Validity of venous blood gas analysis for diagnosis of acid-base imbalance in children admitted to pediatric intensive care unit

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Original article

Background: **Arterial blood gas (ABG) analysis is the major tool for proper diagnosis and treatment of acid-base imbalance, but the invasive nature of arterial puncture and its possible hazards such as arterial spasm have resulted in a worldwide trend toward less-invasive diagnostic methods including venous blood gas (VBG) analysis. This study aimed to evaluate the validity of VBG and its clinical agreement with ABG in the 10 most common diseases in pediatric intensive care unit (PICU), and to answer how far it can replace the ABG test.**

Methods: **In a cross-sectional analytical study from September 2004 to September 2005, 200 patients in 10 disease categories received blood gas analysis. Results of blood-gas tests such as pH, PCO_2 and HCO_3 of both arterial and venous blood samples (simultaneously taken from each patient) were recorded and compared by statistical analysis (kappa statistics) to determine their validity and clinical agreement.**

Results: **In some diseases such as respiratory distress syndrome, neonatal sepsis, renal failure, pneumonia, diabetic ketoacidosis and status epilepticus, VBG analysis showed a good validity (high sensitivity and specificity) accompanied by a suitable clinical agreement (over 40%), but in other diseases such as neonatal seizure, shock, congestive heart failure and congenital heart disease, there was either an inappropriately low validity or a weak clinical agreement (under 20%).**

Conclusions: **VBG can be used instead of ABG in some diseases such as respiratory distress syndrome, neonatal sepsis, renal failure, pneumonia, diabetic ketoacidosis and status epilepticus, but in other diseases such as neonatal seizure, shock, congestive heart failure and congenital heart diseases, ABG is preferable and must not be replaced by VBG. These results may be used for the formulation of future guidelines for PICU.**

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Key words: **acid-base imbalance; arterial blood gas; intensive care unit; pediatric intensive care unit; venous blood gas**

Introduction

Assessment of acid-base imbalances is necessary for most patients who are admitted to pediatric intensive care unit (PICU) every day and this need is routinely accomplished by arterial blood gas (ABG) analysis, but the invasive nature of arterial puncture and its possible hazards such as bleeding, arterial spasm and thrombosis have changed the general trend toward less invasive methods such as venous blood gas (VBG) analysis in all hospitals worldwide. According to a study by Kirubakaran et al[1] 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 and coworkers[2] in Australia showed that pH of venous and arterial blood samples correlate with each other by a high degree of agreement (about 90%). The study of Chu and coworkers[3] on patients under mechanical ventilation due to acute respiratory failure in Taiwan revealed that VBG analysis could accurately predict the expected values of pH, PCO_2 and HCO_3 from ABG analysis. Two separate studies were carried out by Brandenburg et al[4] (on patients with diabetic ketoacidosis in USA) and Gokel et al[5] (on uremic patients in Turkey), and both revealed that VBG analysis could determine the patient's acid-base status as accurately as ABG analysis. Yildizdas et al[6] reported a study on a wide spectrum of diseases including 19 different diagnoses

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showed that pH, PCO_2 and HCO_3 of both arterial and venous blood samples had a meaningful correlation with each other. Although this study covered a relatively large number of patients, practically its results could not be generalized to every disease category because of the inappropriate distribution of studied patients and their small number in each disease group. A study by Ak and coworkers[7] on adult patients with acute exacerbation of chronic obstructive pulmonary disease in Turkey showed that there was a significant correlation between ABG and VBG values of pH, PCO_2 and HCO_3. But another study by Razi and coworkers[8] in Iran on the same disease as Ak's study showed that there was a relatively good correlation between ABG and VBG values of pH and PCO_2 although this correlation is not so close, so they concluded that ABG analysis should not be replaced by VBG analysis in these patients. Eizadi-Mood and coworkers[9] 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 and coworkers[10] 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.

In the above mentioned studies, findings were controversial about the reliability of VBG values for predicting ABG values. Besides, they were predominantly limited to adult patients or a number of diseases. Therefore we attempted to assess the validity of VBG values in determination of acid-base status, specifically in children admitted to PICU and to focus on 10 diseases that consist of the major load of PICU turnover.

Methods

In a cross-sectional and analytical study from September 2004 to September 2005, we analyzed blood gas of 200 patients in 10 disease categories (20 patients in each group) that formed the largest job burden of PICU, including: (1) respiratory distress syndrome, (2) neonatal sepsis, (3) neonatal seizure, (4) status epilepticus, (5) pneumonia, (6) diabetic ketoacidosis, (7) renal failure, (8) congestive heart failure, (9) shock, and (10) congenital heart disease. We also classified these diseases according to their severity, e.g., if a patient with sepsis was in shock at admission, we put him/her in a shock group. The final number of 20 patients was considered for completion and termination of sampling in each group of this study. Venous and arterial blood samplings were done simultaneously for each patient. Arterial blood was drawn from radial or brachial arteries and venous blood from veins on the dorsum of hands or antecubital veins.

All laboratory standard measures adhered to the international protocols for blood gas sampling, sample transport and their analysis for determination and recording of pH, PCO_2 and HCO_3. Each ABG or VBG report sheet was interpreted as a separate diagnostic test by PICU physicians who were blind to this study and their final diagnosis was recorded as one of the four single acid-base imbalances (consisting of main diagnoses of blood gas analysis), including metabolic acidosis, metabolic alkalosis, respiratory acidosis and respiratory alkalosis. Two statistical methods were used to determine the accuracy of VBG-based clinical diagnosis in comparison with the acid-base imbalance revealed by ABG analysis of the simultaneous arterial blood sample from the respective patient. In other words, ABG analysis was considered as the gold standard test for determining if VBG-based diagnoses were compatible and precise enough to be trustful:

1) Validity included calculation of sensitivity, specificity, and positive and negative predictive values.

2) Clinical agreement was determined by the results of "kappa statistics", considering the following scale:[11,12] $\kappa \leq 20\%$ meant negligible or few agreement; $20\% < \kappa \leq 40\%$ meant minimal agreement; $40\% < \kappa \leq 60\%$ meant medium agreement; $60\% < \kappa \leq 80\%$ meant good agreement; $\kappa > 80\%$ meant excellent agreement.

Results

This study consisted of 200 patients, 136 (68%) boys and 64 (32%) girls. Among them, 107 patients (53.5%) were under 2 months of age, 51 (25.5%) were 2-12 months, 21 (10.5%) were 12-60 months, and 21 (10.5%) over 60 months.

Fifty-nine patients (29.5%) were subjected to mechanical ventilation. The components of validity for VBG-based clinical diagnosis (VBG analysis was considered as a diagnostic test) such as sensitivity, specificity, positive and negative predictive values and also its clinical agreement with ABG-based clinical diagnosis (kappa statistics) were acceptable in 6 of 10 study groups (Table 1).

We also assessed the validity of VBG analysis and its clinical agreement with ABG analysis for detection of acidosis and alkalosis regardless of their metabolic or respiratory nature. A good sensitivity and clinical agreement was shown for detection of acidosis unlike a low sensitivity and medium clinical agreement for detection of alkalosis (Table 2).

Table 1. Validity and clinical agreement of acid-base imbalance diagnosed by VBG analysis as compared with ABG in 10 diseases

Diseases	Validity and clinical agreement (%)				
	Sensitivity	Specificity	PPV	NPV	κ
Pneumonia	66	90	80	80	60
Renal failure	90	90	90	90	80
Neonatal sepsis	80	66	80	66	48
Diabetic ketoacidosis	82	66	93	40	46
Status epilepticus	66	80	85	57	42.85
Respiratory distress syndrome	85	60	73	75	46
Neonatal seizure	61	40	80	37.5	19.3
Congestive heart failure	30	30	75	6.6	13
Congenital heart disease	16	6	75	50	8
Shock	33	50	86	7.7	5

PPV: positive predictive value; NPV: negative predictive value; κ: kappa statistics.

Table 2. Validity and clinical agreement for detection of acidosis and alkalosis by VBG analysis as compared with ABG (regardless of their metabolic or respiratory nature) in 10 diseases

Acid-base imbalance	Validity and clinical agreement (%)				
	Sensitivity	Specificity	PPV	NPV	κ
Alkalosis	55	91	84	70	48
Acidosis	76	83	81	79	60

PPV: positive predictive value; NPV: negative predictive value; κ: kappa statistics.

Discussion

As mentioned in the results section, VBG analysis can replace ABG analysis in 6 of 10 diseases (respiratory distress syndrome, neonatal sepsis, renal failure, pneumonia, diabetic ketoacidosis and status epilepticus) which form the major job burden of PICU. Similar results have been reported by many studies. The study of Chu and coworkers[3] in Taiwan showed that VBG analysis is an acceptable alternative for ABG analysis to assess pH, PCO_2 and HCO_3 in patients with acute respiratory failure. Brandenburg et al[4] studied 38 patients with diabetic ketoacidosis, and found that VBG analysis could determine the severity of acidosis as accurately as ABG analysis. Such a substitution was also been recommended by Gokel et al[5] on diabetic and uremic patients. The similarity of all VBG parameters to those of ABG has been confirmed by Yildizdas et al.[6] In another study, Malinoski et al[13] in USA found that central venous and arterial PCO_2, pH and base excess values correlate well in mechanically ventilated trauma patients; however, they suggested that clinically reliable conclusions can be reached with VBG analysis rather than simple substitution of VBG for ABG in mechanically ventilated trauma patients. Ma and coworkers[14] declared that venous pH correlates well and is precise enough with arterial pH to serve as a substitute in patients with diabetic ketoacidosis. Malatesha et al[15] claimed that VBG analysis for pH, PCO_2 and HCO_3 may be a reliable substitute for ABG analysis in the initial evaluation of adult patients presenting to the emergency department. Middleton et al[16] found a high level of agreement between central venous and arterial values for pH, HCO_3 and base excess in ICU patients, therefore central venous values may be an acceptable substitute for arterial measurements in ICU setting.

In our study, VBG values in patients who have disturbed tissue perfusion (hemodynamic instability) showed a very low level of clinical agreement with the arterial values and therefore no validity. As declared by McGillivray,[17] there was a meaningful correlation between results of ABG and VBG analysis only in patients with perfect tissue perfusion; however, Kelly[18] found that venous and arterial pH had sufficient agreement as to be clinically interchangeable in patients with diabetic ketoacidosis who were hemodynamically stable and without respiratory failure. Adrogue et al[19] reported little difference between arterial and venous blood in pH and PCO_2 (0.03 and 5.7 mmHg, respectively) in patients with normal cardiac output, but this difference was higher in patients with moderate heart failure. The mean values of pH in VBG and ABG were 7.21 and 7.31, and their mean PCO_2 were 68 and 44 mmHg, respectively.[19] Our results in congestive heart failure and congenital heart diseases are similar to the results mentioned above, and can justify the related lower levels of validity and clinical agreement.

In conclusion, VBG analysis can replace ABG analysis at least in 6 of 10 diseases with a perfect validity and proper clinical agreement. This can be used for the regulation of guidelines especially in PICU.

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