Original Research Article

Comparison and agreement between arterial versus venous blood gas analysis and pulse oxymetry in children with acute asthma

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ABSTRACT

Background: Blood gas analysis is critical in managing children in intensive care unit primarily in respiratory disorders. This study aimed to ascertain agreement between the arterial and peripheral venous measurement of pH, pCO_2, pO_2 and bicarbonate levels along with SpO_2 in acute asthma.
Methods: Hospital based cross sectional analytical study was conducted at Pushpagiri Institute of Medical Sciences in 50 children within the age group of 5-15 years who presented with symptoms suggestive of acute asthma with a modified PSI>6 after informed consent from parents and assent from child. SpO_2 monitoring and ABG simultaneously with VBG were done immediately after admission. Statistical analysis was done to find out any correlation using Pearson correlation coefficient and Bland Altman plots were drawn to assess agreement.
Results: 50 children in the age group 5 years to 15 years were included in the study. Arterial pH and venous pH were found to be correlated significantly, Pearson correlation coefficient r=0.438. There was a good correlation between the arterial and venous pCO_2 with r= 0.610, bicarbonate values r=0.608. There was poor correlation between arterial PO_2 and venous PO_2 values (r=0.030). The bias plot for pH and pCO_2 showed moderate agreement in with 95% limits of agreement being in acceptably narrow range. The mean bias in pH was 0.0242 (SD=0.04912, 95% limits of agreement = -0.0721 to 0.12045); bias in pCO_2 was -4.04400 (SD=5.53616, 95% limits of agreement = -14.8949 to 6.8069), and in bicarbonate levels -0.0940 (SD=2.09, 95% limits of agreement = -4.1998 to 4.0119).
Conclusions: Even though there was a good correlation and a moderate agreement between ABG and VBG parameters like pH, pCO_2 and bicarbonate, VBG cannot be replaced for ABG in acute asthma. Pulse oximetry also has limitations in children with acute severe asthma as compared to ABG value.

Keywords: Acute asthma, Arterial, Correlation agreement, Pulse oximetry, Venous blood gas analysis

INTRODUCTION

Blood gas analysis is one of the main criteria in the diagnosis and management of oxygenation and acid base disturbances in pediatric practise. An abnormal blood gas report may be the first clue to an acid base or oxygenation problem.[1] The evaluation of oxidation and acid base status of any sick child is crucial to their appropriate management.[2]

Arterial blood gas (ABG) sampling by direct arterial puncture is a procedure often practiced in the hospital ICUs. The relative less incidence of major complications, its ability to be performed at the patient's bedside, rapidity in analysis makes it an important measure used by physicians to direct the treatment of their patients, especially in patients who are critically ill, to determine gas exchange levels in the blood related to respiratory, metabolic, and renal function. Blood gas analysis provides valuable information on the acid-base balance at a particular point of a patient's sickness.

The most common complications associated with arterial puncture are pain, inadvertent arterial injury, and

thrombosis with distal ischemia, hemorrhage, and aneurysm formation. Capillary (CBG) and venous (VBG) blood gas samplings may be used as alternative to arterial blood gas sampling. Capillary and venous blood gas samplings are easier to perform and a less invasive way of evaluating acid-base status in the pediatric intensive care unit (PICU). Recently, studies have shown that values of acid-base balance measured in central or peripheral venous blood correlate well with those measured in arterial blood, at least for values of pH, bicarbonate, and carbon dioxide tension.[3-6] Pulse oximetry represents a good tool in monitoring of oxygenation, replaces the need for ABG analysis. The 2008 British Thoracic Society (BTS) guideline on the management of asthma and the Scottish Intercollegiate Guidelines Network recommend SpO_2 monitoring by pulse oximetry as an objective measure of acute asthma severity, particularly in children, in both primary and secondary care. According to these guidelines, a SpO_2 <92% is considered life threatening and these patients require an ABG measurement.[7]

Asthma is a chronic inflammatory condition of the lung airways resulting in episodic reversible airflow obstruction.[8] The severity of the asthma exacerbation is best measured by gas analysis. Studies regarding the comparison and agreement between arterial and venous method of blood gas analysis are rare. Several researchers have looked at the possibility of using the venous or capillary data instead of ABGs and have reported differing results.

Studying the correlation between arterial and peripheral venous blood gas together with pulse oximetry will be useful to the existing knowledge in this aspect. Also, it will be helping the clinicians to select the type of blood sample apt for blood gas analysis in children with acute exacerbation of bronchial asthma.

METHODS

A hospital based cross sectional study was done at Pushpagiri Institute of Medical Sciences a tertiary care teaching hospital in south central Kerala. 50 children between 5-15 years of age with acute asthma exacerbation as having modified pulmonary score index (PSI) >6 were recruited in the study over a period of 1 year (December 2014 to November 2015) by convenience sampling. Children <5 years of age and >15 years of age and children with other chronic respiratory, cardiovascular, neurological, endocrine metabolic and renal diseases were excluded from the study.

Study was initiated after getting Institutional Ethics committee approval.

Demographic data and detailed history were taken and physical examination done using a structured prepared case proforma after getting parental consent and assent. Physical examination was done including vitals, oxygen saturation, pulse rate, respiratory rate, blood pressure. Oxygen saturation was measured using a Philips Sure Signs VMA patient monitor with appropriately sized probe applied to the finger of the child. Children with a PSI score <10 were managed in the general ward and a PSI value >10 were managed in the PICU.

Arterial blood gas (ABG) was taken by arterial puncture of radial artery in all cases immediately after admission before oxygen administration using a 2-cc syringe with 24 G needle was flushed with heparin. Venous blood gas (VBG) was collected at the same time from the venipuncture site which was done for routine investigation. Blood in syringe was kept cooled to 5°c immediately and was sent to lab for analysis using Radiometer (ABL 80 FLEX) ABG analyzer. The children were started on treatment for the acute exacerbations as per protocol.

Data entry and analysis were done using Epi-Info 7.0, a free software developed by Centre for Disease Control, Atlanta, USA. Correlation between the ABG and VBG parameters were found out using Pearson correlation coefficients. Scattergram were plotted using the corresponding parameters to demonstrate the correlation. Linear regression was done to find the relation between the VBG and ABG values and regression equation were derived. Agreement between ABG and VBG values were demonstrated using Bland Altman plots. The Bland-Altman method calculates the mean difference between two methods of measurement (the 'bias'), and 95% limits of agreement as the mean difference (2 SD) [or more precisely (1.96 SD)]. It is expected that the 95% limits include 95% of differences between the two measurement methods.[9]

RESULTS

50 children (28 male and 22 female) between the age 5 to 15 years who were admitted in the PICU and ward with acute exacerbation of bronchial asthma having modified pulmonary score index >6 were included in the study. Mean age of the study population was 8.4 years with a slight male preponderance (1.27:1) (Table 1).

Table 1: Gender distribution.

Gender	N	Percentage
M	28	56
F	22	44
Total	50	100

All children with acute exacerbation presented with cough and breathing difficulty. 52% of the children also had associated fever (Figure 1). Among the asthma exacerbations 26 patients were (52%) due to respiratory infections. Other important exacerbating factors were exposure to cold, dust, paint and exercise. 50% of the children with acute exacerbation had a history of passive smoking (Table 2).
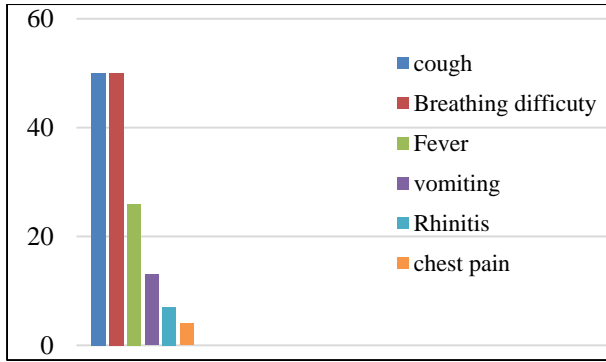
Figure 1: Presenting symptoms.

Table 2: Exacerbating factors.

Factors	N	Percentage
Respiratory infection	26	52
Dust	8	16
Cold (weather change)	6	12
Paint	2	4
Exercise	1	2
others	7	14
Total	50	100

Blood gas analysis

Table 3 shows ABG and VBG parameters differ significantly in their values when they measured simultaneously from the same patient. Linear regression and Bland-Altman plot were analysed to assess linear relation and fixed bias.

Table 3: The mean values of ABG and VBG parameters.

Parameters	Mean value ABG	Mean value VBG
pH	7.3469	7.3227
pCO_2	33.9020	37.9460
pO_2	90.420	50.5860
HCO_3	18.5720	18.6660
SaO_2	94.24	78.9160

Of 30 patients with arterial acidosis (pH<7.35) venous blood gas identified acidosis in 24. The range of arterial pH values with acidosis was from 7.226 to 7.342 and that of venous pH was from 7.218 to 7.344. The venous blood gas could not identify those 3 patients with arterial alkalosis (pH>7.45).

In 33 cases (66%), the absolute value of difference between the arterial and venous pH was <0.05 which was clinically acceptable.

There were 42 patients with arterial oxygen saturation >90%, pulse oximetry identified 29(69%) of these. It identified 5 of the 8 patients with arterial oxygen saturation ($ASaO_2$) <90%.

Correlation between arterial and venous blood gas parameters and also between spo_2 and arterial saturation

When the correlation between arterial and venous blood gas were analysed it was found that, arterial pH and venous pH were found to be correlated significantly, Pearson correlation coefficient r=0.438 (p value: 0.001). There was a good correlation between the arterial and venous pCO_2 with r=0.610 (p<0.001), bicarbonate values r=0.608 (p<0.001) (Table 4).

Table 4: Pearson correlation coefficients between arterial and peripheral VBG measurement.

Variable	Pearson correlation coefficients(r)	P value
Ph	0.438	0.001
pCO_2	0.610	<0.001
pO_2	0.030	0.835
HCO_3^-	0.608	<0.001
Oxygen saturation	0.233	0.104

On the other hand, there was poor correlation between arterial PO_2 and venous PO_2 values (r=0.030). There was also a poor correlation between arterial saturation and the saturation measured by pulse oximeter (r=0.233 p=0.104) Table 4.
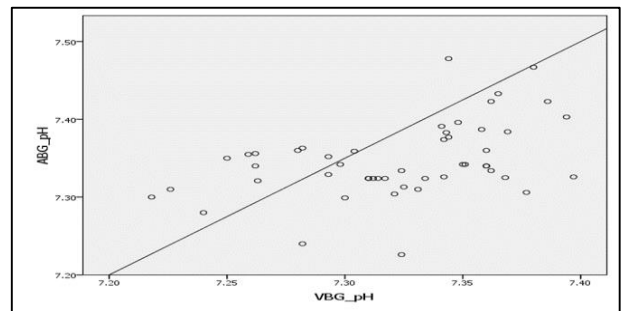

Figure 2: Arterial versus venous pH (r=0.438, p:0.001).

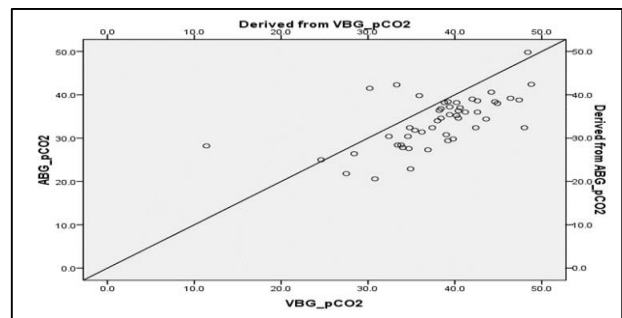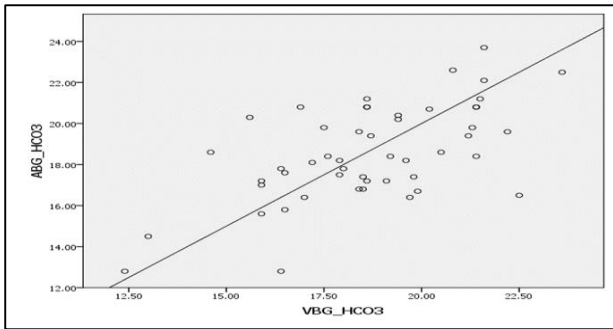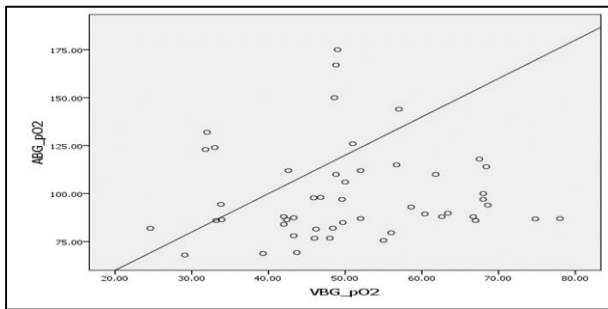Shows that there is some correlation between the two parameters especially pH between 7.3 to 7.4.

Figure 3: Arterial versus venous pCO_2 (r=0.610, p<0.001).

Shows much more correlation than pH mostly between values 30 to 50.
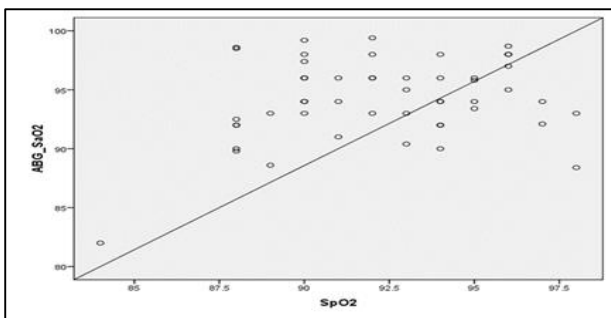
Figure 4: Arterial versus venous HCO₃⁻ (r=0.608, p<0.001).

Figure 5: Arterial versus venous pO₂ (r=0.030, p=0.835).

Shows poor correlation with values arranged haphazardly.

Figure 6: Arterial saturation (SaO₂) versus SpO₂ (spO₂) (r=0.233, p=0.104).

Shows poor correlation.

Linear regression analysis has also given a good correlation between arterial and venous pH (R=0.438, $R^2=0.192$, p=0.001), pCO_2 (R=0.610 $R^2=0.37$, p<0.001) and bicarbonate (R=0.608, $R^2=0.370$, p<0.001). But in case of pO_2 and saturation there was no correlation (pO_2: R=0.030; saturation: R=0.233) (Figure 2-6).

Regression equations could be derived to predict ABG values from peripheral VBG values, and are as follows:

ABG pH = $3.869 + 0.475 \times$ VBG pH ($R2=0.192$):

ABG pCO_2 = $13.469 + 0.538 \times$ VBG pCO_2 ($R2=0.373$)

ABG HCO_3^- = $7.515 + 0.592 \times$ VBG HCO_3- ($R2=0.370$)

Bland and Altman states that if the mean difference between measurements ±1.96 SD (95% limits of agreement) is not clinically important, we could use the two measurement methods interchangeably. Bland-Altman plots was done for pH, pCO_2 and bicarbonate values which had a good correlation and the plots are given below.
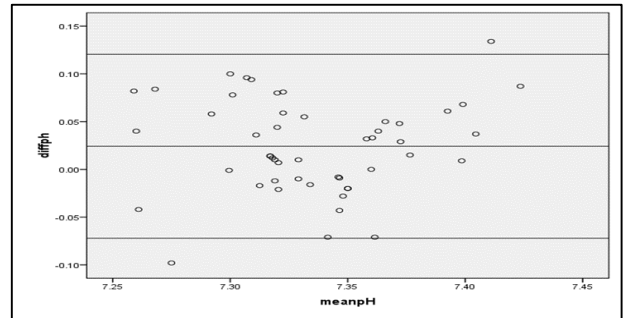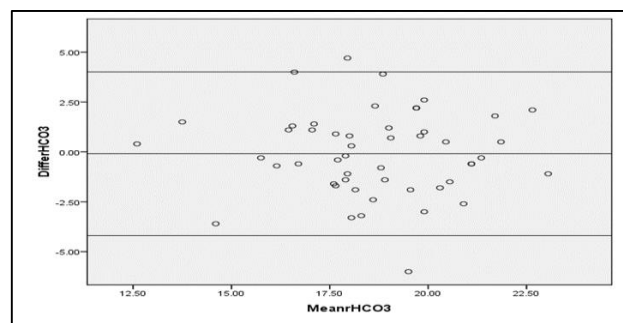

Figure 7: Bland Altman plot for pH.

Differ pH is the difference in the ABG and VBG pH values that is (ABG pH – VBG pH). Mean pH was (ABG pH + VBG pH)/2. To have a good agreement the value should be close to the mean difference line. Between pH 7.3 and 7.4 the values show some agreement. Only few (3 or 4) values were out of the 95% agreement limit which shows a moderate agreement.
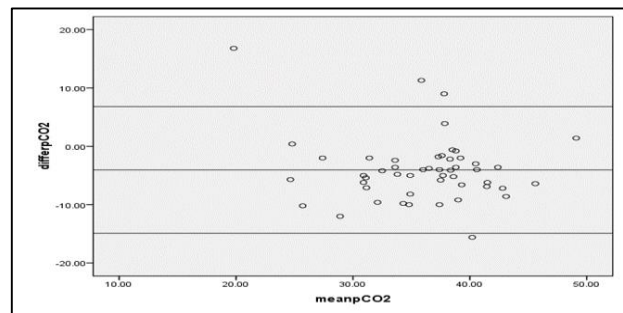
Figure 8: Bland Altman plot for pCO₂.

Differ pCO_2 is difference in the ABG and VBG pCO_2 values that is (ABG pCO_2 – VBG pCO_2). Mean pCO_2 was (ABG pCO_2 + VBG pCO_2)/2 shows better agreement of values between pCO_2 30 to 40.

Figure 9: Bland Altman plot for HCO₃⁻.

Differ HCO_3 is difference in the ABG and VBG HCO_3^- values that is (ABG HCO_3^- – VBG HCO_3^-). Mean HCO_3 was (ABG HCO_3^- + VBG HCO_3^-)/2. Shows moderate agreement. Here the 95% limits of agreement was much narrow which shows better clinical utility.

The bias plot for pH and pCO_2 showed moderate agreement in with 95% limits of agreement being in acceptably narrow range. And in case of bicarbonate, bias plot shows excellent agreement. The mean bias in pH was 0.0242 (SD=0.04912, 95% limits of agreement = -0.0721 to 0.12045); bias in pCO_2 was -4.04400 (SD=5.53616, 95% limits of agreement = -14.8949 to 6.8069), and in bicarbonate levels -0.0940 (SD=2.09, 95% limits of agreement = -4.1998 to 4.0119).

DISCUSSION

In this study pH, pCO_2, pO_2 and bicarbonate values were measured from both arterial and venous blood of children with acute exacerbation of bronchial asthma. The values were compared each other for finding out any correlation and agreement between them so that VBG can be used instead of ABG which is a more cumbersome procedure. The study also compared between the arterial oxygen saturation which was measured from ABG and saturation measured using pulse oximeter.

From the present study it can be concluded that in children with acute exacerbation of bronchial asthma the earliest blood gas change occurring is metabolic acidosis. This was different from the results obtained from various studies in adults like Ahmet (2006 Turkey), Koul et al (2011, Kashmir), Malatesha et al (2007 AIIMS) with respiratory illnesses which included pneumonia, COPD and acute asthma.[4,11,12]

In our study there was good correlation between pH, pCO_2 and bicarbonate obtained from peripheral venous and arterial blood samples. The correlation co-efficient for pH was 0.438, p value 0.001 which show a good correlation. The correlation coefficients for pCO_2 and bicarbonate were 0.610 (p<0.001) and 0.608 (p=0.001) respectively which shows excellent correlation. But in case of pO_2 and saturation the correlation was poor. In the study by Kirubakaran et al in children showed good correlation (r^2=0.8449, p<0.0001). Arterial and venous blood gas PCO2 values had less correlation (r^2=0.5917, p=0.011) and the arterial oxygen saturation ($ASaO_2$) and oxygen saturation by pulse oximetry ($PSaO_2$) were correlated moderately (r^2=0.7241, p<0.0001).[13] Yıldızdas et al in 2004 done in 116 children have concluded that pH, PCO_2, BE, and HCO_3 were all significantly correlated in ABG, VBG, and CBG.[14]

Study done by Koul et al in Kashmir, India in 2011 in adult patients with cardiopulmonary disease found out that that arterial pH and venous pH were correlated significantly (coefficient r=0.88, p<0.001) and significant correlation was also observed between SaO_2 and SpO_2 (r=0.59, p<0.001) and concluded that if venous pH is combined with routine finger pulse oximetry, the ABG analysis might be minimized to a great degree in cardiopulmonary patients.[11]

Study conducted by Ak et al in Turkey in acute exacerbation of COPD found that arterial and venous values of pH, pCO_2 and bicarbonate were correlating well with R value of 0.934, 0.908 and 0.927 respectively.[12] A study by Razi et al (2012, Iran) in mechanically ventilated adult patients revealed a similar conclusion that venous pH, pCO_2 and bicarbonate values can be replaced for ABG values.[15] Study conducted by Malatesha et al (AIIMS, India, 2007) concluded that venous pH, bicarbonate and PCO2 estimation can replace ABGs in initial ED assessment.[18] McKeever et al (2015, UK) conducted a similar study in adult patients with acute exacerbation of COPD found that there was a good agreement between arterial and venous measures of pH and HCO_3.[16]

Table 5: Comparison of correlation coefficients of pH, pCO₂, pO₂ and bicarbonate.

R values	Yıldızdas et al 2004[14]	Ak et al 2006[12]	Koul et al 2011[11]	Adhikari et al. 2015, Nepal[17]	Kirubakaran 2003[13]	Present study 2014
pH	0.907	0.934	0.880	0.969	0.8449	0.438
pCO2	0.978	0.908	0.920	0.949	0.592	0.610
pO2	0.366		0.450			0.030
HCO3-	0.976	0.920	0.320	0.928		0.608

Table 6: Comparison of correlation coefficient (R)for oxygen saturation.

Studies	Razi et al[19]	Malatesha et al[18]	Kirubakaran et al[13]	Present study 2014, Kerala
Saturation' R' value	0.865/0.950 hypox/Nonhypox	0.590	0.7241	0.233(p=0.104)

The bias plot for pH and pCO_2 showed moderate agreement with 95% limits of agreement being in acceptably narrow range. And in case of bicarbonate, bias plot shows excellent agreement. The mean bias in pH was 0.0242 (SD=0.04912, 95% limits of agreement = -0.0721 to 0.12045); bias in pCO_2 was -4.04400 (SD=5.53616, 95% limits of agreement = -14.8949 to 6.8069), and in bicarbonate levels -0.0940 (SD=2.09, 95% limits of agreement = -4.1998 to 4.0119). In the study by Koul et al in Kashmir, India in 2011, the bias plot for each of the variables showed excellent agreement with 95% limits of agreement being in acceptably narrow range in case of all the parameters.[11] The results were almost similar to our study, thus demonstrate an acceptably low bias with good agreement between the arterial and peripheral venous values for pH, pCO_2 and bicarbonate values.

In the study by Kirubakaran et al (2003, Tamil Nadu) Bland-Altman plot showed a good agreement between ABG and VBG pH and pCO_2 values.[13] The study concluded that venous samples though have a good correlation for pH and pCO_2, are not useful for monitoring blood gas status in acutely ill children.

There was a good correlation between pH measured from arterial blood and venous blood but there was only moderate agreement. This can be explained by mean bias between the two values and the 95% limits of agreement. In the case of pH the mean bias was 0.0242. That means the arterial value will be 0.0242 value higher than the venous value. But the difference can range from -0.0721 to 0.12045. Bland and Altman stated that if the mean difference between measurements ±1.96 SD (95% limits of agreement) is not clinically important, we could use the two measurement methods interchangeably. In the present study there are 3 values of pH which shows a difference of >0.1 which is clinically significant. 7 values of pH show a difference range between 0.80 to 0.90 which may also be considered significant clinically. Hence it can be stated that there was a moderate agreement between pH of ABG and VBG. The agreement was more when the pH was between 7.35 to 7.40.

In case pCO_2 the mean difference was -4.0440, means the arterial values will be less than simultaneous venous value. On analysis there was a good correlation and moderate agreement between the values. Here also the limits of agreement for the difference show a little wide range of -14.8949 to 6.8069. But there are only 4 cases with a difference >10 which may be clinically significant by which we can conclude that there is a moderate agreement between the two parameters. But in case of bicarbonate there was a good correlation and an excellent agreement too. The mean difference was -0.0940 with a limit of agreement between -4.1998 and 4.0119, which was not clinically significant.

Our limitations were small sample size and short period of study.

CONCLUSION

From the study it can be noted that there is good correlation between Arterial pH, pCO_2 and bicarbonate and corresponding Venous pH, pCO_2 and bicarbonate and has a poor correlation between Arterial pO_2 and venous pO_2. Poor correlation was observed for oxygen saturation measured using pulse oximeter and that measured from arterial blood gas. Linear regression done for the same parameters showed a good linear relation also. But Venous pH and pCO_2 parameters cannot be used to predict Arterial value in all cases as some of the values were lying outside the 95% limits of agreement. In conclusion, even though there was a good correlation and a moderate agreement between ABG and VBG parameters like pH, pCO_2 and bicarbonate, VBG cannot be replaced for ABG in acute asthma. Pulse oximetry also has limitations in children with acute severe asthma as compared to ABG value.

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