Original Article

The predicting ability of serum potassium to assess the duration of mechanical ventilation in critically ill patients

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Abstract

Background: No previous study has been done to evaluate the admission serum potassium level as a predictor of morbidity or need for mechanical ventilation.The aim of this study is to determine the predictive ability of serum potassium on admission, in critically ill trauma patients, and to evaluate the relation of the potassium level to organ failure, length of stay, ventilator need, and duration of mechanical ventilation.

Materials and Methods: A prospective, observational study was done on 100 patients >16 years old, admitted to the Medical-Surgical Intensive Care Units (ICU), for over one year. Patients were classified into Group A: Patients who required equal or less than five days of mechanical ventilation and Group B: Patients who required more than five days of mechanical ventilation. The total serum potassium concentrations were measured and the Sequential Organ Failure Assessment (SOFA) score was recorded at the time of admission to the ICU, when connected to the ventilator, and then at the time of weaning from the ventilator.

Results: There was no significant difference between the Serum K concentrations between the two groups, on admission. However, there were significant difference between the Serum K concentrations at times of receiving and weaning from mechanical ventilation (MV) between the two groups. We found the best cut-off point of 3.45 for serum potassium concentration, to predict the need for longer duration of MV.

Conclusion: Development of hypokalemia during an ICU stay is associated with the need for mechanical ventilation. Monitoring of the serum potassium levels may be a good prognostic factor for the requirement of mechanical ventilation.

Key Words: Critically ill patients, hypokalemia, mechanical ventilation, potassium, sequential organ failure assessment score

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INTRODUCTION

Most critically ill patients with multiple organ failure require mechanical ventilation. Endotracheal intubation with mechanical ventilation (MV) is the standard supportive therapy for acute respiratory failure. Unfortunately, prolonged mechanical ventilation is associated with significant morbidity and mortality. In critically ill patients, weaning from ventilatory assistance is a key survival factor.[1]

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Patients who have been receiving mechanical ventilation for a prolonged time may have many barriers to overcome in order to wean away from it and this must be taken into consideration during evaluation. Most patients, who are difficult to wean, have problems in one or more areas, which should be corrected. One of these areas is electrolyte abnormality. Abnormalities may include hypokalemia, hypophosphatemia, hypomagnesemia, hyponatremia, and hypocalcemia.[1,2]

Potassium is the major intracellular cation and is involved in many vital processes. The normal plasma concentration of potassium is 3.5 - 5 (mmol/ml). This cation is essential for normal cardiovascular, metabolic, and neuromuscular functioning. Although hypokalemia is usually well-tolerated in healthy subjects and most hypokalemic patients are asymptomatic, the reduced plasma potassium level may cause rhabdomyolysis, cardiac arrhythmias, ascending paralysis, and ultimately respiratory arrest. Tachyarrhythmia and muscle weakness are potentially life-threatening complications of hypokalemia.[3-5]

In critically ill patients, hypokalemia on admission is one of the most frequently observed electrolyte disturbance. This finding was seen more often among those patients with multiple injuries, especially in the head and spinal region. It was hypothesized that hypokalemia occurred more frequently in more severely injured patients, but there are few studies, with no definite explanation to describe this phenomenon.[6]

Clinical trials and observational studies usually use a scoring system for the assessment of the severity of organ function impairment. One of most popular among them is the Sequential Organ Failure Assessment (SOFA) score [Table 1].[7] SOFA is composed of scores from six organ systems (respiratory, cardiovascular, hepatic, coagulation, renal, and neurological), graded from 0 to 4, according to the degree of dysfunction/failure.[8] The predictive ability of the SOFA score as a simple, inexpensive, and dynamic marker of critical illness in patients requiring MV has been studied by few authors.[9,10]

Thus far, as no previous study exists to evaluate the admission serum potassium level as a predictor of morbidity or mortality, in this study, our aim is to determine the predictive ability of serum potassium on admission in critically ill-traumatic patients, and to evaluate the relation of the potassium level to organ failure, length of stay, ventilator need, and duration of mechanical ventilation.

MATERIALS AND METHODS

We conducted a prospective, observational study (approved by the Institutional Ethics Committee for human subjects research), for over one year, in 2013, on 100 adult patients (>16 years old), with multiple trauma, admitted to our Medical and Surgical Intensive Care Units, who received mechanical ventilation. The consent for enrollment was obtained by proxies (close family members) in almost all cases.

Patients with burn injuries, history of drug addiction, and cardiopulmonary resuscitation (CPR) in the Emergency Room before ICU admission were excluded from data collection.

The survey was conducted the total serum potassium level on admission, the variety of laboratory tests related to potassium, type of injury, ventilator need,

Table 1: The SOFA scoring system

Score points	1	2	3	4
Respiration				
PaO_2/FiO_2	<400	<300	<200 With respiratory support	<100 With respiratory support
Cardiovascular				
Hypotension*	Map <70 mmhg	Dopamine ≤5 or Dobutamine in any dose	Dopamine >5 or Epinephrine ≤0.1 or Norepinephrine ≤0.1	Dopamine >15 or Epinephrine >0.1 or Norepinephrine >0.1
Liver				
Bilirubin mg/dl	1.2-1.9	2.0-5.9	6.0-11.9	>12.0
Renal				
Creatinine mg/dl or urine output	1.2-1.9	2.0-3.4	3.5-4.9 or <500 ml/24 h	5.0 or <200 ml/24 h
Coagulation				
Platelets×10^3/mm^3	<150	<100	<50	<25
Central nervous system				
Glasgow coma scale	13-14	10-12	6-9	<6

*Adrenergic agents administered for at least 1h (doses are given in μg/kg/min) duration of mechanical ventilation, ICU length of stay, and general patient demographics.

Heart rate and arrhythmias at admission and during the ICU stay were recorded. Tachycardia was defined as a heart rate of > 90 beats/minute.

The SOFA score was determined and the total serum potassium concentrations were measured and recorded at the time of admission to the ICU, when connected to the ventilator, and then at the time of weaning from the ventilator.

During the study, the duration of ventilation was defined as the number of days with mechanical ventilation. The patients were classified into two groups according to the days for which mechanical ventilation was needed. Group A: Patients who required equal or less than five days of mechanical ventilation and Group B: Patients who required more than five days of mechanical ventilation.

Data was analyzed using the statistical program SPSS 20 for Windows. All values were reported as mean ± SE. Chi-square and independent *t*-tests were used to evaluate the relationship between the duration of MV and the different variables. A P value of < 0.05 was considered as statistically significant. A Receiver Operating Characteristic (ROC) curve depicted the sensitivity, specificity, positive predictive value, and negative predictive value of prolonged MV, each time, for both SOFA score and K concentration. The area under the ROC curve was evaluated. It ranges in value from 0.5 (classification by chance) to 1.0 (perfect discrimination). A larger area under the ROC curve represented more reliability[11-13] and good discrimination each time for K concentration and SOFA score, for prolonged MV..

RESULTS

Among the critical trauma patients requiring mechanical ventilation in the ICU for over a year, in 2013, 100 patients were recruited into our study.

The patients were grouped according to the days of need for MV. Sixty-one patients were in group A (≤5 days of MV) and 39 patients were in group B (>5 days of MV).

We studied 75 males and 25 females, and 33.3% of males and 56% of females were in group B, respectively. This difference between gender was significant [Table 2] ($P = 0.04$).

The age of the patients ranged between 17 and 73 years. The mean average patient's age in group B was 39.9 ± 15.02 years and in group A it was 33.9 ± 11.87 years. This difference was statically significant ($P = 0.03$) [Table 2].

There was no significant difference between height, weight, and the coexisting disease (arrhythmia, diabetes mellitus, and hypertension), between the two groups [Table 2] ($P > 0.05$).

The duration of ICU stay in group A was 7.5 ± 2.8 days and in group B it was 20.1 ± 10 days, this difference was significant [Table 2] ($P < 0.001$).

Serum potassium concentrations were measured thrice in all patients: On admission to ICU, at the time of receiving MV, and at the time of weaning from MV. There was no significant difference between the Serum K concentrations on admission, between the two groups (A group: 3.96 ± 0.41 meq/dl and B group: 3.84 ± 0.34 meq/dl). However, there were significant differences between the serum K concentrations at times of receiving and weaning from MV, between the two groups. The Serum K concentration at the time of receiving MV in group A was 3.71 ± 0.37 and in group B was 3.36 ± 0.46 ($P < 0.001$) and the Serum K concentration at the time of weaning from MV in group A was 3.99 ± 0.31 and in group B was 3.84 ± 0.29 ($P = 0.02$) [Table 2].

Additionally, in the same time intervals, group B had greater SOFA scores when compared with group A. This difference was significant ($P < 0.001$) [Table 2].

We used ROC curves of the Serum K concentrations and SOFA scores to find a best cut-off point as a prediction factor for a need for longer MV. The sensitivity, specificity, and area of the ROC curve at the best cut-off point for longer MV are presented in Table 3 and Figure 1.

We also compared the groups according to the region injured: (1) head (skull, face, and neck); (2) torso (chest, abdomen, and pelvic content); (3) limbs, including pelvic girdle; (4) head and torso; (5) head and limbs (6) torso and limbs, and (7) head and torso and limbs. A high percentage of patients in group B had multiple organ injuries.

DISCUSSION

The aim of this study was to determine the predictive ability of the serum potassium level on admission in critically ill-traumatic patients for, ventilator need, duration of mechanical ventilation, and length of stay in the ICU.

In our study, the potassium level on admission was in a normal range, however, Alen and Smith reported that early posttraumatic hypokalemia did occur frequently.[6,14]

Table 2: Demographic data, SOFA scores, serum K concentration and length of stay in ICU according to duration of need for MV

Variable	Group A (≤5 MV)	Group B (>5 MV)	*P* value
No. of patients	61	39	
Gender		103	
Male	50 (66.6%)	25 (33.3%)	0.04*
Female	11 (44%)	14 (56%)	0.04*
Age	33.9±11.87	39.9±15.02	0.03
Height	172±7.8	169±7	0.14
Weight	72.7±9.7	70.87±11	0.37
ICU days	7.54±2.8	20.13±10.03	>0.001
Serum K concentration			
On admission	3.96±0.41	3.84±0.34	0.15
At receiving MV	3.75±0.037	3.36±0.46	>0.001
At weaning MV	3.99±0.31	3.84±0.29	0.02
SOFA score			
On admission	3.10±0.79	4.77±1.53	>0.001
At receiving MV	3.59±0.93	5.36±1.58	>0.001
At weaning MV	1.33±0.96	2.33±1.38	>0.001

**P* value 0.04 is the *P* value between genders in group B. SOFA: Sequential organ failure assessment, ICU: Intensive care units, MV: Mechanical ventilation

Table 3: Comparison of the assessment scores in need for longer MV

Variable	Cut-off point	Sensitivity (%)	Specificity (%)	PPV[1] (%)	NPV[2] (%)	ROC area
K on admission	3.45	61.5	78.7	64.9	76.2	0.736
SOFA scores						
On admission	3.5	79.5	72.1	64.6	84.6	0.83
At receiving MV	4.5	66.7	83.6	72.2	79.7	0.82

[1]PPV: Positive predictive value, [2]NPV: Negative predictive value, SOFA: Sequential organ failure assessment, MV: Mechanical ventilation, ROC: Receiver operating characteristic

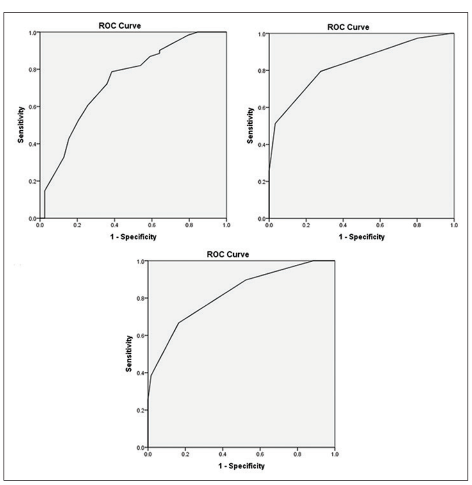

Figure 1: Receiver Operating Characteristic (ROC) curves show need for longer mechanical ventilation drawn of Serum K concentration on admission (curve a), SOFA score on admission (curve b) and SOFA score at receiving MV (curve c)

Grace *et al*. noted the role of epinephrine in hypokalemic trauma patients. They described that epinephrine initially caused a rise in serum potassium due to its release from the liver, but within minutes the levels dropped quite dramatically, as the potassium moved into the cells. This intracellular movement was mediated via beta-2 receptors.[15] Even though, Vanek *et al*. documented that in limited patients, where the epinephrine levels were elevated, hyperkalemia instead of hypokalemia was seen.[16] As we know in stress and traumatic conditions, the serum insulin level will be decreased,[17] in addition stress could cause insulin resistance and this was partly due to the serum hormones produced by the adrenal glands.[18] Insulin had an effect on serum potassium, as it drove potassium into cells. Therefore, it might explain the cause of the normal range of serum potassium level in our study.

Although, we did not find hypokalemia on admission in our critically ill patients, hypokalemia had been seen at the time of receiving mechanical ventilation. We also found the best cut-off point of 3.45, for serum potassium concentration, to predict a longer duration of MV.

The SOFA score provides more information on predicting the need for MV. In our study there was a significant relation between the SOFA score on admission and the need and duration of MV. Other studies also supported our findings. Honarmand *et al*. studied the Infection Probability Score (IPS) and SOFA scoring systems for predicting MV requirement. He reported that the accuracy of the SOFA score is significantly better than that of IPS for the prediction of MV. Ferreira *et al*. also suggested that a sequential record of the SOFA scores may yield greater accuracy.[19] In our study, patients who had more SOFA scores not only needed prolonged MV, but also a longer duration of stay in the ICU.

We found two best cut-off points for the SOFA score at admission and when receiving MV, for predicting longer MV. These are 3.5 and 4.5, respectively.

With regard to the site of trauma and prolonged MV in our study, the patients who were injured at more than one site were slated to be receive prolonged MV. We did not find any study that assessed the injured organ, the need for MV or duration of MV, but about the relation between organ damage and hypokalemia, Alen reported that admission hypokalemia was more frequent in those patients with head injuries when compared to those without head injuries.

The relationship of acute traumatic hypokalemia and traumatic brain injury (TBI) was described by Pomeranz *et al*. when they compared 46 consecutive patients with severe, isolated head trauma (GCS < 8) with 16 patients with multiple traumas, without head injuries.[10] The brain-injured patients had significantly lower admission serum potassium levels.

Our study presents some limitations that must be acknowledged. First, for a full result and review the relation between initial hypokalemia and the need and duration of MV we must monitor the potassium level of patients on admission to hospital and then every hour till we compensate it. Second, it is better to assess all critical trauma patients, not only those who require MV, but also those who do not require MV. Third, the use of SOFA and GCS for neurological evaluation[20] - this computation can be very difficult or impossible in sedated patients and is very prone to errors in data collection.

CONCLUSION

We concluded that the development of hypokalemia in critically ill patients during ICU stay is associated with a high incidence of a need for MV and finally prolonged mechanical ventilation.

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