



REVIEW ARTICLE

Review article: Can venous blood gas analysis replace arterial in emergency medical care

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Abstract

The objectives of the present review are to describe the agreement between variables on arterial and venous blood gas analysis (in particular pH, pCO₂, bicarbonate and base excess) and to identify unanswered questions. MEDLINE search of papers published from 1966 to January 2010 for studies comparing arterial and peripheral venous blood gas values for any of pH, pCO₂, bicarbonate and base excess in adult patients with any condition in an emergency department setting. The outcome of interest was mean difference weighted for study sample size with 95% limits of agreement. The weighted mean arterio–venous difference in pH was 0.035 pH units ($n = 1252$), with narrow limits of agreement. The weighted mean arterio–venous difference for pCO₂ was 5.7 mmHg ($n = 760$), but with 95% limits of agreement up to the order of ± 20 mmHg. For bicarbonate, the weighted mean difference between arterial and venous values was -1.41 mmol/L ($n = 905$), with 95% limits of agreement of the order of ± 5 mmol/L. Regarding base excess, the mean arterio–venous difference is 0.089 mmol/L ($n = 103$). There is insufficient data to determine if these relationships persist in shocked patients or those with mixed acid-base disorders. For patients who are not in shock, venous pH, bicarbonate and base excess have sufficient agreement to be clinically interchangeable for arterial values. Agreement between arterial and venous pCO₂ is too poor and unpredictable to be clinically useful as a one-off test but venous pCO₂ might be useful to screen for arterial hypercarbia or to monitor trends in pCO₂ for selected patients.

Key words: *arterial, blood gas, venous.*

Introduction

In emergency departments, blood gas analysis is used for two main purposes: establishing acid-base state (mainly pH but also bicarbonate) and assessing respira-

tory function (mainly pCO₂ but also pH and to a lesser extent pO₂). Historically, blood gas analyses have been 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

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handling and collection also pose the risk of needlestick injury to staff.

Some authors have suggested that venous blood gas analysis could replace arterial analyses, at least for selected conditions.^{1–5} Venous blood sampling is usually easier, less painful and more convenient. The aims of the present paper are to perform a review of published evidence to determine the agreement for pH, pCO₂, bicarbonate and base excess between arterial and venous blood samples and to identify unanswered questions in agreement between arterial and venous blood gas parameters.

Methods

MEDLINE was searched for studies comparing arterial and peripheral venous blood gas values for any of pH, pCO₂, bicarbonate and base excess in adults in an emergency department setting (1966–January 2010). Studies comparing central venous and arterial analyses were excluded. A repeated search was conducted in May 2010 to identify any further papers published during data collection and analysis. The terms ‘arterial’, ‘venous’, ‘blood gas’ and ‘agreement’ were used and the search was limited to ‘adults’. In addition, similar systematic reviews and meta-analyses were also searched and the PubMed ‘related articles’ feature was used for all identified trials and references of identified papers were checked for additional material cited.

Data were collected explicitly by a single investigator not blinded to the project’s aims. The primary outcome of interest was agreement between venous and arterial measurements (mean difference and 95% limits of agreement). Studies only reporting correlation or regression equations were not included as agreement is the clinically relevant end-point. There were planned subgroup analyses for pH in diabetic ketoacidosis, pCO₂ in chronic obstructive pulmonary disease (COPD) and venous pCO₂ as a screening test for arterial hypercarbia. Data were analysed as weighted pooled data.

Results

pH

Twelve studies compare arterial and venous pH measurements of which ten met inclusion criteria.^{1–4,6–11} One of these is a subgroup analysis of previously published

data.¹⁰ The pooled mean difference between venous and arterial pH was 0.035 pH units ($n = 1252$) (Table 1).

Three studies^{3,4,6} compare arterial and venous pH for patients with diabetic ketoacidosis ($n = 265$). The weighted mean difference between venous and arterial pH in this subgroup was 0.02 pH units. Only one study reports 95% limits of agreement that were -0.009 to 0.02 pH units.⁴ (Table 1) Two studies^{8,9} compare arterial and venous pH for patients with COPD ($n = 239$). The weighted mean difference between venous and arterial pH in the COPD subgroup was 0.03 pH units.

pCO₂

Six studies report agreement between arterial and venous pCO₂.^{8,10,12–14} The weighted mean difference for the group overall was 5.7 mmHg ($n = 760$) and for the COPD subset 6.3 mmHg ($n = 244$). (Table 2) The 95% limits of agreement were diverse and unsuitable for pooling. In four out of five studies where 95% limits of agreement were reported, limits of agreement fell outside ± 10 mmHg and in three of the five studies one of the limits of agreement exceeded 20 mmHg.

Four studies investigate using venous pCO₂ as a screening test for arterial hypercarbia, three with laboratory-based testing^{8,10,12} and one using point of care testing.¹⁴ (Table 3). The three studies using laboratory-based analyses, all report 100% sensitivity at venous pCO₂ of 45 mmHg, although definitions of clinically significant hypercarbia vary slightly. However, the one study reporting use of point of care testing¹⁴ for screening found lower sensitivity (79%) and negative predictive value (90%) at this cut-off. Reasons for this are unclear. When pooled, the data show good diagnostic accuracy and predict that 36% of arterial analyses could be avoided if venous screening for hypercarbia was used.

Bicarbonate

Seven studies compare venous and arterial bicarbonate measurements.^{1,6–9,11,13} Pooled data ($N = 905$) show a weighted mean difference between arterial and venous values of -1.41 mmol/L. In the two studies reporting 95% limits of agreement these range from -5.8 to $+5.3$ mmol/L. (Table 4). In the two studies specifically reporting data for patients with respiratory disease ($n = 239$), weighted mean difference was -1.34 mmol/L (Table 4).

Table 1. Summary of agreement data for pH: overall, for DKA and for COPD

Author, year	No. subjects	Mean difference	95% limits of agreement	Conditions studied
Pooled data				
Brandenburg, 1998 ³	44	0.03	†	DKA
Gokel, 2000 ⁶	152	0.05	†	DKA, uraemia, normal subjects
Kelly, 2001 ¹	246	0.04	−0.11, 0.02	Various
Rang, 2002 ¹¹	218	0.036	†	Various
Ma, 2003 ⁴	200	0.015	−0.009 to 0.02	DKA
Eizadi-Mood, 2005 ⁷	50	0.034	†	TCA OD
Ak, 2006 ⁸	132	0.031	†	COPD
Razi, 2007 ⁹	107	0.0241	†	COPD
Toftgaard, 2008 ²	103	0.026	−0.02 to 0.07	Various
Total	1252	0.035‡		
DKA subset				
Brandenburg, 1998 ³	44	0.03	†	
Gokel, 2000 ⁶	21	0.015	†	
Ma, 2003 ⁴	200	0.015	−0.009 to 0.02	
Total	265	0.02‡		
COPD subset				
Ak, 2006 ⁸	132	0.031	†	
Razi, 2007 ⁹	107	0.0241	†	
Total	239	0.03‡		

†Not reported. ‡Weighted mean difference. COPD, chronic obstructive airways disease; DKA, diabetic ketoacidosis; OD, overdose; TCA, tricyclic antidepressant.

Table 2. Summary of agreement data for pCO₂: overall and for COPD subset

Author, year	No. subjects	Mean difference [mmHg]	95% limits of agreement [mmHg]	Conditions studied
Pooled data				
Kelly, 2002 ¹⁰	196	5.8	−8.8 to 20.5	Mixed respiratory
Kelly, 2005 ¹²	112	6	−14 to 26	COPD
Ak, 2006 ⁸	132	6.6	†	COPD
Malatesha, 2007 ¹³	95	8	−7.6 to 6.8	Various
Ibrahim, 2008 ¹⁴	122	3.3	−17.4 to 23.9	Various
Toftgaard, 2008 ²	103	4.5	−12.8 to 3.9	Various
Total	760	5.7‡		
COPD subset				
Kelly, 2005 ¹²	112	6	−14 to 26	COPD
Ak, 2006 ⁸	132	6.6	†	COPD
Total	244	6.3‡		

†Not reported. ‡Weighted mean difference. COPD, chronic obstructive airways disease; DKA, diabetic ketoacidosis.

Base excess

Only one study has specifically investigated agreement between arterial and venous base excess. In a sample of 103 patients, they report a mean difference of 0.089 mmol/L with 95% limits of agreement −0.974 to +0.552 mmol/L.²

Discussion

The weight of data suggests that venous pH has sufficient agreement with arterial pH for it to be an acceptable alternative in clinical practice for most patients. In most studies, the 95% limits of agreement were smaller than reported laboratory analytical error (0.04 pH units).

Table 3. Performance of venous pCO₂ as a screening test for arterial hypercarbia

Author, year	No.	Screening cut-off (mmHg)	Sensitivity	Specificity	NPV	% ABG avoided	Conditions
Lab-based analyses							
Kelly, 2002 ¹⁰	196	45	100	57	†	43	Respiratory conditions
Kelly, 2005 ¹²	107	45	100	47	100	29	COPD
Ak, 2006 ⁸	132	45	100	†	100	33	COPD
Pooled data	435	45	100 (95% CI –97–100%)	56 (95% CI –50–61%)	100 (95% CI –97–100%)	36% (95% CI –32–41%)	
POC							
Ibrahim, 2008 ¹⁴	122	30	100	100	100	†	Mixed respiratory and metabolic cohort
		45	79	76	90		

†Not reported; ABG, arterial blood gas; NPV, negative predictive value; POC, point of care testing.

Table 4. Summary of agreement data for bicarbonate: overall and for the respiratory disease subset

Author, year	No. subjects	Mean difference (mmol/L)	95% limits of agreement	Conditions studied
Pooled data				
Gokel, 2000 ⁶	152	–1.75	†	DKA, uraemia, normal subjects
Kelly, 2001 ¹	246	–1.5	–2.7, 5.3	Various
Rang, 2002 ¹¹	218	–1.75	†	Various
Eizadi-Mood, 2005 ⁷	50	–1.46	†	TCA OD
Ak, 2006 ⁸	132	–1.39	†	COPD
Razi, 2007 ⁹	107	–1.279	†	COPD
Malatesha, 2007 ¹³	95	*	–5.8, 4.3	Various
Total	905	–1.41‡		
Respiratory disease subset				
Ak, 2006 ⁸	132	–1.39	†	COPD
Razi, 2007 ⁹	107	–1.279	†	COPD
Total	239	–1.34‡		

†Not reported. COPD, chronic obstructive airways disease; DKA, diabetic ketoacidosis; OD, overdose; TCA, tricyclic antidepressant.

A note of caution: there is no data to confirm that this level of agreement is maintained in shock states. There is a theoretical basis for this supported by a small intensive care unit study¹⁵ and a paediatric study¹⁶ suggesting that agreement might deteriorate with worsening shock, particularly in patients with hypotension or cardiac arrest. This question requires further data before conclusions can be drawn. There is also no data specifically comparing agreement in mixed acid-base disturbances. Agreement between arterial and venous bicarbonate also appears to be acceptable for clinical purposes, with the same caveats regarding shock and mixed acid-base disorders as previously mentioned.

The weighted mean difference between arterial and venous pCO₂ is of the order of 5 mmHg; however,

reported 95% limits of agreement are wide: of the order of ± 20 mmHg. This is well outside clinically acceptable agreement, ruling out venous pCO₂ as a clinically acceptable substitute for arterial pCO₂ measurement.

The role of venous pCO₂ to screen for arterial hypercarbia is promising, particularly if laboratory-based analyses are used. This appears to have good diagnostic accuracy and would reduce the requirement for arterial samples by about one-third. More work is needed to further explore the potential role of point of care venous pCO₂ as a screen for hypercarbia. There is also an unexplored potential role for serial venous pCO₂ analysis, perhaps in combination with pH, to monitor trends in respiratory function for patients

undergoing non-invasive ventilation or treatment for chronic obstructive airways disease.

In practical terms, how this will interface with the emerging technology of transcutaneous CO₂ monitoring is yet to be seen. Although there is no data reporting the relationship between the peripheral arterio-venous pCO₂ and pH gap and circulatory state, some studies comparing central mixed venous pCO₂ and pH suggest that there might be a relationship between an increased gap and circulatory status.^{15,17–19} Further research is needed to explore if peripheral arterio-venous difference is a useful indicator of circulatory status.

When any two methods of measurement are being compared it is important to define the clinically acceptable limits of agreement. In other words, how much difference between the two measurements can be tolerated in clinical decision making? This will vary between parameters and probably with clinical context. Unfortunately there is little data to inform these definitions. Rang *et al.*,¹¹ in a survey of 26 clinicians, found that the clinically acceptable limits of agreement were 0.05 pH units, 3.5 mEq/L for bicarbonate and 6.6 mmHg for pCO₂. An unpublished survey of 46 clinicians from my own institution found clinically acceptable limits of agreement of 0.1 pH units, 3 mEq/L for bicarbonate and 0.5 mmol/L for potassium concentration. Further data from a large clinician group are necessary before any definition of clinically acceptable differences can be proposed.

Key unanswered questions remain:

- The agreement between arterial and venous pH, bicarbonate and base excess in shock states
- The agreement between arterial and venous pH, bicarbonate and base excess in mixed acid-base disorders
- The agreement between arterial and venous base excess
- The clinical utility of peripheral arterio-venous pH and pCO₂ difference as an indicator of circulatory status
- Clinically acceptable limits of agreement for blood gas parameters
- The relative clinical utility of serial venous blood gas analysis and transcutaneous pCO₂ monitoring for assessing trend in pCO₂

Conclusion

For patients who are not in shock, venous pH, bicarbonate and base excess have sufficient agreement to be clinically interchangeable for arterial values. Agree-

ment between arterial and venous pCO₂ is too poor and unpredictable to be clinically useful as a one-off test but venous pCO₂ might be useful to screen for arterial hypercarbia or to monitor trends in pCO₂ for selected patients.

Competing interests

None declared.

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