Can Venous Blood Gases Replace Arterial Blood Gases in Diabetic Ketoacidosis/Renal Failure Induced Metabolic Acidosis?

Naveen Mohan*, Gireesh Kumar K.P, Sreekrishnan T.P, Ajith Kumar. J, Ajith.V, Bharath Prasad. S, Krupanidhi Karunanithi, Arun Kumar. K

Amrita Institute of Medical Sciences & Research Centre, India

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Abstract The study aims to identify the correlation between arterial and venous blood gas variables, in patients with metabolic acidosis secondary to renal failure and/or diabetic ketoacidosis(DKA). Paired arterial and venous blood samples of 100 patients, with metabolic acidosis resultant to renal failure and/or diabetic ketoacidosis during 2009-2011, were analyzed and the correlation between the variables were assessed using SPSS software, applying Pearson's product moment correlation coefficient, Linear regression, Statistical parameter R^2 and Chi-square test. Results: Mean ABG values for pH, HCO_3 , pCO_2 and lactate were (7.29 +/- 0.448, 12.12 +/- 2.61, 25.2 +/- 4.0 and 5.39 +/-1.95 respectively) and mean VBG values for the same were (7.292 +/- 0.0451, 12.23 +/- 2.55, 27.8 +/- 3.9, and 5.19 +/- 1.81). Pearson product moment coefficient for pH, HCO_3 , pCO_2 and lactate were 0.919, 0.967, 0.966 and 0.924, with $p < 0.001$. Percentage variation in ABG as explained by VBG for pH = 84.4%, HCO_3 =93.6%, pCO_2 = 93.2% and lactate = 85.4%. Regression equations to predict arterial from venous values:-Arterial pH = $0.631 + 0.913 \times \text{venous pH}$ ($R^2=0.844$), Arterial HCO_3 = $0.990 \times \text{venous } HCO_3$ ($R^2=0.936$), Arterial pCO_2 = $-2.546 + 0.997 \times \text{venous } pCO_2$ ($R^2=0.932$), Arterial lactate = $0.993 \times \text{venous lactate}$ ($R^2=0.854$). Arterial and venous blood gas values showed significant correlation coefficient for pH, HCO_3 , pCO_2 and lactate. Hence, VBG may be used as an alternative to ABG in the initial management metabolic acidosis secondary to diabetic ketoacidosis and/or renal failure.

Keywords Renal Failure, Diabetic Keto Acidosis, Metabolic Acidosis, Venous Blood Gas, Arterial Blood Gas

1. Background

Metabolic acidosis resulting from renal failure and/or diabetic ketoacidosis (DKA) is detected through arterial

blood gases (ABG). Arterial blood gas sampling is invasive; involving patient discomfort, arterial injury, thrombosis or embolism, hematoma, aneurysm, reflex sympathetic dystrophy,[1-3] increased number of penetrations and possibility of needle prick injury to medical personnel. Various studies have revealed significant correlation between arterial and venous blood gas(VBG) values, especially pH, pCO_2 , HCO_3 and lactate with p value < 0.001 in all instances,[4-8] indicating the significance of VBG sampling as an alternative to ABG,[4-16] despite some reservations,[5,17,18]. Our study is intended to identify the significance of VBG as an alternative to ABG for detecting metabolic acidosis in the emergency intensive care unit (ICU).

2. Methods

One hundred patients with proven metabolic acidosis resultant to renal failure and/or diabetic ketoacidosis admitted to the emergency intensive care unit of a referral hospital at Kochi during 2009-2011, meeting the inclusion criteria were selected for the study. Inclusion criteria includes patients with pH < 7.35 and $HCO_3 < 18$ with or without comorbidities.

Paired arterial blood gas samples were collected from the radial artery and venous blood gas samples from adjacent veins (immediately after first intravenous cannulation before any drug or fluid administration) and analyzed using the ABG analyzer. All variables of arterial blood gases were compared with corresponding variables of venous blood, and the correlation between the variables were studied using SPSS software, applying Pearson's product moment correlation coefficient, linear regression, statistical parameter R^2 and Chi-square test.

3. Results and Discussion

- Out of 100 patients studied, 72 (72%) were males and 28(28%) were females, generally in the age group of 41-60 years (TABLE 1), with or without comorbidities (TABLE 2).

Table 1. Demographic distribution of patients

Age	n=100
0-20	7
21-40	23
41-60	53
61-80	17
>80	1

Table 2. Demographics of comorbidities

Co morbidities	Patients
Diabetes Mellitus	60
Hypertension	27
Dyslipidemia	17
Chronic kidney disease	15
Chronic liver disease	13

- Eighty patients (80%) had metabolic acidosis due to renal failure and 20 (20%) due to diabetic ketoacidosis.
- Most common diseases causing renal failure and diabetic ketoacidosis were urosepsis 22(22%), pneumonia 22(22%) and gastrointestinal sepsis 21(21%).
- Mean arterial and venous blood gas values for variables- pH, HCO₃, pCO₂ and lactate are listed (TABLE 3).

Table 3. Mean arterial & venous blood gas values

Variables	ABG(Mean+/-SD)	VBG (Mean+/- SD)
pH	7.29+/-0.0448	7.292+/-0.0451
HCO ₃	12.12+/-2.61	12.23 +/- 2.55
pCO ₂	25.2+/-4	27.8 +/- 3.9
Lactate	5.39+/-1.95	5.19 +/- 1.81

- Mean arterial and venous blood gas values of pH, HCO₃, pCO₂ and lactate exhibited significant correlation as explained by Pearson product moment coefficient of 0.919(FIGURE 1), 0.967(FIGURE 2) 0.966(FIGURE 3) and 0.924 (FIGURE 4) respectively, with p <0.001 in all instances (TABLE 4).

Figure 1. Correlation of arterial and venous pH **Figure 2.** Correlation of arterial and venous HCO₃ **Figure 3.** Correlation of arterial and venous pCO₂

Figure 4. Correlation of arterial and venous lactate

Table 4. Correlation coefficient between ABG and VBG with respect to different variables

Variables	r= correlation coefficient	P value
pH	0.919	<0.001
HCO ₃	0.967	<0.001
pCO ₂	0.966	<0.001
Na ⁺	0.703	<0.001
K ⁺	0.776	<0.001
Cl ⁻	0.525	<0.001
Anion gap	0.577	<0.001
Lactate	0.924	<0.001

- Based on these results regression equations were derived, to predict arterial values from venous values as follows:-
 - Arterial pH = $0.631 + 0.913 \times \text{venous pH}$ ($R^2=0.844$)
 - Arterial HCO₃ = $0.990 \times \text{venous HCO}_3$ ($R^2=0.936$)
 - Arterial pCO₂ = $-2.546 + 0.997 \times \text{venous pCO}_2$ ($R^2=0.932$)
 - Arterial lactate = $0.993 \times \text{venous lactate}$ ($R^2=0.854$)
- Percent of variance (R²) in arterial blood gases for HCO₃, PCO₂, lactate and pH explained by venous blood gases in our study, was 93.6, 93.2, 85.4 and 84.4 respectively. One of the previous studies showed a percent variance of 95, 88, 95 for HCO₃, PCO₂ and pH respectively, [6].
- Arterial blood gases showed non anion gap metabolic acidosis (NAGMA) in 62 (77.5%) and high anion gap metabolic acidosis (HAGMA) in 18 (22.5%) patients with renal failure, and all 20 (100%) patients with diabetic ketoacidosis had HAGMA, $p<0.001$. Mixed acid base disorders in the same patient could have brought this bias.

- Venous blood gases showed NAGMA in 49 (61.3%) of the patients and HAGMA in 31(38.8%) patients with renal failure, and 2(10%) patients with diabetic ketoacidosis had NAGMA and 18(90%) patients with DKA had HAGMA, $p<0.001$. There seems to be some difference between ABG and VBG in while assessing the type of metabolic acidosis. As anion gap is further dependent on variables like Na⁺, K⁺, Cl⁻, HCO₃, serum albumin etc it can get considerably altered because the correlation coefficients of those variables showed only minimal amount of correlation FIGURE 5,6,7,8. This could possibly explain variations in the type of metabolic acidosis between the arterial and venous blood samples. Further studies are warranted in this direction, possibly by utilizing the lab derived serum values of the electrolytes for anion gap determination, rather than the ABG analyzer derived electrolyte values.

Figure 5. Correlation of arterial and venous sodium

Figure 6. Correlation of arterial and venous potassium

Figure 7. Correlation of arterial and venous chloride

Figure 8. Correlation of arterial and venous anion gap

Arterial blood gas analysis is a useful tool for determining the acid base and respiratory status of critically ill patients.

Venous blood gas analysis has got advantages like safety, fewer number of punctures, ease of sampling along with other blood samples at the time of intravenous line insertion etc,[5,17] even though there are some reservations,[18].

Venous blood gas analysis cannot totally replace arterial blood gas, especially in determining pO₂ status and for arterial blood pressure monitoring. But given the accuracy of pulse oximetry, VBG analysis may be a safer alternative to ABG for determining acid base status, reducing the need for frequent invasive arterial sampling.

Arterial and venous values for pH and HCO₃ showed excellent agreement (TABLE 5) with each other as in earlier studies, [4,9,10-12,14-18].

The mean arterial minus venous difference for pH was -0.002^{TABLE 5} in our study, which suggests that VBG pH values very closely correlate with ABG pH values. The previous studies indicated a difference of -0.04 to 0.05, [9-12,14-18], which also supports VBG substitution for ABG.

In the case of HCO₃, the mean arterial minus venous difference was -0.11^{TABLE 5}. Though the previous study results varied from -1.88 to -0.52,[4,11,12,14-16,17,18], they too indicate that venous bicarbonate can be used as a substitute for arterial bicarbonate.

For pCO₂, the mean arterial minus venous difference was -2.6^{TABLE 5} whereas previous results ranged from -6.6 to -3.0,[15-18]. Hence there is considerable agreement between the two studies.

In the case of lactate, the mean arterial minus venous difference was 0.2. Previous study by Middleton P et al,[12] showed a lactate value of 0.08.

Arterial and venous blood gases showed highly significant correlation coefficient for pH, HCO₃, pCO₂ and lactate (r=0.919, 0.966, 0.967 and 0.924 respectively with a p value of <0.001).

Hence, venous blood gas might be used as an ideal alternative to arterial blood gas in the initial management for diabetic ketoacidosis and/or renal failure.

Table 5. Comparison of Arterial & Venous Blood Gas variables

	pH	HCO ₃	pCO ₂	Lactate	
ABG	7.29+/-0.0448	12.12+/-2.61	25.2+/-4.0	5.39+/-1.95	
VBG	7.292+/-0.0451	12.23+/-2.55	27.8+/-3.9	5.19+/-1.81	
Correlation coefficient between ABG & VBG					p value
	0.919	0.967	0.966	0.924	<0.001
n=100	Renal Failure patients(n=80)		Diabetic Ketoacidosis patients(n=20)		
ABG	62(77.5%)	18(22.5%)	20(100%)		<0.001
	NAGMA	HAGMA	HAGMA		
VBG	49 (61.3%)	31(38.8%)	2 (10%)	18 (90%)	
	NAGMA	HAGMA	NAGMA	HAGMA	<0.001

4. Limitations

- Only one paired sample was taken and analyzed. Further studies involving serial paired samples may fetch better results.
- Long period of study over two years can introduce many variables, for example the source of ABG kits used for sample analysis in the hospital lab.
- Patients with metabolic acidosis with pH > 7.18 only were studied. Those with lower pH have to be studied.
- Patients with predominant metabolic acidosis alone were subjected to the study. The extent of correlation in mixed acid base balance has to be studied.
- Utilization of the lab derived serum values of the electrolytes for anion gap determination, rather than the ABG analyzer derived electrolyte values, could have possibly been more accurate while determination of the type of metabolic acidosis, ie. whether NAGMA or HAGMA.

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