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Research Article

Evaluation Of Serum Magnesium Level In Critically Ill Patient And Predict Their Clinical Outcome A Prospective Observational Study

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ABSTRACT:

Background: Magnesium is a crucial electrolyte involved in various physiological processes, and its deficiency is associated with poor outcomes in critically ill patients. This study aims to evaluate the relationship between serum magnesium levels and clinical outcomes, including the need for ventilator support, length of stay in the intensive care unit (ICU), and mortality risk.

Methods: This single-center, prospective observational study was conducted over six months in the ICU of Vivekanandha Medical Care Hospital. A total of 66 patients aged over 18, excluding those with renal impairment, postoperative status, magnesium supplementation, or poisoning, were included. Serum magnesium levels were measured, and the APACHE IV scoring system was utilized to assess severity and predict mortality. Data were analyzed using SPSS Version 22, with a significance level set at $p < 0.05$.

Results: The average age of participants was 69.12 ± 13.59 years, with a majority having normal serum magnesium levels (1.90 ± 0.48 mg/dL). Clinical parameters indicated severe illness, with a mean APACHE IV score of 103.62 ± 48.31. Despite these findings, serum magnesium levels did not significantly correlate with ventilator support duration, mortality rates, or length of ICU stay. Statistical analyses revealed no significant impact of serum magnesium on these outcomes ($p > 0.05$).

Conclusion: The study demonstrates that while serum magnesium plays a role in critical physiological functions, it did not significantly influence clinical outcomes in this cohort of critically ill patients. These findings highlight the complexity of magnesium's role in critical care settings and underscore the need for further research to explore its implications more comprehensively.

Key words: Magnesium deficiency, Critical care, Serum magnesium levels, APACHE IV, ICU outcomes, Mortality risk

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INTRODUCTION:

Magnesium is essential for numerous physiological processes. A chronic magnesium deficit and low intake of the mineral cause modifications in biochemical pathways that raise the risk of disease, especially chronic degenerative disorders.[1] Magnesium really serves as a signalling molecule, controls the

production, storage, and transport of adenosine triphosphate (ATP), and maintains the levels of intracellular calcium and potassium.[2] Almost all of the main biochemical and metabolic reactions that take place within the cell depend on magnesium, including vital processes like glycolysis, oxidative phosphorylation, energy synthesis, storage, and transfer, and the synthesis of proteins and nucleic acids.[3] Magnesium abnormalities are prevalent in clinical practice and can present clinically as dysfunction of the heart, muscles, or other organs.[4] While serum magnesium concentration assessment is not part of standard laboratory testing procedures for chemistry, anomalies arising from low serum levels and body reserves of magnesium can have potentially fatal and life-threatening repercussions.[5] In adults, the normal range for serum magnesium content is 1.7–2.4 mg/dL (0.7–1.0 mmol/L). Serum magnesium levels below 1.7 mg per decilitre are referred to as hypomagnesaemia.10.40 Most people who have borderline hypomagnesaemia don't have any symptoms. There is a suggestion to increase the low cutoff criterion for hypomagnesaemia since patients may have persistent latent magnesium deficiency at blood magnesium levels over 1.5 mg/dL (0.6 mmol/l).[6] It is typical for up to 12% of hospitalised individuals to have hypomagnesaemia.[7] Clinical signs of hypomagnesaemia that may be treated quickly include neuropsychiatric disorders including apathy, delirium, and even coma, as well as neuromuscular hyperexcitability that can present as tremors, fasciculation, tetany, or convulsions. [8] There is evidence that hypomagnesaemia is a significant predictor of death in critically ill patients, and that individuals who have hypomagnesaemia at admission are more likely to die.[9] The study aimed to identify the relationship between serum magnesium levels and clinical outcomes, including the need for ventilator support, length of stay in the intensive care unit (ICU), and mortality risk.

METHODS:

The study was single center, prospective observational study, conducted in intensive care unit of more than 300 bedded multispecialty care teaching hospital Vivekanandha Medical Care Hospital, Elayampalayam. Study duration was of 6 months (march 2024-august 2024). The study was approved by institutional ethics committee.

Inclusion criteria

- Age above 18 years
- All the patients admitted in the critical care unit

Exclusion criteria

- Renal impairment patients
- Post operative patients
- Patient taking magnesium supplements
- Poison patients

Total of 66 Patients were screened and included in the study after getting patient's consent and the required data was collected in the specially designed data entry form. After obtaining the patient's consent, selecting study participants in accordance with the inclusion and exclusion criteria, data was gathered and entered into self designed data entry form. In addition to measuring the serum magnesium level, the APACHE IV scale was used to evaluate the length of stay, mortality risk, andother factors. Data were collected entered in Microsoft excel sheet and analysed using SPSS Version.22. The Correlation between serum magnesium levels and APACHE IV was assessed using Spearman's rho. P value less than 0.05 was considered as statistically significant.

RESULTS:

Magnesium is a critical electrolyte involved in various physiological processes, including neuromuscular functions, enzyme activity, and cardiovascular health (Gonuguntla *et al*. 2023). Abnormal magnesium levels (hypomagnesemia or hypermagnesemia) are often linked to poor outcomes in intensive care settings. This study aims to examine the level of serum magnesium to predict clinical outcomes in critically ill patients.

AGE AND OTHER CLINICAL PARAMETERS OF CRITICALLY ILL PATIENTS

Table 1 presents the summary of the age, clinical parameters, and hospital- related aspects of critically ill patients. It was found that the average age of the patients was found to be 69.12 ± 13.59 years, implying mostly an older population even though the age of patients ranged between 28 to 95 years. Within the clinical parameters, Acute Physiology and Chronic Health Evaluation (APACHE) IV, magnesium (Mg), heart rate, respiratory rate, mean arterial pressure (MAP), Serum Potassium, Serum Creatinine, Acute Physiology Score (APS), Partial Pressure of Oxygen (PaO_2), pH level, Serum Sodium, Glasgow Coma Scale (GCS), total White Blood Cell count, and body temperature of these patients were obtained. A comparison with the illness-free individuals, the average APACHE IV score of these patients revealed a much higher score of more than 100 (mean = 103.62 ± 48.31), implying a severe illness with a high likelihood of mortality risk in these patients. On the contrary, the average level of serum magnesium (mean = 1.90 ± 0.48 mg/dL) in these patients was found to be within the normal range (1.7 to 2.2 mg/dL). Similarly, the average heart rate of these patients (mean = 90.64 ± 20.36) was also found to be within the normal range, varying from 54 beats to 160 beats per minute. The average respiratory rate in these patients was observed to be 27.03 ± 7.05 breaths per minute ranging from a minimum of 16 to a maximum of 45, indicating a higher rate of respiration than usual. The average MAP of these critically ill patients was found to be 99.64 ± 23.60 mm Hg, falling well within the normal range, however, ranging from a minimum of 58 to a maximum of 154 mm Hg. The serum potassium levels in these patients ranged between 2.4 to 36.0 mmol/L with an average of 4.96 ± 5.61, implying that the majority of them were well within the normal range.

The serum creatinine levels in these patients ranged between 0.40 to 16.60 mg/dL with an average of 3.01± 3.36, indicating a higher level of serum creatinine compared to the normal range. The APS in these patients ranged between 18 to 125 with an average of 70.92 ± 28.70, indicating a more severe physiologic derangement in these patients. The PaO_2 levels in

these patients ranged between 41 to 540 mm Hg with an average of 98.94 ± 66.93, indicating the average to be within the normal range.The pH levels in these patients ranged between 6.7 to 7.5 an average of 7.25 ± 0.22, indicating the average to be higher than the normal range. The serum sodium levels in these patients ranged between 110 to 157 mmol/L with an average of 133.50 ± 11.13, indicating the average to be well within the normal range. The GCS in these patients ranged between 6 to 15 with an average of 12.94 ± 3.05, indicating moderate impairment in most of them. The total WBC count levels in these patients ranged between 6380 to 29250 with an average of 13329.71 ± 5005.00, indicating the average to be above the normal range. The body temperature in these patients ranged between 35 to 40 with an average of 37.27 ± 1.07, indicating the average also to be within thenormal range, indicating moderate impairment with respect to hospital-related parameters, it was observed that the length of stay forthe patients in the hospital varied from two to 27 days, with an average stay of 7.88 ± 5.09 days, while the expected length of stay ranged from one to 35 days, with anaverage of 6.20 ± 4.12.

Table 1: Age, clinical, and hospital-related parameters of critically ill patients

Parameter	Minimum	Maximum	Mean	SE
Demographics				
Age (years)	28	95	69.12	13.59
Clinical				
APACHE IV	35	205	103.62	48.31
Mg	1.00	2.90	1.90	0.48
Heart rate	54	160	90.64	20.36
Respiratory rate	16	45	27.03	7.05
MAP	58	154	99.64	23.60
Serum Potassium	2.40	36.00	4.96	5.61
Serum Creatinine	0.40	16.60	3.01	3.36
Acute Physiology Score	18	125	70.92	28.70
Partial Pressure of Oxygen	41	540	98.94	66.93
pH level	6.7	7.5	7.25	0.22
Serum Sodium	110	157	133.50	11.13
Glasgow Coma Scale	6	15	12.94	3.05
Total WBC count	6380	29250	13329.71	5005.00
Body temperature	35	40	37.27	1.07
Hospital related				
Length of stay (days)	2	27	7.88	5.09
Expected length of stay	1	35	6.20	4.12

GENDER OF THE CRITICALLY ILL PATIENTS

Table 2 reveals the gender distribution of the critically ill patients participating in the study. It was observed that the majority of them were men (59.1%), while the rest 40.9% of the patients were women.

Table 2:Gender of the critically ill patients

Gender	Frequency	Percent
Male	39	59.1
Female	27	40.9
Total	66	100

OUTCOME OF THE CRITICALLY ILL PATIENTS

Table 3 presents a summary of the various outcomes of the critically ill patients. It was observed that the majority of them had comorbidities (80.3%) not developing any chronic issues later (78.8%). More than 62% of them were on ventilation and a mortality of 23% was observed and only 19% of them fully recovered.

Table 3:Outcome in critically ill patients

Outcome	Absent		Present	
	Frequency	Percent	Frequency	Percent
Comorbidity	13	19.7	53	80.3
Chronic disorders	52	78.8	14	21.2
On ventilation	25	37.9	41	62.1
Mortality	43	65.2	23	34.8

DIAGNOSIS OF THE CRITICALLY ILL PATIENTS

Table 4 provides the distribution of diagnoses of critically ill patients, with a majority (71.2%) being diagnosed for general medicine and another 27.3% suffering from cardiac issues.

Table 4:Diagnosis of critically ill patients

Diagnosis	Frequency	Percent
Cardio	18	27.3
CVD	1	1.5
Gm	47	71.2

TEST OF NORMALITY

To decide the appropriate statistical tests, the normality of the data was assessed using the two commonly used normality tests, Kolmogorov-Smirnov (KS) and Shapiro-Wilk (SW), considering the rule of thumb that both the statistical tests need to be used when the sample size exceeds N=50. Table 5 represents the outcomeof the normality tests conducted on our study variables. A comparison of the observed and normal cumulative frequencies of N=66 responses is given as the test statistic, D, representing the maximum absolute difference between the curves. Significant values of KS and SW tests less than 0.05 indicated a non-normal data distribution. Since the data was not normal as seen in Table 5, non-parametric tests were adopted for further analysis.

Table 5:Test of normality

Variable	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic (D)	df	Sig.	Statistic (D)	df	Sig.
Age	0.114	65	0.036	0.949	65	0.010
APACHE	0.153	65	0.001	0.904	65	0.000
Mg	0.117	65	0.028	0.965	65	0.063
Heart rate	0.179	65	0.000	0.891	65	0.000
Respiratory rate	0.159	65	0.000	0.943	65	0.005
MAP	0.159	65	0.000	0.950	65	0.011
Serum Potassium	0.407	65	0.000	0.301	65	0.000
Serum Creatinine	0.280	65	0.000	0.710	65	0.000
APS	0.116	65	0.029	0.953	65	0.015
PaO_2	0.280	65	0.000	0.546	65	0.000
pH level	0.343	65	0.000	0.802	65	0.000
Serum Sodium	0.183	65	0.000	0.910	65	0.000
GCS	0.361	65	0.000	0.669	65	0.000
Total WBC count	0.132	65	0.007	0.900	65	0.000
Body temperature	0.376	65	0.000	0.792	65	0.000
Length of stay	0.170	65	0.000	0.859	65	0.000

IMPACT OF SERUM MAGNESIUM LEVELS ON VENTILATOR SUPPORTDURATION

A binary logistic regression was conducted to examine the impact of serum magnesium on the duration of patients on ventilator support (Table 6). The logistic regression model was found to be not statistically significant, $\chi^2(1) = 0.117$, $p = 0.732$, indicating that serum magnesium levels were similar between the critically ill patients.The model explained 0.2% (Cox and Snell R^2 and Nagelkerke R^2) of the variance in the duration of the critically ill patients on ventilator support. Table 7 presents the path coefficients for the effect of serum magnesium on ventilator support duration, where itwas observed that serum magnesium could not individually predict this effect ($p > 0.05$).

Table 6: Model summary for the impact of serum magnesium levels andventilator support duration

Chi-square	df	Sig.	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
0.117	1	0.732	87.461	0.002	0.002

Table 7: Path coefficients for the impact of serum magnesium levels andventilator support duration

Parameter	B	S.E.	Wald	df	Sig.	Exp(B)
Mg	0.184	0.539	0.117	1	0.733	1.202
Constant	0.146	1.049	0.019	1	0.889	1.158

IMPACT OF SERUM MAGNESIUM LEVELS AND MORTALITY OF PATIENTS

Similar to Section 1.8, a binary logistic regression was also conducted to examine the impact of serum magnesium on the mortality of patients as presented in Table 8. The logistic regression model was found to be statistically insignificant with $\chi^2(1) = 0.025$, $p = 0.876$, indicating that serum magnesium levels did not vary in critically ill patients who later died. The model explained 0.1% (Nagelkerke R^2) of thevariance in the mortality of critically ill patients. Table 9 presents the path coefficients for the effect of serum magnesium on rate of mortality, where it was observed that serum magnesium could also not individually predict this effect ($p > 0.05$).

Table 8: Model summary for impact of serums magnesium levels and Mortality

Omnibus Tests of Model Coefficients			Model Summary		
Chi-square	df	Sig.	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
0.025	1	0.876	85.314	0.000	0.001

Table 9: Path coefficients for the impact of serums magnesium levels and Mortality

Parameter	B	S.E.	Wald	df	Sig.	Exp(B)
Mg	-0.086	0.547	0.025	1	0.876	0.918
Constant	-0.463	1.068	0.188	1	0.665	0.629

IMPACT OF SERUM MAGNESIUM LEVELS ON THE LENGTH OF STAY OFCRITICALLY ILL PATIENTS

A linear regression was conducted to investigate the effect of serum magnesium on the length of stay of critically ill patients. Table 10 and Table 11 presents the model summary and path coefficients of the relationship. From the tables, it can be observed that the regression model was insignificant, $F(1, 64) = 0.129$, $p > 0.05$), explaining only 0.2% of the variance in the length of stay of these patients ($R^2 = 0.002$). Thus, it can be implied that serum magnesium had no significant impact on the length of stay of the patients.

Table 10:Model summary for the impact of serum magnesium levels and length of stay

R	R Square	Adjusted R Square	Std. Error ofthe Estimate	Change Statistics		df1	df2	Sig. F Change
				R Square Change	F Change			
0.045	0.002	-0.014	5.126	0.002	0.129	1	64	0.721

Table 11:Path coefficients for impact of serum magnesium levels and length of stay

Parameter	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	SE	Beta		
(Constant)	8.790	2.613		3.363	0.001
Mg	-0.480	1.335	-0.045	-0.359	0.721

CORRELATION BETWEEN SERUM MAGNESIUM LEVELS AND APACHE IV

Since the data is not normally distributed, Spearman's correlation was used. Table 12 presents the level of correlation between serum magnesium and APACHE IV scores. It was observed that there is a 6.3% correlation between the two variables.

Table 12 : Correlation between serum magnesium levels and APACHE IV

Spearman's rho	APACHE	Mg
APACHE	1.000	
Mg	0.063	1.000

DISCUSSION:

The role of serum magnesium has always been under scrutiny as it is known to play a crucial role in the physiological regulatory functions of critically ill patients are seen in these studies which were conducted by (Kongara *et al.*, 2020 ; Singh *et al*., 2020 ; Tan *et a*l., 2021). The impact of magnesium

disturbances, such as hypomagnesemia and hypermagnesemia, on the outcomes of these patients has been the subject of extensive research conducted and reported by (Escuela & García-jalón, 2005 ; Gonuguntla *et al*., 2023 ; Roopa *et al*., 2024). In this section, the results for this study obtained from analyzing 66 critically ill patients were compared with the previous extant of literature.

CLINICAL PARAMETERS OF CRITICALLY ILL PATIENTS

The clinical parameters revealed that among the critically ill patients, the majority of them were males and had higher levels of respiratory rate, serum creatinine, Acute Physiology Score (APS), Glasgow Coma Scale (GCS), pH, total white blood cell count, and APACHE IV score compared to the normal range, while the levels of serum Magnesium, heart rate, mean arterial pressure (MAP), Serum Potassium, Partial Pressure of Oxygen (PaO_2), pH level, Serum Sodium, and body temperature was well within the normal range. Our results for serum magnesium are similar to the Indian studies conducted by Singh *et al*. (2020) and Gonuguntla *et al.* (2023) on critically ill patients, where the majority of these critically ill patients also had normal levels of magnesium, even though some studies reported low levels of serum magnesium mostly in these kinds of patients are (Gupta *et al*., 2022 ; Kumari *et al.*, 2023).

IMPACT OF SERUM MAGNESIUM LEVELS ON VENTILATOR SUPPORT DURATION

Our results showed no statistically significant impact of serum magnesium on the ventilatory support duration of critically ill patients. These results are contradictory to various studies from India where hypomagnesemia or serum magnesium levels was significantly associated with the duration of ventilatory support and the duration of ICU stay which was reported by *(*Gupta *et al.*, 2022 *;* Laddhad *et al.*, 2023 *;* Roopa *et al*., 2024 ; Singh *et al*., 2020). However, there were no significant differences in the duration of ventilator support by the critically ill patients and their normal levels of magnesium was seen in the study which was conducted by (Laddhad *et al*., 2023). Moreover, the need for ventilatory support did not have any association with hypomagnesemia from the studies reported by (Kumari *et al.*, 2023 ; Singh *et al*., 2020).

IMPACT OF SERUM MAGNESIUM LEVELS AND MORTALITY OF PATIENTS

There was no significant influence of serum magnesium on the mortality of the patients from the present study. These findings are supported by linear regression analysis conducted by (Khan *et al.*, 2023). Contradictory to this, mortality was found to be associated with serum magnesium levels of patients of the study conducted by (Kumari *et al*., 2023 ; Laddhad *et al*., 2023). In fact, Gupta *et al.* (2022) study reported magnesium to be a predictor of mortality.

IMPACT OF SERUM MAGNESIUM LEVELS ON THE LENGTH OF STAY OF CRITICALLY ILL PATIENTS

As reported in the results section, serum magnesium was found to not impact the length of stay in the hospital for critically ill patients. None of the previous studies have examined this aspect before, therefore, this aspect could not be compared.

CORRELATION BETWEEN SERUM MAGNESIUM LEVELS AND APACHE IV SCORES

There was hardly any statistically significant correlation was observed between serum magnesium levels and the APACHE IV score of critically injured patients in this study. Similar to our results, Singh *et al.* (2020) study also observed that there was no significant correlation between serum magnesium and APACHE II. However, other studies reported a contradictory outcome where a statistically significant correlation was observed (Gonuguntla *et al.*, 2023 ; Kumari *et al.*, 2023 ; Roopa *et al.*, 2024) studies .Further, Gupta *et al.* (2022) study findings reported a significant negative correlation between APACHE II scores and serum magnesium levels. These conflicting findings emphasize the need for more such studies using APACHE IV scores.

CONCLUSION:

In conclusion, serum magnesium levels play a crucial role in the physiological regulatory functions of critically ill patients, with disturbances linked to poor outcomes in intensive care settings. The study, analyzing 66 critically ill patients, found that the majority were older, with normal magnesium levels despite elevated clinical parameters and Apache IV scores indicating severe illness. However, serum magnesium did not significantly impact ventilator support duration, mortality, or hospital length of stay, contrasting previous studies. Moreover, there was no significant correlation between serum magnesium levels and Apache IV scores. These results, similar to existing literature, highlight the complexity of magnesium's role in predicting clinical outcomes in critically ill patients and the need for further research to understand its implications comprehensively.

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