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The Invalidity of Monitoring Transcutaneous Oxygen Tension in Patients Who Have Chronic Renal Failure

John R. Armstrong, MD,* Thomas W. Kreps, BS†, William A. Conway, MD* Francis Dumler, MD† and John Popovich, Jr, MD*

We assessed accuracy of monitoring transcutaneous oxygen tension (PtcO2) in patients with chronic renal failure (CRF). Sixteen stable individuals undergoing chronic maintenance hemodialysis were studied. Correlations between simultaneously determined PtcO2 and arterial oxygen tension (PaO2) were made both before and during dialysis. Comparisons were made with a group of 22 consecutive patients in whom respiration was mechanically assisted, who were hemodynamically stable (urine output greater than 30 mL/hour, pulse less than 130 beats/min, and mean arterial blood pressure greater than 80 mm Hg in the absence of pressor agents), and who had normal renal function.

The reliability of transcutaneous oxygen monitors using heated platinum electrodes to predict arterial oxygen tension (PaO2) has been demonstrated in neonatal intensive care patients, selected adult intensive care patients, and during exercise cardiopulmonary stress testing (1-3). The correlation between transcutaneous oxygen tension (PtcO2) and PaO2 in hemodynamically unstable patients, however, has been poor, probably as a result of redistribution of blood flow away from the cutaneous vascular bed (4).

The accuracy of transcutaneous oxygen monitoring in patients who have chronic renal failure (CRF) has not previously been studied. In view of the recognized phenomenon of dialysis-induced hypoxemia (5-6), its hemodynamic consequences (7-8), and the relative frequency with which patients who have CRF require intensive care, a simple inexpensive and noninvasive method of monitoring oxygenation could have significant clinical advantages. The present study evaluates the accuracy of PtcO2 monitoring in patients who have CRF and who have been on maintenance output hemodialysis.

Methods

Sixteen stable patients who had undergone chronic maintenance hemodialysis for a mean of 29 months (range of four to 32 months) were studied. Comparisons were made with a control group of 22 consecutive, hemodynamically stable patients in whom respiration was mechanically assisted and who had normal renal function. Hemodynamic stability was defined by the presence of all of the following criteria: mean blood pressure greater than 80 mm Hg in the absence of pressor agents, urine output greater than 30 mL/hour, and pulse rate less than 130 beats/min. PtcO2 and PaO2 were simultaneously determined in both groups, and among chronic hemodialysis patients, measurements were made immediately prior to and during hemodialysis.

PtcO2 was measured using a Radiometer Tcm1 T<sub)t</sub> oxygen monitor (Copenhagen, Denmark). The principle of operation is a Clark electrode consisting of a platinum cathode surrounded by a silver anode containing a heating element and NTC-resistor for temperature control. A two-point calibration using atmospheric air adjusted for barometric pressure and a zero PO2 sodium sulfite solution was established before placing the electrode on the right anterior chest below the clavicle. The electrode was maintained at 45°C and recalibrated every two hours and between each patient. A minimum of 20 min equilibration time was allowed for placement before readings were taken.

Among CRF patients, the correlation between PtcO2 and PaO2 was poor (R = .5232, p ≤ .05), regardless of whether determined immediately before (R = .5454, p ≤ .05) or during hemodialysis (R = .4353, p ≤ .05). In contrast, the PtcO2 correlated well with PaO2 among stable, mechanically ventilated patients (R = .9822, p ≤ .01).

PtcO2 monitoring in patients with CRF requiring maintenance hemodialysis is of limited value whether performed before or during dialysis.
Simultaneously collected arterial blood samples were obtained via direct arterial puncture or an indwelling arterial catheter, when present. Specimens were iced and immediately processed through an IL 513 Blood Gas Analyzer (Instrumentation Laboratories, Lexington, Massachusetts). All arterial blood gasses were temperature corrected according to standard formulas (9). PtcO₂, PaO₂, urine output, pulse, blood pressure, hematocrit value and, when appropriate, length of time on the current hemodialysis run were recorded at the time of measurement.

Results

Table I displays patient data for each group. Except for pulse rate, which was higher among the control patients, there were no significant differences between groups for the variables noted.

The correlation coefficients and regression data for PtcO₂ and PaO₂ for the same groups are shown in Table II. The correlation for PtcO₂ and PaO₂ among patients who have renal failure is significantly lower than controls, whether monitoring occurred during the hemodialysis run or between dialyses. The corresponding scatter plots and regression lines are shown in Figures 1, 2, and 3. The mean difference between PaO₂ and PtcO₂ for control subjects and patients who have CRF was 10.3 ± 1.8 torr and 11.6 ± 3.6 torr, respectively (p < .05). Review of the CRF data showed that the PtcO₂ tracked in the same direction as the PaO₂ in only seven of 15 patients in whom serial determinations were made.

To evaluate the possible effects of anemia on the correlation between PtcO₂ and PaO₂, we matched control subjects and CRF patients by hematocrit levels. Anemic control subjects continued to show a significantly higher correlation coefficient than did patients who had CRF at the same hematocrit level (Table III).

Discussion

The amount of oxygen diffusing through the skin to reach the transcutaneous electrode varies in a number of conditions. Skin thickness, cutaneous oxygen consumption, and local perfusion levels all influence this phenomenon (1,2,10). A fall in PtcO₂ may signify a hemodynamic alteration rather than a true change in arterial oxygenation in some circumstances. Oxygen transport gradients across the skin have clearly been shown to change with local temperature fluctuations, alterations in cardiac output, peripheral vascular resistance, and total oxygen transport (4). Although changes in PtcO₂ do not always reflect changes in PaO₂, they may serve as an early warning sign of subtle alterations in a patient’s condition.

Table I

<table>
<thead>
<tr>
<th>Patient Data</th>
<th>Controls</th>
<th>Chronic Renal Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (M/F)</td>
<td>13/9</td>
<td>6/10</td>
</tr>
<tr>
<td>Age (years)</td>
<td>58.8 ± 2.8</td>
<td>58.9 ± 2.2</td>
</tr>
<tr>
<td>Pulse (beat/min)</td>
<td>110.0 ± 1.5</td>
<td>89 ± 3.1</td>
</tr>
<tr>
<td>Mean blood pressure (mm Hg)</td>
<td>93.8 ± 1.2</td>
<td>91 ± 4.6</td>
</tr>
</tbody>
</table>

Table II

<table>
<thead>
<tr>
<th>Comparison of Correlations of PtcO₂ with PaO₂</th>
<th>Number of Observations</th>
<th>PaO₂ (mm Hg mean ± SE)</th>
<th>Regression Coefficient*</th>
<th>Correlation Coefficient†</th>
<th>PtcO₂ Intercept (mm Hg mean ± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls</td>
<td>41</td>
<td>109 ± 9.4</td>
<td>.9348</td>
<td>.9822</td>
<td>−3.22 ± 3.5</td>
</tr>
<tr>
<td>CRF total</td>
<td>38</td>
<td>79 ± 2.0</td>
<td>.8547</td>
<td>.5232</td>
<td>−3.97 ± 18.0</td>
</tr>
<tr>
<td>CRF interdialysis period</td>
<td>13</td>
<td>84 ± 4.1</td>
<td>.5491</td>
<td>.5450</td>
<td>28.40 ± 21.8</td>
</tr>
<tr>
<td>CRF during hemodialysis</td>
<td>25</td>
<td>76 ± 1.8</td>
<td>.9141</td>
<td>.4353</td>
<td>−11.90 ± 30.0</td>
</tr>
</tbody>
</table>

* p < .05 for PaO₂ and regression coefficient between controls and all CRF groups
† Significant difference between the correlation coefficient of control and CRF groups (p < .01)
Monitoring Transcutaneous Oxygen Tension

The PtcO₂ has been shown to correlate very well with the PaO₂ over a wide range of arterial oxygen levels under conditions of adequate cardiac output (4). This was confirmed in the present study among the hemodynamically stable patients undergoing ventilation. The poor correlation between PtcO₂ and PaO₂ among patients who had CRF, both during hemodialysis and in the interdialysis period, was unexpected. Hypoxia, as well as several hemodynamic changes, has occurred in response to hemodialysis. Decrease in pulmonary arterial pressure, cardiac index, and stroke index, without an increase in heart rate or even a paradoxical bradycardia, have been documented (7,8). These may occur without significant change in mean arterial pressure and perhaps could alter oxygen transport sufficiently to cause a variable and disproportionate lowering of the PtcO₂ relative to PaO₂. However, the reason for the poor correlation of PtcO₂ with PaO₂ during the interdialysis interval remains unclear. Tissue edema may have been a factor although peridialysis weights in these selected patients were not much above their

Table III
Correlation Coefficient of PtcO₂ with PaO₂ Among Patients Matched for Hematocrit

<table>
<thead>
<tr>
<th></th>
<th>Number of Observations</th>
<th>PaO₂ (mm Hg, mean ± SE)*</th>
<th>Correlation Coefficient*</th>
<th>Mean Hematocrit †</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls</td>
<td>19</td>
<td>121 ± 17.7</td>
<td>.9898</td>
<td>29.0 ± .55</td>
</tr>
<tr>
<td>CRF</td>
<td>16</td>
<td>79 ± 3.3</td>
<td>.7009</td>
<td>27.6 ± .82</td>
</tr>
</tbody>
</table>

*Significant difference between controls and CRF patients values, for PaO₂ and correlation coefficients (p<.01)
†No significant difference between control and CRF patients at matched hematocrit

![Fig 1](PtcO₂ vs PaO₂ in 13 patients who had chronic renal failure (CRF) prior to hemodialysis run. R = .5454, p ≤ .05.)

![Fig 2](PtcO₂ vs PaO₂ in 25 patients who had CRF and were undergoing dialysis. R = .04353, p ≤ .05.)

![Fig 3](PtcO₂ vs PaO₂ in 41 control patients. R = .9822, p ≤ .01.)
dry-target weight. Other speculative considerations might include changes in P₅₀ (11) or the presence of a microvascular disease affecting cutaneous perfusion. Even so, the PtCo₂ did not consistently track in the same direction as the PaO₂ in almost 50% of determinations.

In an effort to determine if a lower arterial O₂ content may have affected the transport gradient in our CRF patients, we used control subjects whose low hematocrit values were matched with those of the patients for comparison. Patients who were anemic and who had normal renal function continued to have a significantly higher correlation of PtCo₂ with PaO₂ than patients who had CRF at the same hematocrit level (p<.01).

We conclude that monitoring transcutaneous oxygen concentration in patients who have CRF and who require maintenance hemodialysis is not helpful. This is true whether monitoring occurs during hemodialysis or in the interdialysis interval. PtCo₂ readings in these patients are not a reliable indicator of either changes in arterial oxygenation or other parameters that can affect the cutaneous O₂ gradient. Further studies are needed to explore the potential causative factors for this phenomenon.

References