



ORIGINAL RESEARCH

Agreement between arterial and venous pH and pCO₂ in patients undergoing non-invasive ventilation in the emergency department

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Abstract

- Background:** Blood gas analysis is an important part of the assessment of ventilatory function in patients with respiratory distress. Traditionally, analysis of arterial blood has been used, but recently, there has been a move towards venous blood gas analysis for selected conditions. Arteriovenous agreement for pH and pCO₂ in adult patients undergoing non-invasive ventilation (NIV) has not been explored to date. The aim of this study was to address this question.
- Methods:** This was a prospective study of adult patients undergoing NIV for acute respiratory compromise in an ED. When arterial blood gas analysis was required for clinical purposes, staff also drew a venous sample as close to simultaneously as possible. Data collected included demographics, clinical diagnosis and results of blood gas analyses. Primary outcome of interest was arteriovenous agreement for pH and pCO₂. Bland-Altman bias plot analysis was used.
- Results:** Eighty-nine sample pairs in 53 patients were studied. Median age was 74, and 64% of patients were male. The principal diagnoses were chronic obstructive pulmonary disease (43%) and acute pulmonary oedema (40%). Mean difference for pH (a-v) was 0.04 pH units (95% limits of agreement −0.02, 0.11). Mean difference for pCO₂ (a-v) was −8.02 mmHg (95% limits of agreement −22.63, 6.58).
- Conclusion:** For adult patients undergoing NIV in an ED, arteriovenous agreement for pH was close with narrow limits of agreement making venous pH clinically interchangeable with arterial pH. Agreement for pCO₂ was poor with unacceptably wide limits of agreement.
- Key words:** *blood gas, non-invasive ventilation, pH.*

Introduction

In critical care settings, blood gas analysis is used for two main purposes: establishing acid-base state and assessing ventilation function. Assessment of ventilatory function is particularly important for patients with

severe respiratory compromise, such as those undergoing non-invasive ventilatory support, in order to assess the severity of ventilatory compromise and progression of illness in particular deterioration requiring escalation of ventilatory support. These parameters are measured by blood gas analysis, which historically have been

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performed on arterial blood. This is painful for patients and has the rare but serious complications of vascular injury or occlusion and infection. The methods of handling and collection also pose the risk of needlestick injury to staff.

Available evidence suggests that in adults, arteriovenous agreement for pH is close and probably clinically interchangeable, but data regarding $p\text{CO}_2$ are conflicting with some studies reporting close agreement and others unacceptably wide limits of agreement.^{1–4} Some authors have suggested that venous blood gas (VBG) analysis could replace arterial analysis; at least for selected conditions, in particular assessment of diabetic ketoacidosis and tricyclic antidepressant poisoning.^{5–10} Others, notably in trauma, disagree.¹¹ There is currently no published data specifically exploring arteriovenous agreement for the severely ill group of adult patients requiring non-invasive ventilation (NIV). The aim of this study was to determine arteriovenous agreement for pH and $p\text{CO}_2$ in this high risk group.

Methods

This was a prospective observational study conducted in the ED of a community teaching hospital in Melbourne, Australia. The study ED has an annual census of 36 000 patients, almost all of whom are adults.

Patients were eligible for inclusion in the study if they were undergoing NIV for acute respiratory distress and required arterial blood gas (ABG) analysis (as ordered by the treating physician) to assess their ventilatory function. In addition to the arterial blood gas sample, nursing staff were instructed to collect and analyse a VBG sample as close to simultaneously as possible. Up to three sample pairs at minimum two hourly intervals could be collected per patient care episode if serial ABG were required for clinical care. Samples were excluded if results and timing could not be verified from the pathology results database or if there was more than 5 min between arterial and venous samples. In practice, this was a convenience sample as it relied on staff remembering to conduct the venous sampling and on clinical workload not precluding availability of time for the additional VBG analysis.

Data collected included patient demographics (age and sex), vital signs, clinical diagnosis and results of blood gas analyses. Primary outcome of interest was arteriovenous agreement for pH and $p\text{CO}_2$ expressed as mean difference and 95% limits of agreement. Secondary outcomes of interest were comparison of arteriovenous differences in

pH between acidotic and non-acidotic patients and in $p\text{CO}_2$ for hypercarbic and non-hypercarbic patients. Analysis was by Bland-Altman bias plot techniques and Mann-Whitney *U*-test using Analyse-It™ software (Analyse-it Software, Ltd., Leeds, UK).

During the study, two blood gas analysers were in use. For the first part of the study period a Radiopoint 405 analyser (Siemens Healthcare Diagnostics Inc., Tarrytown, NY, USA) was used. This was replaced by a Radiometer ABL 825 (Radiometer Medical Aps, Brønshøj, Denmark).

This project was approved by the Western Health Low Risk Human Research Ethics Panel (HREC/11/WH/3). Estimation of required sample size was based on achieving acceptably narrow 95% confidence intervals around the point estimates for the upper and lower limits of agreement. Based on available standard deviation data for the difference between arterial and venous values for pH and $p\text{CO}_2$, we estimated that 50 patients would be given accuracy for these measures of ± 0.16 for pH and 3 mmHg for $p\text{CO}_2$.

Results

Eighty-nine sample pairs in 53 patients were analysed. Median age was 74 years (interquartile range [IQR] 67–79). Thirty-four patients were male (64%). Clinical diagnoses in ED were chronic obstructive pulmonary disease ($n = 23$, 43%), acute pulmonary oedema ($n = 21$, 40%), pneumonia/lower respiratory tract infection ($n = 5$, 9%) and other conditions (including asthma) ($n = 4$, 8%).

Median pH was 7.33 (IQR 7.27–7.38); 52/89 (58%) of comparisons were acidotic with pH < 7.35 . Median $p\text{CO}_2$ was 47 (IQR 41–68); 42/89 (47%) had significant hypercarbia defined as $p\text{CO}_2 > 50$ mmHg.

Mean difference for pH (a-v) was 0.04 pH units (95% limits of agreement -0.02 , 0.11) (Fig. 1). Mean difference for $p\text{CO}_2$ (a-v) was -8.02 mmHg (95% limits of agreement -22.63 , 6.58) (Fig. 2). No difference was found in arteriovenous differences of pH between acidotic and non-acidotic patients or in $p\text{CO}_2$ for hypercarbic and non-hypercarbic patients.

Discussion

Evaluation of ventilatory function in patients with severe respiratory compromise is essential in order to ensure that management decisions are made promptly

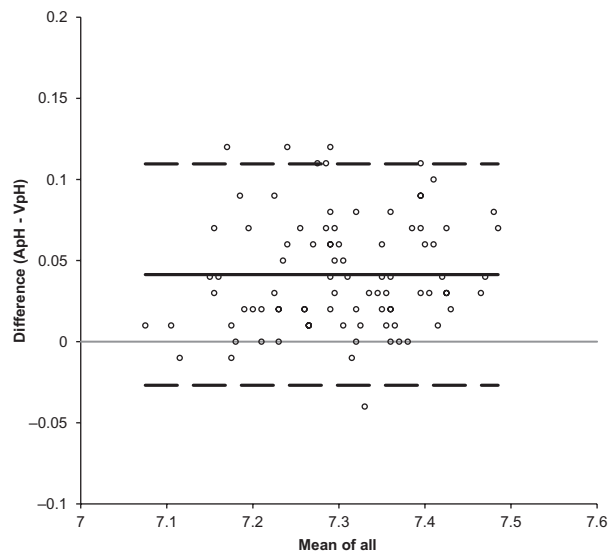


Figure 1. Bias plot of arteriovenous agreement for pH. (—), Identity; (---), Bias (0.041); (---), 95% limits of agreement (-0.027–0.110).

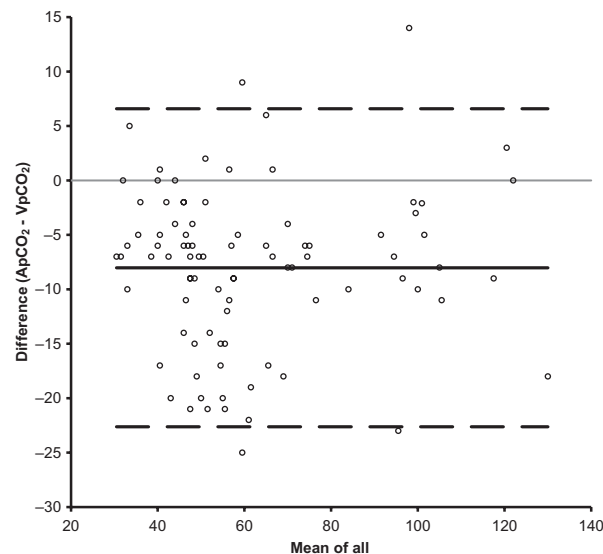


Figure 2. Bias plot of arteriovenous agreement for pCO₂. (—), Identity; (---), Bias (-8.0); (---), 95% limits of agreement (-22.6–6.6).

in response to changing clinical condition. A key component of this evaluation is blood gas analysis, principally looking at pCO₂ and pH. Previous research has suggested that arteriovenous agreement for pH is close with narrow 95% limits of agreement and that venous values are probably clinically interchangeable with

arterial values.¹ Data regarding pCO₂ is less clear. A more recent review reported that the weighted average arteriovenous difference was 6.2 mmHg; however, the included studies varied in the width of the 95% limits of agreement.¹² The width of 95% limits of agreement are important as they are a measure of validity. The underlying assumption is that for a randomly selected patient, the difference between arterial and venous values would be expected to lie within the limits of agreement with approximately 95% probability. Several of the studies to date have reported 95% limits of agreement of the order of ± 20 mmHg. It is also hard to tell from most studies what proportion of patients were acidotic or hypercarbic. Again, this is important as good results from 'well' patients might obscure poor agreement for patients with acidosis or hypercarbia. None of the studies has specifically focused on patients with severe respiratory compromise, such as patients undergoing NIV.

We found good arteriovenous agreement for pH with narrow 95% limits of agreement. For pCO₂, whereas mean arteriovenous difference was 8 mmHg, 95% limits of agreement were unacceptably wide. This is in line with previous studies in patients who are not in shock.^{1,11} We also found that arteriovenous difference for pH was not significantly different in acidotic versus non-acidotic patients, and for pCO₂, was not significantly different for hypercarbic versus non-hypercarbic patients. Taken together, the evidence is now clear that in normotensive patients venous pH is a close reflection of arterial pH and that venous pCO₂ is an unreliable indicator of arterial pCO₂.

This study has some limitations that should be considered when interpreting the results. Although we attempted to collect a consecutive sample, the resulting sample is actually a convenience sample because of operational and resource limitations. We have no reason to suspect any systematic bias in selection; inclusion was based on treating nurses having available time for the additional analyses and remembering about the study. Treatment decisions were made independently by doctors not involved in the study, so there might have been variation in the criteria used for initiation of NIV. This is a single-site study and might not be generalisable to other settings or patient cohorts.

Conclusion

For patients undergoing NIV in an ED, arteriovenous agreement for pH was close with narrow limits of

agreement making venous pH clinically interchangeable with arterial pH. Agreement for pCO₂ was poor with unacceptably wide limits of agreement.

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Author contributions

AMK had the concept for the study, AMK and SK designed the study, SK oversaw data collection and management, AMK analysed data, SK and AMK interpreted data, drafted and approved manuscript. AMK is guarantor of the paper.

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Competing interests

None declared.

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References

1. Kelly AM. Can venous blood gas analysis replace arterial in emergency medical care: a review. *Emerg. Med. Australas.* 2010; **22**: 493–8.
2. McCanny P, Bennet K, Staunton P, McMahon G. Venous vs arterial blood gases in the assessment of patients presenting with an exacerbation of chronic obstructive pulmonary disease. *Am. J. Emerg. Med.* 2012; **30**: 896–900.
3. Kelly A-M, Kyle E, McAlpine R. Venous pCO₂ and pH can be used to screen for significant hypercarbia in emergency patients with acute respiratory disease. *J. Emerg. Med.* 2002; **22**: 15–19.
4. Lim BL, Kelly A-M. A meta-analysis on the utility of peripheral venous blood gas analyses in exacerbations of chronic obstructive pulmonary disease in the emergency department. *Eur. J. Emerg. Med.* 2010; **17**: 246–8.
5. Kelly AM, McAlpine R, Kyle E. Venous pH can safely replace arterial pH in the initial evaluation of patients in the emergency department. *Emerg. Med. J.* 2001; **18**: 340–2.
6. Toftegaard M, Rees SE, Andreassen S. Correlation between acid–base parameters measured in arterial blood and venous blood sampled peripherally, from vena cavae superior, and from the pulmonary artery. *Eur. J. Emerg. Med.* 2008; **15**: 86–91.
7. Brandenburg MA, Dire DJ. Comparison of arterial and venous blood gas values in the initial emergency department evaluation of patients with diabetic ketoacidosis. *Ann. Emerg. Med.* 1998; **31**: 459–65.
8. Ma OJ, Rush MD, Godfrey MM, Gaddis G. Arterial blood gas results rarely influence emergency physician management of patients with suspected diabetic ketoacidosis. *Acad. Emerg. Med.* 2003; **10**: 836–41.
9. Kelly AM. The case for venous rather than arterial blood gases in diabetic ketoacidosis. *Emerg. Med. Australas.* 2006; **18**: 64–7.
10. Eizadi-Mood N, Moein N, Saghaei M. Evaluation of relationship between arterial and venous blood gas values in the patients with tricyclic antidepressant poisoning. *Clin. Toxicol.* 2005; **43**: 357–60.
11. Rudkin SE, Kahn CA, Oman JA *et al.* Prospective correlation of arterial vs venous blood gas measurements in trauma patients. *Am. J. Emerg. Med.* 2012; **30**: 1371–7.
12. Kelly AM. Agreement between arterial and venous blood gases in emergency medical care: a systematic review. *Hong Kong J. Emerg. Med.* 2013 (in press).