Global Academic Journal of Medical Sciences

Available online at www.gajrc.com
DOI: 10.36348/gajms.2023.v05i05.001

ISSN: 2706-9036 (P)
ISSN: 2707-2533 (O)

Original Research Article

Acid-Base Status & Electrolyte Imbalance in Critically ill Ventilated Infants

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Article History
Received: 27.07.2023
Accepted: 01.09.2023
Published: 09.09.2023

Abstract: ***Introduction***: Children who are critically ill typically suffer from a disease process that impacts many organ systems. To improve the outcome, these children are treated in a pediatric intensive care unit. The primary focus of intensive care medicine is the care of patients who are facing immediate life-threatening conditions. The aim of this study was to determine the acid- base status & electrolyte imbalance in critically ill ventilated infants. ***Methods:*** This was a prospective observational study and was conducted in the Department of Intensive Care Unit (ICU) of Bangladesh Shishu Hospital & Institute, Dhaka, Bangladesh during the period from January 2020 to December 2020. In our study, we included 50 critically ill ventilated young infants in ICU of Bangladesh Shishu Hospital & Institute. ***Results*:** In our study, we found that almost three fourth (74.0%) patients died and 13(26.0%) patients survived. Majority of our patients were ≤ 15 days and male. We found 22(59.5%) patients had P^H level <7.25 in death group and 6(46.2%) in survival group and P^H level ≥7.15 was (81.1%) in death group and 10(76.9%) in survival group. Before extubation & death metabolic acidosis was 19(51.4%) in dead group and 2(15.4%) in survival group. Significant relation was found between serum sodium level <135 and outcome of ventilated patients [p=0.039, OR=0.19(0.04-0.89)]. Imbalance of single & more than one electrolyte was found 43.24% & 56.76% in death group and 61.5% & 38.5% in survival group respectively. ***Conclusion*:** We found that arterial blood gas analysis & serum electrolytes level provide valuable information for correction of acid–base imbalance associated with a pathological condition. Electrolyte imbalance, regardless of the basic disease etiology, is a significant prognostic indicator that must be rapidly treated in critically ill children to get a good outcome.

Keywords: Acid- Base Status, Electrolyte Imbalance, Critically Ill Ventilated Infants.

INTRODUCTION

Children who are critically ill typically suffer from a disease process that impacts many organ systems. To improve the outcome, these children are treated in a pediatric intensive care unit [1]. The primary focus of intensive care medicine is the care of patients who are facing immediate life-threatening conditions [2]. In intensive care unit, complex acid-base and electrolyte disorders are common. Understanding of acid–base dysfunction in various pathological conditions is an asset to a pediatrician in treatment of critically ill children. The Henderson–Hasselbach equation mathematically links the variables of pH, partial pressure of oxygen (pO_2), partial pressure of carbon dioxide (pCO_2), and bicarbonate concentration [HCO_3^-][3]. Blood gas analysis (BGA) provides pH, pO_2, pCO_2 from which [HCO_3^-] and base excess (BE) can be derived [4]. This approach has been considered "traditional."

Moreover, it is easily understandable and widely used at the bedside management [5]. Acid–base disorders reflect the seriousness of the underlying disease and are responsible for morbidity and mortality in sick children [6]. In comparison to adults, children exhibit significant structural and functional differences. For example, due to immature respiratory centers and narrow distal airways, in children hypercarbia and hypoxia develop rapidly. In addition, they have reactive vascular beds to maintain their blood pressure until late, so one cannot rely on hypotension to diagnose shock as in adults [7]. Electrolyte abnormalities are common in pediatric children who are critically ill [8]. When present, they have a big impact on how patients turn out. The goal of providing critical care through pediatric intensive care units (PICU) is to keep the body's 'homeostasis,' which is essential for the organ's support and best function. This involves the balance of electrolytes as well as fluids [9]. Major electrolytes important in this regard are sodium, potassium, calcium, magnesium and phosphorus [10]. Their imbalance in either direction i.e., lower or higher than normal values can affect cellular processes, which can significantly affect morbidity and mortality [11]. These imbalances also result in longer stay in hospitals [12], thus adding significantly to the costs of management. Therefore, to prevent a bad consequence, early detection and intervention to correct these imbalances are crucial [13]. Five possible mechanisms for the occurrence of electrolyte imbalance are the underlying disease process, end organ injury, fluid and electrolyte interventions, use of medications with potential of electrolyte derangements and application of critical care technology i.e.positive pressure ventilation [14].

Mechanical ventilation, a life supporting device, invasive technology of intensive care unit mimics the respiratory physiological function at the time of either impending or acute respiratory failure [15]. The percentage of children receiving mechanical ventilation in intensive care units ranges from 17-64% in developed countries [16-19]. Artificial mechanical ventilation has substantially improved outcomes of children until the underlying pathological process resolves [20]. Underlying acid base disorders & electrolyte imbalance influence the outcome of patients who are on mechanical ventilation. In this study, we aimed to determine the acid- base status & electrolyte imbalance in critically ill ventilated infants.

MATERIALS & METHODOLOGY

This observational study was conducted in the Department of Intensive Care Unit of Bangladesh Shishu Hospital & Institute, Sher-e-Bangla Nagar, Dhaka from January 2020 to December 2020. The study was carried out on patients who required ventilation on various indications according to ICU protocol after taking informed written consent from the patient's guardian/attendant. Fifty young infants up to 2 months age consecutively put on mechanical ventilation during the study period were enrolled. Informed written consent was taken confidentially from all patients who fulfilled the inclusion and exclusion criteria. Infants more than 2 months age, with congenital heart disease, congenital malformations & requiring surgical intervention were excluded from this study. Permission from ethical review committee of the hospital was taken. Young infants were monitored clinically (Heart rate, Respiratory rate, Temperature, CRT) along with regular cardiac monitor and pulse Oximetry. The initial parameter (Rate, PIP, PEEP, FiO_2, Inspiratory time) was set according to need of patients & initial ABG analysis. Sedation was applied if indicated. After 2 hours of ventilation ABG was done to adjust the parameters. Then subsequent parameters (PIP, PEEP, Rate of ventilation, FiO_2) on mechanical ventilation were modified according to need of oxygenation and ventilation through SpO_2 and blood gas analysis. Along with this, biochemical (Serum Electrolytes, calcium, Creatinine, Urea, Random blood sugar) and haematological profiles were checked according to patient's clinical condition. All infants were monitored for complications. Patients were extubated when clinically stable both haemodynamically & neurologically, having self-respiration, maintaining oxygen saturation, normal chest X-ray & with low ventilator parameters or after gradual weaning. Patient was followed up till death or extubation. All the data were collected by researcher herself to avoid errors. After collection, data editing and clearing was done manually and prepared for data entry and analysis by using SPSS-25 & MS Excel 2016.

RESULTS

In our study, we found that almost three fourth (74.0%) patients died and 13(26.0%) patients survived. [Figure 1] Majority 27(73%) patients were belonged to age ≤15 days in death group and 7(53.8%) in survival group. 30(81.1%) patients were found gestational age >34 weeks in death group and 12(92.3%) in survival group. Majority 20(54.1%) patients were found weight <2500 gram in death group and 4(30.8%) in survival group. Among them, 22(59.5%) patients were male in death group and 10(76.9%) in survival group.

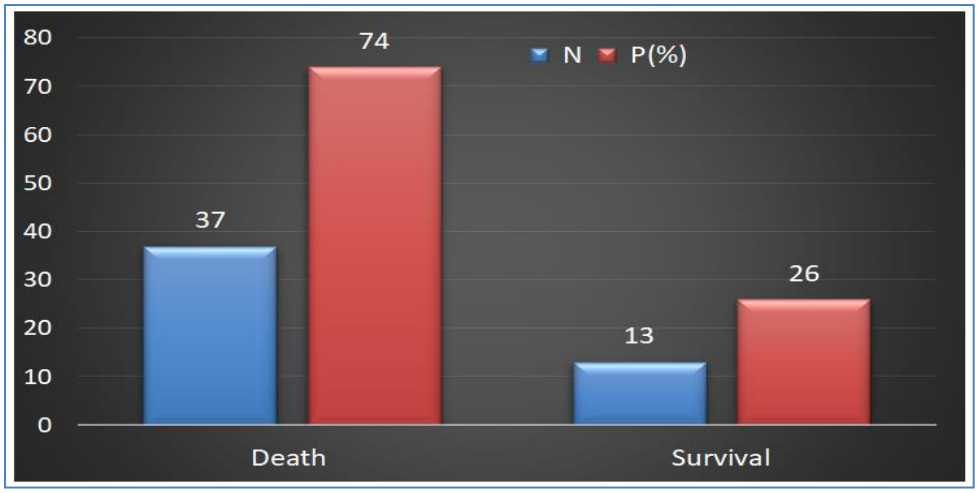

Figure 1: Distribution of our study participants by their outcome (n=50)

Table 1: Demographic characteristics of the study patients (n=50)

Variables	Death (n=37) n (%)	Survival (n=13) n (%)	Odds ratio (95% CI)	P-value
Age				
≤15 days	27 (73)	7 (53.8)		
16-30 days	7 (18.9)	2 (15.4)		
31-45 days	2 (5.4)	3 (23.1)		
>45 days	1 (2.7)	1 (7.7)		
Mean± SD	14.2±10.1	20.2±18.2		
Gestational age				
<34 weeks	7 (18.9)	1 (7.7)	2.8(0.31-25.26)	0.321
>34 weeks	30 (81.1)	12 (92.3)		
Weight				
<2500 gm	20 (54.1)	4 (30.8)	2.6(0.69-10.15)	0.148
>2500 gm	17 (45.9)	9 (69.2)		

Table 2: Relation between sex and outcome of ventilated patients (n=50)

Sex	Death (n=37)		Survival (n=13)		Odds ratio (95% CI)	P-value
	n	(%)	n	(%)		
Male	22	(59.5)	10	(76.9)	0.44 (0.10-1.87)	0.216
Female	15	(40.5)	3	(23.1)		

Table 3: Relation between P^H below 7.25 and 7.15 and acidosis with the outcome of ventilated patients

Parameter	Death (n=37) n (%)	Survival (n=13) n (%)	Odds ratio (95% CI)	P value
P^H				
<7.25	22 (59.5)	6 (46.2)	1.71(0.48-6.11)	[a]0.406
>7.25	15 (40.5)	7 (53.8)		
<7.15	7 (18.9)	3 (23.1)	0.78(0.17-3.59)	[b]0.515
>7.15	30 (81.1)	10 (76.9)		
Before ventilation				
Metabolic acidosis	28 (75.7)	5 (38.5)	4.07 (1.09-15.20)	0.019
Respiratory acidosis	3 (8.1)	1.(7.7)	1.06 (0.10-11.18)	0.725
Before extubation/ death				
Metabolic acidosis	19 (51.4)	2 (15.4)	5.81 (1.13-29.89)	0.024
Respiratory acidosis	5 (13.5)	1.(7.7)	1.88 (0.20-17.74)	0.503

[a]P value reached from Chi square test ; [b]P value reached from Fisher's exact test

Table 4: Distribution of initial PCO_2 among ventilated patients (n=50)

PCO2 (mmHg)	Death (n=37)		Survival (n=13)	
	n	%	n	%
0-20	15	(40.5)	1	(7.69)
21-34	16	(43.2)	6	(46.1)
35-45	1	(2.7)	2	(15.3)
46-60	4	(10.8)	2	(15.3)

Table 5: Relation between PCO_2, HCO_3, BE and outcome of ventilated patient(N=50)

Initials		Death (n=37) n (%)	Survival (n=13) n (%)	Odds ratio (95% CI)	P value
PCO_2 (mmHg)	>60	1 (2.7)	2 (15.4)	0.15 (0.012-1.841)	0.13
	<60	36 (97.3)	11 (84.6)		
HCO_3(mmHg)	<15	26 (70.3)	3 (23.1)	7.88 (1.81-34.28)	0.003
	>15	11 (29.7)	10 (76.9)		
BE	<-10	28 (75.7)	5 (38.5)	4.98 (1.30-19.31)	0.019
	>-10	9 (24.3)	8 (61.5)		

Table 6: Distribution of our study patients by pattern of electrolyte and outcome (N=50)

Pattern of electrolyte	Death (n=37) n (%)	Survival (n=13) n (%)	Odds ratio (95% CI)	P value
Serum sodium (mmol/L)				
>145 (Hypernatremia)	33 (89.2)	8 (61.5)	0.19 (0.04-0.89)	0.039
<135 (Hyponatremia)	4 (10.8)	5 (38.5)		
Serum potassium (mmol/L)				
>5.5 (Hyperkalemia)	34 (91.9)	11 (84.6)	2.06(0.30-13.97)	0.389
<3.5 (Hypokalemia)	3 (8.1)	2 (15.4)		
Serum calcium (mmol/L)				
>3.0 (Hypercalcemia)	31 (83.7)	7 (53.8)	3.16(0.20-11.68)	0.218
<1.2 (Hypocalcemia)	6 (16.2)	6 (46.1)		

Among all participants, 22(59.5%) patients had P^H level <7.25 in death group and 6(46.2%) in survival group. P^H level ≥7.15 was 30(81.1%) in death group and 10(76.9%) in survival group. No relation was found between outcome with P^H level <7.25 and <7.15 in our study. Before ventilation metabolic acidosis was found 28(75.7%) and 5(38.5%) in death and survival group respectively and that was significant. Before extubation/death metabolic acidosis was 19(51.4%) in death group and 2(15.4%) in survival group, that was significant. [Table 3]

Table 4 shows the distribution of initial PCO_2 among ventilated patients. Majority (40.5% & 46.1%) patients in dead & survival group respectively had 21-30 mmHg PCO_2 level. In dead group only 2.7% had 35-45 mmHg PCO_2 level and in survival group 7.69% had ≤ 20 mmHg PCO_2 level**.**

Before stating ventilation 1(2.7%) patients had PCO_2 level>60 mmHg in death group and 2(15.4%) in survival group. No association was found PCO_2 level>60 mmHg and outcome of ventilation patients. After those 26(70.3%) patients had HCO_3 level<15mmHg in death group and 3(23.1%) in survival group. As well as 28(75.7%) patients had BE <-10 in death group and 5(38.5%) in survival group. Significant relation was found between HCO_3, BE and outcome of ventilated patients. [Table 5]

Table 6 shows that 33(89.2%) patients were found with serum sodium >145 mmol/L in death group and 8(61.5%) in survival group. Among all participants, 34(91.9%) patients were found serum potassium >5.5 mmol/L in death group and 11(84.6%) in survival group. Serum calcium >3 mmol/L was found 31 (83.7%) in death group and 7 (53.8%) in survival group. Significant relation was found in serum sodium level <135 and outcome of ventilation patients [p=0.039, OR=0.19(0.04-0.89)], but not in serum potassium & calcium level.

DISCUSSION

Acid base disturbance specially in the form of acidosis is an important predictor of poor outcome. In this study we also found significant relation between metabolic acidosis & outcome. [Table 3] Among the ventilated infants, metabolic acidosis was found 75.7% & 38.5% before ventilation in death & survival group respectively (p=0.019) whereas metabolic acidosis before death was 51.4% in death & 15.4% in survival group (p=0.024). Mathur *et al.,* found significant relation with poor outcome in pH below 7.3 in their study [21]. In this study PCO_2 was higher in survival group than death group (p=0.013), however no significant role was found between PCO_2 more than 60 and poor outcome (p>0.05). [Table 5] But Mathur *et al.,* in their study found significant relation between PCO_2 and outcome [21]. However

Hossain *et al.,* found no significant relation between PCO_2 with poor outcome [22]. Majority of the patients in death group had HCO_3<15 mmHg that was statistically significant. [Table 5] BE<-10 was significantly higher in death patients. [Table 5]

In this study, hypocalcemia & hypercalcemia was noted in 24% & 76% cases respectively. Previous studies have mentioned the incidence of hypocalcemia in critically ill children to be around 40% and 47.5% [23, 24]. One possible explanation for such a high incidence of hypocalcemia is the high prevalence of Vitamin D deficiency in Pakistani children up to77%. [25].

Regarding the patterns of electrolyte imbalance, significant relation was found between serum sodium level and outcome of ventilation patients (p=0.039). [Table 6] No significant relation was found between serum potassium and outcome of ventilated patients (p=0.389). [Table 6]

The presence of dysnatremias (either hypo or hypernatremia) in intensive care unit has been reported to be around 30% [26,27]. Most of the literature has reported hyponatremia to be more prevalent than hypernatremia i.e. 23.2% vs. 16.7%, 27.43% vs. 3.5%, 50.5% vs. 9.4% [23- 29]. Sachdev A. noted hyponatremia to be 19.3% [30]. However, we found hypernatremia in 82% cases and hyponatremia in 18% cases. This might be due to the institutional policy of maintenance intravenous fluid to be the 0.9% saline rather than half strength or other hypotonic solutions in children above one month of age.

Hypokalemia was observed in 10% cases and hyperkalemia in 90% cases. Previous studies have mentioned the incidence of hypokalemia as 40%, 34.4% and 22.1% and hyperkalemia as 11.2%, 16.12% and 29%. [23- 31].

Mathur *et al.,* had found relation between pH below 7.3 and mortality [21], while Hossain *et al.,* reported significant relation in pH <7 with poor outcome where as we found significant relation between pH <7.1 and case fatality [32]. They concluded that initial arterial pH <7.1, O_2 saturation <80%, PCO_2>60 mmHg, FiO_2>60%, hyponatremia, hypokalemia and complications during ventilation were the significant predictors of mortality in ventilated neonates in the intensive care unit. This observation suggests that the damages that have already been occurred reflected by initial acid-base disturbances before ventilation might play role in poor outcome. Morbidity was significant in cases of electrolyte imbalance both in terms of required level of care and emergence of complications. Ventilatory support was required in 82% of these children. Similarly, diuretics were required in 90.90% [33].

It is claimed that medications commonly used in intensive care units may contribute to the electrolyte disturbances as they can interfere with the absorption of electrolytes, alter hormonal responses affecting hemostasis and can directly affect the organ function as well. Their requirement however indicates the severity of illness and they continue to be an important risk factor for later development of electrolyte imbalance [34].

LIMITATIONS OF THE STUDY

Our study was a single centre study. We took a small sample size due to COVID-19 pandemic situation.

CONCLUSION

Blood gas analysis provide valuable information for correction of acid–base imbalance associated with a pathological condition. We found that, electrolyte imbalance & acid base disturbances, regardless of the basic disease etiology, is a significant prognostic indicator that must be rapidly treated in critically ill children to improve the outcome.

ACKNOWLEDGEMENTS

Special thanks for Personnel, Nurses of ICU of Bangladesh Shishu Hospital & Institute.

Financial Support and Sponsorship: Self.

Conflicts of Interest: There are no conflicts of interest.

Ethical Approval: The study was approved by the Institutional Ethics Committee.

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