The Confusing Conundrum of Capillary Blood Specimen Collection and Analysis
Disclosures

• Speaking Honoraria
  – Radiometer
  – Nova Biomedical
  – Draeger

• Research Support (Reagents, Instrumentation, Travel)
  – Nova Biomedical
  – Roche Diagnostics (Canada)
  – Radiometer
  – Instrumentation Laboratories (Canada)

• ALOL Biomedical Inc
  • Clinical Laboratory Consulting Business
Capillary Confusion

- Capillaries are the smallest blood vessel connecting arterioles and venules

- Capillary wall is a single cell thick which promotes the release of $O_2$ and nutrients and capture of $CO_2$ and waste

- Blood collected by skin puncture represents a mixture of arteriole, capillary and venule blood


Capillary Confusion

Micro-collection device
Why are capillary collections so important?
Why are capillary collections so important?

Volume of blood required for laboratory analysis
Coagulation testing **ABSOLUTELY** requires the 9 volume blood to 1 volume (3.2% sodium citrate).
Volume of blood required for laboratory analysis

• Coagulation testing **ABSOLUTELY** requires the 9 volume blood to 1 volume (3.2% sodium citrate)

• Current commercially available blood collection tubes come in 2 sizes
Volume of blood required for laboratory analysis

- Coagulation testing **ABSOLUTELY** requires the 9 volume blood to 1 volume (3.2% sodium citrate)

- Current commercially available blood collection tubes come in 2 sizes
  - **BIG!**
  - **WAY TOO BIG!!**

- [1.8 ml](#)  [2.7 ml](#)
What is the significance of collecting 1.8 or 2.7 ml blood volume?
What is the significance of collecting 1.8 or 2.7 ml blood volume?

- Baby weight 2.5 Kg
- 80 ml whole blood/Kg
What is the significance of collecting 1.8 or 2.7 ml blood volume?

- Baby weight 2.5 Kg
- 80 ml whole blood/Kg

Total Blood Volume (200 ml)
What is the significance of collecting 1.8 or 2.7 ml blood volume?

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- 80 ml whole blood/Kg

Total Blood Volume (200 ml)

1.8ml collection
- 0.9% of total blood volume
- Adult 0.9% = 45 ml

2.7ml collection
- 1.4% of total blood volume
- Adult 1.4% = 70 ml
10ml represents 0.2% of the total blood volume of an adult.
Objective #1

• To briefly review CLSI and WHO guidelines for collection of capillary blood specimens
Objective #2

- To describe the physiological differences in analyte concentrations in arterial, capillary and venous specimens
Objective #3

- To discuss pre-analytical errors associated with capillary specimen collection
  - Hemolysis
  - Clotted specimens
CLSI and WHO guidelines: Collection of Capillary Blood Specimens


WHO guidelines on drawing blood: best practices in phlebotomy, Geneva, Switzerland, 2010
CLSI and WHO guidelines: Collection of Capillary blood specimens

23 Core Recommendations
For each step in the skin puncture technique


WHO guidelines on drawing blood: best practices in phlebotomy, Geneva, Switzerland, 2010
Figure 7. Steps in the skin puncture technique.
1. Preparation of supplies for capillary blood sampling
2. Hand disinfection
3. Approaching the patient
4. Inspecting the test request form
5. Identifying patients
6. Verifying patient preparation for skin puncture
7. Labeling the capillary tubes and capillary blood collection tubes
8. Positioning the patient
9. Putting on gloves
10. Selecting the skin puncture site
11. 1) Selecting lancet length 2) Selecting a microcollection device for capillary blood samples
12. Arterialisation of the puncture site
13. Cleaning the skin puncture site
14. Performing skin puncture
15. Elimination of the first drop of capillary blood sample
16. 1) Capillary blood collection 2) Order of draw in capillary blood collection
17. Disposal of incision device
18. Filling, closure and mixing of capillary tube or microcontainer for capillary blood collection
19. Bandaging the skin after capillary sampling
20. Glove removal
21. Recording relevant information during sampling

Figure 7. Steps in the skin puncture technique.
#10: Selecting the skin puncture site

Table 7.1  Conditions influencing the choice of heel or finger-prick

<table>
<thead>
<tr>
<th>Condition</th>
<th>Heel-prick</th>
<th>Finger-prick</th>
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<tbody>
<tr>
<td>Age</td>
<td>Birth to about 6 months</td>
<td>Over 6 months</td>
</tr>
<tr>
<td>Weight</td>
<td>From 3–10 kg, approximately</td>
<td>Greater than 10 kg</td>
</tr>
<tr>
<td>Placement of lancet</td>
<td>On the medial or lateral plantar surface</td>
<td>On the side of the ball of the finger perpendicular to the lines of the fingerprint</td>
</tr>
<tr>
<td>Recommended finger</td>
<td>Not applicable</td>
<td>Second and third finger (i.e. middle and ring finger); avoid the thumb and index finger because of calluses, and avoid the little finger because the tissue is thin</td>
</tr>
</tbody>
</table>
#10: Selecting the skin puncture site

CLSI Guideline **Section 7.1 Infants**
(Section 7: Sites for Collecting Skin Puncture Blood)
• “punctures must not be performed on earlobes”

Krleza et al., 2015 Capillary blood sampling review
• Earlobe specimen has been used for lactate monitoring in sports medicine
• “Earlobe puncture is recommended for blood gas analysis and will be described in Croatian national recommendations for blood gas and acid base balance”
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Figure 7. Steps in the skin puncture technique.
#11: Selecting Lancet Length

Puncture should be made across the fingerprint; not parallel to the fingerprint.
#11: Selecting Lancet Length

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<th>Recommended Puncture Site</th>
<th>Recommended Incision Depth up to</th>
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<tr>
<td>Premature neonates (up to 3 kg)</td>
<td>Heel</td>
<td>0.85 mm</td>
</tr>
<tr>
<td>Infants under 6 months of Age</td>
<td>Heel</td>
<td>2.0 mm</td>
</tr>
<tr>
<td>Child 6 months-8 years</td>
<td>Finger</td>
<td>1.5 mm</td>
</tr>
<tr>
<td>Child &gt; 8 years Adults</td>
<td>Finger</td>
<td>2.4 mm</td>
</tr>
</tbody>
</table>

Krleza et al., Biochemia Medica 2015;25(3):335-358
#11: Selecting Lancet Length

- Retractable incision devices are preferred
- Use a blade slightly shorter than recommended incision depth
  - “Pressure applied on the device during the puncture results in an incision slightly deeper than the nominal blade length”

Krleza et al., Biochemia Medica 2015;25(3):335-358
#11: Selecting Lancet Length

- Avoid applying strong pressure on the incision device
  - Too much pressure can cause the puncture to be deeper than necessary
  - Risk of damaging bone or nerves

Krleza et al., Biochemia Medica 2015;25(3):335-358
Wrap the heel in warm moist towel (hyperemic or vasodilatory creams)
- 40-45° C
- 3-5 min

Objective
- Increase the blood flow to the puncture site

Outcome
- To obtain an adequate sample without the need to apply pressure to surrounding tissue
Figure 1: Capillary network

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<th>Arterial blood</th>
<th>AV Difference</th>
<th>Venous Blood</th>
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<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>
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Higgins C. Capillary-blood gases: To arterialize or not. MLO. November 2008:42-47
The gold-standard sample for blood-gas analysis is arterial blood obtained via an indwelling arterial catheter or by arterial puncture. For a number of reasons, capillary blood is an attractive substitute sample that is routinely used in some clinical settings. The purpose of this article is to examine the evidence that blood-gas parameters (pH, pCO₂, and pO₂) obtained from a capillary-blood sample accurately reflect arterial blood. There is conflicting opinion that increasing local blood flow (by warming or application of vasodilating agent) prior to capillary-blood sampling is necessary for most accurate results and this controversial issue will be addressed. [Note: The unit of pCO₂ and pO₂ measurement used in this article is kPa—a to convert kPa to mmHg divide by 0.133.]

Blood-gas analyzers measure blood pH, and the oxygen and carbon-dioxide tensions of blood (pCO₂ and pO₂). These measurements, along with parameters (bicarbonate, base excess, and so on) derived by calculation from these measurements, allow evaluation of acid-base status and adequacy of ventilation and oxygenation. Thus, blood-gas analysis is helpful for assessment and monitoring of patients suffering a range of metabolic disturbances and respiratory diseases, both acute and chronic. It is an important component of the physiological monitoring that critically ill patients, particularly those who are mechanically ventilated, require.

The gold-standard sample for blood-gas analysis is arterial blood obtained aseptically via an indwelling arterial catheter (most often in the radial artery in adults and the brachial artery in neonates), or arterial puncture. In an intensive-care setting, arterial blood becomes arterial catheter. Placing the catheter into the artery is the sole purpose of the catheterization procedure, and the catheter is not intended to be a source of infection. The catheter is generally placed in the femoral artery, although other sites include the brachial artery in the arm and the femoral artery in the groin. Although arterial puncture does not place patients at risk of the serious complications associated with arterial catheterization, it is potentially hazardous and certainly not risk free. Furthermore, it is a procedure that is reported by patients to be significantly more painful than venous puncture. Specialist training in arterial puncture is essential for patient safety and comfort, and, in many countries, obtaining arterial blood is the almost exclusive preserve of medically qualified staff.

Capillary blood can be obtained by near-painless skin puncture using a lancet or automated incision device that punctures the skin to a depth of just 1 millimeter. It is the least-invasive and safest blood-collecting technique, and can be performed by all healthcare personnel after minimal training. The relative simplicity and safety profile of capillary-blood sampling and the necessity for only small volumes (100 μL to 150 μL) of blood for pH and gas analysis make capillary blood an attractive substitute for arterial blood, particularly among neonates and infants but also adults. The clinical value of capillary-blood gas results depends, however, on the extent to which pH, pCO₂, and pO₂ of capillary blood accurately reflect pH, pCO₂, and pO₂ of arterial blood.

**Capillary and arterial blood: theoretical considerations**

With a diameter of just 8 μm, capillaries are the smallest blood vessels. They are the connection between arterioles (the smallest artery) and venules (the smallest vein) and, thus, between the arterial and venous sides of the circulatory system. The capillary network (see Figure 1) is the site of nutrient and waste exchange between blood and tissue cells, made possible by the single-cell (1-μm) thickness of the capillary wall. Oxygenated arterial blood arriving via arterioles at the capillary network yields up its oxygen and other essential nutrients to tissue cells and capillaries are similar to the arterioles and the venules. The order of magnitude difference is 13 kPa (196 mmHg) in venules, kPa. The term arteriovenous shunt arterioles, capillaries, and venules. It is the exchange of oxygen and carbon dioxide between arterial and venous blood, via the capillary wall. Arterial pO₂ increases so the arterial capillary difference decreases, while arterial pCO₂ decreases so the arterial capillary difference increases. This is consistent with the principle of diffusion of gases across the capillary wall and the relatively higher pressure on the arterial side of this barrier.

- Arterial pO₂ decreases so does the arterial capillary difference
- Arterial pO₂ increases so does the arterial capillary difference

Capillary pH was similar to Arterial pH
- <0.05 difference
- Clinically insignificant

Capillary pCO₂ was similar to Arterial pCO₂
- 3-5 mmHg difference
- Clinically acceptable

Capillary pO₂ was different from Arterial pO₂
- 20 mmHg difference
- Clinically unacceptable
“There is really no substitute for arterial blood if accuracy of pO2 measurement is important, for example, for the prescription of long-term oxygen therapy”

Higgins C. Capillary-blood gases: To arterialize or not. MLO. November 2008:42-47
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21. Recording relevant information during sampling
#15: Elimination of the first drop of capillary blood sampled

**Primary Concern**
First drop can contaminate the blood specimen due to excess tissue fluid

**CLSI**
“Wipe away the first drop of blood with a clean gauze pad (unless testing the first drop is required by the manufacturer of the point of care device)”
#16: Order of draw in capillary blood collection

Collection Order
- Blood gas analysis
- EDTA samples
- Samples with other additives
- Samples for serum

Primary Concern
If more than two capillary specimens are needed....consider requesting a venipuncture (may provide more accurate results)
CLSI and WHO guidelines: Collection of Capillary Blood Specimens

23 Core Recommendations

For each step in the skin puncture technique

Other Recommendations

Minimize the influence of limitations of capillary blood sampling

Differences in analyte concentrations between capillary and venous specimens


WHO guidelines on drawing blood: best practices in phlebotomy, Geneva, Switzerland, 2010
#24: Patients for whom capillary blood sampling is not recommended

Edematous patients

- Poor Peripheral Perfusion

Sign and Symptoms of Dehydration
- Dry or sticky mouth
- Lethargy
- Sunken eyes
- Weight loss
- Low or no urine input
- Dark yellow urine
- Poor skin turgor
- Delayed capillary refill
- Dizziness
- Confusion/changes in mental status
- Lack of tears/sweat
- Falls/difficulty walking
- Low blood pressure
- Rapid heart rate
- Abnormal labs/electrolytes

Capillary refill time
(normal = < 2 seconds)
Objective 1 Conclusion

• CLSI and WHO guidelines for the collection of capillary blood specimens describe general procedures involved with obtaining capillary specimens.
Objective #2

- To describe the physiological differences in analyte concentrations in arterial, capillary and venous specimens
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<th>Arterial</th>
<th>Central Venous</th>
<th>Peripheral Venous</th>
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<td>ALT (U/L)</td>
<td>62</td>
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<td>81</td>
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<td>Albumin (g/dL)</td>
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Tietz Textbook of Clinical Chemistry, 3rd Edition
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</tr>
<tr>
<td>ALP (U/L)</td>
<td>114</td>
<td>113</td>
<td>107</td>
</tr>
<tr>
<td>Amylase (U/L)</td>
<td>149</td>
<td>148</td>
<td>177</td>
</tr>
<tr>
<td>AST (U/L)</td>
<td>20</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>Calcium (mg/dL)</td>
<td>8.1</td>
<td>8.2</td>
<td>8.3</td>
</tr>
<tr>
<td>Chloride (mmol/L)</td>
<td>99</td>
<td>97</td>
<td>101</td>
</tr>
<tr>
<td>CK (U/L)</td>
<td>82</td>
<td>73</td>
<td>91</td>
</tr>
<tr>
<td>Creatinine (mg/dL)</td>
<td>1.4</td>
<td>1.3</td>
<td>1.2</td>
</tr>
<tr>
<td>GGT (U/L)</td>
<td>13</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Potassium (mmol/L)</td>
<td>4</td>
<td>3.9</td>
<td>3.8</td>
</tr>
<tr>
<td>Sodium (mmol/L)</td>
<td>144</td>
<td>145</td>
<td>144</td>
</tr>
<tr>
<td>Total Protein (g/dL)</td>
<td>6.6</td>
<td>6.8</td>
<td>7.7</td>
</tr>
<tr>
<td><strong>Urea (mg/dL)</strong></td>
<td><strong>32</strong></td>
<td><strong>31</strong></td>
<td><strong>25</strong></td>
</tr>
<tr>
<td>Uric Acid (mg/dL)</td>
<td>8.1</td>
<td>8.1</td>
<td>7.9</td>
</tr>
</tbody>
</table>
Capillary Collection

- Capillaries are the smallest blood vessel connecting arterioles and venules.
- Capillary wall is a single cell thick which promotes the release of $O_2$ and nutrients and capture of $CO_2$ and waste.
- Blood collected by skin puncture represents a mixture of arteriole, capillary and venule blood.
**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
### Objective 2: Analyte Concentration Differences between Capillary and Venous

<table>
<thead>
<tr>
<th>Capillary Value Greater Than Venous Value (%)</th>
<th>No Difference Between Capillary and Venous Values</th>
<th>Capillary Value Less Than Venous Value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose 1.4%</td>
<td>Phosphorus</td>
<td>Bilirubin 5%</td>
</tr>
<tr>
<td>Potassium 0.9%</td>
<td>Urea</td>
<td>Calcium 4.6%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chloride 1.8%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sodium 2.3%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total Protein 3.3%</td>
</tr>
</tbody>
</table>

*Source: Tietz Textbook of Clinical Chemistry, 3rd Edition*
Differences between Arterial, Capillary and Venous Glucose Concentrations
Differences between Arterial, Capillary and Venous Glucose Concentrations

• Arterial Glucose ~ Capillary Glucose
• Capillary Glucose > Venous Glucose
Differences between Arterial, Capillary and Venous Glucose Concentrations

- Arterial Glucose ~ Capillary Glucose
- Capillary Glucose > Venous Glucose

Venous glucose = capillary glucose (fasting specimens)
Differences between Arterial, Capillary and Venous Glucose Concentrations

- Arterial Glucose ~ Capillary Glucose
- Capillary Glucose > Venous Glucose

Venous glucose = capillary glucose (fasting specimens)

Capillary glucose can be up to 20 – 25% higher than venous glucose
- After a meal
- Glucose load
- Glucose clamping studies
Objective 2 Conclusions

- Significant (clinically) variation may exist in analyte concentrations between arterial, capillary and venous specimens.
- To assist with clinical interpretation of results obtained using a capillary specimen, reference intervals specific for capillary blood specimens are advisable.
Objective #3

• To discuss pre-analytical errors associated with capillary specimen collection
  • Hemolysis
  • Clotted specimens
What is hemolysis?
Analyte Concentrations in RBCs and Plasma

**Sodium**: 16 mmol/L
**Chloride**: 52 mmol/L
**Potassium**: 100 mmol/L
**LDH**: 58,000 U/L
**AST**: 500 U/L
**ALT**: 150 U/L

**Sodium**: 140 mmol/L
**Chloride**: 104 mmol/L
**Potassium**: 4.4 mmol/L
**LDH**: 360 U/L
**AST**: 25 U/L
**ALT**: 30 U/L

“Release of K\(^+\) from as few as 0.5% of erythocytes can increase K\(^+\) values by 0.5 mmol/L”
– Tietz Textbook of Clinical Chemistry, 3\(^{rd}\) Edition
How do we currently detect hemolysis?

- Visual inspection of plasma

Problems:
  - time consuming (requires centrifugation)
  - manual qualitative assessment
  - between observer variability
How do we currently detect hemolysis?

- Hemolysis Index (Automated Clinical Chemistry Systems)

- Spectrophotometric assessment
  - Blanked bichromatic measurements
    - 405 nm and 700nm

- Problems:
  - Some time consumed
Can we detect hemolysis in a whole blood specimen?

- Not yet!
What are the rates of hemolysis?
Hemolysis in Serum Samples Drawn in the Emergency Department

Edward R. Burns, Noriko Yoshikawa
Department of Pathology, Albert Einstein College of Medicine and Montefiore Medical Center, New York, NY.

4,021 patients  (ED = 2,992  Med Ward = 1,029)

Both collected by Laboratory Phlebotomists

Rates of hemolysis:  12.4% in ED
1.6% in a Medical Ward
**Distribution of H Index (NICU, Well Baby Nursery)**

![Image of infant feet]

**Frequency vs. H Index Distribution**

- **N = 852**

**Percentile Breakdown**

<table>
<thead>
<tr>
<th>Percentile</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0th</td>
<td>7 (minimum)</td>
</tr>
<tr>
<td>25th</td>
<td>53 (1st quartile)</td>
</tr>
<tr>
<td>50th</td>
<td>97 (median)</td>
</tr>
<tr>
<td>75th</td>
<td>158 (3rd quartile)</td>
</tr>
<tr>
<td>100th</td>
<td>1246 (maximum)</td>
</tr>
</tbody>
</table>
Distribution of H Index (NICU, Well Baby Nursery)

75-80% of all specimens are visually hemolyzed

N = 852

- Minimum: 7
- 1st quartile: 53
- Median: 97
- 3rd quartile: 158
- Maximum: 1246
Will hemolysis affect clinical lab test results?
Effect of Hemolysis of Blood Gases and Electrolytes

pH (-.2%); *pO$_2$ (-4.9%); sO$_2$ (-4.9%); COHb (-11%); *Ca$^{2+}$ (-7%)
*pCO$_2$ (+4.1%); HCO$_3^-$ (+1.4%); *K$^+$ (+152%)

* Clinically Meaningful Bias

<table>
<thead>
<tr>
<th>Degree of change in analyte</th>
<th>Test result increased by hemolysis</th>
<th>Test result decreased by hemolysis</th>
<th>Test result increased or decreased by hemolysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slight change</td>
<td>Phosphate, Total Protein, Albumin, Magnesium, Calcium, Alkaline Phosphatase (ALP)</td>
<td>Haptoglobin, Bilirubin</td>
<td></td>
</tr>
<tr>
<td>Noticeable change</td>
<td>ALT, CK, Iron, Coagulation tests</td>
<td>Thyroxine (T4)</td>
<td></td>
</tr>
<tr>
<td>Significant change</td>
<td>Potassium (K+), Lactate Dehydrogenase (LD), AST</td>
<td>Troponin T</td>
<td>HGB, RBC, MCHC, Platelet Count</td>
</tr>
</tbody>
</table>
Objective #3

• To discuss pre-analytical errors associated with capillary specimen collection
  • Hemolysis
  • Clotted specimens
Sample Handling

• Mixing necessary to dissolve heparin
• Necessary to achieve uniform distribution of RBCs
  • Hemoglobin measurement
Hematocrit in 434 In-patients <7d, October 2007, RRL

The graph shows the distribution of hematocrit values for 434 in-patients within 7 days of admission in October 2007. The x-axis represents hematocrit values, and the y-axis represents frequency. The data is displayed in a histogram with a smooth curve fitting the distribution.

P. D’Orazio, M. Erdeszy, J. Cervera, S. Mansouri, H. Vinnick, L. Boone
Instrumentation Laboratory, Lexington, MA

Abstract

Systems for whole blood analysis in critical care and point-of-care (POC) settings are frequently affected by the presence of blood clots in the sample. Partially clotted blood may result from pre-analytical error or certain pathophysiological conditions. Miniaturized sensors and fluidic pathways, especially in systems for POC testing, increase the likelihood of trapping blood clots on sensors and interfering with sample analysis, often without knowledge of the user. The OEM® Premier® 3000 critical care analyzer (Instrumentation Laboratory) measures pH, PCO₂, PO₂, Na⁺, K⁺, Ca++, glucose, and hematocrit in 150 mL of whole blood. Electrochemical sensors are incorporated in a disposable measurement cartridge for analysis of 75, 150, 300, 450 or 600 samples over a three-week period. Recently, Intelligent Quality Management (IQM™) has been added to the system. IQM is an active, real-time, quality-control system which includes checks for the presence of blood clots on sensors using failure-pattern recognition. Upon detecting a blood clot on a sensor, the system automatically begins corrective action, including vigorous rinsing of the sensor surface. If the clot is not immediately removed, the sensor becomes disabled and results for that channel expressed until the system verifies removal of the clot. To demonstrate the importance of IQM in flagging errors due to clots, we evaluated the magnitude of errors produced by clots on sensors for blood gases, pH, and electrolytes. Clots were purposely formed by adding thrombogenic compounds to blood samples collected from healthy volunteers. Samples were analyzed on several OEM Premier 3000 instruments with IQM until a particular sensor was disabled. Then, blood samples without clots were analyzed both on the system with the disabled sensor and on a control system. Raw signals from the disabled sensor were retrieved and used to calculate what the reported result would have been, had the sensor not been disabled and the result reported while a clot was present on the sensor. Bias was calculated by comparison to the control instrument, and measured against total allowable error using CLIA 88 limits. The sensors with the largest clot-related errors were pH, PCO₂, and PO₂. For pH, 50% of the samples (range: 7.0 – 7.4); for PCO₂, 59% of the samples (range: 25 – 106 mmHg); and for PO₂, 89% of the samples (range: 26 – 66 mmHg) exceeded the allowable error. In the case of PCO₂, the magnitude and direction of the error indicate that the presence of clots interferes with diffusion of analyte across the outer sensor membrane, resulting in sluggish response. For pH, the direction and magnitude of the error are more complex. The presence of a clot not only causes sluggish response, but also appears to shift the local pH at the sensor in the alkaline direction. We conclude that the IQM system for the OEM Premier 3000 is effective in avoiding erroneous results due to the presence of blood clots on sensors, especially for pH and blood gases, the most important critical care analytes.

Introduction

Systems for whole blood analysis in critical care and POC settings are affected by the presence of blood clots in samples. Many traditional laboratory-based systems for critical-care analysis have built-in “clot catchers” to prevent clots from entering the systems fluidics. Clots which are not stopped by the clot catcher, or if a clot catcher is not present, may block fluidic lines and disable the system. The result is system down-time while the lines are removed and cleared by the user. Clots which are stopped by the clot catcher also result in increased maintenance while the clot catcher is replaced or cleaned. Miniaturized sensors and fluidics in unit-one and multi-one, cartridge-based systems for POC applications are particularly problematic in the presence of clots because often no user-performed maintenance is possible. If a clot causes cartridge fluidic problems, the cartridge must be discarded and replaced, a time-consuming and costly process. In addition to increased maintenance, system down-time, and expense, there is risk of incorrect reporting of analyst results if a clot becomes trapped on the surface of a sensor and the system has no mechanism for detecting or removing the clot. In this case, the clot may interfere with normal functioning of the sensor and the system may continue to report incorrect results.
NICU and PICU Cancellations

- 181,498 INR test orders (Saskatoon Health Region)
- 8,158 cancellations (4.5%)

- NICU - 313 INR test orders; 34 cancelled (10.9%)
- PICU – 657 INR test orders; 41 cancelled (6.2%)

Specimen collection issues (hemolysis, clotted and NSQ)

- NICU - 23/34 (67.6%)
- PICU - 29/41 (70.7%)
Objective 3 Conclusion

Pre-analytical errors such as hemolysis and clotting and represent significant challenges for the successful collection and transport for capillary blood specimens.
Capillary Collection Conundrum

Hip dysplasia
Osteogenesis Imperfecta
Internal Debate
Conclusions

• CLSI and WHO guidelines for the collection of capillary blood specimens describe general procedures involved with obtaining capillary specimens

• Significant (clinically) variation may exist in analyte concentrations between arterial, capillary and venous specimens.

• To assist with clinical interpretation of results obtained using a capillary specimen, reference intervals specific for capillary blood specimens are advisable.
Conclusions

• Pre-analytical errors such as hemolysis and clotting represent significant challenges for the successful collection and transport for capillary blood specimens.
Thank you for your time!

Any Questions?