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Comparison of Simultaneously Obtained Central Venous Blood Gas and Arterial Blood Gas Analysis for pH, pCO2, BE and K+ in Patients Presenting to Emergency Medicine and Critical Care Unit

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Abstract

Objective: This study was done to compare Arterial values of pH , pCO2, B.E, K^+ with Central venous values and to establish a correlation between arterial and central venous values of pH , pCO2, B.E, K^+ in the clinical management of selected patients in the emergency department. *Methods*: The study population consisted of 40 critically ill patients in emergency and critical care units. Arterial and Central venous blood gas measurements of pH, pCO2 B.E, K^+ were taken. Simultaneously other variables were noted. Comparision of mean values of pH , pCO2, B.E , K^+ between arterial and central venous was done using t –test. *Results*: As per the linear regression analysis arterial values of pH , pCO2 B.E, were found to be correlated significantly with central venous values (correlation coefficient r being 0.94 for pH and r =.96 for pCO2, r =.97 for B.E), while arterial and venous values of K^+ were found to be poorly correlated (correlation coeffiecient,r =.375 .). *Conclusion:* Central venous blood gas values of pH, pCO2 B.E can be considered instead of arterial blood gas values in continuous assessment of critically ill patients. As per this study estimation of arterial values of potassium cannot be done based on venous potassium levels. Frequent arterial punctures can be avoided by recording central venous blood gas values in monitoring of critically ill patients.

Keywords: Blood Gas Analysis; Venous pH.

Introduction

Arterial blood gas analysis gives important information about physiological status and progress of the disease, It provides valuble information about acid base status and metabolic condition, (pH, pCO_2, pO2, HCO_3, BE,) oxygenation and ventilation, which plays an important role in evaluation and treatment of the patient . It is a commonly performed invasive procedure that is often used to determine the acid base status of critically ill patient, however this test can result in patient discomfort as well as complications such as arterial injury, thrombosis, or embolization, haematoma and aneurysm formation. In addition the procedure has a small but appreciable risk for needle stick injury to health care workers [1, 2].

Where as central venous blood gas analysis requires fewer punctures, is a relatively safer procedure for both the patient and health care provider and may be an alternative to ABG analysis for acid basis status. There is an emerging evidence to suggest that there is agreement between ABG and VBG values [3].

The most obvious advantage of obtaining a VBG instead of ABG is, that a VBG sample can be drawn using the same IV line that is used to draw blood for other lab tests that necessiating only one puncture. This translates into decreased costs, labour, and

decreased risk of needle stick injury to the health care provider, further more complications such as arterial laceration, haematoma, and thrombosis are all but negated with venous blood sampling [2]. Although many studies have been carried out on correlation between analysis of blood gases in arterial and venous samples there is few information on those conditions which can weaken the desired condition. For instance hypoperfusion following hypotension is a condition wich may influence the correlation of analysis of blood gasses in arterial and central venous samples. Similarly hyperventilation is also a condition which may influence the correlation of arterial and central venous blood gas sample[3].

As Emergency department patients are generally critically ill it is important to compare arterial and venous values in acutely ill individuals. In cardiac arrest victims, the disparity between arterial and venous values is even greater, during cardiac arrest, tissue hypoxia is a certainty and is reflected by lower and higher pCO2 on venous side.It has also been found from studies that as cardiac output declines the differences between arterial and venous measurements increase, they have concluded that VBG analysis in cardiac arrest provides values more indicative of true cellular environment. Elevated lactate levels are an early sensitive marker of tissue hypoperfusion predicting both the severity of haemodynamic compromise and over all patient prognosis [4]. Unlike the pH during cardiac arrest , interpreting a venous lactate levels in relation to arterial value could be usefull in the workup and management of critically ill patients as the available evidence suggests that there is close correlation between arterial and venous lactate values [1,4].

Using A.B.G measurements and serum electrolytes levels the emergency physicians can perform the six steps involved in calculating mixed acid base disturbances, venous pH values can aid. In first step because they closely mirror arterial values for several metabolic conditions including Diabetic keto acidosis and uremia.

Other metabolic conditions can still be detected by using information from serum electrolytes , anion and delta gaps [5]. In physiologic terms, ABG composition reflects the relationship between ventilation and perfusion and it is an important reflection of over all pulmonary function. Although a close correlation between arterial and venous pCO2 does not exist a venous pCO2 value that predicts significant arterial hypercarbia might be useful [5].

Since there are few studies in this field ,definitive conclusions regarding importance of identifying conditions which affect validity of ABG and CVBG analysis cannot be obtained yet, so the present study is being done.

Current study is carried out to evaluate results of ABG (Arterial Blood Gas) and CVBG (Central Venous Blood Gas) samples in critically ill patients with diverse etiology.

Material and Methods

Study approval by the Institutional Ethics Committee, Kamineni Institute of Medical sciences and informed consent from patients / relatives for this study was performed over a period of two years in the Emergency and Critical care units in Kamineni Institute of Medical sciences, Narketpally, Nalgonda district, Telangana, India.

Prospective study was conducted on 40 patients in Emergency medicine and critical care units. The samples were analysed as quickly as possible using Blood gas Analyser. Unstable and critically ill patients with respiratory, cardiovascular, neurological, renal dysfunction and hepatic impairment and all polytrauma patients were included in the study.

If length of hospital stay of the patients is < 2hrs, patients below 18yrs of both genders and all pregnant patients were excluded from study.

Arterial and Central venous blood gas values of pH, pCO2 , Base Excess and K^+ were recorded. Arterial and VBG samples were drawn simultaneously for each patient. Arterial samples (0.5–1 ml) were obtained using heparinized plastic syringe either from radial or femoral arteries either by direct puncture of the artery or from arterial catheters and analyzed via blood gas analyzer. For venous sampling, 5 mL blood was obtained from the central catheters and was kept a side. Then 0.1 mL of venous blood was obtained in the heparinized syringe and sent for analysis via blood gas analyzer. Then 5 mL of venous blood was returned back to the patient and the catheter was flushed with normal saline 0.9. Patients were sampled for arterial and venous blood with minimum delay (always 2 min) between the samples. Additional data collected on a standardized data collection form included patients' age, sex, primary diagnosis. The results were analyzed and statistical significance was set at $p < 0.05$.

Continuous variables- (pH, pCO_2, B.E, K^+) were analyzed w mean and standard deviation. Comparison of mean values of above variables

between arterial and central venous blood was done using t-test. Correlation between Arterial and Central Venous values – pH , pCO2 B.E and K^+ was analyzed by linear regression analysis.

p value and correlation coefficient (r) were reported in tabular form.

p value is interpreted as:

>0.05-	not significant
0.01 – 0.05 -	significant
0.001 – 0.01 -	very significant
<0.001 -	extremely significant

The closer r value is to 1 the more significant is the correlation. Statistical analysis was done using SPSS ver 19 software.

Results

Forty critically ill patients admitted to the emergency medicine and critical care units were included in the current study. They consisted of 26 patients (65%) males and 14 patients (35%) females. Among them, 11 (27.5%) of them belongs to the age group 18-30, 16 (40%) belongs to the age group 31-60, and the remaining 13 (32.5%) belongs to the age group 61-90 years.

In relation to the diagnosis of the patients, 18% of the patients were diagnosed with renal disorders, 23% with metabolic disorders, 5% with pulmonary disorders, 10% were diagnosed with cardiovascular disorders, 5% were diagnosed with hepatic disorders, 18% were diagnosed with renal disorders 32.5 % were poisoning , 7.5% sustained stings.

Analysis of pH, pCO2, BE and K+ through ABG and CVBG and their significance and correlation was mentioned in Table 1 & 2.

Identity Plots for Assessing Perfect Agreement

In relation to the identity plots (Figures 1-4), they were used to ascertain agreement between the arterial and central venous measurement of pH, pCO2, B.E , K^+ levels in critically ill patients.

Table 1: Comparision of Mean values of Arterial and Central Venous Blood Gas Values

Parameter	ABG Mean ±S.D	CVBG Mean ±S.D	*p*- value	ABG-CVBG Mean difference
pH	7.17± .24	7.06 ±.27	.432	0.11
pCO_2	39.04 ±18.9	41.30 ±19.1	.886	2.26
B.E	-8.85 ±7.07	-10.93 ± 7.62	.714	2.08
K^+	4.76 ±1.22	3.70 ± 1.36	.590	1.06

Table 2: Correlation between –Arterial and Central Venous Blood Gas Values

Parameter	Correlation Coefficient - (r)	95 % confidence Interval	p- value
P h	.94	o.9o to.96	< .ooo1
pCO2	.96	0.92 to0.95	< .ooo1
B.E	.97	0.93 to 0.94	< .ooo1
K^+	-.14	-.47 to 1.6	.375

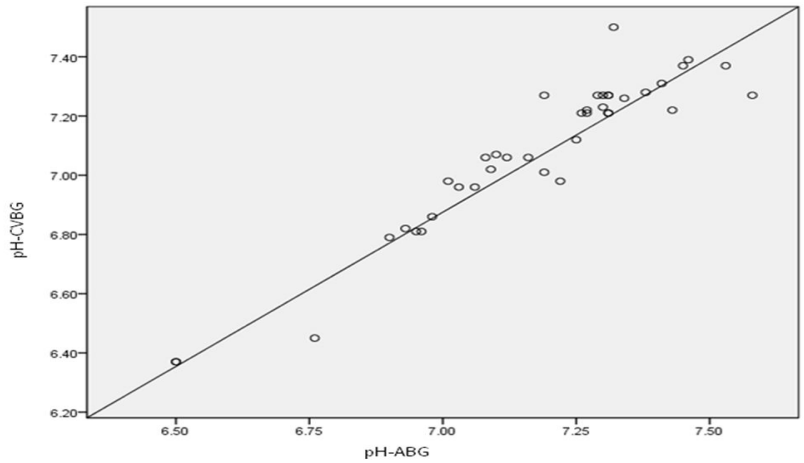

Fig. 1: Identity Plot - Arterial versus Central Venous pH(n=40)

shows the identity plot - arterial versus central venous measurement of pH. Most of the paired measurements were close to the line of perfect agreement (indicated by a diagonal line). Hence it can be concluded a significant agreement between the arterial and central venous measurement of pH.

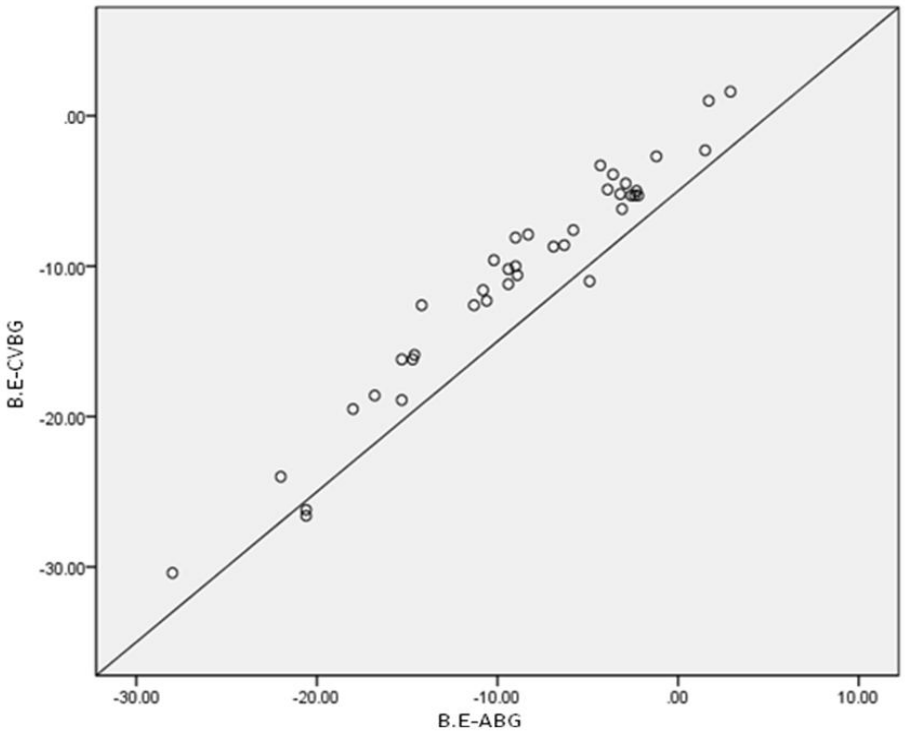

Fig. 2: Identity Plot - Arterial versus Central Venous pCO2 (n=40)

Shows the identity plot - arterial versus central venous measurement of pCO2. Most of the paired measurements were close to the line of perfect agreement (indicated by a diagonal line). Hence it can be concluded a significant agreement between the arterial and central venous measurement of pCO2.

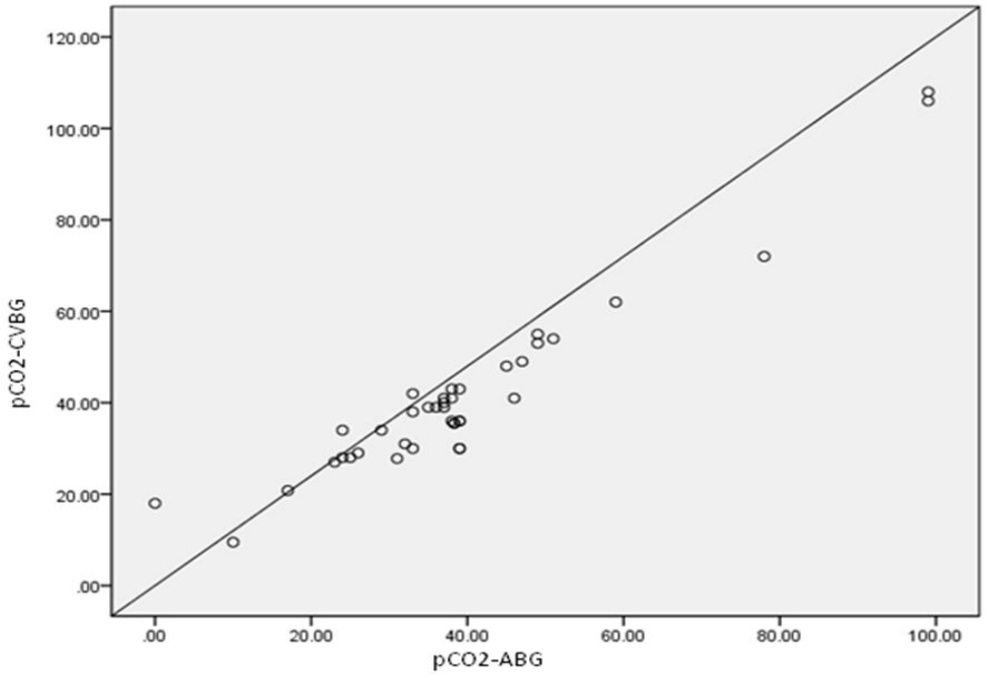

Fig. 3: Identity Plot - Arterial versus Central Venous Base Excess

It shows the identity plot - arterial versus central venous measurement of B.E. Most of the paired measurements were showed a marginal departure from the line of perfect agreement (indicated by a diagonal line). Hence it can be concluded a marginal to significant agreement between the arterial and central venous measurement of B.E

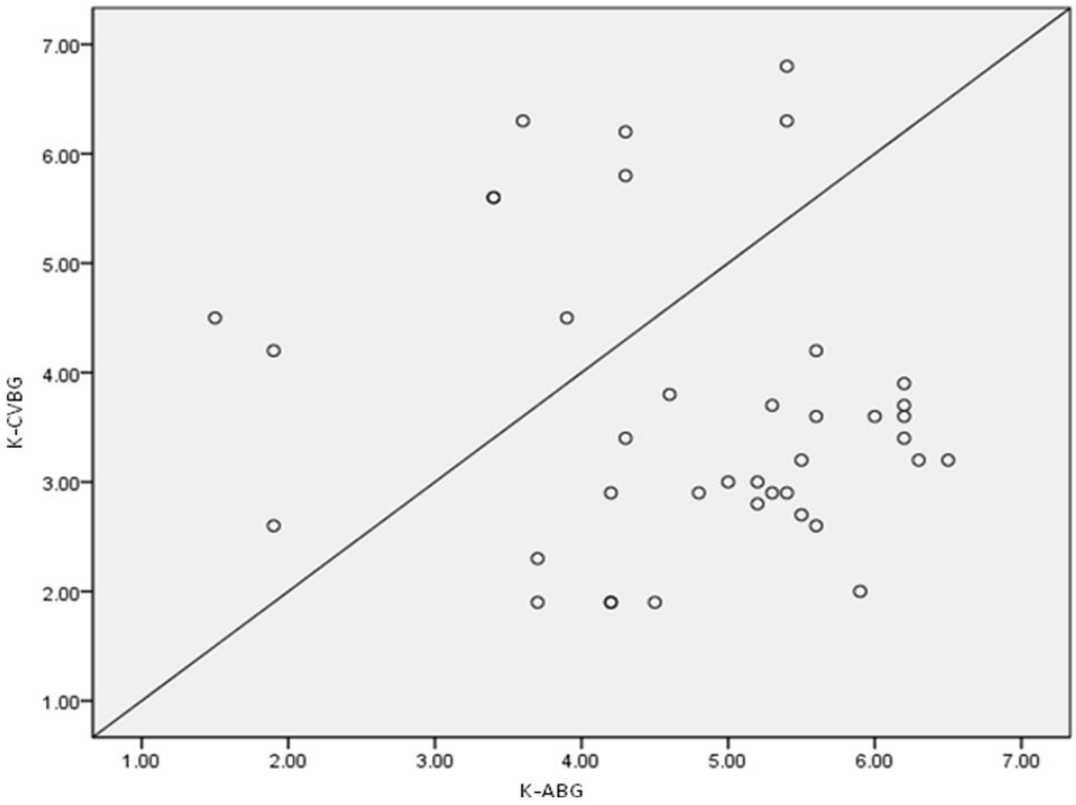

Fig. 4: Identity Plot - Arterial versus Central Venous K^+(potassium)

Shows the identity plot - arterial versus central venous measurement of K^+. Most of the paired measurements were showed a marginal departure from the line of perfect agreement (indicated by a diagonal line) towards lower part of the plot. That in majority of cases, the venous K^+ lower than arterial K^+. Hence it is difficult to conclude at least a basic agreement between the arterial and central venous measurement of K^+.

Discussion

Over the years, researchers have searched for alternatives to arterial sampling to reduce the incidence of the procedure's related complications and to maintain the patient safety. This prospective comparative study was conducted to determine the correlation between the VBG & ABG values. A simple linear regression was used to establish the relationship between the arterial values and the central venous values for pH, pCO2, B.E, K^+. In Arterial & venous of pH, pCO2 & B.E were found to be correlated significantly (p-value <0.05) while arterial and venous K^+ were found to be poorly correlated. This result (poor correlation between K^+) can be explained by that, physiologically, there is a big difference between normal arterial and venous potassium levels .Moreover, identity plots were used to ascertain perfect agreement between the arterial and central venous measurement of pH, pCO2, B.E, and the finding revealed that, significant agreement between the arterial and central venous measurements of acid – base (pH, pCO2, B.E-) levels in the critically ill patients. The high correlation between the arterial and venous pH, pCO2and B.E it can be explained by the same physiological theory. This means that, arterial pH: 7.35–7.45 while venous pH: 7.32–7.42. Arterial pCO2: 35–45 mmHg while venous pCO2: 38–52 mmHg.

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 clinicallyinterchangeable. This is in line with the findings of Malinoski et al, who reported similar 95% limits of agreement [6]. Arterial B.E : -2 to +2 while venous B.E: -3 to +3[1].

It is observed that there is a close correlation between abg and cvbg values of pH , pCO2, b.e in current study when compared to Bo Ra Kim et al study[7].

The study conducted by Walkey and his coworkers, they investigated the reliability of the VBG as a substitute for arterial blood gas (ABG) in multiple care settings and they found a high agreement between normal VBG with a normal ABG and they recommend using of the central VBG as a reliable alternative to ABG [8] . On the same vein, Treger at el performed a prospective trial to assess the agreement between arterial and central VBG measurements in a medical ICU [3]. Adult patients who were admitted to the ICU and required both a central venous line and an arterial line were enrolled. When an ABG was performed, a central venous sample was obtained to examine the agreement among the pH, pCO2, and bicarbonate. They concluded that, central venous pH, pCO2, and bicarbonate can replace their arterial equivalents in many clinical contexts encountered in the ICU [3]. Mean difference of pH current study (n=40) is - 0.11 and 95% limits of agreement = (-.005 t0 .226) which are similar to other studies [1, 9-11].

pCO2 in the current study showed a mean difference of 2.26 and 95 % limits of agreement -.005 to.226. Previous studies demonstrates the weighted mean difference for the group overall was 5.7 mmHg (*n* = 760) and for the COPD subset 6.3 mmHg. The 95% limits of agreement were diverse and unsuitable for pooling [1,2,4,5,11]. When pooled, the data show good diagnostic accuracy and predict that 36% of arterial analyses could be avoided if venous screening for hypercarbia was used.

Base Excess in the current study showed a mean difference of 2.08 and a mean difference of -1.196 to 5.351 mmol/ L. One study has specifically investigated agreement between arterial and venous base excess. In a sample of103 patients, they report a mean difference of 0.089 mmol / L with 95% limits of agreement –0.974 to+0.552 mmol / L[11].

Analysis of potassium concentration in initial care of patients is extremely important for the correct approach and treatment. In Fernando César Robles et al (n=53) study, 66% of the patients assessed presented differences between abg and venous blood greater than 0.5 mmol / L[12]. From 53 patients studied, 17 (32% of the cases) had potassium in blood gas lower than 3.3 mmol / L, and correlation coefficient r was 0.734 which suggested a weak correlation.

In a pilot study published in 2003, Kelly and Middleton evaluated the difference between abg and vbg samples of 43 patients, and found that the difference was greater than 0.5 mmol / L in 23% of them [13].

In Fu et al study, they evaluated the difference in patients with DKA and found a clinically acceptable difference between potassium concentrations in different samples i.e - 0.25 to 1.0 mmol / L, with an average of 0.5 mmol / L[14].

The current study showed a similar results to the previous studies correlation coefficient r =-.145, suggesting a weak correlation and 95% confidence interval being - 0.47 to 1.6, p value of 0.375 (significant) and mean difference was. 1.06. suggesting an acceptable difference between the arterial and serum potassium levels (venous blood).

Furthermore, Koul and his coworkers studied 100 randomly selected patients, who were adjudged to require ABG analysis by the treating physician. All patients had arterial blood sampled, which was drawn via an arterial puncture into a heparinized syringe. Simultaneously, venous blood was also sampled. Venous and arterial blood samples were taken within 5 min of each other. In addition, the measurement of oxygen saturation (SpO2) was obtained from a finger pulse oximeter. The results of the study have demonstrated a very strong correlation between the arterial and venous measurements of pH, pCO2, and HCO3 level with a high degree of agreement and clinically acceptable difference on Bland Altman difference plotting and but much less for pO2. The researchers concluded that, venous blood gas assessment in conjunction with finger pulse oximetry could obviate the routine use of arterial puncture in patients requiring ABG analysis [15].

Similarly, in a cross-sectional and analytical study aimed to evaluate the validity of VBG and its clinical agreement with ABG intensive care unit, and to answer how far it can replace the ABG test, Bilan and his coworkers analyzed blood gas of 200 patients in diverse diagnoses. The researcher concluded that, VBG can be used instead of ABG in some diseases such as respiratory distress syndrome, sepsis, renal failure, pneumonia, diabetic ketoacidosis and status epilepticus, but in other diseases such as shock (hypoperfused patients), ABG is preferable and must not be replaced by VBG [16].

The same result was reported by Kelly and coworkers. They described the agreement between variables on arterial and venous blood gas analysis (in particular pH, pCO2, bicarbonate and base excess) and they concluded that, for patients who are not in shock, venous pH, bicarbonate and base excess have sufficient agreement to be clinically interchangeable for arterial values. Agreement between arterial and venous pCO2 is too poor and unpredictable to be clinically useful as a one-off test but venous pCO2 might be useful to screen for arterial hypercarbia or to monitor trends in pCO2 for selected patients [2].

On the similar vein, Khan and his coworkers studied 100 patients in order to determine a correlation between arterial and venous blood gas values. Patients undergoing lumbar disc surgery. Two blood samples were drawn from each patient 2 hours after induction of anesthesia for ABG and VBG analyses. The result revealed that, there was good correlation between arterial and venous blood samples with regard to pH, pCO2, HCO3-, BE and BB [17].

Similar result has been reported by Malatesha and her coworker. They aimed to determine the agreement between arterial and venous samples in a pathologically diverse patient population presenting at an emergency department (ED) with a view to obviating the need for arterial blood gas (ABG) analysis in initial ED evaluation. The data were analyzed for agreement between pH, pCO2, pO2 and bicarbonate using the Bland–Altman method. As the results shown, agreement was excellent in pH values (95% limits of agreement 0.13 to 20.1), and acceptably narrow in pCO2 and bicarbonate values and venous pO2 and arterial pO2 did not show good agreement in our study. In conclusion, venous pH, bicarbonate and pCO2 estimation can replace ABGs in initial ED assessment [18].

In addition, Darren and her coworkers approved the hypothesis that, central venous blood gas (VBG) measurements of pH, pCO2, and base excess can be substituted for the same values obtainedfrom an arterial blood gas (ABG)analysis in mechanically ventilated trauma patients, obviating the need for arterial puncture. They concluded that, Central venous and arterial pCO2, pH, and base excess values correlate well. They mentioned that, although VBGs cannot be substituted for ABGs in mechanically ventilated trauma patients during the initial phases of resuscitation, clinically reliable conclusions could be reached with VBG analysis [6].

Many studies investigating the usage of venous blood gases instead of arterial blood gas analysis have been conducted in metabolic and respiratory cases. Significant correlation was found between pH (r= 0.969, r= 0.979) and HCO3 (r= 0.954, r = 0.995) values of hemodynamically stable diabetic ketoacidosis and uremic acidosis patients without respiratory failure[18]. Recently, arterial and venous blood gas samples were compared in patients with hypercapnia and respiratory acidosis due to chronic obstructive pulmonary disease (COPD). In some of these studies, correlation was found between levels of pH (r=0.934, r = 0.828, r = 0.826), A rterial p CO2 (r= 0.908, r =0.877, r= 0.838) and HCO3 (r= 0.927, r= 0.896) (p<0.001)[10].

In another study performed in patients with respiratory acidosis, correlation values were found as p<0.001 between arterial and venous blood gas samples regarding p H (r= 0 .864), p CO2 (r= 0 .761), HCO3 (r=0.749) and also including PaO2 (r= 0.702) [22]. In patients undergoing mechanical ventilation for acute respiratory failure in Intensive care unit, venous pH, pCO2 and HCO3 values were found to be able to be used instead of arterial blood gas samples [19,20].

The identification of acute hypercarbia in such patients is usually made using a combination of clinical criteria such as presence of drowsiness and ABG results. Given the close physiological relationship between pH and pCO2 and good agreement between pVBG and arterial values of pH and HCO3, a trend of peripheral venous pH and HCO3 could potentially be used to follow the trend of respiratory acidosis; be it deterioration because of disease progresion or improvement after successful treatment. Clinically, interchangeable pH and HCO3 values between arterial and pVBG results can also potentially be used in COPD patients with an exacerbation in the ED to gain insight into whether a mixed acid–base disorder is present [19].

Acute hypercarbia will result in acidosis and elevation of the HCO3 value. An unexpectedly low HCO3 value with acidosis in a COPD patient should alert the clinician to search for another underlying disease resulting in metabolic acidosis, such as lactic acidosis from septic shock or uremia[21].

In addition, the studies also suggested the use of a screening cutoff value for pVBG pCO2 in the detection of significant arterial hypercarbia. The values reported for this potential use differed between the studies. It was 45–46mmHg in three of the four relevant study, whereas another reported a value of 30mmHg [19].

Although the results of the current study have demonstrated a high degree of support and agreement with the previously mentioned studies, some of the other studies did not support the positive correlation or agreement between arterial and venous pCO2. Poor correlation between arterial and venous pCO2 was also claimed by Parvizi. His study aimed to determine whether venous blood gas values can replace arterial gas values during cardiac surgery. He investigated the correlation of pH, pO2, Base Excess and HCO3 in arterial and venous blood gases. A prospective study was performed on 150 patients undergoing cardiac surgery. Their searcher measured of the arterial and venous blood gases perioperative phase of cardiac surgery. There were considerable correlations between

pH and HCO3 but not in pCO2, and pO2 [22].

Conclusion

Central venous blood gas values of pH, pCO2 and B.E can be considered instead of arterial blood gas values in continuous assessment of critically ill patients. As per this study estimation of arterial values of potassium cannot be done based on venous potassium levels. Frequent arterial punctures can be avoided by recording central venous blood gas values in monitoring of critically ill patients.

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