v-TAC Software

v-TAC can convert Peripheral Venous Acid-Base and Blood Gas values to Arterial Acid-Base and Blood Gas values, with an accuracy and precision useful in clinical practice.

v-TAC will allow clinicians to obviate the need for Arterial Puncture when assessing the Blood Gas and Acid-Base status of the acutely ill patient or the chronic obstructive lung patient during their periods of exacerbation.

This white paper provides a summary of all published v-TAC articles, and gives a quick overview of the v-TAC Software functionality, and how great the Venous v-TAC-converted values compares to Arterial values in different medical segments and specialities.
A method for calculation of arterial acid-base and blood gas status from measurements in the peripheral blood

Introduction
This paper presents and introduces a novel method for calculation of arterial acid-base and blood gas status from a venous blood sample, supplemented by a simultaneous pulse oximetry. The potential use of the method is shown using a few, very different, clinical examples. The paper also examines the sensitivity of the model to e.g. measurement errors and physiological assumptions.

The v-TAC model

![Diagram](image)

The principle of the method is as follows. Peripheral venous blood differs from arterial blood by its content of oxygen and carbon dioxide. Arterial blood values can therefore be calculated by removing CO₂ and adding O₂ in a constant ratio (RQ) that reflects the metabolism of tissue. The method simulates addition of oxygen to the peripheral venous blood until simulated oxygen saturation matches that measured non-invasively from a pulse oximeter. The amount of oxygen added in this simulation is then used to calculate the amount of CO₂ removed, and as a consequence the complete arterial oxygen and acid-base status can be determined.

Results

<table>
<thead>
<tr>
<th>Arterial variable</th>
<th>pH</th>
<th>PCO₂ (kPa)</th>
<th>PO₂ (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum arterialisated-arterial</td>
<td>0.011</td>
<td>-0.30</td>
<td>5.26</td>
</tr>
<tr>
<td>Laboratory acceptable performance criteria [24]</td>
<td>±0.04</td>
<td>±0.67³</td>
<td>±0.6³</td>
</tr>
</tbody>
</table>

* Original value given as ±5 mmHg.
* Original value given as ±3 standard deviations, where one standard deviation is assumed to be 0.2 kPa according to [17].

The proof of concept of the method is illustrated in three patients as shown in the above table 2. In each case measured venous values were given as input to the model, and arterial values are calculated as shown. For each patient calculated values of arterial pH and PCO₂ were very close to those measured, i.e. within 0.011 and 0.30 kPa.

This paper also evaluated the method against measurement errors, i.e. pulse oximetry and air bubbles present in sampled blood. Errors in SpO₂ of + 2% give very little error in the calculation of arterial pH and PCO₂. Errors in SpO₂ give an error in the calculated arterial PO₂ of about 2 kPa when SpO₂ is varied from 97–95%.

In arterial and venous blood air bubbles gave negligible errors in pH and PCO₂. For PO₂, the error in the calculated arterial value is less than that in the directly measured arterial blood with air bubbles.

This paper highlights the potential of the method as a clinical tool and illustrating the need for clinical trials to test its applicability.

Reference
Evaluation of a method for converting venous values of acid-base and oxygenation to arterial values

Introduction
This paper evaluates the method presented previously by comparing the calculated arterial values of pH, carbon dioxide tension (PCO₂) and oxygen tension (PO₂) from venous values and pulse oximetry with simultaneously measured arterial values in 103 adult patients (COLD, stable ICU and unstable ICU patients).

Results
Calculated values of arterial pH and PCO₂ had very small bias and standard deviations regardless of the venous sampling site. In all cases these errors were within those considered acceptable for the performance of laboratory equipment, and well within the limits of error acceptable in clinical practice. In addition, the standard deviation (SD) of calculated values of pH and PCO₂ was similar to the variability between consecutive arterial samples. For peripheral oxygen saturation values < 96%, the method can calculate PO₂ with an SD of 0.93 kPa, which may be useful in clinical practice. Calculations made from peripheral venous blood were significantly more accurate than those from central venous blood.

In conclusion, this paper shows that values of arterial pH and PCO₂ can be calculated precisely from peripheral venous blood in a broad patient population. The method has potential for use as a screening tool in both emergency medical departments and in medical and surgical wards to assess a patient’s acid-base and oxygenation status. In departments where arterial blood gas values are used to monitor patients (eg. pulmonary medicine), the method might be used to reduce the number of arterial samples taken, thereby reducing the need for painful arterial punctures.

The table shows bias (2SD) for the difference between arterial and calculated arterial blood values from venous blood taken from the three sampling sites compared with laboratory performance guidelines

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
<th>PCO₂ (kPa)</th>
<th>PO₂ (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterial - calculated arterial values from peripheral venous blood (n = 103)</td>
<td>0.002 (0.27)</td>
<td>-0.040 (0.517)</td>
<td>0.269 (1.352)</td>
</tr>
<tr>
<td>Arterial - calculated arterial values from central venous blood (n = 73)</td>
<td>0.011 (0.023)</td>
<td>-0.176 (0.354)</td>
<td>0.037 (1.374)</td>
</tr>
<tr>
<td>Arterial - calculated arterial values from mixed venous blood (n = 18)</td>
<td>-0.005 (0.021)</td>
<td>0.055 (0.403)</td>
<td>0.056 (1.544)</td>
</tr>
<tr>
<td>Laboratory acceptable performance criteria</td>
<td>±0.04</td>
<td>±0.67</td>
<td>±0.64</td>
</tr>
</tbody>
</table>

PO₂, carbon dioxide tension; PO₂, oxygen tension ; Spo₂, peripheral oxygen saturation.

The figure below shows Bland-Altman plots of calculated vs. measured arterial values of pH, PCO₂ and PO₂.

Reference
Converting venous acid-base and oxygen status to arterial in patients with lung disease

Introduction
This paper evaluates the method for calculating arterial pH, PCO$_2$ and PO$_2$ from venous blood in 40 patients (22 in-patients and 18 out-patients) with chronic obstructive lung disease (COLD). Blood samples, both arterial and venous, were taken using standard sampling technology and collected as part of daily clinical care.

Results
Measured and calculated values of pH and PCO$_2$ correlated well, with the difference between them having a very small bias and standard deviation within those considered acceptable for laboratory equipment and clinical practice. All but four patients had peripheral oxygen saturation (SpO$_2$) < 96%, and for these measured and calculated PO$_2$ correlated well, with a difference such that the bias and standard deviation suggested that calculated PO$_2$ may be clinically useful.

The present study evaluates a method for calculating arterial pH, carbon dioxide tension and oxygen tension from venous blood. It has been shown that arterial pH and carbon dioxide tension can be calculated precisely, and that oxygen tension can be calculated with reasonable precision in the vast majority of patients. This method might be useful in reducing the need for painful arterial punctures.

The table shows differences between measured and calculated values for arterial blood, compared with laboratory performance guidelines

<table>
<thead>
<tr>
<th>Subjects n</th>
<th>Arterial - calculated arterial values</th>
<th>Laboratory acceptable performance criteria*</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>38</td>
<td>±0.04</td>
</tr>
<tr>
<td>PCO$_2$ kPa</td>
<td>-0.001 ± 0.029</td>
<td>±0.57</td>
</tr>
<tr>
<td>PO$_2$ kPa</td>
<td>-0.00 ± 0.55</td>
<td>±0.57</td>
</tr>
<tr>
<td>SpO$_2$ &lt;96%</td>
<td>0.11 ± 1.05*</td>
<td>±0.67</td>
</tr>
<tr>
<td>SpO$_2$ &lt;96%</td>
<td>-0.13 ± 1.79</td>
<td>±0.57</td>
</tr>
</tbody>
</table>

Data are presented as bias ±2SD, unless otherwise stated. PCO$_2$: carbon dioxide tension; PO$_2$: oxygen tension; SpO$_2$: peripheral oxygen saturation. *: acceptable range, assuming that these guidelines are comparable to a 95% confidence interval given by Ranic. **: original value given as ±0.5 mmHg; ***: original value given as ±200 kPa of measurement equipment error, where 10 is assumed to be 0.2 kPa according to Radiometer AG (Branhøj, Denmark) [10].

The figure shows Bland-Altman plots of measured vs. calculated arterial values of pH, PCO$_2$ and PO$_2$

Reference
Mathematical arterialisation of venous blood in emergency medicine patients

Introduction
This study evaluates the method for mathematically transforming peripheral venous values into arterial values in emergency medicine patients. Patients were divided in two groups, i.e. group A, with a clinical indication for taking an arterial blood sample (51 patients) and group B, who did not have clinical indication for arterial blood sampling and who were (146 patients).

Results
Calculated and measured arterial pH and PCO$_2$ values correlated well with correlation coefficients ($r^2$) for group A being pH 0.94 and PCO$_2$ 0.97; and for group B, pH 0.87, PCO$_2$ 0.83. Bland–Altman limits of agreement were well within the limits of acceptable laboratory and clinical performance. Calculated values of arterial PO$_2$ followed a set of predefined rules relating calculated and measured PO$_2$ levels in all cases. These sets of rules were derived from a previous sensitivity analysis. The method represents an improvement on the use of venous blood alone where the correlation coefficients were as follows: group A, pH 0.85, PCO$_2$ 0.88; group B, pH 0.79, PCO$_2$ 0.59. For venous blood alone Bland-Altman limits of agreement for PCO$_2$ were at the border of (group A) or beyond (group B) acceptable clinical limits.

In conclusion, the mathematical arterialization method presents several potential benefits, e.g. increased patient-comfort and the potential to maximize the information on acid-base and blood gas status from venous blood.

The table shows a Comparison of measured arterial values with calculated arterial and measured venous values

<table>
<thead>
<tr>
<th></th>
<th>Group A (n=47)</th>
<th></th>
<th>Group B (n=101)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Venous conversion method</td>
<td>Venous blood alone</td>
<td>Venous conversion method</td>
<td>Venous blood alone</td>
</tr>
<tr>
<td></td>
<td>BIAS ± 2 × SD</td>
<td>$r^2$</td>
<td>BIAS ± 2 × SD</td>
<td>$r^2$</td>
</tr>
<tr>
<td>pH</td>
<td>-0.001 ± 0.024</td>
<td>0.94</td>
<td>0.034 ± 0.038</td>
<td>0.83</td>
</tr>
<tr>
<td>PCO$_2$ (kPa)</td>
<td>-0.06 ± 0.46</td>
<td>0.97</td>
<td>-0.86 ± 0.98</td>
<td>0.88</td>
</tr>
<tr>
<td>PO$_2$ (kPa)</td>
<td>-0.06 ± NA</td>
<td>0.68</td>
<td>5.86 ± NA</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Clin. accept. clinically acceptable difference [5]; Lab. accept. laboratory acceptable performance criteria [17]; NA, not available.

The figure shows Bland-Altman plots of measured vs. calculated arterial values of pH, PCO$_2$ and PO$_2$ for group A.

Reference
Calculating acid-base and oxygenation status during COPD exacerbation using mathematically arterialized venous blood

Introduction
This study evaluates the method for mathematically transforming peripheral venous values into arterial values to monitor acid-base and oxygenation in 54 patients during admission for exacerbation of chronic obstructive pulmonary disease (COPD). The only deviation from normal clinical practice was the sampling of an extra peripheral venous blood.

Results
Fifty-four patients, median age 67 years (range 62 – 75), were studied on average 3 days. Mean values of pH, PCO₂ and PO₂ were 7.432 ± 0.047, 6.8 ± 1.7 kPa and 9.2 ± 1.5 kPa, respectively. Calculated and measured arterial pH and PCO₂ agreed well, with differences having small bias and SD (0.000 ± 0.022 pH, −0.06 ± 0.50 kPa PCO₂), significantly better than venous blood alone. Calculated values of arterial PO₂ followed a set of predefined rules relating calculated and measured PO₂ levels in all cases. Calculated values could track patients, with p-values showing no significant differences in maximal changes in measured and calculated values (pH p = 0.96, PCO₂ p = 0.62, PO₂ p = 0.33), and time-course plots matching quantity and pattern of change in measurements.

In conclusion, this study has shown that the mathematical arterialisation method provides a real alternative to the discomfort of multiple arterial punctures for patients with COPD admitted during periods of exacerbation.

The table below shows a comparison of measured arterial values with calculated arterial and measured venous

<table>
<thead>
<tr>
<th></th>
<th>Venous conversion method</th>
<th>Venous blood alone</th>
<th>Lab. accept</th>
<th>Clin. accept</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bias±2×SD</td>
<td>r²</td>
<td>Bias±2×SD</td>
<td>r²</td>
</tr>
<tr>
<td>pH</td>
<td>0.000±0.020</td>
<td>0.96</td>
<td>0.025±0.042</td>
<td>0.83</td>
</tr>
<tr>
<td>PCO₂ (kPa)</td>
<td>−0.06±0.50</td>
<td>0.98</td>
<td>−0.75±1.24</td>
<td>0.90</td>
</tr>
<tr>
<td>PO₂ (kPa)</td>
<td>0.11±N/A</td>
<td>0.63</td>
<td>3.83±N/A</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Clin. accept., clinically acceptable difference (8); Lab. accept., laboratory acceptable performance criteria (7). *PO₂ is not normally distributed and therefore SD is not calculated.

The figure below shows Venous (triangles, dot-dash lines), Arterial (circles, solid lines) and calculated Arterial (squares, dotes lines) in a single patient studied on 6 consecutive days

The figure shows Bland-Altman plots of measured vs. calculated arterial values of pH, PCO₂ and PO₂

Reference
v-TAC publications

Publications for the v-TAC technology:

A method for calculation of arterial acid-base and blood gas status from measurements in the peripheral venous blood.
*Computer Methods and Programs in Biomedicine, 81:18-25, (2006).*

Evaluation of a method for converting venous values of acid-base and oxygenation status to arterial values.
*European Journal of Emergency Medicine, 26:268-272, (2009).*

Calculating acid-base and oxygenation status during COPD exacerbation using mathematically arterialised venous blood
*Clin Chem Lab Med 2012;50(12)*

Supporting publications for the v-TAC technology:

L. Gattinoni, E. Carlesso, M. Cressoni.
*Critical Care, 17:18-23, (2011).*

R. Treger, S. Piourou, N. Kamangar, D. Corry.
Agreement between Central Venous and Arterial Blood Gas Measurements in the Intensive Care Unit.
*Journal of American Society of Nephrology, , (2009).*

S.E. Rees, S. Andreassen
Mathematical models of oxygen and carbon dioxide storage and transport: The acid-base chemistry of blood.
*Critical Reviews in Biomedical Engineering, 33(3):209-64, (2005).*

Rang LC, Murray HE, Wells GA, et al.
Can peripheral venous blood gases replace arterial blood gases in emergency department patients.
*European Journal of Emergency Medicine, 4:7-15, (2002).*

Malatesha G, Singh NK, Bharija A, et al.
Comparison of arterial and venous pH, bicarbonate, PCO2 and PO2 in initial emergency department assessment.
*European Journal of Emergency Medicine, 24:569-571, (2007).*

Zavorsky GS, Cao J, Mayo NE, et al.
Arterial versus capillary blood gases: a meta-analysis.

Turner JS et al.
Patients recollection of intensive care unit experience
*Crit Care Med, 18:966-968, (1990)*

Correlation between acid-base parameters measured in arterial blood and venous blood samples peripherally, from vena cavae superior, and from the pulmonary artery.
*European Journal of Emergency Medicine, 15:86-91, (2008).*

Converting venous acid-base and oxygen status to arterial in patients with lung disease.
*European Respiratory Journal, 33:1141-1147, (2009).*

The cost-effectiveness of venous-converted acid-base and blood gas status in pulmonary medical departments.
*ClinicoEconomics and Outcomes Research, 3:1-7, (2011).*

C. Higgins
Central venous blood gas analysis
*Radiometers knowledge site about acute care testing - Central venous blood gas analysis 2011*

Mathematical modelling of the acid-base chemistry and oxygenation of blood: a mass balance, mass action approach including plasma and red blood cells.

S.E. Rees, S. Andreassen
Mathematical models of oxygen and carbon dioxide storage and transport: Interstitial fluid and tissue stores and whole body transport.
*Critical Reviews in Biomedical Engineering, 33(3):265-98, (2005).*

Kelly AM, Kerr D, Middleton P.
Validation of venous PCO2 to screen for arterial hypercarpia in patients with chronic obstructive airways disease.

Lim BL, Kelly AM.
A meta-analysis on the utility of peripheral venous blood gas analysis in exacerbations of chronic obstructive pulmonary disease in the emergency department.
*European Journal of Emergency Medicine, 17:246-248, (2010).*

S.E. Rees.
Correspondance: Accuracy of venous blood pressure depends on arterial blood oxygen pressure: from the author.
*European Respiratory Journal, 5:1208, (2006).*

OBI Medical is a medical technology company that has developed the unique and innovative v-TAC Software application. The v-TAC Software application will allow Point-Of-Care-Testing professionals to obviate the need for Arterial Puncture when performing Blood-Gas Analysis on critically ill patients, or COPD patients during periods of exacerbation, resulting in increased patient safety, comfort and a tremendous reduction in cost of care for hospitals and health insurance companies.

OBI was founded in 2002 by a group of leading scientists, researchers and clinicians from Aalborg University Hospital and from the Center for Model-based Medical Decision Support at Aalborg University. OBI is head quartered in Aalborg, Denmark.