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Evaluation of Venous Blood as a Specimen of Choice in the Monitoring of Acid-Base Metabolic Disorders

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Abstract: *Acid-base metabolic disorders are conditions that alter the normal body physiology that regulate the pH of blood in order to maintain normal biochemical functions. Maintenance of a constant pH is important for enzyme function, cellular uptake and use of metabolites and minerals, conformation of biological structures and uptake and release of oxygen. Such disorders include diabetes mellitus which can lead to development of diabetic ketoacidosis (DKA), with resultant reduction in pH of blood. Acute and chronic kidney diseases (CKD) also usually lead to excessive loss of bicarbonate ion in urine which eventually causes acid-base metabolic imbalance in the body. These two medical conditions necessitate frequent blood sampling for monitoring and managing the resultant acidosis. Traditionally, arterial blood samples collected via the invasive arterial-puncture are used to assess the acid-base status of the blood. However, arterial puncturing is invasive, painful, and prone to formation of hematomas and could lead to sepsis. The alternative is the use of venous blood but the level of agreement between arterial and venous blood in our local population has not been ascertained to validate the use of venous blood. The objective of this study was to evaluate the acid-base parameters of venous blood and its clinical agreement with arterial blood in the diagnosis of acid-base disorders. A cross-sectional study of patients with metabolic acid-base disorders such as those with DKA and CKD was done. A total of 350 study subjects with acid- base metabolic disorders at KNH were recruited. About 1.0 ml of both venous and arterial blood specimens were removed from each patient. Blood gas analysis (pH, pCO_2, pO_2, HCO_3^-, Base excess and percentage oxygen saturation) was done using both venous and arterial specimens. The data obtained was parametric in nature and was tabulated as mean and standard deviation. Parametric method of data analysis was used. Descriptive statistics used included parameters of location and parameters of dispersion. Venous blood base excess (B/E) had a sensitivity and specificity of 93% and 89% respectively using arterial blood as the gold standard. The Pearson correlation coefficient between arterial and venous bloodfor pH, pCO_2, pO_2, HCO_3^-, Base excess and percentage oxygen saturationwas 0.919, 0.846, 0.255, 0.942, 0.966 and 0.204 respectively and all had a p- value of less than 0.001. Using arterial blood pH and arterial base excess as gold standards, kappa statistics were used to establish the degree of association or agreement between arterial and venous pH and base excess levels in blood. Kappa values range from 0 to 1 and values closer to one (1.0) indicate a high degree of agreement while values close to zero (0) indicate a low degree of agreement. Venous blood pH and venous blood base excess had both a kappa value of 0.86. The agreement between arterial and venous blood pH as well as arterial and venous blood base excess was quite significant ($p<0.05$). The results suggest that venous blood can substitute arterial blood in the monitoring and management of acid-base metabolic disorders.*

Key word: *acid-base, venous blood, arterial blood, acidosis, base excess, bicarbonate, DKA, CKD*

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I. Introduction

Metabolic acidosis is a condition where blood bicarbonate level is less than 22 mmol/L with a pH of lessthan 7.35. The condition is caused by either a deficit of base (HCO_3^-) in the bloodstream or an excess of acids other than Carbon dioxide. The main causes of metabolic acidosis include kidney disease and diabetic ketoacidosis (DKA). Excessive utilization of hydrogen ions as happens in diabetic ketoacidosis usually leads to metabolic acidosis.Other minor causes include Diarrhea, intestinal fistulas, starvation, salicylate intoxication, excessive consumption of alcohol, methanol poisoning, pyloric stenosis, dehydration and renal tubular acidosis and anaerobic metabolism (Panteghini*et al,* 2006).The condition is common in patients with chronic kidney disease (CKD) and patients newly diagnosed with diabetes mellitus. The prevalence of metabolic acid-base disorders due to DKA and kidney diseases as per Kraut *et al*. (2011) is 30% and the disorder is managed by infusing sodium bicarbonate solution to correct the acidosis.

Optimal physiological functioning of metabolism, the cardiovascular system, and the neurological system depends on the ability of regulatory mechanisms to prevent and resolve fluctuations in pH, which is primarily determined by hydrogen ion concentration in plasma. Concentration of hydrogen ions in plasma is from 0.000035 to 0.000045 Mmol/l and because this number is cumbersome, the term pH, the negative logarithm of hydrogen ions concentration is used to describe the level of hydrogen ions in the extracellular fluid (ECF). A high pH indicates a low hydrogen ion concentration and a low pH, a high concentration. Hydrogen ions exist in the form of fixed or volatile acids and are the products of normal metabolism and incomplete oxidation of fat and sugar (Yucha, 2004). Maintaining pH within a normal range is accomplished by either buffering or excreting acids. The cellular buffer system responds within seconds to fluctuations in acid concentration. In the extracellular space, the primary buffer is bicarbonate and most acid in the extracellular space is in the form of carbonic acid. The goal ratio for bicarbonate to carbonic acid in the body is 20:1 (Ruholl, 2006).

When carbonic anhydrase is present, carbonic acid is easily formed by combining carbon dioxide and water or hydrogen and bicarbonate. Carbonic anhydrase also catalyzes the breakdown or dissociation of carbonic acid into carbon dioxide and water or hydrogen and bicarbonate (Ruholl, 2006). Carbonic anhydrase is primarily found in the walls of the lung alveoli and in the epithelial cells of the renal tubules (Guyton *et al*., 2006). If acids enter the cells, phosphate buffers and haemoglobin neutralize the acid in the intracellular space. The renal system is the slowest, yet most effective buffering system. Kidneys respond to an alteration in acid-base balance within hours, and complete activation takes days. Renal compensation for acid-base imbalance involves the excretion or retention of hydrogen ions and the generation of bicarbonates (Yucha, 2004). Bicarbonates are small and pass freely into the glomerulli, and if they are not re-absorbed into the plasma from the tubules, the body can be depleted of bicarbonate within several hours. Nearly 80% of the filtered bicarbonate is re-absorbed in the proximal tubules (Carillo *et al*., 2006).

Diabetic ketoacidosis is the commonest cause of metabolic acidosis. It is caused by poorly controlled diabetes mellitus leading to lipolysis with subsequent production of ketone bodies (acetoacetate and β-hydroxybutyric acid) (Kitabchi *et al*., 2006). The ketone bodies, however, have a low pH and therefore turn the blood acidic (metabolic acidosis). The body initially buffers this with the HCO_3^- buffering system, but this is quickly overwhelmed and other mechanisms to compensate for the acidosis, such as hyperventilation to lower the blood carbon dioxide levels are engaged (Kitabchi *et al*., 2006).

The other cause of metabolic disorder is kidney disease which could either be acute or chronic. In acute kidney disease, the organ itself is not diseased but other factors that may interfere with blood circulation such as hypotension and kidney stones may interfere with the functional capacity of the kidney (Kraut *et al*., 2011). In chronic kidney disease the filtration capacity is progressively reduced with consequences of anuria. Some of the causes include diabetes mellitus, hypertension, toxic substances and systemic lupus erythematosus (SLE) (Kovesdy, 2012). In both acute and chronic kidney disease, the reabsorption capacity of the HCO_3^- ions by the renal tubules is interfered with which eventually leads to metabolic acidosis due to loss of $HCO3^-$ in urine.

Metabolic acidosis can produce far reaching repercussions to the normal physiology of the body and consequently has to be corrected by infusing sodium bicarbonate ($NaHCO_3$). The amount of $NaHCO_3$ to be given is calculated using base excess (B/E) and weight of the patient using the formula; B/E x weight (Kg) x 0.3, where 0.3 is a constant depicting 33% of total body water being extra-cellular fluid. Base excess is an empirical formula expressing the amount of $NaHCO_3$ required to titrate 1 litre of blood to a normal pH of 7.4 (Raphael*et al*., 2014). It is traditionally calculated from an arterial blood gas analysis in millimol per litre (mmol/l). The usual sites for arterial sampling include; radial, brachial and femoral artery which is a painful procedure in addition to other hazards associated with arterial puncturing.

Traditionally, arterial blood samples collected via the invasive arterial-puncture are used to assess the acid-base status of the blood. However, arterio-puncture has many side effects and requires special skills as opposed to venipuncture which is easy to perform with minimal complications. Some of the disadvantages of arterio-puncture are its inaccessibility due to periarterial tissues; impalpable pulse, arteriospasm, formation of hematomas, risk of sepsis and severe pain.Therefore the invasive nature of arterial puncture and its possible hazards makes the procedure very unsafe and therefore the need to encourage less-invasive diagnostic procedures including venous blood analysis. Consequently there will also be a need to develop venous blood acid-base reference values that will be used to interpret results.

The objective of the study is tocompare the levels of pH, bicarbonate, base excess, partial pressures of oxygen, carbon dioxide and oxygen saturationbetween venous and arterial blood in patients with acid base metabolic disorders. The study is expected to validate the use of venous blood in acid-base metabolic disorders and determine the venous blood reference ranges for pH, bicarbonate, and base excess, partial pressures of oxygen, carbon dioxide, total carbon dioxideand oxygen saturation. This will eventually minimize the need for arterial sampling which is hazardous and traumatic to the patients.

II. Materials and methods

The studywas a cross-sectional, prospective study involving patients attending Accident and Emergency (A/E) Department and those admitted in Medical Wards, Critical Care Unit (CCU) and Renal Unit of Kenyatta National Hospital (KNH).Control group was recruited among the blood donors at the KNH Blood Transfusion Unit (BTU). Kenyatta National Hospital is a national referral hospital with an in-patient bed capacity of 2,000. It is situated within Nairobi County at an altitude of about 5,889 ft above sea level and a Barometric pressure of about 760 mmHg.The study was composed of two groups of study subjects; control group and patients diagnosed with either diabetic ketoacidosisor chronic kidney disease. The sample size wascalculated using the formula given by Lwanga *et al.*(1986). The study involved a total of 350 subjects with diagnosis of DKA and CKD and 200 (NCCLS, 2008) individuals as control group.

The study consent was sort from the Kenyatta National Hospital-University of Nairobi Ethical and Research Committee (KNH/UON-ERC). Any recruited healthy individual who was found to have pathological disorders in the course of the study were advised to seek medical attention. The clinician would explain the medical disorder thereof and fill a referral form (appendix V) and refer for further review, investigations and management.A clinician assessed and examined the subjects to determine the inclusion and exclusion criteria where medical history and clinical examination was required. The subjects were informed the contents of appendix III containing the information on ethical issues of the study in a language they could understand. They were requested to consent to the study by signing consent form. For very sick subjects, a relative was informed of the benefits of the study and requested to sign on behalf of the patient. All the individuals were asked to participate in the study on a voluntary basis after a brief explanation of the aims and purpose of the study. Those who accepted to participate were subjected to an interview using a questionnaire. Subjects above the age of 18 years who were not obese, hypertensive, pregnant, or under any medication, and not taking any oral contraceptives, none alcohol and tobacco users wererecruitedas healthy subjects. They were also excluded from the study if they tested positive for HIV, Hepatitis B, Hepatitis C and syphilis. Patients with a diagnosis of DKA orchronic kidney disease and were above 18 years were also recruited for the study.Eligible subjects were then requested to sign a consent form. They were required to fill a self-administered questionnaire on social and demographic factors.

After application of the mentioned criteria, 350 study subjects were selected to participate in the present study. They were group as follows: 1) Diabetic ketoacidosis consisting of 170 subjects (80 males and 90 females) admitted in either Medical Wards or Critical Care Unit of Kenyatta National Hospital. Age range was 18-88 years, with 55 ± 15.9 years as mean ± SD; 2) Chronic kidney patients consisting of 180 subjects (108 males and 72 females) admitted in Medical wards, Renal Unit or Critical Care Unit of Kenyatta National Hospital; age range was 30-65 years, with 50 ± 14.8 years as mean ± SD.

About 1.5 ml of both arterial and venous blood specimenswere collected within two minutes in heparinised syringes and kept in ice box prior to delivery to the laboratory. An arterial blood was obtained through arterial-puncture of the radial artery while venous blood was obtained from ante cubital vein. For the healthy individuals, a venous blood specimen (about 1.5 ml) was collected in heparinised syringes from the cubital vein and taken to the laboratory in an ice box.All of the samples were analyzed using the same RapidLab 348 blood gas analyzer as quickly as possible.

In the laboratory, automated testing using the 348 Rapid® Lab Blood Gas Analyzer which is based on electrochemistry technology was used to determine the levels of pH, partial pressures of carbon dioxide and oxygen, base excess, bicarbonate, sodium, potassium, chloride and percent oxygen saturation. The principles involved in the analysis are potentiometry, amperometry and conductivity.

III. Results

The total number of patients used in the study who had diabetic ketoacidosis or chronic kidney disease was 250 of which 128 (51.2%) had CKD while 122 (48.8%) had DKA. Among the patients with chronic kidney disease 77 (60.1%) were males while 51 (39.9%) were females and among those with DKA, 57 (46.7%) were males while 65 (53.3) were females. 200 healthy individuals were recruited for the study of which 101 (50.5%) were males while 99 (49.5%) were females. The mean age of patients with either CKD or DKA was 53 ± 15.6 years while the mean age for healthy individuals was 52 ± 12.6 years and there was no significant difference in the age distribution between the patients and healthy individuals (p=0.463).

Table 1: Demographic characterization of the study population

Diagnosis	Sex	N	Percent of total population	Age (Years)Mean±SD p = 0.463
Chronic Kidney disease	Male	108 (60%)	51%	53 ± 15.6
	Female	72 (40%)		
Diabetic ketoacidosis	Male	80 (47%)	49%	
	Female	90 (53%)		

Levels of acid-base parameters in arterial and venous blood specimens

Table 3 shows the mean levels of measured and calculated acid-base parameters of arterial and venous blood collected from the same patient spontaneously. The mean levels from arterial and venous blood respectively is as follows: pH; 7.164 ± 0.09 and 7.122 ± 0.09 units, Partial Pressure CO_2; 4.2 ± 1.4 and 5.1 ± 1.6 Kpa, Partial Pressure O_2; 12.1 ± 4.9 and 4.9 ± 1.3 Kpa, bicarbonate; 13.2 ± 4.6 and 13.9 ± 4.7 mmol/l, base excess; -9.9 ± 11.6 and -10.0 ± 11.8 mmol/l, Percent Oxygen Saturation**;** 93 ± 7 and 60 ± 14 %.

There were statistically significant differences in the levels of pH, pCO_2, pO_2, HCO_3^- and oxygen saturation between arterial and venous blood specimens ($p<0.001$) but no significant difference was found in the levels of B/E between arterial and venous blood specimens (P=0.166).

Table 2: Levels of acid-base parameters in arterial and venous blood specimens

Parameter	N	Type of Blood	Mean ± SD	p-value
pH (Units)	350	Arterial	7.164 ± 0.09	p<0.001
	350	Venous	7.122 ± 0.09	
Partial Pressure CO_2 (Kpa)	350	Arterial	4.2 ± 1.4	p<0.001
	350	Venous	5.1 ± 1.6	
Partial Pressure O_2(Kpa)	350	Arterial	12.1 ± 4.9	p<0.001
	350	Venous	4.9 ± 1.3	
Bicarbonate (mmol/l)	350	Arterial	13.2 ± 4.6	p<0.001
	350	Venous	13.9 ± 4.7	
Base excess (mmol/l)	350	Arterial	-9.9 ± 11.6	p = 0.73
	350	Venous	-10.0 ± 11.8	
Percent Oxygen Saturation	350	Arterial	92.6 ± 7.3	p<0.001
	350	Venous	59.8 ± 14.0	

Degree of association between arterial and venous pH and base excess levels in blood

Using arterial blood pHand arterial base excess as gold standards, kappa statistics were used to establish the degree of association or agreement between arterial and venous pH and base excesslevels in blood (Tables 3 & 4). Kappa values range from 0 to 1 and values closer to one (1.0) indicate a high degree of agreement while values close to zero (0) indicate a low degree of agreement. Venous blood pHand venous blood base excess had both a kappa value of 0.86. The agreement between arterial and venous blood pH as well as arterial and venous blood base excess was quite significant ($p<0.05$).

Table 3: The sensitivity and specificity of venous blood pH using arterial pH as the gold standard

Arterial blood pH (Acidosis, pH<7.350)			
Venous blood pH (pH < 7.319)	True State (Gold Standard Test)		
	Acidosis (%)	No acidosis (%)	Total
Acidosis	325 (99%)	1(1%)	326 (100%)
No acidosis	4 (17%)	20 (83%)	24(100%)
Total	329 (94%)	21 (6%)	350 (100%)

P < 0.05, Kappa = 0.8

Table 4: The sensitivity and specificity of venous blood base excess using arterial base excess as the gold standard

Arterial blood base excess (B/E <2.0 mmol/l)			
Venous blood base deficit (B/E <-1.4 mmol/l)	**True State (Gold Standard Test)**		
	Acidosis (%)	No acidosis (%)	Total
Acidosis	242 (96%)	10 (4%)	252 (100%)
No acidosis	20 (20%)	78 (80%)	98(100%)
Total	262 (75%)	88 (25%)	350 (100%)

P < 0.05, Kappa = 0.8

Sensitivity and specificity of venous blood levels of pH and base excess

Table 5 shows the sensitivity, specificity, positive and negative predictive values of venous blood pH and base excess using arterial blood pH and base excess as the gold standards. Venous blood pH had a

sensitivity of 98%, specificity of 93%, positive predictive value (PPV) of 99% and negative predictive value (NPV) of 82% while venous base excess had a sensitivity of 93%, specificity of 89%, PPV of 96% and NPV of 80%.

Table 5: Sensitivity and specificity (%) of venous blood pH and base deficit

Measurements (%)	Venous Blood pH	Venous Blood Base Excess
Sensitivity	98%	93%
Specificity	93%	89%
Positive predictive value (PPV)	99%	96%
Negative predictive value (NPV)	82%	80%

Correlations between arterial and venous blood acid-base parameters

Table 6 shows the Pearson's correlation coefficient (r) between the measured arterial and venous acid base parameters. The Pearson's correlation coefficient (r) between arterial blood pH and venous blood pH was 0.92 ($p<0.001$); arterial blood pCO_2 and venous blood pCO_2 was 0.85 ($p<0.001$); arterial blood pO_2 and venous blood pO_2 was 0.26 ($p<0.01$); arterial blood HCO_3^- and venous blood $HCO_3^-$was 0.94 ($p<0.001$); arterial blood B/E and venous blood B/Ewas 0.97 ($p<0.001$); arterial blood oxygen saturation and venous blood oxygen saturationwas 0.20 ($p<0.01$). There were very strong correlations between arterial and venous blood in pH, pCO_2, HCO_3^- and B/E and relatively weak correlations in pO_2 and oxygen saturation.

Table 6: Correlations between arterial and venous blood acid-base parameters

Arterial Blood Parameter	Venous Blood Parameter	Pearson-Correlation Coefficient	p-value
Arterial pH	**Venous pH**	r = 0.919	P<0.001
Arterial pCO_2	**Venous pCO_2**	r = 0.846	P<0.001
Arterial pO_2	**Venous pO_2**	r = 0.255	P<0.01
Arterial HCO_3^-	**Venous HCO_3^-**	r = 0.942	P<0.001
Arterial B/E	**Venous B/E**	r = 0.966	P<0.001
Arterial % O_2	**Venous % O_2**	r = 0.204	P<0.01

IV. Discussion

Assessment of acid-base imbalances is necessary for most patients who are admitted with diabetic ketoacidosis and chronic kidney disease every day and this need is routinely accomplished by arterial blood gas (ABG) analysis. The invasive nature of arterial puncture and its possible hazards such as excessive bleeding (haematoma), arterial spasm, ischaemic injury and thrombosis make the procedure undesirable. The procedure itself can be technically difficult and several attempts may be required. It is also painful, particularly when performed on the radial artery at the wrist. These factors have changed the general trend toward less invasive methods such as venous blood gas (VBG) analysis in all hospitals worldwide and made it necessary to carry out the study reported here. In view of the above, the current study attempted to assess the validity of VBG values in determination of acid-base status, specifically in adults with DKA and CKD.

The present study showed significant differences in the measured pH, pCO_2, pO_2, HCO_3 and $\%O_2$ between the venous and arterial blood ($p<0.001$) but no significant difference in the levels of B/E between venous and arterial blood ($p<0.402$). The findings in this study are in agreement with a study conducted by Sunil (2011) which demonstrated some level of differences between venous and arterial blood gas parameters. According to Sunil (2011), VBG analysis therefore has limitations in the assessment of oxygen delivery in respiratory failure while in primary metabolic disturbances it can be as useful as an ABG. The differences can be explained by the fact that the amount of carbon dioxide in the venous blood is quite high as this blood is coming from the tissues where most oxygen has been consumed in oxidative phosphorylation. The major products of oxidative phosphorylation are adenosine triphosphate (ATP) and carbon dioxide gas. The net effect is increased carbon dioxide and reduction in pH levels in venous blood.

Excess carbon dioxide in venous blood react with water in the presence of carbonic anhydrase to generate carbonic acid which dissociates to hydrogen ions (H^+) and bicarbonate ions (HCO_3^-) consequently pushing the pH level down. Arterial blood, having passed through the lungs and from the heart is highly oxygenated and has low levels of carbon dioxide having been removed from the blood through the lungs. Venous blood had high levels of HCO_3^- due to the fact that most CO_2 in blood is transported in the form of HCO_3^- ion. Arterial blood has less content of carbon dioxide and therefore reduced levels of HCO_3^-. In the present study, there was no significant difference in the levels of base excess (B/E) between venous and arterial blood ($p<0.402$). Base excess is calculated from an empirical formula that determines the amount of sodium bicarbonate ($NaHCO_3$) required to titrate blood back to a normal pH of 7.400 at 37^0 C. It is automatically calculated through an algorithm using pH and HCO_3^- values. The amount of $NaHCO_3$ required to correct the acidosis in patient is then calculated by the clinician using B/E value and weight of the patient. The current study has therefore proved that venous B/E can accurately be used to correct any prevailing acidosis due to

either DKA or CKD. The current study confirmed findings of other investigators that venous B/E can be used to correct metabolic acidosis (Ahmet *et al.,* 2006; Yüksel*et al.,* 2000). A study by Ramesh *et al*. (2016) concluded that venous base excess can replace arterial base excess in trauma patients as a means of identifying and prognosticating early shock.

In this study the sensitivity and specificity of venous blood pH and venous blood B/E were first established. The positive and negative predictive values were also determined using arterial blood pH and arterial base excess as the gold standards. In the current study, a cut-off value of 7.319 Units venous blood pH resulted in a sensitivity of 98%, specificity of 93%, positive predictive value (PPV) of 99% and a negative predictive value (NPV) of 82%. A cut-off value of -1.4 mmol/l venous blood B/E yielded a sensitivity of 93%, specificity of 89%, PPV of 96% and a. NPV of 80%. A study done by Schrauben*et al*. (2018) demonstrated that the central venous blood gas (VBG) had 100% sensitivity for metabolic acidosis, metabolic alkalosis, and respiratory acidosis, and lower sensitivity (71%) for respiratory alkalosis , and higher percentage agreement, ranging from 75 to 94%. The study therefore concluded that in critically ill adult patients, central VBG may be used to detect and diagnose acid-base disturbances with reasonable diagnostic accuracy, even in shock states, compared to the ABG. A similar study done by Nemat *et al*. (2008) in patients with acidosis indicated that venous B/E had a sensitivity of 76%, specificity of 83%, PPV of 81% and a NPV of 79%. The reason for the relatively low values in Nemat *et al*. (2008) could be due to the fact that they used study subjects who had respiratory disorders.

In the current study, the Pearson correlation coefficient values between arterial and venous blood were quit high in patients with acid-base metabolic acidosis ($p<0.001$). On the other hand, there was a poor correlation between arterial pO_2 and venous pO_2 values ($r = 0.26$), and also between arterial $\%SO_2$ and venous $\%SO_2$ ($r = 0.20$). These findings agree to a greater extent with a study conducted by Ahmet *et al*. (2006) who did a study on patients with acute exacerbation of chronic obstructive pulmonary disease.

According to a study by Middleton*et al*. (2006) in India, there was a good correlation between pH of venous and arterial blood samples while their CO_2-concentrations were less correlative. Another study by Kelly*et al.* (2001) in Australia showed that pH of venous and arterial blood samples correlate with each other by a high degree of agreement (about 90%).Two separate studies were carried out by Brandenburg *et al.* (1998) on patients with diabetic ketoacidosis in USA and Gokel *et al.* (2000) on uremic patients in Turkey, and both revealed that VBG analysis could determine the patient's acid-base status as accurately as ABG analysis. Another study by Razi *et al.* (2007) in Iran showed that there was a relatively good correlation between ABG and VBG values of pH and PCO_2 although the correlation was not so close and therefore they concluded that ABG analysis should not be replaced by VBG analysis.Their study differs with the current study due to the fact that they compared arterial and venous blood gas analysis in patients with acute exacerbation of chronic obstructive pulmonary disease which is a respiratory acid-base disorder. The current study was based on metabolic acid-base disorders. Middleton*et al.* (2005) studied patients poisoned by tri-cyclic antidepressants in Iran and found that pH was the only parameter measured by VBG which was a valid and reliable substitute for ABG. Kelly*et al.* (2004) in Australia also found that venous bicarbonate estimation has a high level of agreement with the arterial value and suggested that only venous values of HCO_3 may be an acceptable substitute for arterial measurements.

The slight differences found in the two studies could be due to the fact that Nemat *et al*. (2008) study included several other disease conditions such as pneumonia, renal failure, neonatal sepsis, DKA, respiratory distress syndrome, congestive heart failure, congestive heart disease, shock, status epilepticus and neonatal seizures. These disease conditions were likely to cause either metabolic or respiratory acidosis and the patients were all paediatrics. The current study was focussed on two disease conditions, CKD and DKA which causes metabolic conditions and all patients were adults.

The agreement between arterial and venous pH found in this study is consistent with the findings of other studies (Brandenburg *et al*., 2011; Ma *et al*., 2003; Kelly*et al*., 2001 and Gokel *et al*., 2000). Another study by Singh *et al*. (2015) on 30 paediatric patients admitted in Intensive Care Unit and required assessment of acid-base status showed that it is valid to use central venous blood as a substitute specimen for monitoring acid-base status. Taken together, the evidence implies that arterial and venous measurements of pH, bicarbonate, lactate, and base excess may have sufficient justification 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 of patients potentially reducing the hazards associated with handling. The current study agrees very well with another study conducted by Yuksel *et al*. (2000) who concluded that a venous blood sample can be used to evaluate the acid-base status in uremic and DKA patients.

From this study however, VBG analysis may not entirely replace ABG analysis in determining exact PO_2 status, and arterial puncture may still be required for invasive arterial BP monitoring. Nevertheless, the well-accepted accuracy of pulse oximetry venous blood gas analysis may be a safer alternative to ABG analysis

for determining acid-base status, reducing the need for frequent invasive arterial sampling. Strong agreement between ABG and VBG analysis for pH and PCO_2 and much less for $PO_2$was previously reported by Kraut *et al*. (2011) from which he concluded that it is not clinically acceptable to recommend uniform usage of of venous PO_2 instead of the arterial measurements in clinical situations.

These results are entirely predictable on a physiological basis. Venous blood gas values depend on the arterial PO_2, arterial-tissue exchanges, cardiac output and local blood flow. Normally, venous-arterial PCO_2, pH and HCO_3 differ only in a narrow range because of effective buffering and regulatory mechanisms; whereas PO_2 differs greatly because the normal levels in tissues are 40 mmHg while arterial level is close to 100 mmHg. From the data presented, it is apparent that there were a substantial proportion of subjects with a normal ABG in this study and hence the results are as expected.Nevertheless, VBG has its uses. Normal venous pH, PCO_2 and HCO_3 rule out severe acid-base disturbances. As reviewed by several authors, in several conditions of metabolic acidosis as well as in acute exacerbations of chronic obstructive pulmonary disease (COPD), ABG and VBG provide similar or predictable results for pH, PCO_2 and HCO_3. A venous PCO_2 value above 6.0 kpa detects all cases of significant arterial hypercapnia (Kelly *et al*., 2002; Middleton *et al*., 2006; Chu *et al*., 2003).

It is important to note that the current study established higher values of arterial partial pressure of oxygen (pO_2) compared with venous (pO_2). Venous blood gas analysis therefore has limitations in the assessment of oxygen delivery in respiratory disorders. It is therefore paramount that when one wants to investigate cases of respiratory disorders, then an arterial blood is the specimen of choice. This study has demonstrated beyond reasonable doubt that venous blood can be reliably used to monitor metabolic acid-base disorders. Furthermore, it is easy to obtain percentage oxygen saturation from a patient in the ward using an oxygen oximeter without performing an arterial puncture. The suggestion by Sam *et al*. (2003) is that VBG may be used for pH and PCO_2 and combined with oxygen saturation from the oximeter can give a clear indication on the clinical status of the patient. This is an important finding as far as replacing ABG in serial measurements to monitor patients especially when long-term intensive management is required or sampling is required several times daily.

V. Conclusion

In conclusion, this study suggests that venous blood can be reliably used to monitor and mange acid-base disorders instead of the cumbersome traditional use of arterial blood.

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