ORIGINAL ARTICLE

Agreement between arterial and central venous values for pH, bicarbonate, base excess, and lactate

P Middleton, A-M Kelly, J Brown, M Robertson

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See end of article for authors' affiliations

Correspondence to: Professor A-M Kelly, Department of Emergency Medicine, Western Hospital, Private Bag, Footscray 3011 Australia; Anne-Maree.Kelly@wh.org.au

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Objective: This study aimed to determine the extent of agreement between central venous and arterial values for pH, bicarbonate, base excess, and lactate in a group of intensive care unit (ICU) patients.
Methods: A prospective study of a convenience sample of patients deemed by their treating doctor to require blood gas analysis as part of their clinical care in ICU. It compared pH, bicarbonate, base excess and lactate on arterial and central venous samples taken within five minutes of each other. Data were analysed using bias (Bland–Altman) methods.
Results: A total of 168 matched sample pairs from 110 patients were entered into the study. All variables showed close agreement. The mean difference between arterial and venous values of pH was 0.03 pH units, for bicarbonate 0.52 mmol/l, for lactate 0.08 mmol/l, and for base excess 0.19 mmol/l. All showed acceptably narrow 95% limits of agreement.
Conclusion: Central venous pH, bicarbonate, base excess, and lactate values showed a high level of agreement with the respective arterial values, with narrow 95% limits of agreement. These results suggest that venous values may be an acceptable substitute for arterial measurement in this clinical setting.

Analysis of pH, bicarbonate, base excess, and lactate levels is an important component of the assessment of clinical status and progress of critically ill patients. Measured pH and derived acid–base variables are not only important in the diagnosis and differentiation of acidosis, but are also useful to monitor the severity and progression of disease processes. Lactic acidosis may reveal the presence of insufficient tissue oxygenation, usually as a result of hypovolaemia or global hypoxia.[1]

Bicarbonate, pH, and base excess are usually measured on arterial blood and lactate is more usually measured on venous blood. Access to arterial blood may be problematic, particularly in the early stages of resuscitation when arterial line access has yet to be established. There is a growing body of evidence that for most patients venous pH is a clinically acceptable surrogate for arterial pH,[2–7] and there is also some evidence that agreement between venous and arterial bicarbonate concentration is sufficient for clinical purposes.[6–8] The relation between venous and arterial lactate and base excess is less clear, with conflicting evidence.[9 10] With respect to lactate, only one study (N = 74) has compared peripheral venous lactate levels with arterial levels.[10] It found the mean difference to be 0.22 mmol/l with 95% confidence intervals of −1.3 to 1.7 mmol/l. A much smaller study (N = 7) compared arterial and mixed venous (pulmonary artery) levels and found an average difference of only 0.02 mmol/l.[9] There are no published data regarding blood from central venous catheters. Only one study has compared arterial and venous base excess.[11] Unfortunately it gave no estimate of the mean absolute difference between the arterial and venous values, but it reported (Pearson's) correlation of 0.96 and 95% limits of agreement of −2.2 to 1.8.

This study aims to add to the body of knowledge, particularly with respect to lactate and base excess. Our specific objective was to determine the extent of agreement between venous and arterial values for pH, bicarbonate, base excess, and lactate in a group of adult intensive care unit (ICU) patients.

METHODS

We undertook this study in the ICUs of two hospitals (the Royal Melbourne Hospital ICU, a 24 bed unit within a tertiary referral hospital, and the Western Hospital ICU, a 12 bed unit in a community teaching hospital). Adult patients requiring arterial blood gas and venous blood analyses as part of their clinical care were eligible for inclusion in the study. Multiple samples from the same patient were allowed. The Royal Melbourne Hospital Foundation Human Research Ethics Committee approved the study. Requirement for informed consent was waived.

Eligible patients had an arterial blood sample drawn from an in situ arterial line and a venous sample drawn from an in situ central venous line, as close to simultaneously as possible. Blood was drawn into blood gas syringes and analysed using ICU based analysers (Radiometer Pacific ABL 725, Radiometer Pacific, Australia and Bayer 865, Bayer, USA, respectively) calibrated according to standard quality assurance protocols. The analysis of arterial blood samples is routine practice in both ICUs, and either a registered nurse or a doctor withdrew and prepared the samples for analysis.

The results were entered into a specifically designed database, and we analysed the data using bias plot (Bland–Altman) techniques.[12 13] As there were several patients with multiple samples, cluster analysis was also performed by using the average per patient of the arterial-venous differences for each of the variables in the analysis.

RESULTS

We collected and included in the study a total 168 matched sample pairs from 110 patients. All had matched data for pH and bicarbonate measurements. There were 167 matched sample pairs for lactate and 165 for base excess. The range and medians for each variable are given in table 1. Based on a normal range of pH of 7.35–7.45 pH units, 62 samples were acidotic and 14 were alkalotic.

Agreement between arterial and venous samples was good for all the variables (table 2, figs 1–4) with narrow 95% limits of agreement. The same held true when data were analysed in clusters with patient as the cluster basis (table 3).

DISCUSSION

An important part of the assessment of the clinical status and progress of critically ill patients is analysis of pH, bicarbonate,

Table 1 Characteristics of the study sample

Variable	No. of samples	Median	Range
pH (arterial)	168	7.37 pH units	7.12–7.50
Bicarbonate (arterial)	168	25.0 mmol/l	14.6–42.2
Lactate (venous)	167	1.13 mmol/l	0.38–6.51
Base excess (arterial)	165	−0.1 mmol/l	−12.1–16

Table 2 Agreement between arterial and venous pH, bicarbonate, lactate, and base excess (all samples)

Variable	No. of samples	Mean difference (venous − arterial)	95% limits of agreement
pH	168	−0.03 pH units	−0.07 to 0.01
Bicarbonate	168	0.52 mmol/l	−1.81 to 2.85
Lactate	167	0.08 mmol/l	−0.27 to 0.42
Base excess	165	0.19 mmol/l	−1.86 to 2.24

base excess, and lactate; however, it may not always be practical to obtain arterial samples, particularly in the early stages of resuscitation. For patients managed without arterial lines, arterial punctures pose a small but significant risk of complications.[14 15] The finding of this study that central venous and arterial pH, bicarbonate, lactate and base excess showed good agreement might allow venous sampling to be used for measuring these variables in certain settings, obviating the need for arterial sampling.

Our study is the first to estimate the absolute level of agreement between arterial and venous measurement of base

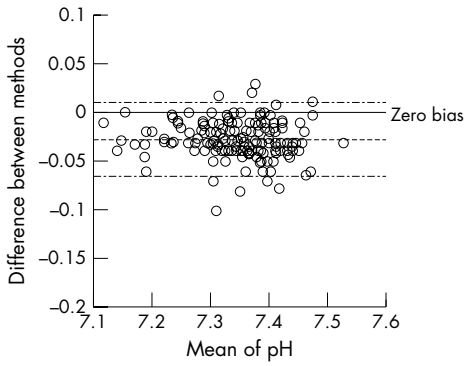

Figure 1. Bias plot for pH.

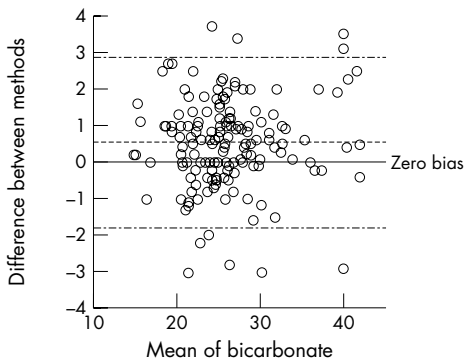

Figure 2. Bias plot for bicarbonate.

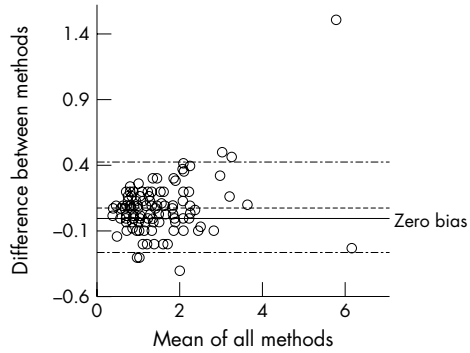

Figure 3 Bias plot for lactate.

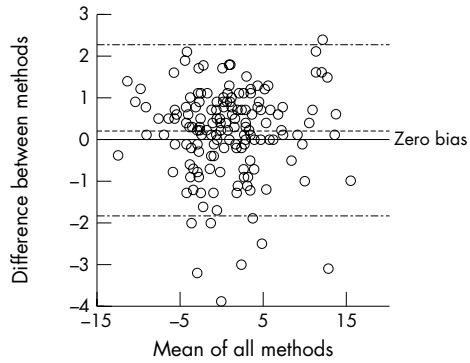

Figure 4 Bias plot for base excess.

excess. Base excess is a way of expressing the metabolic component of acid–base disturbance and can be thought of as the amount of acid or alkali required to return the plasma in vitro to a normal pH under standard conditions. The very small mean arteriovenous difference (0.19 mmol/l) and narrow 95% levels of agreement suggest that venous and arterial base excess estimations may be clinically interchangeable. This is in line with the findings of Malinoski *et al*, who reported similar 95% limits of agreement.[11]

Our study also adds important substantiating data for the agreement between arterial and venous lactate and bicarbonate levels. The agreement between arterial and venous bicarbonate in this study is similar to that of other studies,[6–8] with previously reported mean arteriovenous differences ranging from −1.2 mmol/l to −1.88 mmol/l. The agreement we found in arterial and venous lactate levels is slightly less than that reported by Murdoch *et al*[9] in a series of seven critically ill children (mean arteriovenous difference 0.02 mmol/l) but with similar 95% limits of agreement (−0.20 to 0.24 mmol/l). The mean arteriovenous difference is larger than that reported by Gallagher *et al*[10] (0.22 mmol/l) but they reported much wider 95% limits of agreement (−1.3

Table 3 Agreement between arterial and venous pH, bicarbonate, lactate, and base excess (cluster analysis)

Variable	No. of samples	Mean difference (venous − arterial)	95% limits of agreement
pH	110	−0.03 mmol/l	−0.07 to 0.01
Bicarbonate	110	0.32 mmol/l	−1.75 to 2.40
Lactate	109	0.07 mmol/l	−0.31 to 0.45
Base excess	107	0.24 mmol/l	−1.63 to 2.10

to 1.7 mmol/l). The reasons for these differences are unclear, although Gallagher *et al* studied emergency department rather than ICU patients, and in their study venous blood was drawn from a peripheral vein rather than a central vein. The agreement between arterial and venous pH found in our study is consistent with the findings of other studies.[3–7] Taken together, the evidence implies that arterial and venous measurements of pH, bicarbonate, lactate, and base excess may have sufficient to be clinically interchangeable in many patients. This affords clinicians choice in sampling for these depending on available vascular access. It would allow a single sample to be taken covering all of these measurements rather than both arterial and venous samples, with less handling potentially reducing the likelihood of blood exposure to staff.

Although the variables studied show good statistical agreement, we have not investigated whether this level of agreement is acceptable to clinicians responsible for patient care. The establishment of clinically acceptable limits of agreement and comparison of agreement performance and outliers will determine whether venous sampling becomes accepted as an alternative to arterial sampling for these variables.

Our study has some limitations that should be considered when interpreting the results. We studied a convenience sample of adult ICU patients from two different ICUs and our findings may not be generalisable to other populations. The sample was reasonably small, which precluded meaningful subgroup analyses and measurement of the effects of potential confounders. There may be subgroups of patients in whom arteriovenous agreement for these variables is poorer than the pooled results suggest. For example, the difference between mixed venous and arterial blood P_{CO_2} may increase by a factor of 3 in the presence of severe shock, despite normal oxygen transport patterns.[16] Adrogue *et al*'s small study suggested that agreement between arterial and venous pH is poorer in patients with severe haemodynamic compromise.[17] This needs to be clarified before routine substitution of venous for arterial measures could be recommended. Unfortunately, the study design and waiver of consent conditions did not allow us to collect data on patient demographics, diagnosis, severity of illness, or requirement for inotropic support. Detailed data, allowing analyses that include these potentially important variables, would answer some of the remaining questions. Lastly, the venous samples were taken from central venous catheters and as such may not necessarily be representative of peripheral venous values.

CONCLUSION

In the present study, central venous pH, bicarbonate, base excess, and lactate values showed a high level of agreement with the arterial value, with acceptably narrow 95% limits of agreement. Our results suggest that central venous values may be an acceptable substitute for arterial measurement.

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Authors' affiliations

P Middleton, Public Health and Community Medicine, University of New South Wales and Prince of Wales Hospital, Randwick, NSW, Australia
A-M Kelly, Joseph Epstein Centre for Emergency Medicine Research and Department of Medicine, University of Melbourne, Melbourne, Australia
J Brown, Emergency Medicine, Western Hospital, Melbourne, Australia
M Robertson, Intensive Care, Royal Melbourne Hospital, Melbourne, Australia

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