

Usefulness of the VBG analysis as an option of ABG analysis in Congenital Heart Disease in pediatric age group

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Abstract

Aim: Evaluation of different alternatives for Blood Gas Analysis of paediatric Cardiac surgical patients.

Objectives: Arterial blood gas (ABG) analysis is very important tool for assessment of the clinical condition of patients in various critical conditions; however, arterial puncture may associate with many complications, particularly in paediatric patients. This study is conducted to determine whether venous blood gas (VBG) values can replace arterial blood gas values in paediatric age group patients undergoing cardiac surgery for congenital heart disease. To study correlation between arterial blood gas and venous blood gas we have examined arterial as well as venous blood pH, PCO₂, PO₂, HCO₃⁻, Base excess, Ct O₂, SO₂ and Ct CO₂.

Method: The study was conducted during June 2008 to December 2010 at an academic tertiary care hospital in Ahmedabad where DM and MCH super specialist are available as a consultant. Totally, 50 paediatric patients suffering from congenital heart disease included in this study and arterial as well as venous blood sample were collected for blood gas analysis.

Result: There was no significant difference observed between arterial and venous blood respectively in pH (7.37 +/-0.04, 7.33+/-0.04), PCO₂ (35.51+/- 5.08, 43.54+/-4.94), HCO₃⁻ (20.64+/-1.69, 21.30+/-1.81) but significant difference observed in PO₂ (77.26+/-37.43, 38.05+/-6.81), Ct O₂ and SO₂.

Conclusion: We do not recommend venous blood sample as an alternate of arterial blood sample for blood gas analysis as there is poor correlation in PO₂, CtO₂ and SO₂.

Keywords: Arterial blood, Venous blood, Congenital heart disease, pH, PO₂, PCO₂

Introduction

Patients with congenital heart disease (CHD) may have different clinical scenario. The patients having anomalies involving communication between cardiac chambers or the great arteries are associated with increased pulmonary blood flow and pressure leading to progressive remodeling of pulmonary arteries and increased pulmonary vascular resistance (PVR). Patient may have left to right shunt or right to left shunt or pulmonary arterial hypertension (PAH). About 2/3rd of the patients suffering from CHD have surgically correctable lesion with gratifying prognosis, provided that the surgical intervention is done in the very first year of life. For the children suffering from CHD posted for surgical correction, Arterial blood gas (ABG) analysis is extremely significant for the management. Clinician needs frequent arterial blood sample of such patients as ABG sampling is the gold standard method to obtain acid-base as well as blood gas status of the patients^{1,2}. But the arterial puncturing for sample collection is associated with some common complications like pain, arterial injury, local hematoma, infection, thrombosis with distal ischemia, emboli, hemorrhage, aneurism formation and potential hazards for sampler.³ This adds risk and suffering to patients by puncturing of artery. The risks bump up with repeated arterial punctures especially in paediatric age group. Keeping these things in mind alternative to arterial blood sampling is very much essential. In such

situation venous blood gas (VBG) analysis could be safer alternative as it is easier to obtain, less invasive and avoiding the risks of arterial punctures.^{1,2,4} Apart from less painful procedure, VBG sample can be drawn using the same intravenous line that is used to draw blood for the other laboratory tests and from central venous line which is nearer to superior vena cava. Thus, only single puncture provides sample for investigation. Our study is boost up by several other studies showing good correlation between venous and arterial blood gas values.^{5,6} However, other works suggest different conclusions due to no or weak associations.^{7,8,5}

Usefulness of the VBG analysis as an option of ABG analysis in CHD patient is an interesting area of study. In post-operative cardiac surgical ICU all paediatric patients already have an in-situ central venous line required for blood sampling, CVP measurement and drug administration during and after surgical procedure; so advantage of this site is that, it is a reliable way and can eliminate possible other sites of side effects. Considering these facts we evaluated the usefulness of the VBG analysis as an option of ABG analysis in paediatric cardiac-surgical patients.

Material and Methods

This cross-sectional observational study was conducted at an academic tertiary care hospital in Ahmedabad, during June 2008 to December 2010. Non-randomized purposive sampling was done from the

patients having congenital heart disease, who required haemodynamic study during the above mentioned study period. On the basis of hospital admission rate of this group of patients the appropriate sample size was predetermined as minimum 50 patients to be included. Informed consent was taken from parent/guardian of each patient participated in the study according to the standard guidelines of institutional ethical committee.

Inclusion criteria:

1. All the paediatric age group patients with CHD; who required haemodynamic study by catheter-angiography, to see operability and/or coronary and pulmonary artery anatomy evaluation before corrective surgery.

Exclusion criteria:

1. Age <1 year and > 14 years
2. All patients suffering from any other co-morbidity to affect oxygenation and pH (excluded on the basis of history and clinical examination and investigations for example: acquired valvular heart diseases, pulmonary diseases affecting the cardiovascular system, metabolic and endocrine disorders affecting cardiovascular system)
3. All patients, in whom the time of sample collection and analysis was more than thirty minutes.
4. All patients with missing of any important information like clinical presentation, registration number and/or time of sample (ABG and VBG) collection.

Methodology: The CHD patients require blood sampling from all the major vessels and cardiac chambers by cardiac catheter-angiography to know the anatomical abnormality, for hemodynamic study and to see the operability of the patient before undergoing corrective surgery. During cardiac catheterization, pre-oxygenation blood samples were collected from femoral artery and superior vena cava. Samples were received for blood gas analysis in the clinical biochemistry laboratory. Blood collected from femoral artery represent the arterial blood gas analysis and

blood collected from superior vena cava represent the venous blood gas analysis.

Sample Handling and Transfer: 5-c.c arterial and venous blood samples were collected simultaneously in heparinized syringes from femoral artery and superior vena cava. Absolute care was taken to eliminate visible gas bubbles, as these bubbles can dissolve into the sample and cause inaccurate result. The sealed syringes were taken to a blood gas analyzer and were analyzed within 30 minutes. Blood gas analyses were done in the Cobas b-121 system by Roche Diagnostics. A complete pH and blood gas analysis were performed.

Statistical Analysis: All parameters of arterial and venous blood gas analysis except PO₂, SO₂ and CtO₂ were following normal Gaussian distribution (bell shaped curved). Appropriate arterial & venous parameters were compared by applying unpaired t-test. In this analysis, variable showing P- value less than 0.05 were considered to be statistically significant. Data analysis is done by using Graph pad 3.0 Software. Data of Arterial PO₂, CtO₂ and Arterial as well as venous SO₂ were not normally distributed. Therefore, Mann-Whitney test was applied for comparison. Assuming a Pearson product-moment correlation coefficient (r) of 0.9 as defined by Brandenburg and Dire, we determined that a sample of 50 patients would provide a sufficiently narrow confidence range (0.89 – 0.94) around the point estimate for r.

Observation and Results

We have studied total 50 patients suffering from CHD. Out of all patients, 31 (62 %) had Ventricular Septal Defect, 14 (28%) had Tetralogy of Fallot, 1(2%) had Atrial Septal Defect, 1(2%) had Patent Ductus arteriosus, 1(2%) had PDA and VSD both, 1 (2%) had Total Anamolous Pulmonary Venous Return and 1 (2%) had VSD and PS both. We have observed 7 different varieties congenital cardiac diseases. Out of them Ventricular Septal Defect were maximum in number followed Tetralogy of fallots. Other cases were 1 each.

Table 1: Biochemical parameters in arterial & venous blood gas analysis

Sr. No.	Parameters	Arterial		Venous		'p' value	Significance
		Mean	Std. Deviation	Mean	Std. Deviation		
1	pH	7.37	0.04	7.33	0.04	0.7229	NS
2	PO ₂	77.26	37.43	38.05	6.81	P<0.001	S
3	SO ₂	89.76	10.83	63.67	13.58	P<0.001	S
4	PCO ₂	35.51	5.08	43.54	4.94	0.8429	NS
5	HCO ₃ ⁻	20.64	1.69	21.30	1.81	0.6213	NS
6	BE	-4.52	2.16	-3.60	2.34	0.5678	NS
7	CtCO ₃	17.39	2.22	19.80	2.22	0.986	NS
8	CtO ₂	19.28	4.00	13.94	3.77	P<0.001	S

We have observed significant difference in the level of CtO₂ (19.28 +/- 4.0; 13.94 +/- 3.77), SO₂ (89.76 +/- 10.83; 63.67 +/- 13.58) & PO₂ (77.26 +/- 37.43; 38.05 +/- 6.81) in arterial and venous blood respectively (p- value <

0.001 or < 0.05). Other parameters like pH, PCO_2 , HCO_3^- , BE and CtCO_3 showed no significant difference (p-value > 0.05). Arterial PO_2 , CtO_2 and Arterial as well as venous SO_2 were not normally distributed, Mann-Whitney test was applied for comparison. All other parameter followed normal distribution so unpaired t test was applied in them.

According to our study mean pH in arterial and venous blood correlated well. p value is 0.7229 which is > 0.05 and hence it is statistically not significant. ABG and VBG values for pH correlated satisfactorily ($r = 0.841$). The associations of arterial and venous pH values are shown graphically and mathematically in Fig. 1. The figures demonstrate linear correlation of arterial and venous pH in total 50 cases.

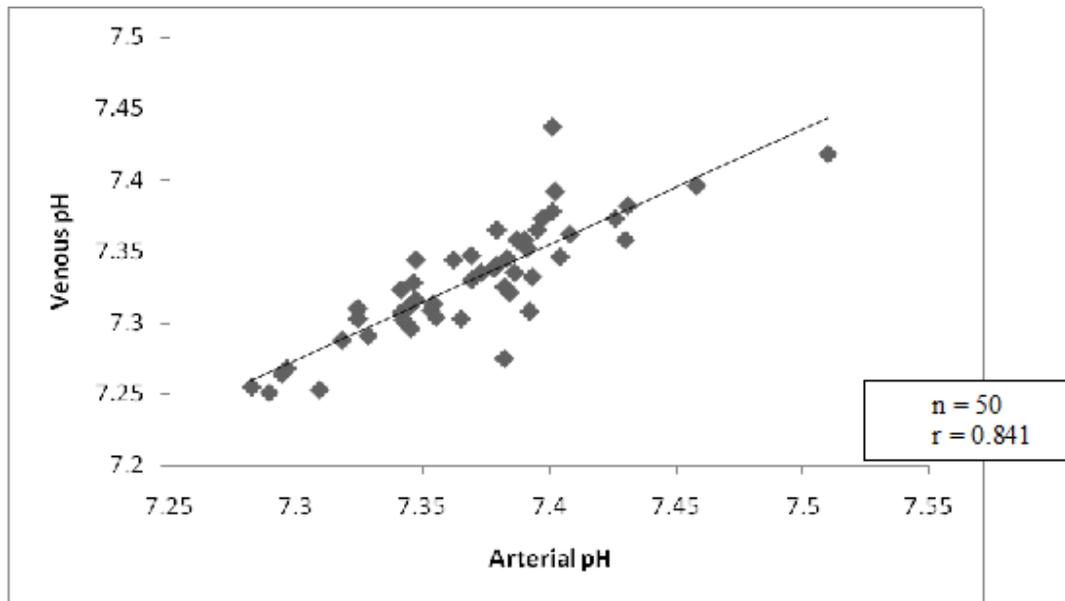


Fig. 1: Linear correlation of arterial and venous pH

Mean pCO_2 value in our study is 35.51 ± 5.08 and 43.54 ± 4.94 in arterial and venous blood respectively. P-value is 0.8429 which statistically not significant. Study also shows that ABG and VBG values correlated satisfactorily ($r = 0.747$) for PCO_2 . It shows that there is a close correlation in the level of pCO_2 between arterial and venous blood among all the samples under study (Fig. 2).

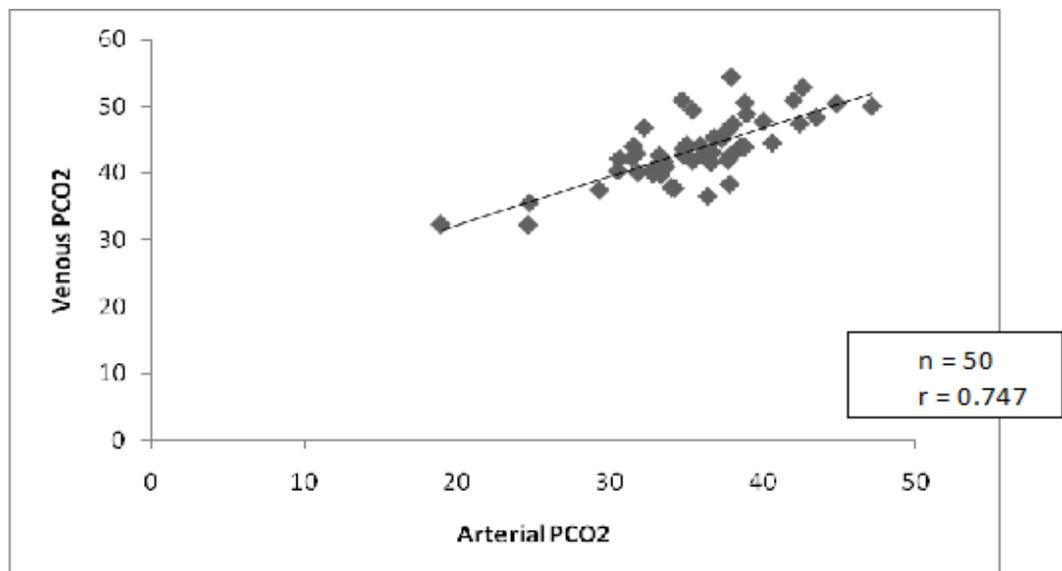


Fig. 2: Correlation in the level of pCO_2 between arterial and venous blood

In present study mean PO_2 in arterial and venous blood is 77.26 ± 37.43 and 38.05 ± 6.81 , if we calculate p value it is < 0.001 which is statistically highly significant. When we calculate r value, it is 0.336 which shows poor correlation in the level of pO_2 in arterial and venous blood (Fig. 3).

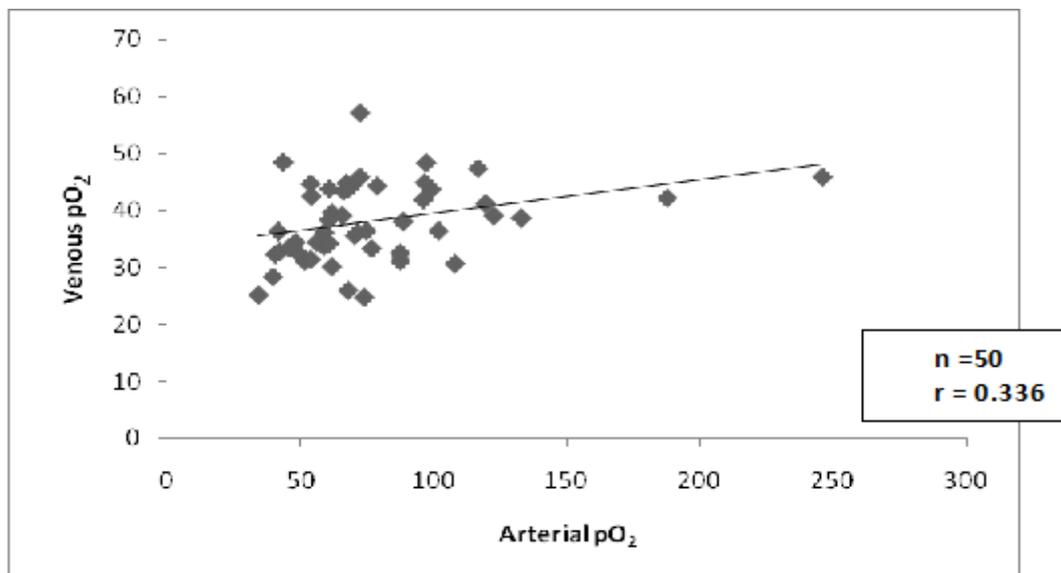


Fig. 3: Correlation of PO₂ in arterial & venous blood

Discussion

Blood gas analysis has two principal purposes: assessment of patient's acid-base status and assessment of blood oxygenation status. For many years, biochemists have been looking for alternatives to ABG sampling specially in children. Studies have investigated ABG, VBG, and CBG samples and the correlation between the values.^(5,9,10) In Critically ill children patients it is difficult to obtain arterial samples, many times. More over arterial puncture for blood gas also carries risk. This procedure itself is painful and long-term in-situ arterial catheters pose a small but significant risk of many other complications.⁽¹¹⁾

Blood gase sampled from central venous catheter (CVC) nearer to superior vena cava potentially represent an alternative to ABG testing. Although there is an absolute requirement for arterial blood if PO₂ and SO₂ (measures of patient oxygenation) are required, there is accumulating evidence to suggest that venous blood might be an acceptable alternative to biochemist as well as to the clinician. It would be logistically convenient for clinical staff to do gas analysis by having a central venous catheter that allows sampling of venous blood and more comfortable as well safer for the patient, if this kind of sample could also be used for blood gas analysis to determine acid-base status. There is plenty of reported evidence on agreement in ABG and VBG.⁽¹²⁻¹⁸⁾ Still the popularity of VBG is low and few studies have even expressed reservations regarding the accuracy of VBG value in patient evaluation.^(16,19,20)

A study by McBride et al. on infants and children after cardiothoracic surgery shows the mean difference of pH and PCO₂ values between ABG and VBG, 0.04 +/- 0.02; 8 +/- 4 mm Hg respectively.⁽²¹⁾ They concluded that VBG values did not provide clinical

useful estimate of ABG value following cardiothoracic surgery.⁽²¹⁾

The focus of this present study included those patients who require assessment of oxygen saturation and acid-base status during their hemodynamic study for cardiac surgery. In our study mean pH in arterial and venous blood correlated well. p value is >0.05 which is statistically not significant. ABG and VBG values for pH correlated satisfactorily (r=0.841). Our result for pH correlate with study carried out by Kelly et al. on 196 patients with acute respiratory disorder and 50 patients with suspected metabolic derangement, the venous and arterial pH showed a high degree of correlation (r = 0.92) and with an average difference between the samples of - 0.04 units.⁽²²⁾ In another study conducted on 44 episodes of diabetic ketoacidosis, the mean difference between arterial and venous pH values was 0.03, which showed a high correlation (r=0.9689).⁽²³⁾

In study by Kelly et al. on 196 patients with acute respiratory disease, for pH a good agreement between arterial and venous samples was found, but no sufficient agreement was detected for venous PCO₂ to replace arterial PCO₂ in clinical assessment of ventilator function.⁽¹⁶⁾ In contrast to Kelly et al study our study shows mean pCO₂ 35.51 +/- 5.08 and 43.54 +/- 4.94 in arterial and venous blood respectively. Calculation of p-value is 0.8429, which is statistically not significant. Finding of correlation between PCO₂ values, ABG and VBG gives satisfactory correlation (r=0.747). Our study findings correlate well with Walkey et al. study, which showed good agreement between VBG and ABG PCO₂ in adult patients of medical, surgical and cardiac ICU. He stated central venous PCO₂ largely able to replace arterial PCO₂ in the most clinical circumstances.⁽²⁴⁾

In the present study mean arterial and venous PO₂ is 77.26 +/- 37.43 and 38.05 +/- 6.81 respectively, calculation of p-value is < 0.001 which is highly significant but it shows poor correlation (r = 0.336). In a study carried out at paediatric intensive care unit by Yildizdas D et al., significant correlation between ABG and VBG values observed in pH, PCO₂, and HCO₃⁻.⁽⁵⁾ Correlation in PO₂ was also significant, but to a lesser extent.⁽⁵⁾ Our study goes in hand to hand with Yildizdas D et al. study in respect to PO₂. According to our study mean arterial and venous SO₂ is 89.76 +/- 10.83 and 63.67 +/- 13.58 with p-value < 0.001 which is highly significant and lesser extent correlation (r=0.495).

In our study mean HCO₃⁻ in arterial and venous blood is 20.64 +/- 1.69 and 21.30 +/- 1.81 respectively, calculation of p value is statistically not significant (p = 0.6213) but VBG shows showed a good correlation (r=0.838) with ABG for HCO₃⁻. A study by Rang et al. on 218 patients suffering from respiratory and metabolic disease, the correlation coefficient of pH, PCO₂ and HCO₃⁻ values in arterial and venous samples was 0.913, 0.921, and 0.953 respectively.⁽²⁵⁾ Our results match with Rang et al. study, considering correlation coefficient of pH, PCO₂ and HCO₃.

As far as our best knowledge, until now there was no any study like ours on paediatric patients with CHD is conducted. In the present study, there is a poor correlation between the arterial and venous measurements of PO₂ level, the difference in value is not clinically acceptable enough to support uniform usage of venous PO₂ instead of arterial measurements in clinical situations. Similar to our findings, McLain et al, in preterm infants, found good correlations for pH and PCO₂ in CBG and ABG, but unsatisfactory correlation for PO₂.⁽²⁶⁾

A limitation of the study is a small proportion of patients with wide abnormal blood gas values. Further study of the differences in the clinical decision making based on a VBG from a patient population pre and post corrective surgery for CHD patients with a likelihood of abnormal blood gases is necessary.

Conclusions

We can conclude from present study that there is a significant correlation in pH, PCO₂, ct CO₂, BE, and HCO₃ among ABG and VBG except for a poor correlation in PO₂, ctO₂ and SO₂. Hence, we do not recommend VBG for determining PO₂ to avoid the risks of arterial punctures unless there is acute emergency. However venous blood may be useful if there is acute emergency.

References

1. Trowbridge CC, Vasquez M, Stammers AH, Glogowski K, Tremain K, Niimi K, et al. The effects of continuous blood gas monitoring during cardiopulmonary bypass: a prospective, randomized study--Part II. *J Extra Corpor Technol.* 2000;32:129-37.

2. Kirubakaran C, Gnananayagam JE, Sundaravalli EK. Comparison of blood gas values in arterial and venous blood. *Indian J Pediatr.* 2003;70:781-5.
3. Elborn JS, Finch MB. Non-arterial assessment of blood gas status inpatients with chronic pulmonary disease. *Ulster Med J* 1991;60:164-167.
4. Rees SE, Toftegaard M, Andreassen S. A method for calculation of arterial acid-base and blood gas status from measurements in the peripheral venous blood. *Comput Methods Programs Biomed.* 2006;81:18-25.
5. Yildizdas D, Yapicioglu H, Yilmaz HL, Sertdemir Y. Correlation of simultaneously obtained capillary, venous, and arterial blood gases of patients in a paediatric intensive care unit. *Arch Dis Child* 2004;89:176-180.
6. Gennis PR, Skovron ML. The usefulness of peripheral venous blood in estimating acid-base status in acutely ill patients. *Ann Emerg Med* 1985;14:845-849.
7. Malinoski DJ, Todd SR, Slone S, Mullins RJ, Schreiber MA. Correlation of central venous and arterial blood gas measurements in mechanically ventilated trauma patients. *Arch Surg.* 2005;140:1122-5. [PubMed: 16342377]
8. Bilan N, Behbahan AG, Khosroshahi AJ. Validity of venous blood gas analysis for diagnosis of acid-base imbalance in children admitted to pediatric intensive care unit. *World J Pediatr.* 2008;4:114-7. [PubMed: 18661766]
9. Rose BD. Introduction to simple and mixed acid-base disorders. In: Rose B, editor. *Clinical Physiology of Acid-base and Electrolyte Disorders.* 2nd ed. New York: McGraw-Hill; 1984. p. 363.
10. McBride ME, Berkenbosch JW, Tobias JD. Correlation of Venous and Arterial Blood Gas Values Following Cardiothoracic Surgery in Infants and Children. *Journal of Intensive Care Medicine.* 2001;16:231-5.
11. AARC clinical practice guideline. Sampling for arterial blood gas analysis. American Association for Respiratory Care. *Respir Care.* 1992;37:913-7.
12. Kelly AM., McAlpine R, Kyle E. Agreement between bicarbonate measured on arterial and venous blood gases. *Emerg.Med.Australas* 2004;16(5-6):407-9.
13. Kelly AM., McAlpine R, Kyle E. Venous pH can safely replace arterial pH in initial evaluation of patients in the emergency department. *Emerg. Med J* 2001;18:340-2.
14. Ma OJ, Rush MD, Godfrey MM, et al. Arterial blood gas results rarely influence emergency physician management of patients with suspected diabetic ketoacidosis. *Acad Emerg. Med* 2003;10:836-41.
15. Gokel Y, Paydas S, Kosecoglu Z, et al. Comparison of blood gas and acid-base measurements in arterial and venous blood samples in patients with uremic acidosis and diabetic ketoacidosis in the emergency room. *Am J Nephrol* 2000;20:319-23.
16. Kelly AM., McAlpine R, Kyle E. Venous pCO₂ and pH can be used to screen for significant hypercarbia in emergency patients with acute respiratory disease. *J Emerg Med* 2002;22:15-9.
17. Middleton P, Kelly AM, Brown J, et al. Agreement between arterial and central venous values for pH, bicarbonate, base excess and lactate. *Emerg Med J* 2006;23:622-4.
18. Chu YC, Chen CZ, Lee CH, et al. 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;102:539-43.
19. Brashear RE, Oei TO, Rhodes ML, et al. Relationship between arterial and venous bicarbonate values. *Arch Intern Med* 1979;139:440-2.

20. Malinoski DJ, Todd SR, Slone S, et al. Correlation of central venous and arterial blood gas measurement in mechanically ventilated trauma patients. *Arch Surg* 2005;140:1122-5.
21. McBride ME, Berkenbosch JW, Tobias JD. Correlation of Venous and Arterial Blood Gas Values Following Cardiothoracic Surgery in Infants and Children. *Journal of Intensive Care Medicine*.2001;16:231-5.
22. Kelly AM, McAlpine R, Kyle E. Venous pH can safely replace arterial pH in the initial evaluation of patients in the emergency department. *Emerg Med J* 2001; 18 (5): 340- 2.
23. Brandenburg MA, Dire DJ. Comparison of arterial and venous blood gas values in the initial emergency department evaluation of patients with diabetic ketoacidosis. *Ann Emerg Med* 1998;31(4):459-65.
24. Walkey AJ, Farber HW, O'Donnell C, Cabral H, Eagan JS, Philippides GJ. The accuracy of the central venous blood gas for acid-base monitoring. *J Intensive Care Med*. 2010;25:104-10.
25. Rang LC, Murray HE, Wells GA, Macgougan CK. Can peripheral venous blood gases replace arterial blood gases in emergency department patients? *CJEM* 2002;4(1):7-15.
26. McLain BI, Evans J, Dear PFR. Comparison of capillary and arterial blood gas measurements in neonates. *Arch Dis Child* 1988;63:743-7.