

How to Cite:

Maqbool, S., Kidwai, A. A., Sohail, S., Mehraj, S. K., Jhatial, H. A., Memon, S. A., Domki, M. H., & Memon, S. A. (2023). Co-Morbidities associated with hypomagnesemia and affecting in-hospital mortality in tertiary care hospital of Sindh Pakistan-2021. *International Journal of Health Sciences*, 7(S1), 2222–2231. <https://doi.org/10.53730/ijhs.v7nS1.14386>

Co-Morbidities associated with hypomagnesemia and affecting in-hospital mortality in tertiary care hospital of Sindh Pakistan-2021

Dr Sidra Maqbool

Registrar of Medicine, Abbasi Shaheed Hospital Karachi Sindh, Pakistan.
Email: sidra.maqbool@hotmail.com

Dr Aneela Altaf Kidwai

Professor of Medicine, Abbasi Shaheed Hospital Karachi Sindh, Pakistan.
Email: dr_aneelaaltaf@yahoo.com

Dr Sorath Sohail

Senior Registrar, Lyari Medical College Hospital Karachi, Sindh, Pakistan.
Email: ismail.sehar@yahoo.com

Dr Sandeep Kumar Mehraj

Deputy THO, Government of Sindh, Sindh, Pakistan
Corresponding author email: drsandeepguriro@gmail.com

Dr Hussain Ahmed Jhatiyal

National STOP Officer, Sindh, Pakistan.
Email: jhatyalhussain@gmail.com

Shoaib Ahmed Memon

Independent Researcher, Sindh, Pakistan
Email: Shoab130221@hotmail.com

Dr Mudassar Hussain Domki

Deputy Director, Director General Health Services, Government of Sindh, Sindh, Pakistan.
Email: mudassar.rauf18@gmail.com

Dr Sohail Ahmed Memon

Deputy Director, Health Services, Government of Sindh, Sindh, Pakistan.
Email: sohi_am@hotmail.com

Abstract---Background: Hypomagnesemia may cause severe and fatal complications if not timely diagnosed and properly treated, and associated with increased In-Hospital Mortality. Methods: A case-control study was conducted. The case definition was any patient of any age and sex having hypomagnesemia and admitted to ICU. The controls were taken in 1;2. We defined Hypomagnesemia with less than 1.46mg/dl level of magnesium and In-Hospitals mortality as the primary endpoint. Demographic, risk factor data were taken and analyzed using EPI INFO TM 7. The association was calculated using Odds Ratios and reported at 95% CI and P value less than 0.05. Results: Of 139 patients, 42 were cases. The average age was 53 years (14 to 85 Years $\pm$ 16 years). Males were 72 (49%) and 78 (66%) participants were from rural setup. Diabetes mellitus was found in 33 (78%) of cases and 44 (46%) in controls, hypertension in 36 (85%) of cases and 41 (42%) of controls, dyslipidemia in 20 (48%) of cases and 37 (38%) of controls, obesity in 26 (62%) of cases and 37 (38%) of control, and anaemia in 28 (67%) of cases and 41 (42%) of control. Hypertension (OR 8.1, 95% CI 3.1-21.2, P Value 0.00), Diabetes Mellitus (OR 4.4, 95% CI 1.9-10.2, P Value 0.00). Sofa Score 2 to 3 (OR 3.2, 95% CI 1.4-7.2, P Value 0.00), Anaemia (OR 2.7, 95% CI 1.2-5.8, P Value 0.00), and Obesity (OR 2.6, 95% CI 1.2-5.5, P Value 0.00) were all significantly associated with the hypomagnesemia. A total of 59 (42%) patients died, of which 35 (59%) had documented hypomagnesemia. In-Hospital Mortality was significantly associated with hypomagnesemia (OR 15, 95% CI 5.9-38.6, P Value 0.00). Conclusions: Hypomagnesemia is common in patient admitted in ICU. Hypertension, Diabetes Mellitus and Anaemia tend to increase the frequency of hypomagnesemia in patient who are severely ill and In-Hospital Mortality.

Keywords---Magnesium, Hypomagnesemia, Critical Illness, Intensive Care Unit and In-Hospital Mortality.

Introduction

Magnesium (Mg) is placed at the fourth position among the positively charged ion in the human body, and the second most abundant intracellular ion with a positive charge preceded by potassium. It plays an essential physiological role in many functions of the body¹. Magnesium also regulates enzymes controlling intracellular calcium, which ultimately affects smooth muscle vasoconstriction, important to the underlying pathophysiology of several critical illnesses². Several diseases and clinical conditions, also various medications such as antibiotics, antihypertensive agents, and proton pump inhibitors may lead to magnesium loss and hypomagnesemia³. Hypomagnesemia may have serious implications in critically ill patients as the low level of magnesium activates neuroendocrine pathways⁴, which in turn increases the hospital duration as the pathway starts the stress response in critical patients. It is well documented that critically ill patients are found to have an association between hypomagnesemia and an

increase in the need for mechanical ventilation and also days of mechanical ventilation⁵.

Mg level assessment is difficult because Mg is mostly intracellular and no simple method exists to measure total body Mg⁶. The practice of measuring magnesium in blood serum alone has been questioned because Mg is predominantly a cofactor in intracellular metabolic activities and over 99% of the whole body's Mg is intracellular. Instead, techniques for measuring total cellular Mg in erythrocytes (tMge) have been developed⁷.

However, intracellular ionized Mg concentration is physiologically much more relevant, and the question of whether ionized Mg should be measured in clinical practice has been raised. Different studies have shown that, depending on the population studied and the tMgs threshold value chosen, the incidence of hypomagnesemia ranges from 15% in critically ill COPD patients⁸ to 53% in postoperative ICU patients⁹. The high prevalence of hypomagnesemia, based on tMgs can probably be explained by Mg shift from extracellular to intracellular compartments, whereby iMg2+s concentration can remain unchanged, in contrast with tMgs. A study by K Okubo et al confirms that changes in magnesium level in a critically ill patient are not comparable by tMg measurements only¹⁰ but it needs iMg concentration which are very difficult to measure. This finding shows that iMg2+ measurement is preferred to tMgs measurement in clinical circumstances (like sepsis) where aberrant albumin and protein concentrations are anticipated. As a result, if tested directly, iMg2+ would be the best predictor of the actual magnesium level.

There are ample evidence that hypomagnesemia is directly related to in hospital mortality and longer ventilation support¹¹. Comorbid patients having more than two illnesses are at risk of bad outcomes. Patients who are admitted to ICU have high losses of Magnesium from Urinary and Gastrointestinal routes¹², therefore measuring magnesium properly in critically ill patients will reduce the mortality and ICU stay. In the Asian country, Bangladesh it was documented by Mamun GM et al. that magnesium levels were a well-established cause of in-hospital mortality in severely ill patients of diarrhoea¹³. As the genetics, way of life, and eating habits of the Pakistani people differ from those of the rest of the world, this study intends to ascertain the risk factors which lead to hypomagnesemia in order to establish the local perspective.

Therefore the current study is planned to know the risk factors which cause hypomagnesemia and to identify the effect on in-hospital mortality. Moreover, in light of the information obtained from this study, an effective management plan will be developed giving hypomagnesemia prime importance.

Methods

A case-control study was conducted from December 2020 to June 2021 at the Department of Medicine, Abbasi Shaheed Hospital, Karachi. All the admission to the respiratory ICU unit were included in the study and 42 cases were identified by using case definition for case selection that any patient of any age and sex having hypomagnesemia and admitted to ICU for > 3 hours with sepsis (SOFA

score ≥ 2) during 1 December 2020 to 30 June 2021. The controls were taken from the same hospital that did not have hypomagnesemia in the ratio of 1:2. Those cases which were having hypo or hyperthyroidism, pregnant women, history of blood transfusion and malabsorption, those who were on calcium or magnesium supplements, and patients having any comorbidities like stroke, chronic renal failure, chronic obstructive pulmonary disease, asthma, congestive heart failure, myocardial infarction, and chronic liver disease have been excluded. We defined Hypomagnesemia as a laboratory assessment of blood magnesium with less than 1.46mg/dl level of magnesium in blood¹⁴. And in hospitals mortality was defined as the primary end point¹⁵.

A brief history of demographic data (age, gender, and residence status) and ICU admission duration were taken. The blood samples were collected in a sterile manner and sent to the laboratory to determine the serum magnesium levels. Patients were labeled as having hypomagnesemia as per the operational definition. The data on demographic variables (age, financial income status, occupational status, height, weight, BMI, and duration of admission to ICU) and risk factor variables (diabetes mellitus type II, hypertension, dyslipidemia, obesity status, anemia status, and in-hospital mortality) were collected by using a structured questionnaire.

Data were analyzed using EPI INFO TM 7. Mean and standard deviation was calculated for continuous variables such as age, height, weight, BMI, serum magnesium level, and ICU admission duration. Frequency and percentages were calculated for categorical variables like gender, residence status, diabetes mellitus type II, hypertension, dyslipidemia, obesity status, anemia status, smoking status, financial income status, occupational status, hypomagnesemia and in-hospital mortality. The outcome variable was Hypomagnesemia and the dependent variable was diabetes mellitus type II, hypertension, dyslipidemia, obesity status, anemia status, hypomagnesemia, and in-hospital mortality. The association between the dependent and independent variable were calculated using Odds Ratios and reported at 95% CI and P value less than 0.05.

Results

A total of 139 patients were entered in the final analysis. Of which 42 were cases, meeting the case definition and two control were taken for each case (n=97). The average age in our study was 53 years (Range 14 to 85 Years) with a standard deviation of ± 16 years. As is shown in Table 1, Males were 72 (49%) and 57 (51%) were female. The areas-wise distribution showed 78 (66%) participants were from rural set up and 61 (34%) of participants were of urban residence. The duration of ICU admission showed that out of 139 patients, 118 (85%) were admitted for more than 6 hours in ICU and 21 (15%) were admitted to ICU for less than 6 hours. The mean BMI was 25 ± 5 kg/m², height was 64 ± 3.4 inches and weight was 66 ± 13 kg in our study.

Table 1 Socio-Demographic Characteristics of Respondent

<i>Socio-demographic Character of Participants</i>				
		<i>Cases (n=42)</i>		<i>Control (n=97)</i>
Gender	Male	Female	Male	Female
	28 (66%)	14 (34%)	54 (56%)	43 (44%)
Residence	Rural	Urban	Rural	Urban
	18 (42%)	24 (58%)	60 (61%)	37 (39%)
ICU Admission	More than 6 Hours	Less Than 6 Hours	More than 6 Hours	Less Than 6 Hours
	30 (72%)	12 (28%)	88 (90%)	9 (10%)
Age Group	10-50 Years	51-80 Years	10-50 Years	51-80 Years
	48 (34%)	91 (66%)	48 (34%)	91 (66%)

Likewise, Table 2 showed that comorbidities diabetes mellitus type II was found in 33 (78%) of cases and 44 (46%) in controls, hypertension in 36 (85%) of cases and 41 (42%) of controls, dyslipidaemia in 20 (48%) of cases and 37 (38%) of controls, obesity was found in 26 (62%) of cases and 37 (38%) of control, and anaemia was present in 28 (67%) of cases and 41 (42%) of control. SOFA Score of more than 3 was calculated in 31 (73%) of cases and 43 (44%) of controls whereas 16 (38%) of cases and 45 (46%) of controls were having SOFA Scores between 2 to 3.

Table 2 Co-Morbidities among the Respondents

Co-Morbidity	Cases (n=42)		Control (n=97)	
	Yes	No	Yes	No
Diabetes	33 (78%)	9 (22%)	44 (46%)	53 (54%)
Hypertension	36 (85%)	6 (15%)	41 (42%)	56 (58%)
Dyslipidemia	20 (48%)	22 (52%)	29 (30%)	68 (70%)
Obesity	26 (62%)	16 (38%)	37 (38%)	60 (62%)
Anemia	28 (67%)	14 (33%)	41 (42%)	56 (58%)
Sofa Score >3	31 (73%)	11 (27%)	43 (44%)	54 (56%)
Sofa Score between 2 to 3	16 (38%)	26 (62%)	45 (46%)	52 (54%)

Out of 139 total patients, 59 (42%) patient died. Among those who died 35 (59%) had been having documented hypomagnesemia whereas 24 (41%) had not been having hypomagnesemia. In Hospital Mortality was significantly associated with hypomagnesemia as the patients who had documented hypomagnesemia were 15 times likely to die as compared to the controls (OR 15, 95% CI 5.9-38.6, P Value 0.00) as is shown in table 3.

Table 3 In Hospital Mortality

Variable	Cases (n=42)		Control (n=97)		Odds Ratio	95% CI	P Value
	Yes	No	Yes	No			
In Hospital Mortality	35 (83%)	7 (17%)	24 (25%)	73 (75%)	15	5.9-38.6	0.00

Among comorbidities, Hypertension was found in 36 (85%) of cases as compared to control 41 (42%). The cases with hypertension were 8.1 times more likely to develop hypomagnesemia (95% CI 3.1-21.2, P Value 0.00). Diabetes Mellitus was the second most documented comorbidity which had been associated with the development of hypomagnesemia. It was found in 33 (78%) of cases versus 44 (46%) of control (OR 4.4, 95% CI 1.9-10.2, P Value 0.00). Sofa Score 2 to 3 (OR 3.2, 95% CI 1.4-7.2, P Value 0.00), Anaemia (OR 2.7, 95% CI 1.2-5.8, P Value 0.00), and Obesity (OR 2.6, 95% CI 1.2-5.5, P Value 0.00) were all significantly associated with the development of hypomagnesemia. However, increasing Sofa Score > 3 and Dyslipidaemia were statistically not proven as the risk factor for the development of hypomagnesemia among hospital patients as is shown in table 4.

Table 4 Factor affecting Hypomagnesaemia in ICU Patients

Risk Factors	Cases (n=42)		Control (n=97)		Odds Ratio	95% CI	P Value
	Yes	No	Yes	No			
Hypertension	36 (85%)	6 (15%)	41 (42%)	56 (58%)	8.1	3.1-21.2	0.00
Diabetes	33 (78%)	9 (22%)	44 (46%)	53 (54%)	4.4	1.9-10.2	0.00
Sofa Score between 2 to 3	16 (38%)	26 (62%)	45 (46%)	52 (54%)	3.2	1.4-7.2	0.00
Anemia	28 (67%)	14 (33%)	41 (42%)	56 (58%)	2.7	1.2-5.8	0.00
Obesity	26 (62%)	16 (38%)	37 (38%)	60 (62%)	2.6	1.2-5.5	0.00
Sofa Score >3	31 (73%)	11 (27%)	43 (44%)	54 (56%)	2.2	1.0-4.9	0.04
Dyslipidemia	20 (48%)	22 (52%)	29 (30%)	68 (70%)	2.1	1.0-4.4	0.00

Discussion

Lack of magnesium is known as Hypomagnesemia. If not promptly detected and effectively treated, hypomagnesemia may result in serious and sometimes deadly consequences and is linked to higher mortality. We found in our study that hypomagnesemia was common which are consistent with an observational study on 102 medical ICU patients by Reinhart et al. They showed that hypomagnesemia was present in 20% of patients, and of all ions, Mg had the highest prevalence of abnormal values¹⁶. Another cohort study by Zeineldin showed that, on ICU admission, 57% of patients had hypomagnesemia and hypomagnesemia was associated with long ICU stay as well as mortality¹⁷. The longer stay of patients with hypomagnesemia patients had also been documented in many studies along with the frequent need for mechanical ventilator support (73% (38 of 52) vs. 53% (22 of 41), P < 0.05), longer duration of mechanical ventilation (average 5 days versus 3 days), increased incidence of sepsis (twice) and higher mortality (twice) compared to patients with normal Mg levels¹⁸. This is consistent to our study findings.

It has been also been documented by recent research that COVID-19 pneumonia has also been having synergistic effect with hypomagnesemia. Razieh Avan, Afroz Mazidimoradi and Hamid Salehiniya have documented that COVID-19 severely ill patients should be screened for magnesium and this laboratory documentation should be included in the routine markers of COVID-19 infection¹⁹. We have also found in our study that magnesium is among the major causes of severity of respiratory diseases in critically ill patients, although we have not included patients with COVID-19 in our study. However, a study done by Mitra Kazmikehromi and colleagues showed contrasting results for the association of COVID-19 severity and magnesium level in the same setting as we have adopted²⁰.

Past literature reviewed revealed that hypomagnesemia is a key biochemical component contributing to in-hospital mortality. There are significant disparities in mortality between ICU septic patients with hypomagnesemia and those with normomagnesemia, according to a 2022 observational study by Pranav Ravi Kulkurani et al (81% versus 14%)²¹. We have also documented same finding in our study.

In a study done by Cojocaru et al, in which they have assessed sepsis patients. They documented that Mg level was severely decreased in septic patients²². We have also concluded that cases have severely low Mg levels however comorbidities are mainly discussed in our study design. Therefore every patient in ICU needs proper attention towards Mg level irrespective of the cause of the hospital admission. The study of Cojocaru et al has also documented that Mg concentration fluctuated in these patients irrespective of the cause of the hospital admission and tend to increase the hospital stay longer than other patients.

Our finding of comorbidities and in-hospital mortalities are widely studied in the current literature. However, the role of hypomagnesemia in comorbid critical patients is a new concept. We have found that Diabetes Mellitus, Hypertension, Anaemia, and Dyslipidaemia are all prevalent comorbidities that are accompanied by the severity of the patients admitted to the ICU. It is documented by many studies that hypomagnesemia is a predictor of progression in chronic kidney diseases²³. In children, hypomagnesemia is also associated with extended attacks of asthma making magnesium level a sensitive marker for the severity of asthma, which has been evident by measurements by pulmonary function tests²⁴. We have also concluded same that hypomagnesemia could be a possible reason for these enhanced mortalities in ICU patients and can be referenced as a predictor for critical patients who have comorbidities as well.

The major strength of our study is that we demonstrated the role of magnesium in busy hospital catering populations all over the country. The strict inclusion criteria, follow-up of the patients, and laboratory evidence are all among the strength of the study. We have limitations in that the hospital setting was chosen because critically ill patients are usually hospitalized. This study was an attempt to discover the effect of the cation which is almost neglected. Our findings are consistent and we found that magnesium should be considered especially in critically ill patients in future courses.

Conclusions

Hypomagnesemia is common in patient admitted in ICU. Chronic diseases like Hypertension, Diabetes Mellitus and Anaemia tend to increase the frequency of hypomagnesemia in patient who are severely ill. Ultimately the risk of death increases in severely ill patient patients after the development of hypomagnesemia. Further clinical trials and critical evaluation of empiric Mg replacement strategies is needed.

List of Abbreviations

ICU: Intensive Care Unit; BMI: Body Mass Index; CPSP: College of Physician and Surgeon of Pakistan; Mg: Magnesium; mm: mmHg: Total Serum Magnesium; Millimole; dl: decilitre; mg: milligram; JPMC: Jinnah Post Graduate Medical Centre, APACHE: The Acute Physiology and Chronic Health Evaluation;

Declarations

Ethics approval and consent to participate were taken.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available at the DHO Office Tharparkar (drsandeepguriro@gmail.com) on a reasonable request.

However the data is also present at url as follow;

<https://figshare.com/account/items/23703459/edit>

and at DOI 10.6084/m9.figshare.23703459

Competing interests

The author (s) declares that they have no competing interests.

Funding

No funding was received for this research. The findings and conclusions in this report are those of the authors. The cost of the study were borne by the principle investigator.

Authors' Contributions

Conceptualization: DSM, DAAK, DSS. Data curation: DSAM, DSM, DSKM. Formal analysis: DSKM.DSAM Funding acquisition: DAAK, DSM. Methodology: DSM, DAAK.DSMK Project administration: DSM, DAAK, Writing - original draft: DSM, DSKM, DSAM, DHAJ. Writing - review & editing: DSAK, DSS.MSAM, MHD. All authors reviewed and approved the manuscript.

References

1. Dent A, Selvaratnam R. Measuring magnesium—Physiological, clinical and analytical perspectives. *Clinical Biochemistry*. 2022 Apr 2.
2. Melaku LS. Molecular Physiology of Magnesium in Cardiovascular System and Pathobiology of Hypomagnesaemia in Cardiovascular Diseases. *Int J Clin Exp Physiol*. 2022;9(2):63-74.
3. Barbagallo M, Veronese N, Dominguez LJ. Magnesium in aging, health and diseases. *Nutrients*. 2021 Jan 30;13(2):463.
4. Pickering ME. Cross-Talks between the Cardiovascular Disease-Sarcopenia-Osteoporosis Triad and Magnesium in Humans. *International Journal of Molecular Sciences*. 2021 Aug 23;22(16):9102.
5. Kim JY, Lee HJ, Lee HY, Lee SM, Lee J, Park TY. The effects of hypomagnesemia on delirium in middle-aged and older adult patients admitted to medical intensive care units. *Acute and Critical Care*. 2022 Jul 5;37(3):407-14.
6. Fiorentini D, Cappadone C, Farruggia G, Prata C. Magnesium: biochemistry, nutrition, detection, and social impact of diseases linked to its deficiency. *Nutrients*. 2021 Mar 30;13(4):1136.
7. Barbagallo M, Veronese N, Dominguez LJ. Magnesium in Type 2 Diabetes Mellitus, Obesity, and Metabolic Syndrome. *Nutrients*. 2022 Feb 8;14(3):714.
8. Al Alawi AM, Berhane T, Majoni SW, Falhammar H. Patients characteristics and health outcomes of patients hospitalised with hypomagnesaemia: a retrospective study from a single centre in the Northern Territory of Australia. *Internal Medicine Journal*. 2021 Jul 4.
9. Bhatia K, Singh P, Paul M, Ameta N. A study of serum magnesium levels in postoperative ICU patients undergoing major GI surgeries. *Medical Journal Armed Forces India*. 2022 Jul 1;78(3):302-7.
10. Okubo K, Kato T, Shiko Y, Kawasaki Y, Inoda A, Koyama K. Two Cases of Liver Transplantation With a High Ionized Magnesium to Total Magnesium Ratio. *Cureus*. 2022 Mar 26;14(3).
11. Scarpati G, Baldassarre D, Oliva F, Pascale G, Piazza O. Ionized or Total Magnesium levels, what should we measure in critical ill patients?. *Translational Medicine@ UniSa*. 2020 Sep;23:68.
12. Hansen BA, Bruserud Ø. Hypomagnesemia in critically ill patients. *Journal of intensive care*. 2018 Dec;6(1):1-1.
13. Mamun GM, Sarmin M, Alam A, Afroze F, Shahrin L, Shahid AS, Shaima SN, Sultana N, Chisti MJ, Ahmed T. Prevalence and predictors of hypomagnesemia among critically ill diarrhoeal patients and their outcome in a developing country.
14. Gragossian A, Bashir K, Friede R. Hypomagnesemia. *InStatPearls [Internet]* 2022 May 15. StatPearls Publishing.
15. Palaiodimos L, Chamorro-Pareja N, Karamanis D, Li W, Zavras PD, Chang KM, Mathias P, Kokkinidis DG. Diabetes is associated with increased risk for in-hospital mortality in patients with COVID-19: a systematic review and meta-analysis comprising 18,506 patients. *Hormones*. 2021 Jun;20(2):305-14.
16. Fairley JL, Zhang L, Glassford NJ, Bellomo R. Magnesium status and magnesium therapy in cardiac surgery: a systematic review and meta-analysis focusing on arrhythmia prevention. *J Crit Care*. 2017;42:69-77.

17. Zeineldin KH, Kandeel A, Omar E, Sabry S. Effect of Hypomagnesaemia on Critically Ill Patients: A Retrospective Study. *Egyptian Journal of Critical Care Medicine*. 2022 Jun 1;9(2):46-50.
18. Jiang P, Lv Q, Lai T, Xu F. Does hypomagnesemia impact on the outcome of patients admitted to the intensive care unit? A systematic review and meta-analysis. *Shock*. 2017;47:288-295.
19. Avan R, Mazidimoradi A, Salehiniya H. Effect of magnesium on severity and mortality of COVID-19 patients: A systematic review. *Journal of Acute Disease*. 2022 Jul 1;11(4):120.
20. Kazemijahromi M, Samimagham H, Moradkhani A. The association of serum magnesium and risk of morbidity and mortality in patients admitted to the intensive care unit: A stratified analysis based on COVID-19 infection classification. In *Endocrine Abstracts 2022 May 7 (Vol. 81)*. Bioscientifica.
21. Jayachandran PR, Raja A, Murali R, Mohanan J, Suthakaran PK, Rajendran K, Mageshkumar Sivanesan D. Comparison of serum magnesium levels and sequential organ failure assessment score in patients with systemic inflammatory response syndrome. *European Journal of Molecular & Clinical Medicine*. 2022 Sep 12;9(6):802-9.
22. Pham PC, Pham PA, Pham SV, Pham PT, Pham PM, Pham PT. Hypomagnesemia: a clinical perspective. *Int J Nephrol Renovasc Dis*. 2014;7:219-230.
23. Abdel-Hameed AR, Ahmed MF, Elsanawy AA, Mohammad MB. Prevalence, risk factors and impact of proteinuria-associated hypomagnesemia in chronic kidney disease patients: cross-sectional study. *The Egyptian Journal of Internal Medicine*. 2022 Dec;34(1):1-8.
24. Gaber EM, Mohammed EK, Abdelwahab AE, Mohammed EE. Serum magnesium level in asthmatic children as an indicator of asthma severity. *The Scientific Journal of Al-Azhar Medical Faculty, Girls*. 2021 Apr 1;5(2):271.