Original contribution

The importance of blood sampling site for determination of hemoglobin and biochemistry values in major abdominal and orthopedic surgery

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Abstract

Study Objective: To determine whether sampling of blood from different sites influences laboratory results.

Design: Prospective, double-blind study.

Setting: University-affiliated hospital in Israel.

Patients: 100 ASA physical status I, II, and III patients undergoing major orthopedic or colon surgery (total hip and revision of total hip replacement, colon resection, or radical cystectomy).

Measurements: Blood was sampled simultaneously for hemoglobin, electrolytes, glucose, pH, blood gases, and lactate from three sampling sites (peripheral vein, central vein, and radial artery) at 5 time frames (after induction of anesthesia [baseline], one hr after induction of anesthesia, at the end of surgery, after one hr in the recovery room, and 4 hrs after surgery). At the same time points, recorded rectal temperature, mean arterial pressure, heart rate, and central venous pressure were recorded. Anesthesia, monitoring, and dwell volumes before sampling were standardized.

Main Results: There were no significant differences between the results of hemoglobin, electrolytes, glucose, pH, and blood gases obtained from different sampling sites and at different time frames. Lactate level (mmol/L) was higher in peripheral venous blood than it was in either the central vein or radial.

Keywords:
Blood hemoglobin and biochemistry;
Sampling sites;
General anesthesia;
Surgery
1. Introduction

The effect of sampling site on the measured values of various laboratory analyses has been questioned repeatedly in previous publications. Laboratory measurement values may vary between different sampling sites. It is well known that laboratory tests results obtained from capillary sampling via a percutaneous puncture may be different from those taken from peripheral venous and arterial samples, possibly owing to the mechanical and chemical effects during the sampling process [1-4]. Other authors have found no such a difference [5,6].

Further controversy on this topic is provided by Johnson et al [7], who showed that intraosseous and central venous blood biochemical and hemoglobin (Hb) values were similar during hemodynamic stability and throughout 30 minutes of resuscitation if no drugs were given through the intraosseous site. However, differences existed after 30 minutes of cardiopulmonary resuscitation and infusions through the intraosseous site. The authors concluded that laboratory values may be erroneous when intraosseous blood is used during periods of resuscitation lasting longer than 5 minutes and if drugs and fluid boluses have also been infused through this site [7].

Because there are certain clinical situations in anesthesia (ie, perioperative hypovolemia) where biochemical measurements (ie, blood lactate level) must be tracked closely and clinical decisions are affected by such readings, it is important to make the monitoring of these data more valid. Our hypothesis was that sampling of blood from different sites might have an influence on laboratory test results.

2. Materials and methods

After obtaining approval from Edith Wolfson Medical Center institutional review board for the study, and written, informed consent from patients, some 100 patients undergoing major surgeries (total hip and revision of total hip replacement, colon resection, and radical cystectomy) with general anesthesia that required peripheral, central venous, and arterial catheterization, were recruited to this prospective, double-blind study. These surgeries were chosen for study because they are the most frequently encountered major surgeries in our operating room (OR). We did not include liver and cardiac surgeries because of their propensity to affect lactate levels by producing regional or systemic low perfusion states. Patients with known hematologic disorders were also excluded from the study.

Each patient served as his or her own control. The patients were connected to the standard ASA monitors, and a 16-gauge intravenous (IV) catheter was inserted in the antecubital vein (peripheral vein). After induction of anesthesia with propofol, fentanyl, rocuronium, and isoflurane, central venous catheters via the right internal jugular vein and radial artery catheters were placed. The central line catheters were not heparin-coated. If the insertion of one of these three catheters (large peripheral vein, central vein, or arterial cannula) failed, the case was excluded from the study. As per routine, after surgery, a chest radiograph was performed in the recovery room to confirm the correct placement of the central venous catheter within the superior vena cava. If the catheter was incorrectly placed (ie, in the subclavian vein), the case was subsequently excluded from the study. A second peripheral vein was used for fluid administration.

The blood sample was drawn in preheparinized syringes and analyzed immediately in our OR laboratory. Blood was obtained for Hb and blood chemistry (glucose, sodium, potassium, lactate, pH, and blood gases). The samples were analyzed with the GEM Premier 3000 blood gas and electrolyte analyzer (Model 5700, GMI, Inc, Ramsey, MN). Blood sampling was performed simultaneously from the three sampling sites at 5 time points during the perioperative period: after induction of anesthesia (baseline), one hour after induction of anesthesia, at the end of surgery, after one hour in the recovery room, and 4 hours after surgery. Arterial oxygenation (PaO₂) was measured while the patient was receiving an inspired oxygen concentration (FiO₂) of 0.30. Arterial carbon dioxide concentration (PaCO₂) was measured while the patient was ventilated 10 breaths a minute with a tidal volume of 8 mL/kg. Mean arterial pressure (MAP), heart rate (HR), central venous pressure (CVP), and urine output (UO) were also recorded at the same time frames. The blood was obtained from a stopcock connected to the vein/artery through an extension tube (15-cm microspace pressure monitoring line; Biometrix Israel, Ltd, Jerusalem, Israel), and for the sampling from the central catheter, the stopcock was directly connected to the distal lumen of a double-lumen catheter. Volume of the dwell (“dead”) space volume of the extension + stopcock was 0.4 mL, whereas the volume of the distal lumen of the 7-French double-lumen catheter (Vygon, Ecoun, France) was 0.56 mL (0.4 mL + plus the stopcock 0.16 mL). All blood samples were obtained from catheters after discarding the first 10 mL (>5 times tubing and cannula “dead space” vol) of blood from each site [8]. For each patient, the total
2.1. Data analysis

Amount of sampled blood was 165 mL [10 mL discard × 15 samplings (5 time sampling points × 3 sampling sites) + (one mL blood for analysis × 15 samplings)]. This volume was replaced by lactated Ringer’s solution in a ratio of 3 mL for each milliliter of blood lost by the patient. The appropriate volume was replaced after each sampling.

The arterial catheter and central and peripheral veins dedicated to blood sampling were flushed with a 0.9 NaCl solution containing 2 IU/mL heparin at a rate of 1.2 mL/h. A dedicated flush system containing 2 IU/mL heparin was used to flush the sampling stopcock. The flushing was stopped two minutes before each sampling. The flushing system was placed near the sampling stopcock. The continuous flushing was stopped two minutes before each sampling. An independent researcher who was unaware of the sample site from which the blood was drawn analyzed all the blood samples. Intraoperatively, all patients received lactated Ringer’s solution at a rate of 10 mL kg⁻¹ h⁻¹ plus replacement of ongoing blood loss as required.

Postoperatively, patients were given lactated Ringer’s solution at a rate of 100 mL/h. Cell savers were not used. Patients were kept normothermic with fluid/blood warmers and forced-air warmers. Rectal temperature was monitored throughout the procedure. All patients had an indwelling urinary bladder catheter.

2.1. Data analysis

Data are presented as means ± standard deviation for continuous variables and as number of occurrences (percentage) or median (range) for noncontinuous variables. To calculate the necessary sample size for the study, a power analysis for analysis of variance was performed. A repeated-measure general linear analysis with Bonferroni adjustment was used to evaluate the between-subjects effects.

We also performed a multivariable analysis with repeated-measure general linear models. Primary outcome was difference in lactate levels between sampling sites (during all time point measurements). The effects of type of surgery, total fluid administered, age, gender, and patient’s body mass index on the primary outcome variable were studied. Data analysis was performed using the SPSS for Windows (SPSS, Inc, Chicago, IL). Statistical significance was achieved when P value is less than 0.05.

3. Results

Results are presented in Tables 1, 2, and 3. PaO₂, PaCO₂, UO, MAP, CVP, and rectal temperature did not change significantly at different sampling time points (Table 2). Table 3 presents laboratory results from the three sampling sites at different sampling time points. Only the serum lactate values changed significantly among the three sampling sites, but there was no correlation with the sampling time. Lactate level (mmol/L) was higher in peripheral venous blood than it was in the central vein or artery (<0.05) and higher in central venous blood than in arterial blood (2.04 ± 1.16, 1.74 ± 0.78, and 1.54 ± 0.68, respectively; P < 0.05).

Multivariable regression analysis did not reveal any effect of the type of surgery, total fluid administered, age, gender, or patient’s body mass index on the primary outcome variable (lactate levels) studied.

4. Discussion

In this study, sampling of blood from three different sites in major surgical procedures resulted in significant differences in serum lactate values. Our results clearly showed a higher lactate level in the peripheral venous sample compared with the other two sample sites, and a higher lactate level in central venous blood as compared with arterial blood.

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Table 1: Demographic data and intraoperative fluid balance

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean ± SD or median (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>68.5 ± 11</td>
</tr>
<tr>
<td>ASA physical status</td>
<td>II (I-III)</td>
</tr>
<tr>
<td>Surgery time (min)</td>
<td>172 ± 85</td>
</tr>
<tr>
<td>Rectal temperature (°C)</td>
<td>36.2 ± 0.8</td>
</tr>
<tr>
<td>Average intraoperative UO (mL/h)</td>
<td>110 ± 40</td>
</tr>
<tr>
<td>Blood loss (mL)</td>
<td>404 ± 271</td>
</tr>
<tr>
<td>Fluid input (mL)</td>
<td>3480 ± 1089</td>
</tr>
<tr>
<td>Blood transfused (mL)</td>
<td>150 ± 90</td>
</tr>
</tbody>
</table>

Table 2: Time-related oxygenation, ventilation, hemodynamics, and temperature

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sampling times¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>PaO₂ (mmHg)</td>
<td>128 ± 15</td>
</tr>
<tr>
<td>PaCO₂ (mmHg)</td>
<td>38 ± 6</td>
</tr>
<tr>
<td>Urinary output (mL/h)</td>
<td>115 ± 40</td>
</tr>
<tr>
<td>MAP (mmHg)</td>
<td>110 ± 10</td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>78 ± 12</td>
</tr>
<tr>
<td>CVP (mmHg)</td>
<td>12 ± 6</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>36.4 ± 0.9</td>
</tr>
</tbody>
</table>

Results are expressed as means ± SD. CVP = central venous pressure.

¹ Sampling times: 1 = before anesthesia (baseline); 2 = 1 hour after induction of anesthesia; 3 = end of surgery; 4 = after 1 hour in the recovery room; 5 = 4 hours after surgery.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Baseline (Peripheral)</th>
<th>1 h intraoperative (Peripheral)</th>
<th>End of surgery (Peripheral)</th>
<th>1 h in the PACU (Peripheral)</th>
<th>4 h in the PACU (Peripheral)</th>
<th>Baseline (Central)</th>
<th>1 h intraoperative (Central)</th>
<th>End of surgery (Central)</th>
<th>1 h in the PACU (Central)</th>
<th>4 h in the PACU (Central)</th>
<th>Baseline (Arterial)</th>
<th>1 h intraoperative (Arterial)</th>
<th>End of surgery (Arterial)</th>
<th>1 h in the PACU (Arterial)</th>
<th>4 h in the PACU (Arterial)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemoglobin (g/dL)</td>
<td>12.3 ± 1.6</td>
<td>12.1 ± 1.7</td>
<td>12.2 ± 1.6</td>
<td>11.5 ± 1.3</td>
<td>11.5 ± 1.3</td>
<td>11.3 ± 1.2</td>
<td>11.3 ± 1.1</td>
<td>11.4 ± 1.2</td>
<td>11.3 ± 1.2</td>
<td>11.3 ± 1.2</td>
<td>13.3 ± 25</td>
<td>129 ± 25</td>
<td>129 ± 28</td>
<td>130 ± 31</td>
<td>136 ± 29</td>
</tr>
<tr>
<td>Glucose (mg/dL)</td>
<td>123 ± 28</td>
<td>122 ± 36</td>
<td>125 ± 40</td>
<td>136 ± 37</td>
<td>131 ± 39</td>
<td>135 ± 29</td>
<td>129 ± 27</td>
<td>130 ± 31</td>
<td>129 ± 28</td>
<td>129 ± 28</td>
<td>133 ± 25</td>
<td>129 ± 25</td>
<td>129 ± 28</td>
<td>130 ± 31</td>
<td>136 ± 29</td>
</tr>
<tr>
<td>Sodium (mEq/L)</td>
<td>138 ± 4</td>
<td>136 ± 13</td>
<td>138 ± 4</td>
<td>137 ± 4</td>
<td>137 ± 4</td>
<td>137 ± 4</td>
<td>138 ± 11</td>
<td>137 ± 3</td>
<td>137 ± 4</td>
<td>137 ± 4</td>
<td>137 ± 4</td>
<td>137 ± 4</td>
<td>137 ± 4</td>
<td>137 ± 4</td>
<td>137 ± 4</td>
</tr>
<tr>
<td>Potassium (mEq/L)</td>
<td>4 ± 0.7</td>
<td>3.8 ± 0.6</td>
<td>3.8 ± 0.6</td>
<td>4 ± 0.7</td>
<td>3.8 ± 0.5</td>
<td>4 ± 0.5</td>
<td>4 ± 0.5</td>
<td>3.9 ± 0.5</td>
<td>4 ± 0.5</td>
<td>3.9 ± 0.5</td>
<td>4 ± 0.5</td>
<td>4 ± 0.5</td>
<td>4 ± 0.5</td>
<td>4 ± 0.5</td>
<td>4 ± 0.5</td>
</tr>
<tr>
<td>pH</td>
<td>7.38 ± 0.05</td>
<td>7.37 ± 0.06</td>
<td>7.39 ± 0.06</td>
<td>7.37 ± 0.05</td>
<td>7.37 ± 0.05</td>
<td>7.33 ± 0.03</td>
<td>7.36 ± 0.03</td>
<td>7.36 ± 0.05</td>
<td>7.29 ± 0.07</td>
<td>7.37 ± 0.08</td>
<td>7.37 ± 0.06</td>
<td>7.37 ± 0.05</td>
<td>7.37 ± 0.05</td>
<td>7.37 ± 0.05</td>
<td>7.37 ± 0.05</td>
</tr>
<tr>
<td>Lactate (mmol/L)</td>
<td>1.9 ± 1</td>
<td>1.7 ± 0.9</td>
<td>1.4 ± 0.7</td>
<td>1.8 ± 1</td>
<td>1.5 ± 0.8</td>
<td>1.4 ± 0.7</td>
<td>1.8 ± 0.7</td>
<td>1.6 ± 0.7</td>
<td>2.2 ± 1.5</td>
<td>1.9 ± 0.8</td>
<td>1.7 ± 0.7</td>
<td>2.1 ± 1.1</td>
<td>1.8 ± 0.7</td>
<td>1.6 ± 0.6</td>
<td>Peripheral 2.04 ± 1.16*</td>
</tr>
</tbody>
</table>

Results are expressed as means ± SD.

*P < 0.05.
Some studies found no difference in the lactate levels sampled from the central vein, pulmonary artery or arterial site, in hemodynamically stable but critically ill patients [8-11]. Others found an arteriovenous lactate level discrepancy [12] or reported that lactate level may be higher in blood collected from the inferior vena cava [13]. Lavery et al [14] showed a high correlation between arterial and peripheral venous lactate levels in trauma patients. However, Gallagher et al [15] suggested that caution be used in the routine substitution of venous as compared with arterial lactate.

The reason for these differences is unclear. Sound explanations for our finding may be differences in regional organ perfusion and/or peripheral venous vasoconstriction as causative factors.

In view of our findings, we support the opinion of Gallagher et al [15], that caution should be used in the routine substitution of venous as compared with arterial lactate.

In spite of these statistical differences, the biological significance of these findings is uncertain at low lactate levels, such as those encountered in our patients. However, such a 20% difference between the arterial and venous lactate levels may be important at higher, pathological lactate levels.

The time of sampling did not influence this trend because all the factors that might have adversely affected serum lactate (oxygenation, ventilation, temperature, fluid balance, and patient’s hemodynamic and volume status as reflected by UO, CVP, MAP, and HR) did not differ over time.

The lack of differences among other laboratory parameters may be explained in part by the hemodynamic stability, normovolemia, normothermia, and normal oxygenation and ventilation throughout surgery and the immediate postoperative period. On the other hand, the lack of hemodynamic changes and hypothermia may strengthen the importance of our finding, that there is a real difference in the lactate levels measured at different sampling sites.

Laboratory testing includes collection and analysis of blood samples. Both the method and site of blood collection might contribute to analytical variability. In 1985, Neptun et al [16] reported the effect of different blood collection procedures and sampling site selection on analysis of serum chemistry parameters in rats. Their conclusion was that sampling site and collection method may be a major source of variation in clinical chemistry measurements, and might have an influence over the interpretation of treatment-related changes in individual parameters.

In conclusion, our study demonstrated that blood lactate levels differed among the three sampling sites, and that it was highest in the peripheral vein site.

Because there are certain clinical situations where the lactate levels are tracked closely and clinical decisions are affected by such readings, we recommend that once lactate sampling is started from a certain sampling site (preferably arterial), it should be continued from the same site to render interpretation of the laboratory results more reliable.

References