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ASSESSMENT OF SERUM ELECTROLYTE LEVELS AMONG SICKLE CELL ANEMIA PATIENTS

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Abstract

Introduction:
Sickle cell anemia (SCA) is an inherited hemoglobin disorder characterized by chronic hemolysis, vaso-occlusion, and multi-organ complications. Electrolyte imbalance is a common yet under-recognized problem in SCA due to hemolysis, dehydration, renal tubular dysfunction, and repeated vaso-occlusive crises. Monitoring electrolyte levels is essential for preventing life-threatening complications such as arrhythmias, metabolic acidosis, and acute kidney injury.

Methods:
A cross-sectional study was conducted on 50 confirmed SCA patients aged 18–50 years at a tertiary care hospital in Lahore. Simple random sampling was used. Blood samples were analyzed using an automated electrolyte analyzer based on the Ion-Selective Electrode (ISE) method. Data were analyzed in SPSS using descriptive statistics and t-tests.

Results:
Serum electrolyte abnormalities were highly prevalent among SCA patients. Hyponatremia and hyperkalemia were the most common findings. Many patients also showed decreased bicarbonate levels consistent with metabolic acidosis, along with disturbances in chloride, calcium, magnesium, and phosphate.

Conclusion:

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Electrolyte imbalance is frequent in SCA and arises largely due to ongoing hemolysis, renal medullary damage, and dehydration during crises. Routine monitoring of electrolytes is recommended for early intervention and prevention of complications.

INTRODUCTION

Sickle cell anemia (SCA) is an inherited hemoglobin disorder caused by a point mutation in the β-globin gene on chromosome 11, resulting in the formation of hemoglobin S (HbS).[1]Under low oxygen conditions, HbS polymerizes, forcing red blood cells into a rigid sickle shape.[2]These abnormal erythrocytes are fragile and survive for only 10–20 days compared to the normal lifespan of approximately 120 days, leading to chronic hemolytic anemia.[4]

The increased rigidity of sickled cells also causes obstruction of small blood vessels, triggering painful vaso-occlusive crises and progressive organ dysfunction.[1],[2]Globally, sickle cell anemia affects nearly 300,000 newborns each year, with the highest disease burden reported in sub-Saharan Africa, the Middle East, India, and South Asia.[6]

In Pakistan, the true prevalence of SCA remains uncertain due to the absence of nationwide screening programs.[7] However, regional studies suggest that approximately 1.9% of the population carries the sickle cell gene, with higher prevalence observed in Balochistan and among certain ethnic groups such as the Sheedi community.[8],[22]

Limited awareness and inadequate diagnostic facilities result in late presentation of many patients, leading to delayed management and increased disease-related complications.[23]

One of the most significant yet under-recognized complications of sickle cell anemia is electrolyte imbalance.[9] Electrolytes including sodium, potassium, chloride, bicarbonate, calcium, magnesium, and phosphate play essential roles in maintaining fluid balance, nerve conduction, muscle function, and acid–base homeostasis.[10]

Chronic hemolysis, dehydration, recurrent infections, fever, and repeated sickling episodes contribute to renal damage, disrupting the regulation of these essential ions.[11],[12]As a result, patients with SCA commonly develop electrolyte abnormalities such as hyponatremia, hyperkalemia, and metabolic acidosis.[13]

Renal involvement plays a central role in the development of electrolyte disturbances in sickle cell anemia.[15]The unique microenvironment of the renal medulla characterized by low oxygen tension, high osmolarity, and slow blood flow—promotes persistent sickling, leading to tubular injury and impaired reabsorption of sodium and bicarbonate.[16],[24]

This impairment results in an inability to concentrate urine, increased fluid loss, and disturbances in acid–base balance.[25]With repeated injury, these changes may progress to sickle cell nephropathy, further exacerbating electrolyte abnormalities.[26]

Despite the increasing burden of sickle cell anemia in Pakistan, limited local data are available regarding electrolyte patterns among affected individuals.[6]

Understanding these disturbances is essential for early detection, timely correction, and prevention of serious complications such as arrhythmias, seizures, muscle weakness, and worsening vaso-

occlusive crises.[7],[8]Therefore, evaluation of serum electrolytes in patients with sickle cell anemia is crucial for improving clinical outcomes and guiding effective patient management strategies.[22],[23]
The pathophysiological processes underlying sickle cell anemia also contribute significantly to progressive oxidative stress, which further disrupts cellular ion transport and membrane stability.[39]Continuous generation of reactive oxygen species damages red blood cell membranes, impairs the sodium–potassium ATPase pump, and promotes potassium leakage from cells.[41]
These changes accelerate hemolysis and contribute to red blood cell dehydration, thereby enhancing the tendency for sickling.[39]Such molecular disturbances highlight the systemic nature of sickle cell anemia, extending beyond hematological abnormalities to widespread biochemical imbalances.[41]
Dehydration during vaso-occlusive crises plays a particularly important role in worsening electrolyte disturbances.[9]
Painful crises are often accompanied by fever, increased metabolic demands, poor oral intake, and insensible fluid losses.[20]These conditions promote significant electrolyte shifts, reduce plasma volume, and increase blood viscosity.[29]
Progressive dehydration further impairs renal perfusion, limiting the kidneys' ability to regulate sodium, potassium, and bicarbonate levels.[9] Consequently, complications such as hyponatremia, hyperkalemia, and metabolic acidosis may worsen pain severity, trigger cardiac arrhythmias, and prolong the duration of vaso-occlusive crises.[20],[29]
Medication use in sickle cell anemia may also influence electrolyte homeostasis.[18]Hydroxyurea, although beneficial in reducing the frequency of vaso-occlusive episodes, may indirectly affect renal concentrating ability with long-term use.[20]
Similarly, medications such as angiotensin-converting enzyme inhibitors and diuretics can alter sodium and potassium balance, necessitating careful monitoring.[51]
Frequent blood transfusions, a key supportive therapy in SCA, may contribute to oxidative stress and secondary metabolic alterations, further complicating electrolyte regulation.[18]
Given the complex interplay between hemolysis, renal dysfunction, oxidative stress, dehydration, and treatment-related factors, electrolyte imbalance in sickle cell anemia is multifactorial and progressive.[19]
In regions such as Pakistan, where diagnostic facilities, disease awareness, and routine monitoring are limited, the risk of undiagnosed electrolyte disturbances is substantially higher.[29]
This underscores the need for local research to characterize electrolyte patterns in sickle cell anemia, strengthen early detection strategies, and improve clinical interventions.[38],[52]
A clearer understanding of these biochemical alterations will assist clinicians in preventing serious complications and enhancing the overall quality of care for individuals living with sickle cell anemia.[53]

Materials and Methods

This cross-sectional study was conducted at a tertiary care hospital in Lahore and included 50 confirmed sickle cell anemia patients aged 18–50 years selected through simple random sampling. Venous blood samples (5 mL) were collected from each participant, and serum electrolytes including

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sodium, potassium, chloride, bicarbonate, calcium, magnesium, and phosphate were measured using an automated electrolyte analyzer based on the Ion-Selective Electrode (ISE) method. Patients with chronic kidney disease, acute kidney injury, malignancy, infection, or those taking electrolyte-altering medications were excluded. Data were analyzed using SPSS version 25, applying descriptive statistics and appropriate inferential tests, with a p-value < 0.05 considered statistically significant.

Results

The study revealed that a significant proportion of sickle cell anemia patients exhibited abnormalities in multiple serum electrolytes. Hyponatremia and hyperkalemia were the most frequently observed disturbances, indicating impaired sodium regulation and increased potassium retention likely due to hemolysis and renal tubular dysfunction. Many patients also demonstrated reduced bicarbonate levels, consistent with metabolic acidosis, while chloride levels varied, reflecting underlying acid-base imbalance. Additionally, several participants showed altered calcium, magnesium, and phosphate levels, suggesting broader renal involvement and nutritional deficiencies. Overall, the findings confirm that electrolyte imbalance is common in sickle cell anemia and affects several biochemical parameters simultaneously.

Table: Descriptive Analysis of electrolytes in sickle cell anemia

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Gender	50	1	2	1.46	.503
Age	50	18	49	35.58	9.721
Serum Sodium	50	1	3	2.44	.907
Serum Chloride	50	1.0	33.0	3.0	4.4263
Serum Potassium	50	2.0	33.0	3.3	4.3106
Serum Bicarbonate	50	1.0	3.0	2.36	.9424
Serum Calcium	50	1.0	3.0	2.32	.9570
Serum Magnesium	50	1.0	3.0	2.28	.9697
Serum Phosphate	50	1.0	3.0	2.64	.5628

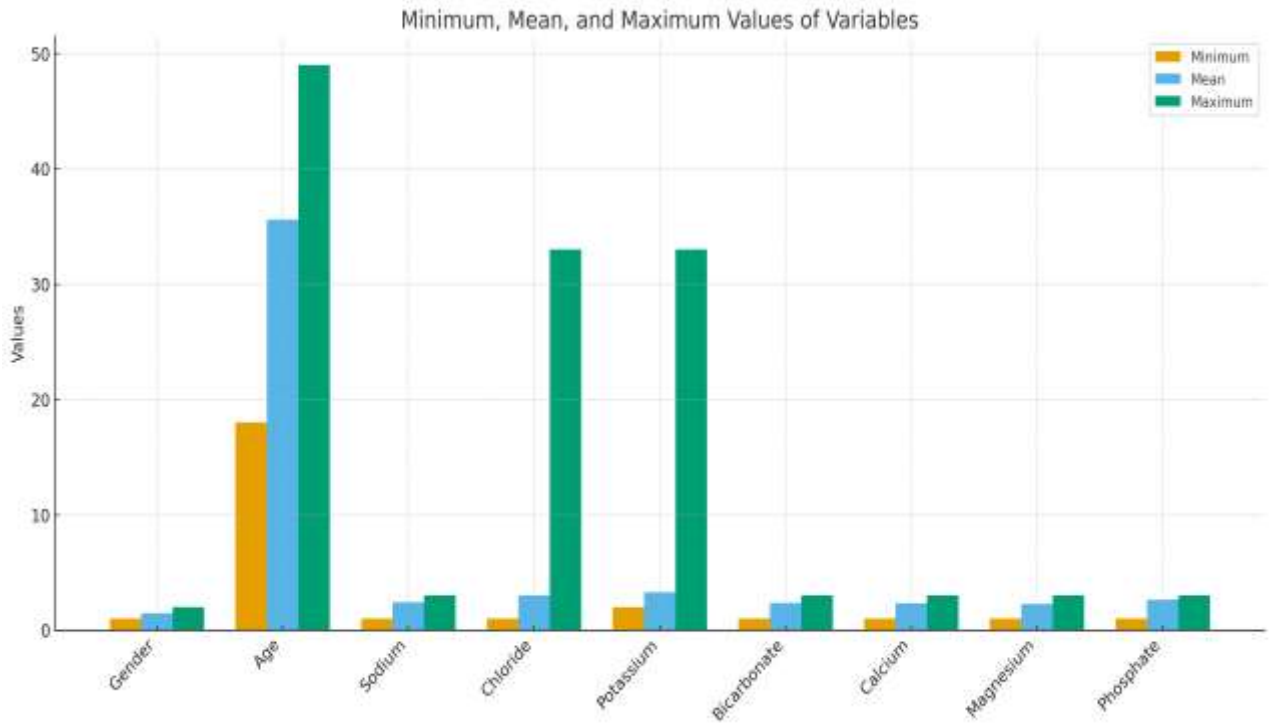

Figure 1: The graph shows the minimum, mean, and maximum values of all variables electrolytes in sickle cell anemic Patients.

Discussion

The most frequent abnormalities observed in our study were hyponatremia and hyperkalemia, followed by reduced bicarbonate levels indicative of metabolic acidosis.[5,9]These abnormalities reflect the significant impact of chronic hemolysis, dehydration, and renal tubular dysfunction, which are key mechanisms involved in the pathophysiology of sickle cell anemia.[1,2]The altered electrolyte profile observed in this study highlights the complex interplay between persistent sickling, impaired renal function, and oxidative stress, all of which contribute to widespread physiological disturbances in affected individuals.[5,9]

The presence of hyponatremia in many patients may be attributed to impaired sodium reabsorption within the renal tubules, a well-documented consequence of repeated vaso-occlusive episodes and renal medullary ischemia.[11,15]Damage to the renal medulla reduces the kidney's ability to concentrate urine, resulting in excessive sodium loss and relative water retention.[24,27]

International studies have similarly reported renal tubular injury as a common complication of sickle cell anemia, frequently manifesting as chronic sodium-wasting.[28,33]The consistent pattern of reduced sodium levels observed in our study further supports this mechanism and suggests a substantial

burden of renal involvement among the study population.[54],[60]Hyperkalemia was also identified as one of the most prominent electrolyte abnormalities in the present study.[12],[19]

Chronic hemolysis in sickle cell anemia leads to increased potassium release from erythrocytes into the circulation, contributing significantly to elevated serum potassium levels.[29],[34]Additionally, renal impairment associated with sickle cell disease reduces potassium excretion, further exacerbating hyperkalemia.[35],[42]Previous studies have described hyperkalemia as a characteristic biochemical feature during hemolytic episodes and vaso-occlusive crises.[59]

The elevated potassium levels observed in our study emphasize the importance of routine monitoring to prevent serious complications such as cardiac arrhythmias.[12]A considerable number of patients in this study exhibited reduced bicarbonate levels, consistent with metabolic acidosis.[13],[24] Sickle cell–related metabolic acidosis primarily results from impaired bicarbonate reabsorption due to chronic renal tubular dysfunction.[25],[26]Repeated sickling events cause ischemic injury in the renal medulla, diminishing the kidney's ability to maintain normal acid–base balance.[35],[42]Previous studies have similarly reported metabolic acidosis as a common finding in sickle cell anemia, contributing to dehydration, fatigue, and increased susceptibility to vaso-occlusive crises.[60]The presence of metabolic acidosis in our cohort underscores the progressive nature of renal involvement and the importance of early biochemical assessment.[13]

Disturbances in other electrolytes, including chloride, calcium, magnesium, and phosphate, were also observed among the study participants.[14],[30]These abnormalities may arise from nutritional deficiencies, altered renal reabsorption, increased cellular turnover, and hormonal dysregulation associated with chronic hemolysis.[31],[32]Previous research has linked such secondary electrolyte disturbances to early stages of sickle cell nephropathy and chronic inflammatory stress.[36],[37]

The findings of this study support the concept that sickle cell anemia affects multiple metabolic pathways simultaneously, resulting in widespread biochemical instability.[55],[56]Overall, the patterns observed in this study strongly correlate with existing literature identifying electrolyte imbalance as a common and clinically significant complication of sickle cell anemia.[1],[2]Sodium, potassium, and bicarbonate were the most frequently affected electrolytes, highlighting a strong association between sickling, renal injury, and impaired ion regulation.[5],[9]The consistency of these findings with global data reinforces the need for routine electrolyte monitoring in all sickle cell anemia patients, particularly in resource-limited settings such as Pakistan.[20],[52]

Early detection and timely correction of electrolyte disturbances can reduce severe complications, improve clinical outcomes, and decrease hospital admissions related to vaso-occlusive crises and renal dysfunction.[53],[61]

Conclusion

This study concludes that electrolyte imbalances are highly prevalent among patients with sickle cell anemia. The most frequent disturbances observed were hyponatremia, hyperkalemia, and reduced bicarbonate levels, indicating significant disruption in sodium regulation, potassium handling, and acid–base balance. These abnormalities reflect the combined impact of chronic hemolysis,

dehydration, and renal tubular dysfunction, these key pathophysiological processes consistently associated with SCA.

The pattern of electrolyte changes observed in this study highlights the early involvement of the kidneys, particularly the renal medulla, where repeated sickling leads to impaired sodium reabsorption and reduced ability to maintain acid–base homeostasis. The presence of metabolic acidosis and altered levels of chloride, calcium, magnesium, and phosphate indicates broader biochemical instability, further supporting the progression toward sickle cell nephropathy.

Findings from this research are consistent with existing international literature and reinforce that electrolyte disturbances are not isolated findings but are characteristic and clinically significant complications of SCA. These abnormalities, if left unmonitored, can contribute to severe outcomes including arrhythmias, muscle weakness, increased fatigue, prolonged vaso occlusive crises, and worsening renal damage.

Overall, the study emphasizes the importance of routine electrolyte assessment as part of the clinical management of sickle cell anemia. Regular monitoring enables early identification and correction of abnormalities, helps prevent serious complications, and ultimately improves patient outcomes. The results underline the need for strengthened diagnostic practices, especially in regions with limited resources, to ensure timely and effective clinical care for individuals living with sickle cell anemia.

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