Capillary blood gases in acute exacerbations of COPD

Ross Murphy*, Sanjeet Thethy, Simon Raby, Jean Beckley, John Terrace, Christine Fiddler, Michelle Craig, Colin Robertson

Department of Accident and Emergency Medicine, The Royal Infirmary of Edinburgh, Old Dalkeith Road, Little France, Edinburgh EH16 4SU, UK

Received 15 June 2005; accepted 21 July 2005

Summary
Objectives: To assess the correlation and agreement between measurements of \( P_{O_2} \), \( P_{CO_2} \), \( H^+ \) and \( HCO_3^- \) in arterial and capillary blood in patients with acute exacerbations of COPD. To assess the repeatability of capillary measurements.

Design: Method comparison study.

Setting: Accident and emergency department in a university teaching hospital.

Main outcome measures: Measurements of \( P_{O_2} \), \( P_{CO_2} \), \( H^+ \) and \( HCO_3^- \) in one arterial and two capillary samples taken from consecutive patients with acute exacerbations of COPD.

Results: The agreement between measurements of \( P_{CO_2} \), \( H^+ \) and \( HCO_3^- \) in arterial and capillary blood was good with mean differences of 0.087 kPa, 1.044 nmol/l and 0.513 mmol/l, respectively. The corresponding 95% limits of agreement were narrow. The agreement between measurements of \( P_{O_2} \) was poor with a mean difference of 1.256 kPa and wide 95% limits of agreement. There was good repeatability between capillary samples with mean differences of 0.094 kPa, 0.674 nmol/l and 0.028 mmol/l for measurements of \( P_{CO_2} \), \( H^+ \) and \( HCO_3^- \) respectively and narrow coefficients of repeatability.

Conclusions: Capillary blood gas measurements provide an accurate assessment of \( P_{CO_2} \), \( H^+ \) and \( HCO_3^- \) and can be used to reliably measure the ventilatory status of patients. Combined with continuous pulse oximetry they can be used as an alternative to arterial blood gas measurements in patients with acute exacerbations of COPD.

© 2005 Published by Elsevier Ltd.

*Corresponding author. Tel.: +44 7712 761172.
E-mail address: rossmurphy@doctors.org.uk (R. Murphy).

0954-6111/$ - see front matter © 2005 Published by Elsevier Ltd.
doi:10.1016/j.rmed.2005.08.007
Introduction

Acute exacerbations of COPD account for a large percentage of presentations to Emergency Departments in the UK each year. A crucial part of every patient’s assessment is measurement of arterial blood gases.¹ This is a painful and uncomfortable procedure with potentially dangerous complications.²

Capillary blood gases have been used for many years in children as a less distressing and safer alternative and some studies suggest that they agree well with arterial values.³ Varying levels of agreement between arterial and capillary samples are found in adult patients with different pathologies.⁴ It is felt that this agreement can be improved if the capillary sampling site is first "arterialised" by applying vasodilating pastes or warming it.⁴

It has not been determined as to whether, in patients with acute exacerbations of COPD, capillary blood gases are a viable alternative. Patients with COPD most often need blood gas analysis within an Emergency Department setting.

In this study we assessed the correlation and level of agreement between measurements of \( P_{O_2} \), \( P_{CO_2} \), \( H^+ \) and calculated \( HC_3 \) in arterial and capillary blood in patients with acute exacerbations of COPD.

Methods

The study was approved by the Lothian Research Ethics Committee and was performed in the Accident and Emergency department at the Royal Infirmary of Edinburgh between September 2002 and February 2003.

Consecutive patients presenting with a recent increase in cough, wheeze or shortness of breath and a prior diagnosis of COPD, made by a consultant physician were eligible for inclusion. Patients were excluded if there was an obvious alternative cause for their respiratory symptoms.

Enrolment was performed whenever the study authors, who represent one of three teams providing a 24 h service, were in the department.

Informed written consent was obtained prior to entry. Some patients were drowsy or confused due to their illness and in these cases informed written assent was obtained from accompanying relatives.

It was aimed to recruit over 50 patients as this is the minimum sample size recommended for a method comparison study.⁵

On entry, patients had a vasodilating nicotinate paste applied to their earlobe. After 10 min the paste was removed and the inferolateral part of the earlobe pricked with a sterile needle. The surrounding tissue was squeezed and the blood collected into two capillary tubes. Two samples were taken in order to assess the repeatability of capillary sampling. Immediately afterwards an arterial sample was taken from the radial artery in order to assess the agreement between the capillary and arterial samples. The samples were aspirated in the same order into the department’s blood gas analyser (GEM premier 3000, Instrumentation Laboratory) and the blood gas measurements for each sample recorded.

Each patient was treated appropriately for their condition with oxygen, nebulised bronchodilators and other treatments deemed appropriate by a second attending doctor.

Results

Sixty patients were eligible for entry into the study. Three refused consent and two were inadvertently not considered leaving a study sample of 55. In 15 of these cases assent was given by relatives and in 40 consent was given by the patient. In five patients a second capillary sample was not obtained.

The results are illustrated in Figs. 1–4 on which each first capillary measurement is plotted against each arterial measurement. They also show the line of equality on which all points would lie if there were exact agreement. A similar evaluation was performed between the two sets of capillary measurements.

The results were further analysed using methods described by Bland and Altman to assess the agreement between two methods of clinical
The results of the analysis between the arterial samples and the first set of capillary samples are illustrated in Figs. 5–8. For measurements of $PCO_2$, $H^+$, $HCO_3^-$/$CO_2$ and $PO_2$, 95% of capillary values would expect to fall within 2 standard deviations above and below the mean differences when compared with arterial measurements. These are the 95% limits of agreement.

The results of all the above are summarised in Table 1.

The results of the analysis of repeatability between the 2 sets of capillary measurements are summarised in Table 2.
Discussion

This study is the first to show that for measurements of $P_{CO_2}$, $H^+$ and $HCO_3^-$ arterialised capillary blood samples agree well with arterial blood samples in patients with acute exacerbations of COPD. For $P_{O_2}$ the agreement is insufficient to allow capillary sampling to replace standard analysis in clinical use.

These results are consistent with previous reports that have suggested a use for capillary blood gases as a means of estimating the ventilatory status of patients but not the degree of oxygenation.4,7

Although the study authors feel that the level of agreement shown is good it is possible that in reality the agreement could be even better.

A vasodilating paste was used at the capillary sampling site to promote conformity between the arterial sample and the capillary sample and make the sample easier to obtain. Other studies have used methods such as heating the site with other pastes, towels, lamps and water.8 The nicotinate paste used in this study is cheap, easily obtained and applied and fast-acting enough to be used in daily clinical practice.

It has been stated that the capillary sampling site should not be squeezed as this may result in contamination with venous blood, lymph and fatty tissue.9 We found that unless the site was squeezed insufficient blood was obtained for analysis.

It has also been recommended that metal filings be inserted into each capillary tube to aid sample mixing with a magnet.9 This was impractical and difficult to reproduce. Care was taken with all samples to ensure a continuous line of blood and the sample was taken as quickly as possible to limit contamination with room air.

Our results therefore represent capillary samples that are unmixed, arterialised with a simple paste and taken quickly from a site that has been squeezed. They can easily be performed in a busy Emergency Department.

As the capillary samples were taken and processed before the arterial sample it is possible that this increased discrepancy between measurements.

### Table 1  Agreement between arterial and first capillary sample.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Correlation coefficient ($r$)</th>
<th>Mean difference</th>
<th>Standard deviation (SD)</th>
<th>95% limits of agreement (Mean ± 2SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{CO_2}$ (kPa)</td>
<td>0.984</td>
<td>0.087</td>
<td>0.370</td>
<td>0.827 to −0.653</td>
</tr>
<tr>
<td>$H^+$ (nmol/l)</td>
<td>0.961</td>
<td>1.044</td>
<td>1.612</td>
<td>4.268 to −2.180</td>
</tr>
<tr>
<td>$HCO_3^-$ (mmol/l)</td>
<td>0.977</td>
<td>−0.513</td>
<td>1.364</td>
<td>2.215 to −3.241</td>
</tr>
<tr>
<td>$P_{O_2}$ (kPa)</td>
<td>0.830</td>
<td>1.256</td>
<td>3.371</td>
<td>7.998 to −5.486</td>
</tr>
</tbody>
</table>

### Table 2  Agreement between two capillary samples.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Correlation coefficient ($r$)</th>
<th>Mean difference</th>
<th>Standard Deviation (SD)</th>
<th>Coefficient of repeatability (Mean ± 2SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{CO_2}$ (kPa)</td>
<td>0.993</td>
<td>0.094</td>
<td>0.228</td>
<td>0.550 to −0.362</td>
</tr>
<tr>
<td>$H^+$ (nmol/l)</td>
<td>0.964</td>
<td>0.674</td>
<td>1.494</td>
<td>3.662 to −2.314</td>
</tr>
<tr>
<td>$HCO_3^-$ (mmol/l)</td>
<td>0.992</td>
<td>0.028</td>
<td>0.821</td>
<td>1.67 to −1.614</td>
</tr>
<tr>
<td>$P_{O_2}$ (kPa)</td>
<td>0.967</td>
<td>0.062</td>
<td>1.088</td>
<td>2.238 to −2.114</td>
</tr>
</tbody>
</table>

Figure 8  Mean difference and limits of agreements for $P_{O_2}$.
When a patient first had capillary sampling they may have hyperventilated due to the slight discomfort resulting in an increase in \( P_{O_2} \) and a decrease in \( P_{CO_2} \) before the arterial sample was taken. It is also possible that the arterial sample degraded while waiting for the capillary samples to be processed further increasing any discrepancy.

An important part of the assessment of any new measurement method is the assessment of its repeatability. In this study we took and processed two capillary samples consecutively. These would be subject to the same sources of error as above. We found that the coefficient of repeatability for the capillary samples was small indicating good repeatability. We did not assess the repeatability of the arterial samples.

The first step in the management of patients with acute exacerbations of COPD is ensuring adequate and controlled oxygenation. It is recommended that patients receive enough oxygen to consistently achieve a target oxygen saturation of about 90–92% or lower in some cases. Continuous pulse oximetry is preferable to blood gas analysis for this in most instances. It is non-invasive, painless and can be performed by any trained personnel. Provided there is a good tracing it will give an acceptable estimate of oxygenation, will rapidly detect hypoxia and provides continuous information on oxygenation rather than a single estimate which will be subject to transient changes in a patient’s ventilatory pattern.

Subsequent steps involve establishing the ventilatory status by measuring \( P_{CO_2} \), \( H^+ \) and \( HCO_3^- \) and using these to establish prognosis and decide if non-invasive or invasive ventilation is indicated. Often repeated measurements are needed. This study shows that this can be done using capillary blood gases. They are less invasive, less painful and more easily performed by trained personnel than arterial samples.

Combined with continuous pulse oximetry, capillary blood gases can be used as an alternative to arterial blood gases in the initial assessment and subsequent management of all patients with acute exacerbations of COPD.

**Contributors**

Ross Murphy and Colin Robertson designed the study, recruited patients, analysed the results and wrote the paper. Sanjeet Thethy recruited patients, analysed the results and wrote the paper. All the other authors recruited patients and wrote the paper. Ross Murphy acts as guarantor.

**Acknowledgements**

The study was funded by a grant from the British Association for Accident and Emergency Medicine.

**References**