Arteriovenous blood gas agreement in intensive care patients with varying levels of circulatory compromise: a pilot study

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ABSTRACT

Objective: Venous blood gas (VBG) analysis is suggested as an alternative to arterial blood gas (ABG) analysis. In haemodynamically stable patients, there is clinically acceptable arteriovenous (AV) agreement for pH and bicarbonate (HCO_3^-) concentration, but in haemodynamically unstable patients, evidence is conflicting. We aimed to evaluate the level of AV agreement for the values of pH, PCO_2, base excess, HCO_3^- and lactate between ABGs and VBGs in critically ill patients with varying degrees of hypotension.

Design and setting: A prospective cohort study of a convenience sample of patients in an intensive care unit of a metropolitan teaching hospital.

Intervention: Paired ABG and central VBG samples were drawn within 5 minutes of each other from existing arterial lines and central venous lines, and analysed for AV agreement of pH, PCO_2, base excess, HCO_3^- and lactate. The outcome of interest was AV agreement with varying levels of blood pressure (BP). Analysis was by descriptive statistics, box whisker plot and Bland–Altman bias plot analysis.

Results: We studied 50 patients with 117 paired ABG and VBG samples. The AV differences (venous–arterial) were: pH, –0.04; HCO_3^-, –0.37 mmol/L; base excess, 0.08 mEq/L; and lactate, 0.16 mmol/L. There was not a clinically relevant deterioration in agreement for these parameters with falling BP.

Conclusion: In critically ill patients with varying degrees of hypotension in the ICU, there is clinically acceptable AV agreement for the values of pH, HCO_3^-, base excess and lactate, an agreement that does not deteriorate significantly with falling blood pressure.

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Arterial blood gases (ABGs) are used to determine pH, partial pressure of oxygen, partial pressure of carbon dioxide (PCO_2), bicarbonate concentration (HCO_3^-), base excess and lactate concentration in seriously ill patients, to assess metabolic and respiratory function. Obtaining a sample for an ABG measurement can be a technically challenging procedure, is more painful for patients, and has a small but clinically relevant rate of significant adverse consequences, such as infection, haematoma, aneurysm, thrombosis and embolisation.[1]

Venous blood gas (VBG) analysis has been suggested as an alternative and is easier, safer and quicker to collect. For haemodynamically stable patients, there is clinically acceptable arteriovenous (AV) agreement for the blood gas parameters of pH and HCO_3^-,[2] but for haemodynamically unstable patients there is conflicting evidence.[3,4]

We aimed to evaluate the level of AV agreement for the values of pH, PCO_2, base excess, HCO_3^- and lactate between ABGs and VBGs in critically ill patients with varying degrees of hypotension in the intensive care unit setting.

Methods

Ours was a prospective cohort study of a convenience sample of patients admitted to the ICU of a metropolitan teaching hospital in Melbourne, Australia. This ICU treats adult patients (age > 18 years) only and does not manage patients with major trauma or neurosurgical or cardiac surgical patients.

Patients were eligible for inclusion if they were managed in the ICU between 3 February and 30 April 2014 and required blood gas analysis as part of routine care. Patients

Abbreviations

ABG	arterial blood gas
AV	arteriovenous
ED	emergency department
HCO_3^-	bicarbonate
MAP	mean arterial pressure
PCO_2	carbon dioxide partial pressure
PO_2	oxygen partial pressure
SBP	systolic blood pressure
VBG	venous blood gas

Table 1. Sample characteristics ($N = 50$)

Variable	Data
Median age, years (IQR)	64.5 (55–75)
Sex (male), *n* (%)	27 (54%)
Non-operative APACHE diagnostic group, *n* (%)	
Respiratory	10 (20%)
Sepsis	9 (18%)
Cardiovascular	7 (14%)
Neurological	6 (12%)
Gastrointestinal	5 (10%)
Other	5 (10%)
Operative APACHE diagnostic group, *n* (%)	
Gastrointestinal	6 (12%)
Other	2 (4%)
APACHE II score, *n* (%)	
0–9	2 (4%)
10–19	18 (36%)
20–34	24 (48%)
> 34	6 (12%)
Median SOFA score (IQR)	10 (8–12)
Systolic BP, *n* (%)	
> 100 mmHg	92 (78%)
90–99 mmHg	15 (13%)
< 90 mmHg	10 (9%)
Mean arterial pressure, *n* (%)	
⩽ 80 mmHg	55 (47%)
65–79 mmHg	51 (44%)
< 65 mmHg	11 (9%)
Ventilatory assistance, *n* (%)	
None	28 (24%)
Non-invasive ventilation	14 (12%)
Mechanical ventilation	75 (64%)
Inotrope use, *n* (%)	115 (98%)
Severe sepsis or septic shock, *n* (%)	20 (40%)
Cardiogenic shock, *n* (%) (1 measure missing)	10 (20%)

IQR = interquartile range. APACHE = Acute Physiology and Chronic Health Evaluation. SOFA = sequential organ failure assessment. BP = blood pressure.

were excluded if they had a haemoglobin level < 70 g/L, had already been sampled three times or if they did not have arterial and central venous access, if it had been > 24 hours since they were admitted, or if was not possible for samples to be taken within 5 minutes of each other. We chose the 24-hour cut-off time to select patients in the acute phase of their illness.

The data we collected included patient demographics, diagnostic categories, vital signs, blood gas parameters and data to calculate illness severity scores. We classified patients as being in severe sepsis, septic shock or cardiogenic shock, according to established definitions.[5,6]

Paired ABG and central VBG samples were drawn within 5 minutes of each other from existing arterial lines and central venous lines. Before collection, 5 mL of blood was drawn and discarded from each line to ensure any substances in the line were removed. Blood gases were analysed using the on-site blood gas machine (ABL800 FLEX [Radiometer]) immediately after collection. Systolic blood pressure (SBP) was recorded within 5 minutes of collection of blood gases. Up to three paired samples could be collected from each patient.

Our outcome of interest was AV agreement of pH, P_{CO_2}, HCO_3^-, base excess and lactate with varying levels of blood pressure (BP). BP was analysed by SBP group (> 100 mmHg, 90–99 mmHg, < 90 mmHg) and mean arterial pressure (MAP) group (⩾ 80 mmHg, 65–79 mmHg, > 65 mmHg). Data were analysed using descriptive statistics, box whisker plot analyses and Bland–Altman bias plot analysis. No a priori sample size calculation was made, as this was a pilot study. Our study was approved by the institutional low-risk ethics panel and patient consent was not required.

Table 2. Overall arteriovenous agreement (bias plot analysis) for pH, P_{CO_2}, HCO_3^-, base excess and lactate

Parameter	Bias (venous–arterial)	95% limits of agreement
pH	–0.40	–0.09 to 0.02
P_{CO_2} (mmHg)	6.4	–1.50 to 14.30
HCO_3^- (mmol/L)	–0.37	–1.90 to 1.10
Base excess (mEq/L)	0.08	–1.30 to 1.50
Lactate (mmol/L)	0.16	–1.10 to 1.40

Results

Our study involved 50 patients with 117 paired ABG and VBG samples. Twenty-five patients had three samples included, 17 patients had two included, and eight patients had one included (median, 2 samples; interquartile range, 1–3 samples). Characteristics of the patients are shown in Table 1.

Overall AV agreement for pH, P_{CO_2}, HCO_3^-, base excess and lactate are shown in Table 2. AV agreement by BP group is shown in Table 3, Figure 1 and Figure 2.

Discussion

Our study failed to demonstrate clinically relevant deterioration in AV agreement with falling BP for blood gas parameters in our resuscitated ICU patient sample. It has also shown that AV agreement for pH, HCO_3^-, base excess and lactate is close and probably acceptable for clinical decision-making purposes. As with haemodynamically stable

Table 3. Arteriovenous differences (venous - arterial) for pH, Pco_2, HCO_3^-, base excess and lactate, by blood pressure (median [interquartile range])

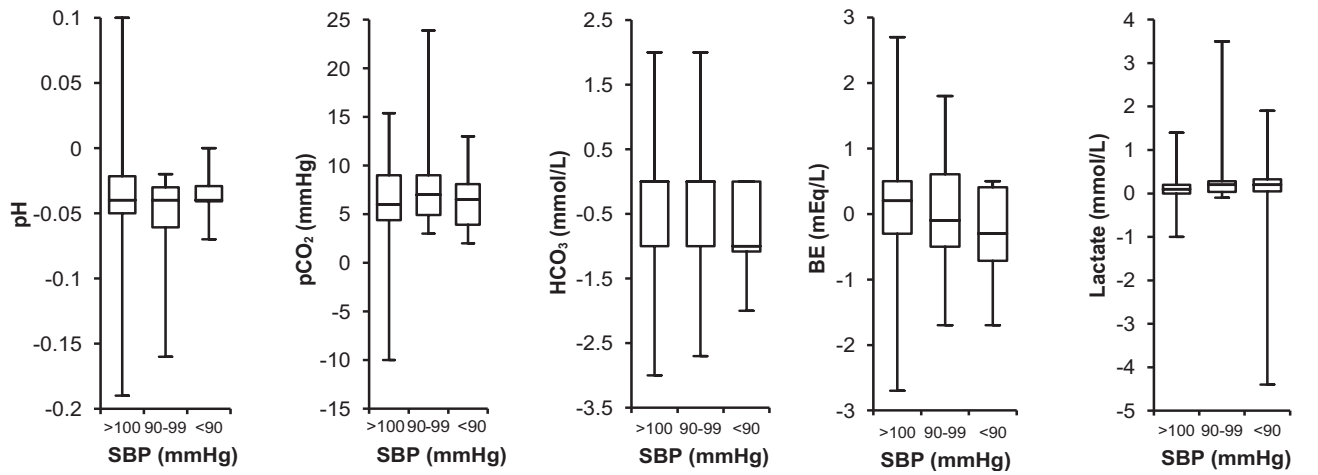
	Systolic blood pressure group		
Variable	**> 100 mmHg (*n* = 92)**	**90–99 mmHg (*n* = 15)**	**< 90 mmHg (*n* = 10)**
pH	– 0.04 (– 0.05 to – 0.02)	– 0.04 (– 0.06 to – 0.03)	– 0.04 (– 0.04 to – 0.03)
Pco_2 (mmHg)	6 (4.4 to 9.0)	7 (4.9 to 9)	6.5 (3.9 to 8.1)
HCO_3^- (mmol/L)	0 (– 1.0 to 0)	0 (– 1.0 to 0)	1.0 (– 1.1 to 0)
Base excess (mEq/L)	0.20 (– 0.30 to 0.50)	– 0.10 (– 0.50 to 0.61)	– 0.3 (– 0.72 to 0.41)
Lactate (mmol/L)	0.10 (0 to 0.20)	0.20 (0.03 to 0.28)	0.20 (0.05 to 0.33)
	Mean arterial pressure group		
	⩾ 80 mmHg (*n* = 55)	**65–79 mmHg (*n* = 51)**	**< 65 mmHg (*n* = 11)**
pH	– 0.04 (– 0.05 to – 0.03)	– 0.04 (– 0.05 to – 0.03)	– 0.04 (– 0.04 to – 0.02)
Pco_2 (mmHg)	6 (4.2 to 8)	6 (4.0 to 9)	7.2 (5.3 to 8)
HCO_3^- (mmol/L)	0 (– 1.0 to 0)	0 (– 1.0 to 0)	0 (– 1.0 to 0)
Base excess (mEq/L)	0.20 (– 0.30 to 0.50)	0 (– 0.40 to 0.51)	0.10 (– 0.28 to 0.50)
Lactate (mmol/L)	0.10 (0 to 0.20)	0.10 (0 to 0.20)	0.20 (0.12 to 0.28)

patients, AV agreement of Pco_2 has wide 95% limits of agreement and thus is not clinically interchangeable.

Our findings on overall agreement are similar to a previous similar study of ICU patients.[7] Our findings on AV agreement with falling BP contrast with the limited previous research on this topic. Adrogue and colleagues[3] studied 105 patients with varying levels of cardiac output including those in cardiac arrest. In their small group of five hypotensive patients, they found widening of the AV difference for pH and Pco_2, which they considered clinically significant. The AV differences for lactate were not reported. Shirani and colleagues,[4] in a study of 192 emergency department (ED) patients, compared normotensive patients (defined as BP > 90/60 mmHg) with hypotensive patients and reported a statistical deterioration in AV agreement for pH, HCO_3^- and base excess, but concluded that the difference was small and probably not clinically relevant. Again, AV agreements for lactate were not reported.

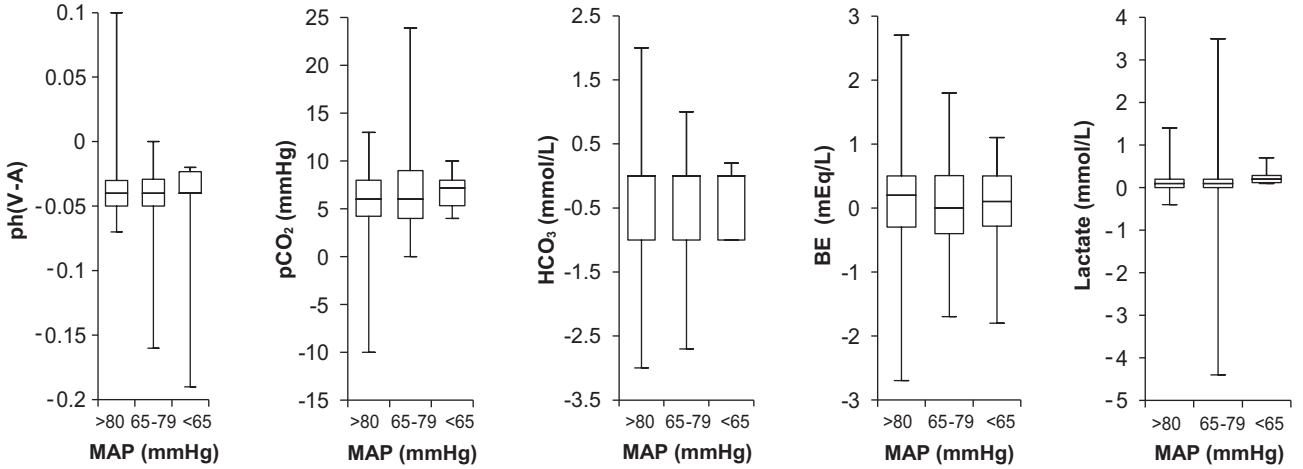
Taken together with our data, the evidence suggests that AV agreement for pH, HCO_3^-, base excess and lactate does not change markedly in resuscitated patients. The data on patients with very low BP or in cardiac arrest are too small to draw valid conclusions from. This is of relevance in environments where immediate arterial access is not available or is competing with other clinical priorities, such as resuscitations in the ED, in developing world environments or in disaster situations. In these situations, venous parameters may be an acceptable alternative to guide initial care.

Figure 1. Arteriovenous agreement of parameters, by systolic blood pressure group



SBP = systolic blood pressure. BE = base excess.

Figure 2. Arteriovenous agreement of parameters, by mean arterial blood pressure group



MAP = mean arterial pressure. BE = base excess.

Limitations

Our study has some limitations that should be considered when interpreting the results. It is a single-site study in a predominantly medical ICU, so results may not be generalisable to all ICU patients. The sample size is relatively small and was a convenience sample based on the availability of the principal researcher to collect data. This may have introduced bias but it is unlikely to have been systematic bias. Samples were taken from central venous lines rather than peripheral lines, so the same level of agreement cannot be assumed for peripheral venous samples.

Patients were undergoing aggressive cardiovascular support, so results may not be generalisable to patients in the early phases of critical illness. Most patients had more than one sample included in the analysis. We did not analyse for within-patient correlations which may have influenced the results.

Conclusion

In critically ill patients with varying degrees of hypotension in the ICU setting, there is clinically acceptable AV agreement for the values of pH, HCO_3^-, base excess and lactate. This AV agreement does not deteriorate significantly with falling BP. As is the case for haemodynamically stable patients, AV agreement for P_{CO_2} is unacceptable, due to wide limits of agreement.

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Competing interests

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