- FIO2 and application of device
  - Mode of ventilation and Patient compliance with supplemental O2

- Duration of changes in vent settings
  - Approximately 5-10 minutes post change up to 20% in stable Patient (Cakar, 2001, Intensive Care Medicine)
  - Up to 30 minutes post change in Patient with Obstructive Lung Disease (Parsons, 2002)

- Patient's respiratory rate, temperature, position, activity

- Ease of (or difficulty with) blood sampling
Safety

- Blood exposure and needlestick injuries are common
  - 23,908 injuries in 85 hospitals in 10 states (1995-2005)\(^1\)

- All healthcare staff involved in patient care are affected
  - Medical technologists, Physicians, Respiratory Therapists, and Nurses

\(^2\) Adapted from http://www.cdc.gov/niosh/stopsticks/sharpsinjuries.html
Exposure Causes and Consequences

• **Causes:**
  – Unavailability of safety devices
  – Lack of procedure for operator safety
  – Procedures for safety not known or followed

• **Consequences:**
  – Needle-stick injury
  – Anxiety
  – Infection
  – Therapy
Risk Reduction

• **To avoid risks:**
  – Use PPE
  – Use a safety device that limits contact with patient blood
  – Use a protection device for the safe removal of needles
  – Ensure procedure for operator safety is established and followed
SAMPLING
Sampling: Arterial Puncture

- Label the syringe with patient ID
- Choose Wisely
  - Note location and direction of flow for IV fluids relative to draw site
  - Confirm Arterial vs. Venous collection
  - *Adequate flushing of ports or lines*
- Expel any air bubbles immediately after sampling
- Mix the sample thoroughly immediately after sampling
Don’t Assume

• Emergency Department, 5:23am.

<table>
<thead>
<tr>
<th>Type</th>
<th>Arterial</th>
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<tbody>
<tr>
<td>pH</td>
<td>6.975</td>
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<tr>
<td>pCO2</td>
<td>8.2</td>
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<tr>
<td>pO2</td>
<td>187</td>
</tr>
<tr>
<td>HCO3</td>
<td>&lt;1.0</td>
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<tr>
<td>BE</td>
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<tr>
<td>sO2</td>
<td>98.9</td>
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<tr>
<td>tHgb</td>
<td>13.8</td>
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<tr>
<td>K</td>
<td>3.0</td>
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<tr>
<td>Na</td>
<td>142</td>
</tr>
<tr>
<td>Gluc</td>
<td>290</td>
</tr>
</tbody>
</table>

• Sample cancelled as possible contamination due to rapid increase in glucose

• Previous glucose was 145 mmol/L @~3am

• Patient does not have history of diabetes.

• Physician in ED requested investigation
Don’t Assume (cont.)

• Previous Sample: 02:52am

<table>
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<tr>
<td>pO2:</td>
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<td>HCO3:</td>
<td>4.5</td>
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<tr>
<td>BE:</td>
<td>-27.7</td>
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<tr>
<td>sO2:</td>
<td>83.5</td>
</tr>
<tr>
<td>tHgb:</td>
<td>7.0</td>
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<tr>
<td>K:</td>
<td>1.6</td>
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<tr>
<td>Na:</td>
<td>143</td>
</tr>
<tr>
<td>Gluc:</td>
<td>145</td>
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• Note similar Acid-Base pattern, but dramatically different electrolyte, metabolite, and hemoglobin concentrations.

• Admission sample was determined to be contaminated with normal saline bolus on admission for patient with alcohol intoxication.

• 05:23 sample was determined to be a more accurate representation of patient condition.
Poll

Contaminated sample

- Type: Arterial
- pH: 6.923
- pCO2: 12.4
- pO2: 49.3
- HCO3: 4.5
- BE: -27.7
- sO2: 83.5
- tHgb: 7.0
- K: 1.6
- Na: 143
- Gluc: 145

Accurate sample

- Type: Arterial
- pH: 6.975
- pCO2: 8.2
- pO2: 187
- HCO3: <1.0
- BE: -28.2
- sO2: 98.9
- tHgb: 13.8
- K: 3.0
- Na: 142
- Gluc: 290

POLL QUESTION

If unrecognized, what are the potential consequences of this error?

A). Unnecessary blood transfusion
B). Excess potassium supplementation
C). Confusion & concern for misidentification
D). Lack of appropriate insulin therapy
Blood Gas Sampling

To avoid errors:

• Check the specific catheter package for the exact volume of dead space

• Rule of thumb: discard at least three times the dead space
  – (CLSI recommends 6x)

• Draw the blood gas sample with a dedicated blood gas syringe containing dry electrolyte-balanced heparin

• If in doubt, consider resampling
Air bubbles

- Any air bubbles in the sample must be expelled as soon as possible after the sample has been drawn—before mixing the sample with heparin.

- Even small air bubbles may seriously affect the $pO_2$ value of the sample.

- An air bubble whose relative volume is 0.5 to 1.0 % of the blood in the syringe is a potential source of a significant error.
Air bubble Effects depend on:

- Size of bubble
- Number of bubbles
- Initial oxygen status of sample
- Longer time
- Lower temperature
- Increased agitation
Effect of Air Bubbles

Sample was transferred between collection devices to inject low sample volume.

<table>
<thead>
<tr>
<th>Air Contaminated sample</th>
<th>Accurate sample</th>
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</thead>
<tbody>
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<td><strong>Type:</strong> Not specified</td>
<td><strong>Type:</strong> Not specified</td>
</tr>
<tr>
<td><strong>pH:</strong> 7.50</td>
<td><strong>pH:</strong> 7.37</td>
</tr>
<tr>
<td><strong>pCO2:</strong> 37.1</td>
<td><strong>pCO2:</strong> 56.7</td>
</tr>
<tr>
<td><strong>pO2:</strong> 163</td>
<td><strong>pO2:</strong> 43.8</td>
</tr>
<tr>
<td><strong>HCO3:</strong> 28.9</td>
<td><strong>HCO3:</strong> 31.9</td>
</tr>
<tr>
<td><strong>BE:</strong> 5.6</td>
<td><strong>BE:</strong> 6.7</td>
</tr>
<tr>
<td><strong>sO2:</strong> 99.0</td>
<td><strong>sO2:</strong> 81.1</td>
</tr>
</tbody>
</table>
Hemolysis

- Hemolysis releases intracellular components
- Is not visible in a whole blood sample

After 5% hemolysis
(~ 0.8 g/dL free hemoglobin)
Hemolysis

• Hemolysis of the sample can lead to:
  – Biased results
  – Possible misdiagnosis
  – Possible erroneous patient treatment/lack of treatment

• To avoid errors:
  – Do not milk or massage the tissue during sampling
  – Use self-filling syringes
  – Use recommended procedures for mixing of samples
    • Discussed later
  – Store the sample at proper temperature
TRANSPORTATION
MIXING & STORAGE
Should Samples Be Delivered on Ice?

Cellular Metabolism

Gas Changes
What is the most important consideration for sample transport?

- A). Temperature
- B). Time
- C). Delivery mode (pneumatic tube station vs. runner)
- D). Type of syringe
CLSI Storage recommendations

• General storage recommendation
  – Do not cool the sample
  – Analyze within 30 minutes

• For samples with high $pO_2$
  – Analyze within 5 minutes

• For special studies, e.g. shunt
  – Analyze within 5 minutes

• For samples with high leukocyte or platelet count
  – Analyze within 5 minutes

• Expected delayed analysis
  – When analysis is expected to be delayed for more than 30 minutes, the use of glass syringes and storage in ice slurry is recommended
Continued cellular metabolism in sample

- $pO_2$: Oxygen consumption
- $pCO_2$: Carbon dioxide production
- pH: Change in $pCO_2$ and continued glycolysis
- $iCa^{2+}$: pH affects binding of $Ca^{2+}$ to protein
- Glucose: Glucose catabolism
- Lactate: Glycolysis
Ice Storage Affects PO2 Variably

- PO2 may increase or decrease during storage on ice
- High (>160 mmHg) initial PO2 with decrease
- Low (<100 mmHg) initial PO2 increases
- Cannot predict initial PO2
Know Your Analyte

“...icing or not icing specimens in each setting must be based on a thorough understanding of the study performed, collection device, pre-existing variables, anticipated storage time, and analytes measured.”

— Blonshine AARC Times August 2000
PROCESSING
Visually inspect the sample

- Before analyzing the sample, make a visual check of the blood
- Inspect for air bubbles
- Expel a few drops of blood from the syringe to inspect for clots
What Happens to the Instrument If a Clotted Sample is Analyzed?

**POLL QUESTION**

- A). No effect, ABG instruments have a hemolyzer
- B). Instrument will be unusable until clot is removed
- C). Electrolyte results will decrease
- D). Electrolyte results will increase
What Happens to the Instrument If a Clotted Sample is Analyzed?

Error!!
Sample mixing before analysis

- If the sample is visibly sedimentsed, it needs mixing for **several minutes**
  - Rolling it between the hands AND
  - Inverting it vertically
Sample mixing before analysis

• How fast does a whole-blood sample sediment?

• Depends on age and immunological condition

• Can you spot a sample that is only 5% sedimented?
Automatic Mixing vs. Standard Practice

A. Manual-Standardized Mixing

B. Automatic Mixing

C. Manual-True Practice Mixing

D. Automatic Mixing
Summary

• We’re all in this together → Help the patient!

• Preanaytical errors can lead to harm

• Preanalytical errors can occur both inside and outside the laboratory

• A bad sample is worse than no sample
Intro Video: Special Thanks

- Dr. Steven Cotten, The Ohio State University
- Dr. Laura Hicks, Labcorp America
- Chris Parker, McLendon Clinical Laboratories, University of North Carolina
- Music: Moby- *Extreme Ways*
- Penelope McCudden
Additional Resources

- [http://www.radiometeramerica.com/](http://www.radiometeramerica.com/)
- [www.acutecaretesting.org](http://www.acutecaretesting.org)
- A discard volumes arterial blood gas sampling. Critical Care Medicine: June 2003 - Volume 31 - Issue 6 - pp 1654-1658
List of Potential Preanalytical Errors

- Missing or wrong patient/sample identification
- Use of the wrong type or amount of anticoagulant
  - dilution due to the use of liquid heparin
  - insufficient amount of heparin
  - binding of electrolytes to heparin
- Inadequate stabilization of the respiratory condition of the patient
- Inadequate removal of flush solution in a-lines prior to blood collection
- Mixture of venous and arterial blood during puncturing
- Air bubbles in the sample
- Insufficient mixing with heparin
- Incorrect storage
- Hemolysis of red blood cells
- Not visually inspecting the sample for clots
- Inadequate mixing of sample before analysis
- Failure to identify the sample upon analysis