
Original Contributions

VALIDATION OF VENOUS $p\text{CO}_2$ TO SCREEN FOR ARTERIAL HYPERCARBIA IN PATIENTS WITH CHRONIC OBSTRUCTIVE AIRWAYS DISEASE

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□ **Abstract**—To validate a previously derived venous $p\text{CO}_2$ ($p\text{vCO}_2$) cut-off for ruling out arterial hypercarbia in patients with chronic obstructive pulmonary disease (COPD), matched arterial and venous blood gas samples were taken from a convenience sample of patients who presented to the Emergency Department (ED) with COPD deemed by their treating doctor to require arterial blood gas (ABG) analysis as part of their care. The screening cut-off was defined as $p\text{vCO}_2$ of > 45 mm Hg and arterial hypercarbia was defined as arterial $p\text{CO}_2$ ($p\text{aCO}_2$) of > 50 mm Hg. Descriptive statistics were employed. Sensitivity, specificity and negative predictive value were calculated. There were 112 patients enrolled in the study, of whom 107 had complete data for analysis. Forty-three patients had arterial hypercarbia (range of 51 to 90 mm Hg, median 60 mm Hg). All cases of arterial hypercarbia were detected by the screening cut-off (sensitivity 100%; 43/43; 95% CI 91–100%; specificity 47%, 95% CI 35–59%). The negative predictive value of $p\text{vCO}_2 < 45$ mm Hg was 100% (30/30, 95% CI 89–100%). Assuming the ABG was performed to assess hypercarbia, 29% of ABGs potentially could have been avoided if a venous screening test was employed. In conclusion, $p\text{vCO}_2$ can be used as a screening test for arterial hypercarbia, and if employed, can potentially reduce the requirement for ABG sampling. © 2005 Elsevier Inc.

□ **Keywords**—blood gas; hypercarbia; $p\text{CO}_2$; COPD

INTRODUCTION

Management of acute exacerbations of chronic obstructive pulmonary disease (COPD) is challenging. Blood gas analysis, in particular measurement of $p\text{CO}_2$ for the detection of CO_2 retention, is useful in guiding oxygen therapy and the need for ventilatory support. But arterial blood gas samples are not without problems. They are painful and have a small incidence of complications including local hematoma, infection, occlusion and embolization with consequent ischemic injury to the digits. There is also a risk of needlestick injury to health care workers associated with an additional vascular puncture.

Previous research has shown excellent agreement between pH measured on arterial and venous samples and good agreement between oxygen saturation measured by pulse oximeter and by arterial blood gas (ABG) (1–9). We have previously reported a derivation study exploring a potential screening cut-off for $p\text{vCO}_2$ in the detection of arterial hypercarbia (10). That study showed that a $p\text{vCO}_2$ screening cutoff of > 45 mm Hg was 100% sensitive in detecting cases of arterial hypercarbia with a specificity of 51.7%. The objective of this study was the validation of that screening cut-off.

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METHODS

This prospective study was conducted in the Emergency Department (ED) of Western Hospital, a 250-bed community teaching hospital in Melbourne, Australia. The ED has an annual census of approximately 32,000 adult patients.

Patients were eligible for entry into the study if they presented with an acute exacerbation of COPD (judged and documented by the treating clinician) and were deemed by the treating doctor to require an ABG analysis to determine their ventilatory status. Confirmation of COPD by respiratory function testing was not performed. After obtaining verbal consent from the patient or a relative, patients had arterial and venous blood gas samples drawn with minimum delay between the taking of samples. For patients receiving supplemental oxygen therapy, this was kept constant for the 10-min period preceding the taking of samples. Both samples were analyzed as soon as possible after collection by the same blood gas analyzer. Cases with missing or unclear diagnosis, missing pvCO_2 or paCO_2 data were excluded from analysis. The study was approved by the institutional clinical research committee.

For the purposes of analysis, significant systemic hypercarbia was defined as a $\text{paCO}_2 > 50$ mm Hg.

Data were analyzed using descriptive statistics and sensitivity, specificity and negative predictive values were calculated based on the previously derived pvCO_2 screening cut-off of 45 mm Hg. Agreement between arterial and venous pCO_2 was measured by bias plot (Bland-Altman) analysis.

RESULTS

There were 112 patients enrolled in the study, of whom 107 had complete data for analysis. The median age of patients was 73 years. The median paCO_2 was 45 mm Hg (range 24–90 mm Hg). Forty-three patients (40%) had arterial hypercarbia (range of 51–90 mm Hg, median 60 mm Hg). Agreement between arterial and venous pCO_2 was poor with a bias of 6 mm Hg and 95% limits of agreement of -14 to $+26$ mm Hg.

All cases of arterial hypercarbia were detected by the screening cut-off (sensitivity 100%; 43/43; 95% CI 91–100%; specificity 47%, 95% CI 35–59%) (Table 1). The negative predictive value of $\text{pvCO}_2 < 45$ mm Hg was 100% (30/30, 95% CI 89–100%). Assuming the ABG was performed to assess hypercarbia, 29% (30/102) of ABGs potentially could have been avoided if a venous screening test was employed.

Table 1. Diagnostic Performance of pCO_2 Screening Test for Hypercarbia

| | Hypercarbia present | Hypercarbia absent |
|-------------------------------------|---------------------|--------------------|
| Venous $\text{pCO}_2 > 45$ mm Hg | 43 | 34 |
| Venous $\text{pCO}_2 \leq 45$ mm Hg | 0 | 30 |

DISCUSSION

ABG analysis is the standard method for obtaining an estimation of pCO_2 in the clinical evaluation of patients suffering exacerbations of COPD. ABGs, however, are unpleasant and carry a small risk of complications for both patients and staff. If there was an alternative method of obtaining this information without an additional puncture, there would be potential benefits for staff and patients.

Although several studies have shown good correlation between arterial and venous pCO_2 , this study and a previous study have shown that there is poor agreement between pCO_2 measured on arterial and venous blood gases (10–12). However, the clinical question is not the absolute value of pCO_2 . Rather, is this patient hypercarbic? With that in mind, in previous work, we derived a potential screening cut-off for pvCO_2 for the prediction of arterial hypercarbia (10). We found that a cut-off of venous $\text{pCO}_2 > 45$ mm Hg was 100% sensitive and 57.1% specific in the prediction of arterial hypercarbia.

This study has validated that screening cut-off and estimated that the use of the screening test could obviate the need for arterial blood gases in 29% of cases. The implications for clinical practice are that a significant proportion of ABGs may be able to be avoided, based on the result of the screening pvCO_2 .

An argument could be made for eliminating arterial gases in this group of patients, as pH on venous blood is clinically equivalent to that of arterial blood and determination of whether an acute respiratory acidosis is contributing should be possible. Although we believe that monitoring progress and response to treatment using venous pH is possible, a venous blood gas alone will not accurately quantify the level of hypercarbia. This may be important in guiding therapy such as oxygen therapy or non-invasive ventilation. The lack of an accurate pCO_2 would also make it difficult to identify mixed metabolic disorders.

This study has some limitations that should be considered when interpreting the results. The study sample was a convenience sample based on when time and resources allowed patient enrollment. Although this limited sample size, it would not be expected to introduce systematic bias in the sample. The relatively small sample size (107) contributes to the width of the confidence interval for sensitivity. A larger sample would be needed to narrow this. The

study was conducted at a single institution and for practical reasons required consent to be given in English. Thus, generalizability to other patient populations might be in question. Importantly, any screening test needs to be interpreted in the context of the clinical situation and judgement should be applied when a value of any test does not agree with the clinical picture.

CONCLUSION

Venous CO₂ can be used as a screening test for arterial hypercarbia and, if employed, can potentially reduce the requirement for ABG sampling.

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