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Plasma Ionic Levels in Patients with Septic Shock Before and After Treatment with Different Antioxidants

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Abstract

Background: Septic shock is the most severe form of sepsis, and electrolyte levels have been associated with septic shock in intensive care units, although it has been underdiagnosed

Objective: This study aimed to evaluate plasma ionic levels in patients with septic shock before and after treatment with different antioxidants.

Methods: Plasma ionic levels were measured in 129 healthy control patients, 14 with septic shock without treatment, and 51 under treatment with four different antioxidant therapies.

Results: We found essential differences when comparing the plasma ionic levels of K^+, Ca^{2+} y Mg^{2+} between the control groups versus both groups with sepsis at the time of hospital admission. In patients with septic shock, there is a decrease in the serum levels of ionized Na^+, K^+, Cl^- and Ca^{2+} and Mg^{2+} Antioxidant treatment as an adjunct to the standard management of patients with septic shock increases the electrolyte deficit.

Conclusions: The correction of the magnesium deficit also increases serum calcium and potassium levels. Managing antioxidant therapy in patients with septic shock within the first hours of admission can help improve their ionic levels of Ca^{2+} y Mg^{2+}, mainly in patients with lung damage.

Keywords: Ionized levels; Septic shock; Antioxidants; Ionized magnesium; Ionized calcium

Introduction

Septic shock is the most severe form of sepsis and occurs when it is associated with hypotension and tissue hypo-perfusion. Timely intervention is vital, and identifying risk factors for sepsis on admission can be helpful for patient triage, individualized treatment, and medical decision-making [1].

Serum ion testing is part of the routine comprehensive biochemistry panel, and electrolyte levels associated with septic shock in intensive care units have been underdiagnosed. There are reports [2] that correlate serum magnesium levels (Mg^{2+}) with the admission of patients to the Intensive Care Unit (ICU), the duration of their stay in the ICU, the requirement and duration of mechanical ventilator support, and the outcome of the patient (discharge/death) [3].

The incidence of hypomagnesemia is reported in 2% of the general population, between 10-20% of hospitalized patients, and 50-60% of patients in an intensive care unit [4,5].

The serum magnesium increases the risk of acute respiratory failure, acute kidney injury, and septic shock. Therefore, abnormalities in magnesium levels may affect the prognosis of septic shock.

Another electrolyte recognized as a factor in sepsis is calcium [6]. Calcium exists in three forms or fractions in plasma or serum: ionized (iCa, free calcium), only this fraction is physiologically active, chelated (bound to phosphate, bicarbonate, citrate), and bound to protein. Vitamin D deficiency, "relative" hypoparathyroidism, vitamin D resistance, and 1α hydroxylase deficiency are proposed mechanisms for hypocalcemia in critically ill patients [7]. Average ionic calcium concentrations are between 4.4 and 5.2 mg/dL (1.1-1.3 mmol/L) [8]. Studies carried out in animals demonstrated that interleukin 1β induces hypocalcemia in association with a decrease in Parathyroid Hormone (PTH) and an increase in the expression of Calcium-Sensing Receptors (CASR) in the kidneys and parathyroid [9-11].

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Therefore, the measurement of ionized calcium can be critical in determining the actual levels of calcium in an individual's serum. In this way, the recognition of serum electrolytes in patients of the Medical Intensive Care Unit (ICU) may be vital since it could be associated with the severity of the disease or with an increase in mortality and morbidity.

On the other hand, antioxidants have been defined as substances that delay or prevent oxidative when present at low concentrations compared to an oxidizable compound, so many exogenous antioxidants have been used.

Some reports indicate that supplementation with antioxidants helps oxygenation rates, with an increase in glutathione and a more significant immune response [12]. It leads to a reduction in hospital stays and intensive care units, in addition to a decrease in the rates of multi-organ dysfunction and the rate of morbidity and mortality. However, in this regard, more studies in this context are needed and, therefore, require more significant efforts to reinforce the benefits of antioxidant supplementation.

Based on the above, the purpose of this work was to assess the ionic levels of calcium and ionized magnesium, as well as sodium, potassium, and chlorine, in patients with septic shock in an intensive care unit before and after treatment with different antioxidants such as n-acetylcysteine, vitamin C, melatonin, and vitamin E.

Patients and Methods

A case-control clinical trial was carried out. We studied 65 patients > 18 years of age with septic shock in the last 24 hours, characterized by refractory hypotension and requirement for vasopressors, despite adequate fluid resuscitation (20 ml/kg of colloids or 40 ml/kg of crystalloids) to maintain blood pressure ≥ 65 mmHg, included administration with lactate >2 mmol/L. In addition, samples from 129 patients considered as controls were analyzed. Upon hospital admission, the Acute Physiology and Chronic Health Assessment (APACHE) II and SAPS II scores were determined, as well as the Sequential Organ Failure Assessment (SOFA) score and the MEXSOFA organ dysfunction score, for each of the sections (Neurological, respiratory, hemodynamic, hepatic, hematological). The MEXSOFA is a score validated in a Mexican cohort that uses the same sections of the SOFA score with two modifications: PaO2/FiO2 is changed to SpO2/FiO2 and the neurological evaluation is eliminated. A MEXSOFA ≤9 points during the first hours of admission to the unit have a mortality of 14.8%, while patients with a MEXSOFA ≥10 points have a mortality of 40%.

Ethical Approval

We obtained signed informed consent from each participant after thoroughly explaining the purpose and nature of all procedures used in the research study, following the provisions of the World Medical Association Declaration of Helsinki. The research was approved by the Ethics, Biosafety and Research Committees of the National Institute of Cardiology (Registration number: INCAR-DG-DI-ACEP-039-2021). The protocol was registered (TRIAL REGISTRATION: ClinicalTrials.gov Identifier: NCT 03557229). https://clinicaltrials.gov/ct2/show/NTC03557229?term=aISA+ALFREDO&draw=2&rank=1

Laboratory Analysis

Blood samples were taken from all subjects upon admission to the ICU in sterile tubes with EDTA, tubes with heparin, and tubes with a gel polymer for serum separation. The serum was immediately separated by centrifugation, and the serum electrolytes were determined. Kept the blood samples in the heparin-containing blood tubes on ice and analyzed for ionized Ca^{2+} and Mg^{2+} ionized levels using an electrolyte analyzer (Nova Biomedical, Waltham, Mass; USA). The Nova can analyze Na^{+}, K^{+}, Cl^{-} and Ca^{2+} y Mg^{2+} ionized. The results were expressed in mmol/L. In addition, we analyzed blood biometry, blood chemistry, liver function tests, c-reactive protein, procalcitonin, and venous and arterial blood gases for each study subject.

Randomization, Masking, and Drug Administration

Patients were randomized and masked into groups to start treatment in the first 24 hours after admission to the ICU and used five treatments, each in an independent group of 18 patients. Group 1 received Vitamin C (Vit C), Group 2 Vitamin E (Vit E), Group 3 N-acetyl Cysteine (NAC), Group 4 Melatonin (MT), and Group 5 control. The control group did not receive treatment since the treating physician disagreed with the patient receiving any antioxidants. All antioxidants were administered orally or through a nasogastric tube for five days in addition to the standard therapy. The random allocation sequence for administering the antioxidants was generated at the coordinating center using a computer-generated random program. Blinding was maintained by the investigational pharmacy at each institution. Researchers were also blinded from the study's onset until the outcomes analysis.

After each treatment, we performed the same blood and electrolyte tests.

The doses of antioxidants were chosen according to what has been reported in the literature [13-16]. All data entry was monitored at the coordinating center, with site visits for source data verification. Also, patients were equally distributed, and all patients were analyzed.

Groups:

1) For the N-acetyl cysteine group, two effervescent tablets of 600 mg of N-acetyl cysteine (1200 mg) were administered every 12 hours by oral route or naso-enteral tube for five days.

2) For the melatonin group, melatonin was administered in 5 mg prolonged-release capsules at night, at 50 mg (10 capsules) orally or by naso-enteral tube for five days.

3) For the vitamin C group, 1-gram vitamin C tablets were used, which were administered every 6 hours by oral route or naso-enteral tube for five days.

4) For the vitamin E group, vitamin E (d-alpha tocopheryl acetate) capsules of 1200 IU equivalent to 1200 mg were used, which were administered every 24 hours for five days.

5) Control groups. This group did not receive any antioxidant therapy.

Statistical Analysis

The SPSS 21 program was used for statistical analysis. The Student's t test was used to evaluate the differences between the mean values obtained between the groups. An ANOVA test was used to compare plasma ion concentrations. Pearson's chi2 test or Fisher's exact test was used for standard data. The Shapiro-Wilk test was used to determine whether the distributions of the variables were normal. Numerical data are shown

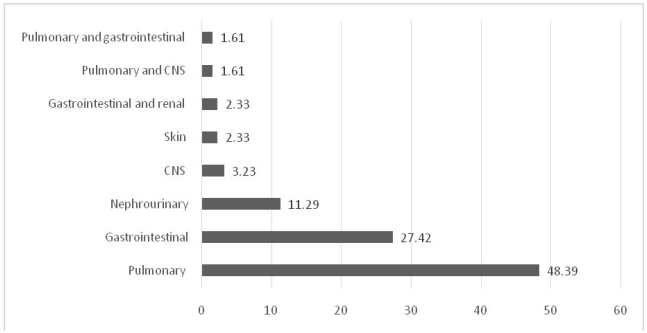
as mean±SD and nominal data are reported as percentages; a logarithmic transformation was applied for ionized Mg^{2+} levels due to the non-normal distribution of the variables. The value of $p<0.05$ was considered statistically significant. The STROBE case-control reporting guidelines [17] were used.

Results

One hundred ninety-four subjects were studied: 129 healthy control patients, 14 patients with septic shock without treatment and 51 on treatment with antioxidants. The mean age of healthy patients was 35.4±12.04, which showed a statistically significant difference compared to patients with sepsis without treatment, 73.0±10.49 (p=0.000) and with treatment, 64.16.±17.38 (p=0.000), these last two groups being older; There were no significant differences between the two groups with septic shock with and without treatment (p=0.096). Regarding gender and BMI, no statistically significant differences were found between the three study groups. When comparing our two groups with septic shock, we found significant differences in the APACHE II score (p=0.039) and in the assessment of the risk of malnutrition (p=0.020) (Table 1).

When comparing only our group of patients with septic shock with the different antioxidant treatments, we did not find significant differences in any parameter. It is worth mentioning that, at the time of hospital admission, the most frequent site of infection was the pulmonary system (48.3%), followed by the gastrointestinal system (17.3%) (Figure 1).

Figure 1: Site of infection of patients with sepsis (%).



CNS: Central Nervous System.

Subsequently, were analyzed the ionic levels in our 3 study groups: controls, patients with sepsis under treatment, and patients without treatment (Table 2). According to the results, we found significant differences when comparing the plasma ionic levels of K^+, Ca^{2+}, and Mg^{2+} between the control group versus both groups with sepsis at the time of hospital admission. At the end of treatment with the different antioxidant drugs, we observed significant differences in all plasma ion values of patients with sepsis compared to controls, except for chlorine levels.

When performing the analysis comparing only the septic shock groups, with and without antioxidant treatment, we did not find statistically significant differences in the plasma levels of the study ions at the beginning and end of the treatment. In the same way, we compared ionic levels between the groups under treatment with the different antioxidants and between the patients with each one of the antioxidants before and after it (Table 3); however, we did not find a significant difference either.

Despite not finding significant differences in our patients with sepsis and treatment, we observed a physiological response. In patients treated with vitamin C, an increase in Na^+, K^+, and Mg^{2+} levels were observed, as well as a decrease in the post-treatment levels of Cl-. When comparing these values with the control group, we found a statistically significant difference in all the above ions ($p\leq0.001$). In patients post-treated with vitamin E, we observed increased Na^+, Cl^-, Ca^{2+}, and Mg^{2+} levels. When compared with our control group, ionized calcium presented a significant difference before treatment (p=0.013), but after treatment, this difference was lost (p=0.378); in the case of chlorine, there were no differences versus control before and after treatment. The most crucial parameter for patients treated with n-acetylcysteine was ionized calcium, with an increase after treatment. Compared to control patients, there was a significant difference before treatment (p=0.008), but they lost it after treatment (p=0.129). In the case of treatment with melatonin, the most important differences were observed in chlorine and magnesium since both decreased after treatment. However, only magnesium significantly differed from the con-

Table 1: General characteristics of the study subjects and divided according to treatment.

	Healthy control Subjects (n=129)	Untreated Sepsis patients (n=14)	Sepsis patients with treatment (n=51)	P	Sepsis patients divided according to treatment (n=51)				
					Vitamin C (n=14)	Vitamin E (n=13)	n-acetylcysteine (n=11)	Melatonin (n=13)	P
Women (%)	46.2	50	49.23	0.000	30.8	64.3	54.5	46.3	0.949
Age (years)	35.4±12.04	73.0±10.49	64.16±17.38	0.937	63.14±21.33	65.66±16.02	62.36±20.25	65.15±12.65	0.653
Weight (kg)	74.04±13.56	70.57±15.26	70.06±18.81	0.251	67.0±20.29	75.92±20.89	67.09±19.52	70.0±14.68	0.342
Size (mts)	1.59±27.9	1.64±0.09	1.65±0.100	0.000	1.62±0.09	1.67±0.11	1.67±0.13	1.67±0.78	0.000
BMI(kg/m2)	28.96±16.4	25.90±4.56	25.73±6.81	0.331	25.18±7.09	26.87±6.24	23.44±4.35	27.13±8.93	0.741
SAPS II	----	44.14±17.85	36.61±13.79	0.311	36.64±12.79	45.53±15.72	36.45±11.74	39.53±13.93	0.384
APACHE II	----	18.07±6.45	15.84±5.85	0.221	14.14±5.66	19.46±5.59	13.09±5.00	16.38±5.56	0.039
SOFA	----	9.07±3.09	7.75±2.58	0.108	7.64±2.34	8.76±3.13	6.81±3.12	7.61±1.38	0.221
NUTRIT	----	5.21±1.25	3.80±1.70	0.005	3.57±2.02	4.46±1.76	3.18±1.40	3.92±1.44	0.020
DM (%)	----	21.4	19.6	0.882	14.3	15.4	9.1	38.5	0.415
HT (%)	----	42.9	37.9	0.708	21.4	46.2	45.5	38.5	0.685
COPD (%)	----	-----	9.8	0.229	7.1	23.1	----	7.7	0.175
AMI v (%)	----	7.1	3.9	0.617	----	----	9.1	7.7	0.701

BMI: Body Mass Index; DM: Diabetes Mellitus; HT: Hypertension; COPD: Chronic Obstructive Pulmonary Disease; AMI: Acute Myocardial Infarction

Table 2: Ionic levels at hospital admission and discharge.

	Hospital Admission						Hospital Discharge				
	Control	No Treatment	Treatment	P1	P2	P3	No Treatment	Treatment	P1	p2	p3
Levels of Na^+	139.21±5.23	140.03±11.18	134.10±11.68	0.792	0.096	0.004	140.74±9.83	135.63±7.481	0.000	0.088	0.001
Levels of K^+	6.48±3.23	4.25±0.869	4.16±0.554	0.000	0.706	0.000	4.21±0.572	4.15±0.555	0.001	0.718	0.000
Levels of Cl^-	108.27±8.90	111.06±8.085	106.71±8.044	0.24	0.089	0.257	110.21±7.117	105.39±14.41	0.202	0.089	0.222
Levels of Ca^{2+}	1.16±0.98	1.09±0.060	1.10±0.097	0.001	0.486	0.001	1.12±0.086	1.12±0.087	0.008	0.948	0.008
Levels of Mg^{2+}	0.68±0.043	0.63±0.115	0.63±0.141	0.003	0.915	0.043	0.66±0.098	0.65±0.119	0.001	0.588	0.001

P1: Control vs sepsis without treatment
P2: Sepsis without treatment vs sepsis with treatment
P3: Control vs sepsis with treatment

Table 3: Plasma ion levels at admission (initial) and after 5 days of treatment (final).

	Untreated sepsis patients	Patients with sepsis and with treatment				
	(n=14)	Vitamin C (n=14)	Vitamin E (n=13)	n-acetylcisteine n=11)	Melatonin (n=13)	p
at admission Na^+	140.03±11.18	135.26±10.11	131.98±15.58	134.41±6.54	134.70±13.08	0.504
after the treatment Na^+	140.84±9.83	137.48±8.54	135.57±6.98	135.55±6.37	133.75±7.97	0.232
p	0.828	0.269	0.498	0.591	0.759	
at admission K^+	4.25±0.86	4.23±0.61	4.20±0.61	4.08±0.62	4.12±0.51	0.956
after the treatment K^+	4.21±0.57	4.31±0.30	4.16±0.66	4.01±0.70	4.09±0.52	0.700
p	0.890	0.618	0.755	0.725	0.898	
at admission Cl^-	111.06±8.08	108.34±7.24	104.27±9.63	105.93±4.26	108.05±8.88	0.264
after the treatment Cl^-	110.21±7.11	101.84±26.65	107.26±4.97	105.85±4.62	106.94±5.65	0.588
p	0.712	0.314	0.406	0.953	0.668	
at admission Ca^{2+}	1.09±0.06	1.12±0.82	1.08±0.13	1.08±0.06	1.12±0.10	0.622
after the treatment Ca^{2+}	1.12±0.08	1.11±0.11	1.13±0.08	1.12±0.08	1.12±0.05	0.965
p	0.224	0.620	0.148	0.162	0.976	
at admission Mg^{2+}	0.63±0.11	0.60±0.19	0.63±0.11	0.61±0.09	0.66±0.13	0.868
after the treatment Mg^{2+}	0.66±0.09	0.65±0.12	0.67±0.11	0.62±0.13	0.63±0.10	0.876
p	0.221	0.378	0.330	0.804	0.487	

Table 4: Correlation between ionic levels according to the site of infection between cases vs controls (P value).

	Na^+ at admission	Na^+ after the treatment	K^+ at admission	K^+ after the treatment	Cl^- at admission	Cl^- after the treatment	Ca^{2+} at admission	Ca^{2+} after the treatment	Mg^{2+} at admission	Mg^{2+} after the treatment
Pulmonary (n=26)	0.616	0.266	0.038	0.457	0.657	0.443	0.845	0.257	0.039	0.000
Pulmonary + CNS (n=1)	0.315	0.933	0.932	0.780	0.114	0.369	0.431	0.788	0.204	0.391
Gastrointestinal (n=17)	0.461	0.517	0.280	0.936	0.835	0.090	0.916	0.732	0.432	0.004
Nephrourinary (n=7)	0.530	0.671	0.523	0.265	0.241	0.881	0.109	0.047	0.183	0.793
Pulmonary + Gastro (n=1)	0.927	0.899	0.054	0.350	0.316	0.840	0.845	0.788	0.359	0.031
SNC (n=2)	0.447	0.939	0.425	0.460	0.407	0.231	0.664	0.919	0.744	0.872
Skin + Soft tissue (n= 2)	0.705	0.847	0.357	0.069	0.740	0.922	0.790	0.983	0.816	0.277
Pulm + CNS+ Gastro (n=2)	0.240	0.888	0.150	0.893	0.449	0.555	0.731	0.430	0.028	0.112

trol group before and after treatment. Subsequently, we correlated the ionic levels before and after the treatment according to the site of infection concerning the control subjects (Table 4). For patients with a lung infection, there was a significant difference in the pretreatment K^+ (p=0.038) and Mg^{2+} pretreatment (p=0.039) and post-treatment (p<0.001) values. In patients with urinary tract infections, was found an increase in calcium levels after treatment (p=0.047). There was a significant difference in pretreatment magnesium levels in patients with pulmonary + CNS + gastrointestinal infection (p=0.028). Finally, the ionic levels were analyzed according to the SOFA score, categorized as mild, moderate, and severe in pretreatment and post-treatment (Table 5). We found a progressive increase in ionic levels from mild to severe of Na^+, K^+, and Cl^-, both pretreatment and post-treatment, and a decrease in ionized calcium and magnesium before treatment. After treatment, we found a significant increase in chlorine levels (p=0.008) and ionized magnesium (p=0.001) in patients with severe SOFA scores.

Table 5: Ionic levels according to the SOFA score.

	Mild	Moderate	Severe	P
Na^+ Pretreatment	134.70±7.05	133.66±11.36	137.36±12.74	0.472
Na^+ Post treatment	140.92±9.26	135.55±9.33	176.10±20.68	0.520
K^+ Pretreatment	3.64±0.42	4.21±0.51	4.24±0.73	0.129
K^+ Post treatment	3.99±0.47	4.13±0.57	4.23±0.55	0.615
Cl^- Pretreatment	104.78±0.03	107.34±0.08	108.47±0.10	0.628
Cl^- Post treatment	89.04±4.36	107.94±6.75	107.81±5.02	0.008
Ca^{2+} Pretreatment	1.12±0.03	1.09±0.08	1.10±0.10	0.796
Ca^{2+} Post treatment	1.12±0.02	1.11±0.09	1.13±0.08	0.695
Mg^{2+} Pretreatment	0.64±0.14	0.63±0.01	0.62±0.12	0.974
Mg^{2+} Post treatment	0.53±0.06	0.62±0.09	0.70±0.12	0.001

Discussion

This work analyzes plasma ionic levels in patients with septic shock before and after treatment with different antioxidants (n-acetyl cysteine, melatonin, vitamin C, and vitamin E). After treatment with four types of antioxidants, we found a change in ionic levels, mainly in ionized magnesium.

Different studies have tried to establish the electrolyte alterations associated with septic shock, particularly in the length of stay in an ICU. However, the studies still need to be more extensive.

There are reports where Mg^{2+} deficiency and other electrolyte abnormalities coexist in up to 40% of patients [13]. Various factors can contribute to hypomagnesemia in patients with septic shock, such as decreased absorption caused by impaired gastrointestinal activity, malnutrition, diabetes mellitus, hypokalemia and hypocalcemia [18], hyperaldosteronism, renal tubular disorder, use of drugs such as amphotericin, cisplatin, cyclosporine, diuretics, proton pump inhibitors, and aminoglycoside antibiotics of which some are used during the management of septic shock. Before septic shock, others may be applied due to cancer or other conditions.

Thus, several reports indicate that hypomagnesemia is associated with a higher mortality rate [19-21]. Our study found low magnesium levels compared to control subjects in both groups of patients with sepsis. After treatment with different antioxidants, there was an increase in the serum levels of ionized magnesium. However, these values did not reach the levels of the control subjects. Hypomagnesemia can lead to neurological disorders such as diffuse muscle spasms, lethargy, ataxia, nystagmus, twitching, tetany, or seizures. At the muscular level, there may be a weakness of the respiratory muscles, hypoventilation, dysphagia, and dysphonia.

In contrast, the P-R and Q-T segments may be prolonged at the cardiovascular level, atrial and ventricular arrhythmias, and congestive heart failure. On the other hand, we also observed alterations in the levels of other serum electrolytes such as sodium, potassium, and calcium. Some reports indicate that the decrease in magnesium levels may be accompanied by a reduction in the levels of K^+ (hypokalemia) and Ca^{2+} (hypocalcemia) [22,23]. It could be because part of calcium metabolism is controlled by the activity of Parathyroid Hormone (PTH), which seems to be the site of action of magnesium for modulation of calcium balance, since serum magnesium deficiency inhibits the action of PTH in bone, directly preventing calcium release [24,25]; furthermore, PTH secretion is prevented, since magnesium is a cofactor of the adenylate cyclase enzyme in parathyroid tissue. It has been observed that when hypokalemia occurs, there is the presence of hypomagnesemia in 40%; Likewise, when hypocalcemia is present, hypomagnesemia is present in 22% [22,25,26]. On the other hand, when there is a decrease in potassium levels (hypokalemia), it is known that Mg^{2+} participates in the flow of Na^+ and K^+ in the cell membrane since it acts as a cofactor in the Na-K ATPase, generating an electrochemical gradient and therefore an alteration in the membrane potential that can cause changes in excitability or irritability at the neuromuscular level. Our results show an apparent decrease in the serum levels of Na^+, K^+, and Ca^{2+} concerning the control subjects. In the different treatments with antioxidants, we found an increase in the levels of these electrolytes despite not finding a statistically significant increase. These differences were independent of the type of treatment given. It may be due to different reasons, including the number of patients with septic shock, the time between the initial and final sampling, and the time of treatment with antioxidants. However, despite the preceding, a physiologically significant change was observed in the serum levels of the studied ions. Therefore, correcting magnesium levels to maintain adequate calcium and potassium levels in patients with septic shock is essential.

Finally, when analyzing the electrolytes studied before and after the treatment with antioxidants, according to the SOFA score, a meaningful change was observed mainly in the subjects with severe scores in Na^+ and Mg^{2+} levels. It indicates that the greater the severity of the damage, the more antioxidant therapy, regardless of what it is, causes an improvement in the patient, mainly in the levels of magnesium, which, as mentioned above, is an ion that participates in the regulation of other electrolytes and that can help improve the patient's condition.

This study proposes that in patients admitted with septic shock, medical management should consider antioxidant therapy, specific electrolyte monitoring, and standard therapy. The importance of determining magnesium in the basal state allows for defining the deficit, which leads to septic shock. Determining ionized magnesium could be a helpful biomarker during the study and follow-up of extremely severe patients.

One limitation of our study was the number of participants. Also, the time between the first and the last sample was only five days. However, as it is an intensive care unit, obtaining informed consent from the patient is difficult. In addition to the medical urgency of the treatment, it is difficult to recruit them.

Conclusion

In an intensive care unit, serum levels of Na^+, K^+, Cl^- and ionized Ca^{2+} and Mg^{2+} were analyzed in control and septic shock patients. In patients with septic shock, there is a decrease in all serum ionized levels. Antioxidant treatment as an adjunct to standard treatment of patients with septic shock increases electrolyte deficit. Correction of magnesium deficiency also leads to an increase in serum calcium and potassium levels. This preliminary result allows us to propose multicenter clinical trials with more cases to confirm the importance of monitoring and monitoring these ions in the comprehensive therapy of septic shock.

Author Statements

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Competing of Interest

The authors declare no conflict of interest.

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