ORIGINAL RESEARCH PAPER

Biochemistry

PATIENT OUTCOME RELATED TO ARTERIAL BLOOD GAS PARAMETERS IN MEDICINE INTENSIVE CARE UNIT

KEY WORDS: Arterial Blood Gases, Medical Icu, Mortality

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ABSTRACT

INTRODUCTION: Most serious diseases involve variable degree of acid-base disorder requiring rapid identification and treatment to achieve improved survival.

OBJECTIVES: Identify differences in Arterial blood gas (ABG) parameters in patients visiting the Medical ICU and relate initial ABG results to mortality.

METHODS: 300 patients admitted to the MICU irrespective of underlying pathology and undergoing complete ABG analysis were included and divided into groups of survivors and non survivors depending upon mortality within 7 days of admission. Possible differences in ABG parameters were then compared between survivors and non-survivors.

RESULTS: Dividing the patients on the basis of reference range, acidosis (pH<7.35), hypercapnia (pCO_2>45mHg), hyperoxia (pO_2 >99%), hyperkalemia (>4.5 mmol/L), hyperglycaemia (>105mg/dL), hyperlactataemia (>1.6 mmol/L), decreased bicarbonate (<22.0mmol/L and hypochloremia (<98.0mmol/L) were related to high mortality.

CONCLUSION: ABG analysis in patients presenting to the ICU can help in predicting adverse outcome.

INTRODUCTION

A number of patients are admitted daily in the Medicine Intensive Care Unit (MICU) for various reasons. The work-up of these patients may include various physical assessment scales as well as laboratory parameters. In addition to clinical observations, laboratory test results can be used to reject or support a certain diagnosis. They can also be used to evaluate the course of disease or trauma and also to distinguish patients at risk of deterioration. (Vroonhof, Solinge, Rovers, & Huisman, 2005)

Categorization of a patient's illness into grades of severity occurs frequently in MICU. Numerous severity-of-illness (SOI) scoring systems have been developed and validated over the last few decades. (Knaus, Draper, Wagner, & Zimmerman, 1985) These combine laboratory results as well as other methods such as physical examination, non-invasive methods and clinically relevant history to predict the outcome of the patient and also to classify the patients into certain categories.

Although these scoring systems have been validated as tools to assess populations of critically ill patients, their utility in predicting individual patient outcome is not clear. And hence severity of illness scoring systems cannot be used to predict survival in individual patients. (Loscalzo, 2013)

Management of most serious and acute diseases involves variable degree of acid-base disorder which needs to be identified and treated rapidly. Because respiratory and circulatory failure occurs commonly in critically ill patients, monitoring of the respiratory and cardiovascular systems is undertaken frequently in the MICU. The "gold standard " remains arterial blood gas (ABG) analysis, in which pH, partial pressures of O_2, CO_2 and O_2 saturation are measured directly. With arterial blood gas analysis, the two main functions of the lung- oxygenation of arterial blood and elimination of CO_2 can be assessed directly.(Loscalzo, 2013)

The aim of our study was to identify clinically relevant differences in ABG parameters (pH, pCO_2, pO_2, SO_2, Na^+, K^+, Ca^{2+},Cl^- , glucose, lactate and bicarbonate) in an unselected group of patients presenting to the MICU irrespective of the underlying etiology and relate these laboratory values to mortality within 7 days of admission in the MICU.

MATERIAL AND METHODS

This was a prospective observational study conducted on 300 patients admitted to the Medical ICU of Dayanand Medical College and Hospital, Ludhiana from 1st January 2013 to 31st December 2014.

Patients above 18 years of age presenting to the MICU irrespective of the underlying etiology and undergoing complete arterial blood gas analysis were included in the study. Patients that died within 24 hours after admission to the MICU and who suffered a fatal out-of-hospital event as well as palliative care admissions were excluded.

The arterial blood sample was obtained by arterial puncture by the MICU staff within 24-48 hours of admission in a BD Vacutainer® A-Line™ syringes prefilled with 80 units of lyophilized lithium heparin with draw volume of 3.0 mL. The sample was then immediately sent to the clinical biochemistry lab to be analyzed on ABL825 FLEX Blood Gas Analyzer (Radiometer, Copenhagen, Denmark, using software licensed by Radiometer Medical ApS from Microsoft Licensing Inc. or its affiliates) for investigation. (pH, pCO_2, pO_2, SO_2, Na^+, K^+, Cl^-, Ca^{2+}, Glucose, Lactate, HCO_3^-) The analyzer underwent daily calibration and quality control checks to validate the analyzer's performance by evaluating accuracy and precision.

Depending upon mortality within 7 days of admission to M ICU, these patients were then divided into 2 groups of survivors and non-survivors. The data collected was recorded in a proforma and analyzed using descriptive statistics. Mean and median values of the blood gas parameters were compared between survivors and non-survivors using student's t-test. X^2 tests was used to study possible differences in the percentage mortality after selecting groups according to the reference ranges with one group of patients with blood gas results within the reference range, one group with results below and one group with results above the reference range. All statistical analyses were performed with SPSS version 21 (SPSS Inc, Chicago, IL, USA)

RESULTS AND DISCUSSION

Out of the 300 adult patients included in this study, 255 (85.0%) survived and 45 patients (15.0 %) succumbed to their illness within 7 days of MICU admission. 195 (65 %) were males and 105 (35%) were females. Among survivors, 162 (66.1%) were males and 93 were females (37.95%). Among non-survivors, 33 (73.3%) were males and 12(26.6%) were females.

Table 1 Patient parameters with mean/median along with the reference ranges.

Parameter	Mean	Reference range
Gender M/F	195/105	
Age, years	52.18 ± 17.06 (18-90)	
pH	7.39 ± 0.12 (6.4-7.73)	7.35-7.45
pCO2, mmHg	38.9 ± 17.3 (11.1-178)	35-45
pO2, mmHg	100.2 ± 63.8 (12.6-557.3)	83-108
Percentage Saturation	93.5 ± 6.4 (55.1-100.9)	95-99
Sodium, mmol/L	138 ± 4.0 (131-150)	136-146
Potassium, mmol/L	4.0 ± 0.57 (1.93-5.54)	3.4-4.5
Chloride, mmol/L	101.6 ± 6.4 (84.1-124.5)	98-106
Ionized Calcium, mmol/L	1.2 ± 0.1(1.0-1.6)	1.15-1.29
Glucose, mg/dL	158.0 ± 106.0 (45-1261)	70-110
Lactate, mmol/L	2.7 ± 1.7 (0.1-13.7)	0.5-1.6
Bicarbonate, mmol/L	23.4 ± 7.5 (10.0-41.6)	22-28

Table 2 Comparison between means or medians of surv ivors and non-survivors for various characteristics studied.

Parameters	Survivors (n=255)	Non-survivors (n=45)	P value
Gender M/F	162/93	33/12	0.237
Age, years	52.02 ± 17.15 (18-90)	53.16 ± 16.72 (18-89)	0.682
pH	7.42 ± 0.09 (6.8-7.73)	7.33 ± 0.17 (6.4-7.55)	**0.001**
pCO2, mmHg	37.2 ± 13.6 (11.1-87)	43.0 ± 23.9 (17.8-178.0)	**0.022**
pO2, mmHg	94.6 ± 55.4 (19.6-557.3)	109.4 ± 73.2(12.6-348)	0.201
SO2	93.6 ± 6.1 (59.2-100.8)	96.0 ± 8.0 (55.0-101.0)	**0.044**
Sodium, mmol/L	138 ± 3.9 (132-150)	137.2 ± 5 (131-149)	0.295
Potassium, mmol/L	4.0 ± 0.5 (1.9-5.5)	4.12 ± 0.7 (3.1-5.3)	0.301
Chloride, mmol/L	101.7 ± 6.6(84.1-124.5)	96.8 ± 5.0 (92-110.0)	**0.004**
Ionized Calcium, mmol/L	1.21 ± 0.07(1.0-1.6)	1.19 ± 0.07 (1.0-1.32)	0.215
Glucose, mg/dL	138.4 (30-1261.3)	197 (45-721)	**0.000**
Lactate, mmol/L	2.0 ± 1.1(0.3-5.3)	3.8 ± 2.6 (0.1-13.7)	**0.000**
Bicarbonate, mmol/L	23.9 ± 7.8 (10.0-41.7)	20.7 ± 4.6 (11.3-31.1)	**0.000**

Table 3 Difference between the mortality when patients were divided into groups according to the reference range of the parameters

Parameters	Groups according to the reference range	N (%)	Mortality (%)	p value when compared with the group within reference range
pH	< 7.35	63 (21.0%)	24 (38.0%)	**0.000**
	7.35 - 7.45	160 (53.3%)	16 (10%)	
	> 7.45	77 (25.67%)	5 (6.4%)	0.374
pCO2, mmHg	< 35	107 (35.67%)	15 (12.3%)	0.814
	35 - 45	78 (26.0%)	10 (11.4%)	
	> 45	70 (23.33%)	20 (28.6%)	**0.017**
pO2, mmHg	<83	119 (39.67%)	16 (13.44%)	0.345
	83-108	68 (22.67%)	6 (8.82%)	
	>108	113 (37.67%)	23 (20.35%)	**0.041**
SO2	< 95	136 (45.33%)	12 (8.8%)	0.174
	95 - 99	104 (34.67%)	15 (14.4%)	
	> 99	60 (20.0%)	18 (30.0%)	**0.017**
Na+, mmol/L	< 136	105 (35.0%)	21 (20.0%)	**0.088**
	136 - 146	184 (61.3%)	23 (12.5%)	
	> 146	11 (3.7%)	1 (9.09%)	0.738
K+, mmol/L	< 3.4	37(12.3%)	5 (13.5%)	0.437
	3.4 - 4.5	193 (64.3%)	18 (9.33%)	
	> 4.5	70 (23.3%)	22(31.43%)	**0.000**
Cl-, mmol/L	<98	97 (32.3%)	97 (32.3%)	**0.005**
	98-106	132 (44.0%)	15 (11.4%)	
	>106	71 (23.7%)	5 (7.0%)	0.325
Ca2+, mmol/L	< 1.15	17 (5.7%)	4 (23.53%)	0.271
	1.15-1.29	232 (77.3%)	32 (13.79%)	
	> 1.29	51 (17.0%)	9 (17.65%)	0.479
Glucose, mg/dl	<70	37(12.3%)	3 (8.11%)	0.283
	70-105	62 (20.7%)	2(3.17%)	
	>105	201 (67.0%)	40 (20.0%)	**0.002**

Lactate, mmol/L	<0.5	20 (6.7%)	1 (5%)	0.273
	0.5-1.6	89 (29.7%)	3 (3.37%)	
	>1.6	191 (63.7%)	41 (21.46%)	**0.000**
Bicarbonate, mmol/L	<22	146 (48.7%)	34 (23.28%)	**0.019**
	22-28	77 (25.7%)	8 (10.39%)	
	>28	77(25.7%)	3 (3.9%)	**0.079**

In our study, there was no significant difference in age between the group of survivors and non-survivors (p=0.682). Some studies have shown similar trends between difference in ages of survivors and non-survivors. (Burri, et al., 2011) (Shoemaker, et al., 2001) (Asiimwe, Wangoda, Kwizera, Makobore, & Galukande, 2014) However, others have shown a significant difference in mean age of survivors and non-survivors.(Olsson, Terent , & Lind, 2004) (Hucker, et al., 2005)

In the present study there was significant difference between pH of survivors and non-survivors. (p=0.001). We observed that low pH, and hence acidosis, is correlated with high mortality, which is consistent with literature. (Lee, Hwang, Yang, & Hong, 2002) (Hucker, et al., 2005) (Kaplan & Kellum, 2004). Twenty four out of our 63 patients (38.0%) with pH < 7.35 succumbed to their illness in our study and this difference was statistically significant (p = 0.000). Studies in intensive care settings have documented similar effects of metabolic acidosis on mortality. (Maciel & Park, Differences in acid-base behavior between intensive care unit survivors and nonsurvivors using both a physicoc hemi cal and a standard base excess approach: a prospective observational study, 2009) (De Campos, Braga, & Kuryura, 2008) (Maciel & Park, 2009) (Jung, Rimmele, & Le Goff, 2011) In a prospective observational study of a large cohort of 530 patients, pH at presentation predicted not only long-term mortality but also ICU admission, in-hospital mortality, and mortality after 30-day follow-up (Burri, et al., 2011) A study of 205 patients of acute pancreatitis suggested that pH at presentation predicts an adverse outcome and worse prognosis in patients with acute pancreatitis, including the occurrence of organ failure, need for intervention and mortality. (Sharma, et al., 2014)

In our study there was a statistically significant difference between the mean values of pCO_2 of survivors and non-survivors. (p = 0.022) Our data showed that with increasing pCO_2 above the reference range, mortality increased. In exacerbated COPD, elevated pCO_2 along with decreased pH has been found to be independent predictors of hospitalization and readmission. (Kessler, Faller, Fourgaut, Mennecier, & Weitzenblum, 1999) Some authors believe that arterial pCO_2 at the time of admission is a significant prognostic factor in patients with traumatic head injury, (Dumont, Visioni, Rughani, Tranmer, & Crookes, 2010) whereas others have denied it as a reliable indicator of short term outcome in these patients. (Henzler, Cooper, & Mason, 2001) According to Dumont et al (Dumont, Visioni, Rughani, Tranmer, & Crookes, 2010) survival was related to admission pCO_2 in 65 patients with traumatic brain injury patients requiring intubation. The survival rate in patients with normocarbia was significantly better than that in cases with either hypo- or hypercarbia. In contrast, in a study by Henzler et al (Henzler, Cooper, & Mason, 2001) pCO_2 was similarly elevated in both head trauma survivors and non-survivors on arrival in the emergency department. Similar results were also seen in a study by Amirmohammad Bazzazi et al which showed no significant association between admission pCO_2 and prognosis of the patients with head injury. (Amirmohammad, Mohammad Amin Valizade, Alireza, Mahdia, & Habibeh, 2014) However, in a study of 453 patients hospitalized with community acquired pneumonia with abnormal pCO_2 levels at presentation to the hospital were more likely to die within 30 days of admission when compared with those with normal pCO_2. (Elena, et al., 2012)

In our study there was no significant difference seen between the mean pO2 in survivors and non-survivors (p = 0.201). The mean pO2 was higher in non-survivors (109.4 ± 73.2) compared to survivors (94.6 ± 55.4) Similar results were seen in a study by Amirmohammad Bazzazi (Amirmohammad, Mohammad Amin Valizade, Alireza, Mahdia, & Habibeh, 2014) where, the mean pO2 was higher, although marginally insignificant, in the survived patients comparing with those who expired (128.00 ± 58.33 mmHg vs. 104.62 ± 46.06 mmHg; p=0.08). In contrast, a study of 1806 patients, pO2 values showed significant differences between survivors and non-survivors. (Vroonhof, Solinge, Rovers, & Huisman, 2005) In our study, the group with pO2 above the reference range showed significant higher mortality (p=0.041). In a Japanese group undergoing lower extremity surgery and therefore at risk of DVT and pulmonary embolism, (Oshima, Tachibana, & Hirota, 2006) the researchers found that decrease in pO_2 may be used to evaluate patient conditions after surgery. Hypoxia is shown to be an independent predictor of 30 day mortality in acute pulmonary embolism (Subramanian , Ramdurai , Arthur , & Gopalan , 2018)

Saturation of oxygen showed significant difference between the group of survivors and non-survivors in our study (93.6 ± 6.1 vs 96.0 ± 8) with a p value of 0.044. and the group with SO2 values above the reference range showed higher mortality (p=0.017) as shown in Table 3. Another study showed mean O_2 saturation of 95.75 ± 5.82% vs. 92.88 ± 7.82%; p=0.08 between survivors and non-survivors. (Amirmohammad, Mohammad Amin Valizade, Alireza, Mahdia, & Habibeh, 2014) However, Valadka et al (Valadka, Gopinath, Contant, Uzura, & Robertson, 1998) determined thresholds of brain tissue pO_2 that are critical for survival after severe head trauma similar to our study.

We found no significant difference between the mean values for sodium in our study between survivors and non-survivors (p = 0.295). The group of patients with a sodium level above the reference range was very small (11, 3.7% with mortality of 1, 9.09%) and there was no difference in mortality when the groups were divided according to the reference range for sodium. Reports in the literature concerning the relation between sodium levels and outcome are not consistent. Skrifvars et al (Skrifvars, Pettila, Rosenberg, & Castren, 2003) found no correlation in patients who were resuscitated, whereas others found that hyponatremia was related to poor outcome in patients hospitalized for heart failure (Lee, et al., 2003) (VillaCorta, et al., 2003) or in the adult internal medicine ED population. (Lee, Guo, & V, 2000) Hyponatremia is the most common electrolyte abnormality in hospitalized patients, with very diverse causes. (Palmer, Gates, & Lader, 2003) B.Whelan and colleagues showed serum sodium at admission to be an important determinant of in-hospital mortality. (Asadollahi, Hastings, Beeching, & Gill, 2007)

We found that the group of patients with a potassium level above the reference range showed higher mortality than the group within the reference range (p = 0.000). Skrifvars et al (Skrifvars, Pettila, Rosenberg, & Castren, 2003) concluded in their study that elevated potassium levels during the first 72 h of hospital treatment were associated with higher mortality in patients resuscitated from ventricular fibrillation. Our study corroborates earlier results showing that hyperkalemia is associated with poor outcome. (Skrifvars, Pettila, Rosenberg, & Castren, 2003) Our data showed that the group with potassium levels below the reference range was not different than the reference range group. In some reports hypokalemia

is described as a benign laboratory abnormality, (MacDonald, Atkinson, & Mooney, 2003) other reports are in concordance with our data and also showed that hypokalemia is associated with poor outcome. (Jensen, Brabrand, Vinholt, Hallas, & Lassen, 2014) (Szeto, Chow, Kwan, Leung, & Chung, 2005) (Sica, Struthers, Cushman, Wood, & Banas, 2002) (Qingdong, et al., 2014)

This study showed significant differences in level of chloride between survivors and non-survivors (p = 0.004). Also, the group of patients with chloride level below the reference range showed higher mortality than the group within the reference range. (p = 0.005) However, hyperchloremia was associated with mortality in critically ill patients in a study by Boniatti et al. (Boniatti, Cardoso, Castilho, & Vieira, 2011) In contrast, an observational study on major vascular trauma patients reported no correlation between hyperchloremia and mortality. (Kaplan & Kellum, 2004) An observational study on 488 critically ill patients admitted to the ICU showed that hypochloremia is associated with poorer outcomes with hypochloremia correlating significantly with higher APACHE II scores. (Tani, Morimatsu, Takatsu, & Morita, 2012)

Critically ill patients are known to have low calcium values that are correlated to higher mortality. (Hastbacka & Pettila, 2003) (Ward, et al., 2004) Our study however showed no difference in groups with ionized calcium both above and below the reference range when compared to the group within the reference range. Probable reason for this could be that the number of patients in the group below reference range was too small for statistical comparison.

Our study showed a correlation between hyperglycaemia and increased mortality in a large unselected group of patients (p = 0.002). Studies have shown that hyperglycemia is an independent predictor of mortality in several selected groups of non-diabetic patient's most notably myocardial infarction (Capes, Hunt, Malmberg, & Gerstein, 2000), stroke (Capes, Hunt, Malmberg, Pathak, & Gerstein, 2001) and intensive care. (Finney, Zekveld, Elia, & Evans, 2003). High blood glucose levels in patients admitted for Acute Coronary Syndrome /Acute Myocardial Iinfarction are common and are associated with an increased risk of death in both patients with diabetes (Ainla, Baburin, Teesalu, & Rahu, 2005) (Wahab, et al., 2002) and patients without diabetes. (Ainla, Baburin, Teesalu, & Rahu, 2005) (Bolk, et al., 2001) (Straumann, Kurz, & Muntwyler, 2005)

Several reports have shown a relationship between high initial lactate concentration and poor outcome (Weil & Afifi, 1970) (Maillet, et al., 2003) (Mullner, et al., 1997) (Kasirajan, Mascha, Heffernan, & Sifuentes, 2004) (Galic, et al., 2018)There was statistically significant difference between lactate values for survivors and non-survivors in our study (p = 0.000) with the group of patients having lactate values above the reference range showing higher mortality (p = 0.000). Here we confirm those previous results, showing that with increasing initial lactate levels outcome worsens.

Our study showed significant differences in level of bicar bonate levels between survivors and non-survivors (p = 0.000).The group of patients with bicarbonate level below the reference range showed higher mortality when compared to the group with bicarbonate levels within the reference range. (p = 0.019). Studies in intensive care settings have documented the effects of metabolic acidosis on mortality. Bicarbonate levels of less than 18 meq/L was seen in 23 out of 71 acute pancreatitis patients (32%) in a Brazilian study. (De Campos, Braga, & Kuryura, 2008) A study of 107 patients admitted to intensive care for various reasons demonstrated a significantly severe metabolic acidosis in non-survivors. (Maciel & Park, 2009) Vishal Sharma et al in a study of 205 patients of acute pancreatitis suggested that low bicarbonate levels at presentation predicts an adverse outcome and worse prognosis in patients with acute pancreatitis (Sharma, et al., 2014)

Our goal was to identify clinically relevant differences in ABG parameters in a large unselected group of patients who presented to the MICU. The diagnosis of the patients involved was therefore not taken into consideration for this study. The results of our study are only based on data obtained from patients for whom ABG analysis was ordered by the clinician. An observation period of 7 days was selected to check for mortality in this study. A change in the observation period would also change the incidence of mortality but with increase in the observation period, the likelihood of mortality being related to the ABG results at the time admission would be decreased.

For glucose we classified the patients according to the fasting reference range however we could not ensure the fasting status of the patients.

In our study 37.67% of the patients had pO_2 values above the reference range, suggesting that the samples might have been drawn after oxygenation had been started for the patient. Therefore it is difficult to relate the pCO_2, pO_2 and saturation to mortality as oxygenation status of the patients was not available to us.

Lactate values are not always requested and should be routinely sent with ABG requests. Our study showed that even for values within the reference range for ionized calcium, there was an increased risk of mortality hence it is recommend that reference ranges for ionized calcium be interpreted with care.

We conclude that a simple diagnostic analysis of arterial blood gas in patients presenting to the intensive care unit can help in predicting adverse outcome. Lactate has additional clinical value in blood gas analysis; and therefore should be routinely added to a blood gas analysis request. In addition to results acquired in selected groups of patients, our study shows differences in mortality for laboratory parameters in patients visiting the MICU, irrespective of the underlying diagnosis.

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