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Comparison Of Arterial and Venous Blood Gas Values Among Critically Ill Patients

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Abstract

Background and objectives: Arterial blood gas analysis evaluates metabolic and ventilation conditions. Nevertheless, the procedure is characterized by intense discomfort and technical intricacy. In contrast, central venous sampling is a safer and more readily available option for patients with a central line. This research evaluates the agreement between central venous and arterial blood gas measurements in critically ill patients.

Methods: In this single-center cross-sectional study, data was collected from May to August of 2023 in the intensive care unit of Shar Hospital in Sulaymaniyah City, Iraq. One hundred pairs of arterial and central venous blood gases were obtained from 100 adult patients. All were mechanically ventilated; the mean age was 54, and 60% of patients were male. For each pair of arterial and central venous samples, pH, partial pressure of carbon dioxide standard bicarbonate, extracellular base excess, lactate, and ionized calcium were recorded using a single point-of-care blood gas analyzer.

Results: Using the Bland–Altman method, arterial and central venous blood gas values showed high levels of agreement, with mean arteriovenous differences of pH 0.036 ± 0.033, partial pressure of carbon dioxide −4.10 ± 3.581, bicarbonate 0.46 ± 1.542, base excess −0.38 ± 2.625, Lactate −0.172 ± 0.624, and ionized calcium −0.022 ± 0.224.

Conclusions: The pH, partial pressure of carbon dioxide, standard bicarbonate, extracellular base excess, lactate, and ionized calcium levels in central venous blood can be used instead of arterial blood gas measures in the intensive care unit.

Keywords: Arterial blood gas, Central venous blood gas, Intensive care unit

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Introduction

Arterial blood gas analysis (ABG) is the most dependable method for diagnosing ventilatory function and acid-base imbalance in critically ill patients and one of the best mortality indicators, while ABG analysis is known for its speed and precision, it might be difficult to obtain arterial blood, especially in the early stages of resuscitation, before an arterial line is set up.[1,2] Due to the necessity of multiple blood gas measurements during intensive care unit (ICU) admission to assess the disease progression, prolonged arterial catheterization and repeated arterial punctures are needed, which can be painful and carry the risk of rare but severe complications, such as hematoma, bleeding, arterial injury, aneurysms, thrombosis, limb ischemia, infection, reflex sympathetic dystrophy, and potential danger of needle-stick injuries for the medical staff.[3,4] According to recent studies, there isn't much difference between ABG and central venous blood gas (VBG), however, some of these research findings may not be representative due to limited sample numbers and the inability to demonstrate connection and agreement between all regularly used parameters, furthermore, many of these trials have been conducted with certain patient groups, such as those with chronic obstructive pulmonary disease(COPD), acute respiratory distress syndrome(ARDS), or diabetic ketoacidosis (DKA), conversely, some have been carried out in the intensive care unit, yielding inconsistent outcomes.[5-9]In contrast to prior studies that questioned the accuracy of venous blood gas, VBG can potentially replace ABG in the future, although it is already established that the correct partial pressure of oxygen (pO2) cannot be measured by VBG, and pulse oximetry is widely and internationally considered more exact at saturation of more than 80%.[10,11] That's why pO2 is not included in this trial. The use of central VBG as a stand-in for ABG has not yet been the subject of official study in Iraq, especially in the Kurdistan area. This is the first research to evaluate blood gas values utilizing arterial and central venous blood in ICU patients at a single facility in Sulaymaniyah City. The goal of this study is to assess the correlation and interchangeability (agreement) between arterial and central venous measurements for pH, pCO2, HCO3(st), BE(Ecf), lactate, and Ca+2, in a group of undifferentiated critically ill adult patients; independent of the patient's primary pathology, comorbidities, and hemodynamic state.

Patients and methods

A single-center cross-sectional study was conducted in a 24-bed ICU unit of Shar Teaching Hospital in Sulaymaniyah, Iraq, with mixed medical and post-surgical patients. One hundred patients enrolled, with 100 pairs of ABG and central VBGs collected from May to August 2023. Inclusion criteria were any adult ICU patients 17 to 93 years of age who already had central venous access and required blood gas analysis during ICU stay. Exclusion Criteria were patients with limb ischemia, pregnancy, and coagulopathy. Verbal consent was taken from the caregivers of all patients, as the patients were all on mechanical ventilation and in a state of unconsciousness (induced or otherwise), and around 40% of the patients were unstable on vasopressors. The presenting illnesses for the included patients were pathologies such as sepsis, ventilator-associated pneumonia, COPD, heart failure, renal failure, traumatic brain injury, post-surgical, poly-trauma, diabetic ketoacidosis, post-cardiac arrest, myopathies, and stroke. When a blood gas was deemed necessary for any participant by the attending doctor, a resident physician, or a nurse, drew (1–2 mL) blood from the radial or femoral artery and one sample from the indwelling central venous catheter to a (2.5 ml) plastic syringe with minimum heparinization. The samples were collected

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one to two minutes apart and analyzed as quickly as possible using a RADIOMETER ABL 800 FLEX machine (Akandevej 21, DK-2700 Bronshoj, Denmark), which was calibrated. The measuring and calculating capabilities of the analyzer are pH, pCO2 (partial pressure of carbon dioxide), pO2 (partial pressure of oxygen) electrolytes (sodium, potassium, chloride, ionized calcium), HCO3 (standard and actual), base excess(Ecf and Blood), anion gap, hematocrit (Hct), hemoglobin (Hb), p50, oxygen saturation (SO2), FO2Hb (fraction of oxyhemoglobin), FCOHb (fraction of carboxyhemoglobin), FMetHb (fraction of methemoglobin), FHHb (fraction of reduced hemoglobin) glucose, and lactate. The pH, pCO2, HCO3 (st), BE(Ecf), Lactate, and Ca+2 were recorded for each arterial and central venous sample, along with the patient's age and gender. The Council of Clinical Specialty approved this study protocol at the Kurdistan Higher Council of Medical Specialties (KHCMS) in Erbil, Iraq. The study used the Statistical Package for the Social Sciences (SPSS, IBM, Chicago, USA, version 27). Categorical data were represented as numbers and percentages, while numerical data were expressed as mean ± standard deviation (SD). To measure the relationship between arterial and central venous blood parameters, we used Pearson's correlation coefficient (R). We also measured the ability of central venous levels to predict arterial levels using a linear model's coefficient of determination (R2). The degree of agreement between the arterial and central venous pH, pCO2, HCO3, BE, lactate, and Ca+2, was evaluated by plotting the difference between the paired determinations against the mean of the two described by Bland and Altman. This plot is bounded by "limits of agreement (LOAs)" defined as the mean of the arteriovenous differences ± 1.96 (SD).

Results

The mean age was 54.24 ± 21.13 years, ranging from 17 - 93 years. Most patients were aged > 60 years. (49%), followed by <40 years (28%), then 40-60 years old (23%). The male-to-female ratio was 3:2. Regression equations (Pearson correlations) were derived to predict arterial values from venous values, as shown in Table (1). There was a strong positive correlation between arterial and central venous blood for pH, pCO2, HCO3, and base excess, and a moderate correlation for lactate and Ca+2.

Table (1): Mean A-V differences and results of Regression equations (Pearson correlation coefficient (R) and linear model's coefficient of determination (R2) for examining the correlation between ABG and central VBG indices.

Parameter	ABG	Central VBG	A-V difference	Pearson’s correlation p-value <0.001 for all	
	Mean ± SD			R	R^2
pH	7.42 ± 0.11	7.38 ± 0.11	0.036 ± 0.033	0.950	0.902
pCO_2 (mmHg)	36.85 ± 14.09	40.95 ± 14.27	−4.10 ± 3.581	0.968	0.937
HCO_3 (mmol/L)	24.27 ± 5.55	23.81 ± 5.66	0.46 ± 1.542	0.962	0.926
BE (mmol/L)	−0.51± 6.76	−0.13 ± 7.23	−0.38 ± 2.625	0.932	0.868
Lactate(mmol/L)	1.69 ± 1.08	1.86 ± 1.16	−0.172 ± 0.624	0.848	0.719
Ca^{+2} (mmol/L)	0.98 ± 0.23	1.00 ± 0.21	−0.022 ± 0.224	0.477	0.227

https://doi.org/10.56056/amj.2025.362

Additionally, the graphic depictions of the scatter of data and the analysis of agreement for arterial and central venous blood parameters are shown in Table (2). According to the Bland-Altman method, the examined variables all showed acceptable limits of agreement and replaceability. (p-value >0.05).

Table (2): Results of the Bland-Altman method for determining agreement between ABG and central VBG indices.

Parameter	The Bland-Altman method			
	R	R^2	p-value	95% limits of agreement
pH	0.019	0.001	0.851	0.102 to −0.029
pCO_2 (mmHg)	0.052	0.003	0.606	2.919 to −11.119
HCO_3 (mmol/L)	0.074	0.005	0.465	3.482 to −2.562
BE (mmol/L)	0.182	−0.033	0.07	4.766 to −5.0
Lactate(mmol/L)	0.143	0.021	0.155	1.051 to −1.395
Ca^{+2} (mmol/L)	0.118	0.014	0.242	0.417 to −0.461

Discussion

In the present study, we found a significant correlation as depicted in Table (1) between arterial and central venous pH and a strong agreement with 95% LOAs of 0.102 to −0.029 units (P=0.851), these results are in alliance with Bijapur et al. (with 95% LOAs of −0.09 to 0.19).[6] And other studies. [2,7,12-14] The correlation between arterial and central venous pCO2 was statistically significant, and the Bland-Altman method showed a high level of agreement. Our results are identical to those of other studies.[2,4,6,13] In contrast, Kelly et al. compared venous and arterial pCO2 in patients on noninvasive ventilation in the emergency department and found unacceptably wide 95% LOAs (−22.63 to 6.58).[15] However, this trial did not mention whether the venous samples were obtained from peripheral or central veins. Standard bicarbonate HCO3(st) is the concentration of HCO3 from the blood that is balanced with a normal pCO2 (40 mmHg) and a normal pO2 (over 100 mmHg) at an average temperature (37°C) by point of care analyzers. While actual bicarbonate HCO3(act) levels are calculated from pH and pCO2 directly, it is markedly affected by pCO2 levels, so we examined standard HCO3. In our trial, ABG and central VBG values for HCO3 showed excellent correlations and high levels of agreement with 95% LOAs of 3.482 to −2.562 mmol/L. These findings are harmonious with several other authors.[2,6,10,11,13,14] On the contrary, Islam et al. found a significant correlation but no agreement (95% LOAs −7 to 15.6) between arterial and central venous HCO3.[7] Modern blood gas machines calculate base excess in standard (extracellular) and actual (blood) forms. The difference is that BE (Ecf) considers the interaction of blood with the interstitial fluid (the machine does this by equilibrating hemoglobin to 5 g/dl); this gives a better view of the base excess of the entire extracellular fluid. Thus, we only recorded extracellular BE (Ecf). ABG and central VBG values were positively correlated, and showed acceptable agreement with 95% LOAs 4.766 to −5.0 (p=0.07), these outcomes are in agreement with those of other studies.[2,6,16] Although Rudkin et al. found 95% LOAs of −3.9 to 4.4 and considered these ranges unacceptably broad for replacement.[17] Arterial blood lactate concentration is closely linked to the development of multiple organ failure and mortality in patients with septic shock and trauma. It is recommended that intensivists monitor the progression of lactate levels in

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patients experiencing shock to assess and guide treatment.[18] In our study, we found central VBG and ABG lactate to be well correlated and suitable for substitution (p >0.155). These results were as close as those of Hynes et al.[16] with 95% LOAs of −1.1 to 1.4. Our study's LOAs were narrow compared to Kelly et al. who found 95% LOAs of −2 to 2.3, and Réminiac et al. with 95% LOAs of −1.2 to 1.2. Both studies concluded an acceptable agreement for replacement.[12,18] Bloom et al. found no agreement between arterial and venous lactate in a meta-analysis with a pooled mean difference of 0.25 and 95% LOAs ranging from −2.0 to 2.3 mmol/L.[19]Lastly, we examined arterial and central venous ionized calcium; with a moderate level of correlation (R=0.477), and 95% LOAs of 0.417 to −0.461 mmol/L (p=0.242) indicating that the central VBG can replace ABG for Ca+2 measurement. Unfortunately, no other studies regarding central venous ionized calcium could be found. Still, Prasad et al. found a strong correlation and agreement between peripheral venous and arterial Ca+2 with R=0.7 and LOAs of −0.28 to 0.31.[4]

Limitations

Our study had some strengths and weaknesses. It was a single-center trial, our sample size was relatively small compared to some other studies, and we did not consider the patient's hemodynamic status, ongoing vasopressor treatment, and concurrent respiratory disease. Despite these limitations, we evaluated significant acid-base parameters in diverse ICU patients using the same blood gas machine with minimal delay and minimized bias by assessing non-respiratory components of acid-base disturbances like standard bicarbonate and extracellular base excess, often overlooked in other studies.

Conclusions

The research revealed acceptable agreement levels between the pH, pCO2, HCO3(st), BE(Ecf), lactate, and Ca+2 readings derived from the central venous blood and their corresponding arterial values in ICU patients, Therefore, central venous blood gas data may be regarded as dependable substitutes for arterial values.

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Conflicts of interest

None declared.

References

1. Awasthi S, Rani R, Malviya D. Peripheral venous blood gas analysis: An alternative to arterial blood gas analysis for initial assessment and resuscitation in emergency and intensive care unit patients. Anesth Essays Res. 2013 Sep 1;7(3):355-8.

2. Esmaeilivand M, Khatony A, Moradi G, Najafi F, Abdi A. Agreement and correlation between arterial and central venous blood gas following coronary artery bypass graft surgery. J Clin Diagn Res. 2017 Mar; 11(3): OC43–OC46.

3. Bohloli HB, Nazarian S, Habibi M, Fallahnia M, Zare A, Bahmanimehr A. Prediction of arterial blood gas factors from venous blood gas factors in intensive care unit admitted patients. Arch Iran Med. 2018 Jun 1;21(6):246-50.

4. Prasad H, Vempalli N, Agrawal N, Ajun UN, Salam A, Subhra Datta S, et al. Correlation and agreement between arterial and venous blood gas analysis in patients with hypotension—an emergency department-based cross-sectional study.Int J Emerg. 2023 Mar 10;16(1):18.

5. Schrauben SJ, Negoianu D, Costa C, Cohen RM, Goldfarb S, Fuchs BD, et al . Accuracy of acid-base diagnoses using the central venous blood gas in the medical intensive care unit. Nephron. 2018 Apr 12;139(4):293-8.
6. Bijapur MB, Kudligi NA, Asma S. Central venous blood gas analysis: an alternative to arterial blood gas analysis for pH, PCO2, bicarbonate, sodium, potassium and chloride in the intensive care unit patients. Indian J Crit Care Med. 2019 Jun; 23(6): 258–262.
7. Islam MS, Ahmed SM, Bano S, Nadeem A, Shafi M. Correlation and agreement between arterial and central venous blood pH, PO2, PCO2 and HCO3− values of mechanically ventilated patients in intensive care unit: A prospective observational study. Rev Colomb Anestesiol. 2013 Jul 1;41(3):190-5.
8. Zeserson E, Goodgame B, Hess JD, Schultz K, Hoon C, Lamb K, et al. Correlation of venous blood gas and pulse oximetry with arterial blood gas in the undifferentiated critically ill patient. J Intensive Care Med. 2018 Mar;33(3):176-81.
9. Chung PA, Scavone A, Ahmed A, Kuchta K, Bellam SK. Agreement and correlation of arterial and venous blood gas analysis in a diverse population. Clin. Med. Insights, Trauma Intensive Med. 2019 Apr;10:1179560319845869.
10. Byrne AL, Bennett M, Chatterji R, Symons R, Pace NL, Thomas PS. Peripheral venous and arterial blood gas analysis in adults: are they comparable? A systematic review and meta-analysis. Respirology. 2014 Feb;19(2):168-75.
11. McKeever TM, Hearson G, Housley G, Reynolds C, Kinnear W, Harrison TW, et al. Using venous blood gas analysis in the assessment of COPD exacerbations: a prospective cohort study. Thorax. 2016 Mar 1;71(3):210-5.
12. Kelly AM. Can VBG analysis replace ABG analysis in emergency care?. Emerg Med J. 2016 Feb 1;33(2):152-4.
13. Singh NG, Prasad SR, Manjunath V, Nagaraja PS, Adoni PJ, Gopal D, et al. Evaluation of adjusted central venous blood gases versus arterial blood gases of patients in post-operative paediatric cardiac surgical intensive care unit. Indian J Anaesth. 2015 Oct 1;59(10):630-5.
14. Kim BR, Park SJ, Shin HS, Jung YS, Rim H. Correlation between peripheral venous and arterial blood gas measurements in patients admitted to the intensive care unit: A single-center study. Kidney Res Clin Pract. 2013 Mar 1;32(1):32-8.
15. Kelly AM, Klim S. Agreement between arterial and venous pH and pCO2 in patients undergoing non-invasive ventilation in the emergency department. Emerg Med Australas. 2013 Jun;25(3):203-6.
16. Hynes D, Bates S, Loughman A, Klim S, French C, Kelly AM. Arteriovenous blood gas agreement in intensive care patients with varying levels of circulatory compromise: a pilot study. Crit Care Resusc. 2015 Dec 1;17(4):253-6.
17. Rudkin SE, Kahn CA, Oman JA, Dolich MO, Lotfipour S, Lush S, et al. Prospective correlation of arterial vs venous blood gas measurements in trauma patients. Am J Emerg Med. 2012 Oct 1;30(8):1371-7.
18. Réminiac F, Saint-Etienne C, Runge I, Ayé DY, Benzekri-Lefevre D, Mathonnet A, et al. Are central venous lactate and arterial lactate interchangeable? A human retrospective study. Anesth Analg. 2012 Sep 1;115(3):605-10.
19. Bloom BM, Grundlingh J, Bestwick JP, Harris T. The role of venous blood gas in the emergency department: a systematic review and meta-analysis. Eur J Emerg Med. 2014 Apr 1;21(2):81-8.