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Prediction of Arterial Blood Gas Factors from Venous Blood Gas Factors in Intensive Care Unit Admitted Patients

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Abstract

Background: Blood gas analysis is very important in the patients with respiratory problems. Arterial puncture may cause complications such as pain, local hematoma, infection and nerve injury. The procedure itself can be technically difficult. In contrast, venous sampling is an easier procedure with fewer complications. Therefore, this study aims to determine the possibility of replacement of venous blood gas (VBG) values by ABG values in ICU wards admitted patients.

Methods: In this study, 155 paired blood gas samples collected from patients admitted to ICU wards in Motahari hospital, Marvdasht, Fars, Iran. Statistical means of blood gas parameters, including P_{O2}, P_{CO2}, HCO_3 and PH have been compared in both, arterial and venous, blood samples in parallel using paired t-test.

Results: Mean difference of arterial and venous gas parameters, P_{O2}, P_{CO2} and HCO_3, was significantly differ. All paired gas parameters in arterial and venous blood samples were significantly correlated, while this correlation was stronger between P_{CO2} and HCO_3.

Conclusion: To predict the arterial blood gas parameters from VBG parameters, single regression models are of more statistical value compared to multiple regression models. Defined single regression prediction models could be used to predict arterial P_{CO2} and HCO_3, which may reduce arterial sampling in ICU wards.

Keywords: Acid-base equilibrium, Arterial blood gas, Venous blood gas

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Introduction

For most patients who are admitted to the intensive care unit (ICU), it is necessary to assess the imbalances of acid-base and gas exchange of blood gas factors and also respiratory status. To obtain information on oxygenation, ventilation and acid base status of the body, arterial blood gas (ABG) analysis is the main source.[1] As the arterial puncture has its own technical method and an invasive nature, it has some complications such as; arterial injury, hemorrhage, thrombosis with distal ischemia, aneurysm formation and pain. Routinely, to help assess the patient's treatment course, blood gases are obtained more than once during ICU admission. This, therefore, may increase the risk of this invasive method, particularly when performed by inexperienced technicians.[2]

The importance of the data provided by ABG, its possible hazard and complications of repeated punctures, persuade to change its values to a general trend toward less invasive methods such as venous blood gas (VBG) analysis.

The clinical status of the patient is very important for interpretation of blood gas values, thus, valid prediction of ABG factors (PH, P_{CO2}, P_{O2} and HCO_3) from venous blood gas factors should be done in the context of the individual's clinical condition.[3] Mean difference of arterial P_{O2}, P_{CO2} and HCO3 from venous blood gas parameters also correlation of paired blood gas parameters in the arterial and venous samples should be calculated for a target population.

The statistical results could be used to design single or multiple regression models to predict the ABG parameters from venous blood gas parameters.

This study aims to design a regression model for prediction of each ABG factor (PH, P_{CO2}, P_{O2} and HCO_3) from venous blood gas factors to determine whether venous samples can be used as an alternative to arterial values in the patients admitted to the ICU.

Materials and Methods

In this study, 45 adult patients who were admitted to the ICU in the Motahari hospital of Marvdasht, Fars, Iran and required ABG analysis, were enrolled in the study

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with the consent of the patients or their guardians. In this cross-sectional and analytical study, paired blood samples were collected and analyzed at the same time. Arterial and venous samples were obtained within 2 minutes, as paired samples, and were analyzed using the same blood gas analyzer as quickly as possible. For some patients, more than one paired samples were obtained and recorded for a patient to prevent dominating the data set.

Statistical Analysis

Statistical means of blood gas parameters including P_{O2}, P_{CO2}, HCO_3 and PH have been compared in the arterial and venous blood samples in parallel using paired t-test. Pearson correlations of arterial and venous values are reported and linear regression was used to establish equations for estimation of arterial values from venous values. Coefficient of determination (R^2) and Pearson correlation coefficient (r) of the parameters in the regression model are important characteristics of the model to explain its importance and power in the prediction of ABG parameters. Data was analyzed using SPSS version 21.0 software[4] and statistical characteristics of regression models were compared to select the best model of ABG factors.

Results

Of 155 paired samples included in the analysis, 114 paired samples were obtained from patients under mechanical ventilation and 41 paired samples were obtained from patients with spontaneous ventilation. The studied patients consisted of 105 (67.8%) men and 50 (32.2%) women, with a mean ± SD age of 39.6 ± 10 and 54.4 ± 12 years respectively. In the group under mechanical ventilation, three paired samples were obtained from patients receiving bicarbonate also 14 paired samples were obtained from patients receiving blood products.

The detailed information on blood gas values and their mean differences are given in Table 1.

The arterial PH values ranged from 7.11 to 7.68, the arterial P_{CO2} values ranged from 18.3 to 84 mm Hg, arterial bicarbonate values ranged from 7.4 to 48 mEq/L and arterial P_{O2} values ranged from 7.1 to 199 mm Hg. These ranges for venous were 7.06–7.9 for PH, 18.9–87.7 mm Hg for P_{CO2}, 11.6–43 mEq/L for bicarbonate and 10.2–126.7 mm Hg for P_{O2}.

Table 2 shows the correlation between parameter values of VBG and ABG. There were significant correlations between arterial and venous blood gas factors. A high positive significant (*P* value = 0) correlation was observed between arterial and venous P_{CO2} and bicarbonate, while positive correlation between arterial and venous P_{O2} and PH were medial and significant (*P* value < 0.01). For arterial P_{CO2} and bicarbonate a high direct significant correlation was observed as well as venous P_{CO2} and bicarbonate.

The correlation between arterial and venous blood gas factors was used to derive regression equations to predict arterial values from venous values. Single equation was designed according to statistical parameters of the model

Table 1. Arterial and Venous Blood Gas Values and Their Mean Differences

Blood Gas Parameters	ABG (Mean ± SD)	VBG (Mean ± SD)	A-V Difference (Mean ± SD)	Correlation Coefficient (R Value)	*P* Value
PH	7.37 ± 0.08	7.36 ± 0.07	0.015 ± 0.03	0.46**	0.005**
P_{O2}	88.23 ± 37.7	54.74 ± 24.2	33.48 ± 34.47**	0.45**	0**
P_{CO2}	41.05 ± 12.06	44.62 ± 12.75	-3.56 ± 7.29**	0.83**	0**
HCO_3	22.82 ± 5.85	23.85 ± 5.88	-1.02 ± 3.71**	0.8**	0**

** Statistically significant in the level of *P* value < 0.01.

Table 2. Pearson Correlation of Arterial and Venous Blood Gas Factors

	Arterial Blood Gas (ABG)				Venous Blood Gas (VBG)			
	PH	P_{O2}	P_{CO2}	HCO_3	PH	P_{O2}	P_{CO2}	HCO_3
ABG								
PH	1	-	-	-	-	-	-	-
P_{O2}	-0.039	1	-	-	-	-	-	-
P_{CO2}	-0.503**	0.017	1	-	-	-	-	-
HCO_3	0.081	-0.029	0.734**	1	-	-	-	-
VBG								
PH	**0.462****	0.059	0.11	-0.051	1	-	-	-
P_{O2}	-0.087	**0.449****	0.028	-0.031	0.156	1	-	-
P_{CO2}	-0.371**	0.135	**0.829****	0.62**	0.014	-0.015	1	-
HCO_3	0.054	0.022	0.637**	**0.8****	-0.102	0.003	0.743**	1

** Statistically significant in the level of *P* value < 0.01.

Table 3. Regression Model Parameters for Blood Gas Factor Pairs

Blood Gas Factors	Correlation Coefficient R	Coefficient of Determination (R2)	ABG Unstandardized Coefficients (B)	ABG Standardized Coefficients (Beta)	VBG Unstandardized Coefficients-constant (B)	*P* Value
PH	0.462**	0.213	0.366**	0.462**	4.68**	0
PO2	0.449**	0.202	0.698**	0.449**	49.99**	0
PCO2	0.829**	0.687	0.784**	0.793**	6.087**	0
HCO3	0.8**	0.639	0.795**	0.756**	3.862**	0.001

** Statistically significant in the level of *P* value < 0.01.

for each factor.

Shapiro-Wilk test was used to assess the normal distribution of variables, also Pearson correlation test was used to measure the linear relationship between two variables, then the ANOVA test was used to evaluate the regression model. Regression model parameters for blood gas factors are shown in Table 3.

According to measured parameters of the model, regression coefficient of arterial P_{CO2} (ABG-B= 0.784, *P* value < 0.01) can be predicted significantly by venous P_{CO2} through the following regression model:

$ABG.P_{CO2} = 6.087 + (0.784 \times VBG.P_{CO2})$

This model and its coefficient of determination are demonstrated in Figure 1. High coefficient of determination of this model (R^2 linear = 0.687) is indicative of its great ability to predict arterial P_{CO2} with well repeatability and determination in patients admitted to the ICU.

Measured parameters of regression model of arterial bicarbonate and also its regression coefficient showed significant potential to be predicted by venous HCO_3 (ABG-B= 0.795, *P* value< 0.01) through the following regression model:

ABG.HCO3 = 3.862 + (0.795 × VBG.HCO3)

This model, and its coefficient of determination, is demonstrated in Figure 2. The great ability of the model to predict arterial HCO_3, is inferred from its high coefficient of determination measured for this model (R^2 linear = 0.639) which is indicative of good repeatability and determination in patients admitted to the ICU.

We assessed the parameters of the regression models of arterial PH and PO2 and used them to design predictive regression equations. For both of these blood gas factors, poor coefficients of determination (0.213 and 0.202 respectively) were measured which were indicative of weak repeatability of the models to predict arterial PH and PO2. The designed regression models are as follows:

ABG.PH = 4.68 + (0.366 × VBG.PH)

$ABG.P_{O2} = 49.99 + (0.698 \times VBG.P_{O2})$

However, regression models of these two factors were statistically significant (ABG-B = 0.366 for PH and ABG-B= 0.698 for Po_2, *P* value < 0.01) in predicting their arterial values, but due to the sensitivity of the situation in the ICU and low ability of these models to predict efficiently, they are not recommended to be used as predictive models.

Discussion

Management of the patients admitted to the ICU requires acid-base analysis as an essential tool to achieve valuable information about a variety of disease processes. Non-invasive methods have been proven to be useful in this process, but they do not give information about PH, P_{O2}, P_{CO2} and bicarbonate.[5] Thus, ABGs are frequently determined for these patients, regardless of its complications such as; mostly local hematoma related to arterial puncture. In this study, we tested paired samples

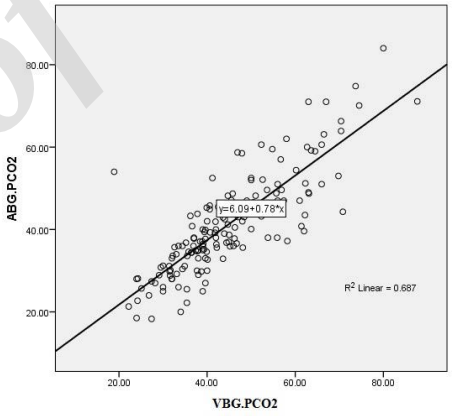

Figure 1. Scatter Plot and Regression Model Line for Prediction of Arterial P_{CO2}.

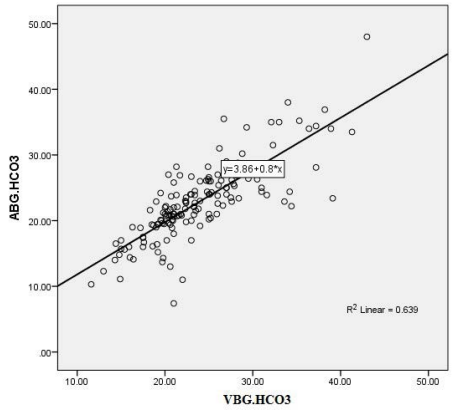

Figure 2. Scatter Plot and Regression Model Line for Prediction of Arterial HCO_3.

of arterial and venous blood to evaluate the possible potentials to replace venous blood sampling instead of arterial blood sampling to predict ABG factors, due to venous blood sampling is easier to be obtained and is a less painful process also reduces the risk of arterial hematoma and thrombosis.

The difference in arterial and venous blood parameters in the patients is very important and it is making the possibility to evaluate the respiratory condition. Some reports showed a mean difference of PH in arterial and venous blood between 0.04 and 0.05.[2,3,6] Treger et al[6] reported this difference for PH around 0.027 which is highly compatible to our report (0.015) in this study.

They also calculated the difference of bicarbonate and CO_2 in arterial and venous blood samples, which were -0.8 and -3.8 respectively. This difference, in our study, was -0.02 and -3.56 for bicarbonate and CO_2 respectively. Generally the difference of bicarbonate in arterial and venous blood has been reported among -1.88 to -0.52[2,7] which is in great agreement with our study.

According to the results of comparing the ABG and VBG factors, the mean difference of paired arterial and venous blood factors was significant. This is indicative of correct sampling and normal activity of the acid-base system in the patients. The measured correlation between blood gas parameters in this study, has an excellent agreement with some previous reports. Razi et al[7] showed a high Pearson correlation for PH, P_{CO2} and HCO3 (0.801, 0.835, 0.786 respectively) and low correlation for P_{CO2} (0.287). These correlations in the study of Honarmand et al[8] on patients under mechanical ventilation, who were admitted to ICU, was 0.791, 0.774, 0.874, and 0.734 for PH, $P_{CO2,}$ HCO3 and P_{O2} respectively. Thus, it is inferred that the measured correlation of PH in the paired blood samples in this study was significantly lower than previous studies.

We assessed the ABG factors could be predicted from venous blood factors (99% significance level), but the coefficient of determination in regression models was different in the blood parameters. The coefficient of determination of the prediction model of PH and P_{O2} was 0.213 and 0.2 respectively, which are not adequately informative to predict arterial factors. These findings are in contrast to the reports of Treger et al[6] which evaluated it 0.945 and 0.883 for the coefficient of determination of PH and P_{O2} respectively.

In regard to P_{CO2} and bicarbonate, coefficient of determination of regression models was 0.687 and 0.639 respectively, which is in agreement with previous reports as the study of Treger et al which reported it 0.883 and 0.95 respectively.

Comparing the predictive regression models and their repeatability of this study and previous reports,[9] it seems these models have good predictability for P_{CO2} and bicarbonate. On the other hand, the regression models of PH and P_{O2}, due to their weak repeatability and correlations, are not recommended to be used for patients admitted to ICU.

Due to specificity of blood gas factors for each patient, it is necessary to predict arterial blood factors in the context of each patient's condition considering all significant correlated factors.[10] For this issue, it is suggested to design a multivariate regression model that includes all sufficient significant correlated parameters. The study of Kim et al.[11] to compare bivariate and multivariate models shows that the multivariate models will have significantly more accurate results for prediction of the parameters. They also reported that repeatability and accuracy of multivariate models will be higher than bivariate models. They designed multivariate models to predict ABG factors from venous samples by a combination of all variables and stated that this model was highly accurate and reliable to estimate the acid-base condition of the patients.

Based on the suggestions of previous studies,[12,13] this study also attempted to design multivariate models to predict ABG factors from venous blood samples. In this regard, parameters with high and significant correlations were considered in the model for each parameter and the result was compared with bivariate models.

For prediction of arterial PH, we used venous PH and P_{CO2} as predictive variables according to their significant correlation to arterial PH (0.462 and -0.371 respectively).

ABG.PH = 5.236 + (0.3 × VBG.PH) – (0.002 × VBG. P_{CO2})

However, this model was significant in coefficient of regression, but its coefficient of determination was very low (0.263) and this model was evaluated as not recommended to be used in ICU admitted patients.

For prediction of arterial P_{CO2}, we used venous PH, HCO_3 and P_{CO2} as predictive variables according to their significant correlation to arterial P_{CO2} (0.31, 0.637 and 0.829 respectively). Coefficient of regression for PH and HCO_3 in this model was not significant. It means that despite of the high correlation of these factors to arterial P_{CO2}, they do not have good predictive values for P_{CO2}.

For prediction of arterial HCO_3, we used venous HCO_3 and P_{CO2} as predictive variables according to their significant correlations to arterial HCO_3 (0.8 and 0.62 respectively). Coefficients of regressions were not significant in this multivariable model, for accurate prediction of arterial bicarbonate, and therefore this model is not recommended to be used in ICU admitted patients. In this study, we could not use any predictive variables to predict arterial P_{O2} due to insignificant correlation between arterial P_{O2} and venous blood gas

parameters.

Conclusion

Peripheral venous P_{CO2} and bicarbonate can replace their arterial equivalents in many clinical contexts, for patients admitted to ICU. The arterial values should be predicted by suggested regression models.

Comparing the bivariate and multivariate models regarding coefficient of determination and their repeatability, it shows that the multivariate models cannot be considered significantly more variable than the corresponding simple linear regression equations. This demonstrates that using the more complicated multivariate equations has no advantage to linear equations and is not recommended to be used in ICU patients.

Authors' Contribution

HBB, SN; Conceived and devised the study. MF, AZ; Was responsible for sample collection. AB; did statics and analyzed the results. MH, SN, HBB; Assisted in defining the idea and writing the manuscript. The manuscript was revised by HBB and SN. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Conflict of Interest Disclosures

The authors have no conflicts of interest.

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References

1. 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;30(8):1371-7. doi: 10.1016/j.ajem.2011.09.027.
2. 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;59(10):630-5. doi: 10.4103/0019-5049.167492.
3. Adrogue HJ, Rashad MN, Gorin AB, Yacoub J, Madias NE. Assessing acid-base status in circulatory failure. Differences between arterial and central venous blood. N Engl J Med. 1989;320(20):1312-6. doi: 10.1056/nejm198905183202004.
4. IBM Corp. Released 2010. IBM SPSS Statistics for Windows, Version 19.0. Armonk, NY: IBM Corp; 2010.
5. Wilson BJ, Cowan HJ, Lord JA, Zuege DJ, Zygun DA. The accuracy of pulse oximetry in emergency department patients with severe sepsis and septic shock: a retrospective cohort study. BMC Emerg Med. 2010;10:9. doi: 10.1186/1471-227x-10-9.
6. Treger R, Pirouz S, Kamangar N, Corry D. Agreement between central venous and arterial blood gas measurements in the intensive care unit. Clin J Am Soc Nephrol. 2010;5(3):390-4. doi: 10.2215/cjn.00330109.
7. Razi E, Moosavi GA. Comparison of arterial and venous blood gases analysis in patients with exacerbation of chronic obstructive pulmonary disease. Saudi Med J. 2007;28(6):862-5.
8. Honarmand A, Safavi M. Prediction of arterial blood gas values from arterialized earlobe blood gas values in patients treated with mechanical ventilation. Indian J Crit Care Med. 2008;12(3):96-101. doi: 10.4103/0972-5229.43677.
9. 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;33(3):176-81. doi: 10.1177/0885066616652597.
10. Chu YC, Chen CZ, Lee CH, Chen CW, Chang HY, Hsiue TR. Prediction of arterial blood gas values from venous blood gas values in patients with acute respiratory failure receiving mechanical ventilation. J Formos Med Assoc. 2003;102(8):539-43.
11. 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;32(1):32-8. doi: 10.1016/j.krcp.2013.01.002.
12. Shirani F, Salehi R, Naini AE, Azizkhani R, Gholamrezaei A. The effects of hypotension on differences between the results of simultaneous venous and arterial blood gas analysis. J Res Med Sci. 2011;16(2):188-94.
13. 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(2):86-91. doi: 10.1097/MEJ.0b013e3282e6f5c5.