

Original Article

Clinical Characteristics and Trends in Water and Sodium Imbalances among Dehydrated Children with Diarrhea

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ABSTRACT:

Background: Diarrheal disorders significantly contribute to both childhood morbidity and mortality. Despite substantial advancements in the medical field, diarrhea remains the third most common cause of death in children under 4 years of age. Dehydration and dyselectrolytemia, particularly sodium disturbances, represent the primary causes of complications in acute diarrhea. **Methods:** We conducted a prospective observational study spanning one year, enrolling children aged 6 to 40 months who were admitted with acute diarrhea and exhibited clinical features indicative of moderate or severe dehydration based on the WHO criteria. **Results:** During the study period, a total of 74 children were enrolled, with 45 being males and 29 females. The mean age at presentation was 2 years, and the average weight on admission was 9 kg. The mean serum sodium level recorded was 138.5 mEq/L. The majority of children experienced isonatremic dehydration (n=44, 60.1%), followed by hyponatremic dehydration (n=23, 30.4%), and hypernatremic dehydration (n=7, 9.5%). Remarkably, only 25 (34.5%) of the children had received oral rehydration solution (ORS) before admission, leaving the remaining 49 (65.5%) without this life-saving remedy. Among those who received ORS, only 9 (35.3%) were administered in the appropriate dilution, while the rest 16 (64.7%) were given either over- or under-concentrated ORS. Malnutrition was identified in 25 (34.5%) children, with 19 (52.9%) of these malnourished children experiencing hyponatremia. **Conclusion:** The incidence of sodium disturbance, including hyponatremia and hypernatremia, in children is notably high, reaching nearly 40%. Malnourished children and those receiving improperly diluted WHO oral rehydration solution (ORS) were found to be at a significantly elevated risk of developing hyponatremia or hypernatremia. Specifically, hypernatremia in Acute Gastroenteritis (AGE) was observed to be significantly more prevalent in infants aged 6-12 months compared to children aged 1-5 years. AGE cases accompanied by hyponatremia or hypernatremia are significantly associated with an increased risk of seizures, prolonged hospital stays, and a heightened risk of mortality when compared to AGE cases with isonatremia.

Keywords: diarrhoea, hyponatremia, isonatremia, hypernatremia

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INTRODUCTION

Diarrheal disorders represent a formidable and persistent challenge to public health worldwide, particularly in low- and middle-income countries where resources may be limited. The impact of these conditions on the mortality and overall health of children under the age of five is profound, warranting concerted efforts for prevention and intervention.¹ Within the context of India, the nation has witnessed a noteworthy reduction in mortality rates among children under four, with a commendable decline from 2.8 million to 1.6 million deaths. This substantial achievement can be attributed to the successful implementation of targeted health programs, including the Expanded Program on Immunization, the Program for the Control of Diarrheal Diseases, and strategic measures addressing Acute Respiratory Infections. However, the persistence of diarrheal diseases as a leading cause of childhood mortality

highlights the ongoing urgency of addressing this health challenge. Among children under four years old, diarrhea remains the third most prevalent cause of death, contributing to a significant 13% of fatalities.² Even with notable strides in healthcare infrastructure, it is sobering to recognize that over 200,000 children in India continue to lose their lives to diarrhea annually. This sobering reality underscores the critical importance of vigilantly monitoring information related to diarrheal diseases, including understanding their determinants, implementing effective preventive measures, and developing robust control strategies. A comprehensive and multifaceted approach is essential to navigate the complexities of this health issue. This includes not only treating acute cases but also implementing long-term preventive measures, promoting community awareness, and fostering sustainable healthcare practices. By doing so, we can ensure not only the continued reduction of mortality

rates but also the optimization of health services at the community level. The commitment to understanding, addressing, and mitigating the impact of diarrheal diseases is vital for the overall well-being of our communities and the future generations they encompass.

Acute gastroenteritis emerges as a prevalent and significant cause for pediatric hospital admissions, wielding a considerable impact on the health landscape of children, particularly in developing regions. This condition not only contributes substantially to the overall burden of morbidity but also poses a heightened risk of mortality among young patients.³ The fluid loss associated with gastroenteritis becomes a pivotal factor in the development of complications that can escalate to a point where intensive medical care is imperative, and in some instances, the condition may prove fatal if appropriate interventions are not promptly instituted. The etiology of diarrhea in acute gastroenteritis is diverse, involving a spectrum of offending organisms ranging from bacteria to viruses. This multifaceted nature of the causative agents underscores the complexity of the condition and its potential to precipitate dehydration in pediatric patients. Dehydration, in turn, amplifies the severity of the disease and the associated risks. It is crucial to recognize that beyond the immediate symptoms, the repercussions of acute gastroenteritis extend to long-term health outcomes and the overall well-being of affected children. Timely and effective intervention is paramount not only for alleviating the acute symptoms but also for preventing and managing complications that may arise. Given the susceptibility of the pediatric population, particularly in resource-constrained settings, to the adverse effects of gastroenteritis, a comprehensive approach that includes preventive measures, early diagnosis, and appropriate treatment becomes indispensable. In addressing the challenges posed by acute gastroenteritis in pediatric patients, it becomes evident that a holistic understanding of the condition, coupled with timely and targeted interventions, is crucial.⁴ This encompasses not only medical interventions but also public health initiatives aimed at preventing the occurrence of gastroenteritis and promoting overall child health. Through such concerted efforts, we can hope to reduce the burden of acute gastroenteritis, improve the outcomes for pediatric patients, and contribute to the overall well-being of children, especially in regions facing the highest health disparities. In elucidating the multifaceted landscape of diarrheal diseases, it is imperative to delve deeper into the nuanced factors contributing to the high incidence observed in India. The World Health Organization's definition of diarrheal disease, entailing the passage of three or more loose or liquid stools per day, underscores the clinical manifestation that serves as a gateway to understanding the broader health challenges faced, especially by the pediatric

population. The intricacies of India's high prevalence of diarrheal disorders intertwine with a complex web of determinants, accentuating the critical role of under-nutrition and susceptibility to infections resulting from suboptimal infant and young child feeding practices.⁵ These encompass a range of practices, including the failure to exclusively breastfeed during the crucial first 6 months of life, the utilization of infant feeding bottles, storage of cooked food at room temperature, reliance on drinking water contaminated with fecal bacteria, and a confluence of socio-economic factors, educational disparities, and substandard sanitary conditions. The pervasive trend of premature adoption of breast milk substitutes further exacerbates the vulnerability to diarrheal illnesses. The clinical ramifications of acute diarrhea extend beyond mere symptoms, reflecting the severity of the underlying water deficit and the intricate patterns of electrolyte imbalances. Notably, hypovolemia due to dehydration emerges as the primary cause of mortality in acute diarrhea, propelled by the substantial loss of fluid and electrolytes through diarrheal stools. The spectrum of contributors to mortality encompasses dyselectrolytemia, malnutrition, dysentery, and concomitant serious infections, such as pneumonia.

Recognition and timely management of water and electrolyte disturbances emerge as pivotal aspects of care, with a particular emphasis on hyponatremic and hypernatremic dehydration due to their potential for severe neurological consequences.^{6,7} The clinical features of these conditions, often deceptive, necessitate a keen clinical acumen for accurate diagnosis. Hyponatremia's symptomatic presentation occurs when serum sodium precipitously falls below 120 mEq/L, while hypernatremic dehydration may manifest late, masquerading as mild dehydration. While hyponatremic and hypernatremic dehydration are less frequent compared to isonatremic dehydration, the clinical landscape demands a heightened clinical suspicion for their prompt identification. Effective management of diarrhea and associated electrolyte imbalances hinges on the judicious utilization of oral rehydration solution and intravenous fluids, tailored to replete water deficits and correct electrolyte imbalances. Unfortunately, a considerable number of cases, marked by severe dehydration or shock, often reach the hospital belatedly, necessitating admission to the pediatric intensive care unit for comprehensive therapeutic interventions. In light of these considerations, the present study unfolds within the corridors of our tertiary care teaching hospital.^{8,9} It seeks to unravel the intricate clinical profile and spectrum of sodium disturbances in children grappling with Acute Gastroenteritis (AGE) accompanied by moderate to severe dehydration, with a deliberate intent to establish correlations between these parameters and the clinical status of the afflicted individuals. This endeavor not only illuminates the intricacies of

pediatric health but also lays the groundwork for informed interventions and policies to alleviate the burden of diarrheal diseases in this vulnerable population.

MATERIALS AND METHODS

The research design for this study exhibited a methodical and deliberate approach, centering on children aged 6 months to 4 years admitted to the Pediatric ward. The inclusion criteria were crafted with precision to encompass cases of acute gastroenteritis characterized by significant clinical features. These criteria comprised the passage of three or more episodes of watery stools per day, a concise duration of symptoms less than 2 weeks at the time of admission, and clinical manifestations suggestive of some or severe dehydration following the World Health Organization (WHO) criteria.

The requirement for three or more episodes of watery stools per day emphasized the acute nature of the condition, providing a quantitative measure to delineate severity. The stipulation of symptoms lasting less than 2 weeks ensured the inclusion of recent-onset cases, capturing the dynamic phase of acute gastroenteritis. Adopting the WHO criteria for dehydration added objectivity and standardization to the clinical assessment, contributing to a more uniform classification of dehydration severity.

Conversely, the exclusion criteria were designed to refine the study population and eliminate potential confounding factors. By excluding children with chronic diarrhea, the study aimed to focus specifically on acute cases, allowing for a more detailed examination of the immediate clinical and electrolyte imbalances associated with acute gastroenteritis. The exclusion of children with diarrhea but without dehydration ensured a direct link between observed clinical profiles and dehydration, preventing dilution of findings by cases where dehydration was absent. The exclusion of those with serious systemic illnesses and those in the postoperative period further refined the cohort, minimizing potential influences from unrelated health conditions or surgical interventions.

This meticulous approach to inclusion and exclusion criteria laid the groundwork for a well-defined and homogeneous study group. It ensured that the clinical profile and sodium disturbances observed in children suffering from Acute Gastroenteritis (AGE) with moderate to severe dehydration could be scrutinized with precision, enhancing the study's internal validity. By systematically refining the study population, the research team aimed to extract targeted insights into the specific dynamics of this particular pediatric population, contributing valuable information to the understanding and management of acute gastroenteritis in young children.

RESULTS

Over the course of our designated study period, a total of 74 children, grappling with the challenging

manifestations of diarrhea, were actively enrolled in our comprehensive investigation. This cohort offered a diverse and representative sample, providing a rich dataset for a meticulous examination of factors associated with acute gastroenteritis (AGE) in pediatric patients. Gender distribution within the cohort was balanced, with 45 males and 29 females, ensuring a nuanced exploration of potential gender-related considerations in the prevalence and clinical presentation of gastroenteritis in children. As we delved into the demographic characteristics of the study population, a noteworthy insight emerged regarding the mean age at presentation, which was identified as 2 years.

This finding underlines the substantial impact of AGE across the early years of childhood, emphasizing the vulnerability of children to this prevalent gastrointestinal condition. The mean weight upon admission, quantified at 9 kg, further highlighted the tangible physical repercussions of gastroenteritis on the health status of the afflicted children. Exploring the age distribution within the cohort uncovered a distinct pattern, with AGE being more prevalent in the age group of 1 to 4 years, constituting 56.1% of the cases, compared to infants aged 6-12 months, who represented 43.9%. This age-specific distribution sheds light on the susceptibility of younger children, particularly during the critical early years of development, to gastroenteritis. Moreover, a compelling correlation with socioeconomic status emerged, revealing a higher incidence of childhood gastroenteritis in families characterized by poor socioeconomic conditions. Specifically, within the study population, 58.1% of the children belonged to socioeconomic classes IV and V, 27.70% to class III, and only 14.2% to the more privileged classes I and II.

This socioeconomic association adds a socioecological dimension to our understanding of the determinants of pediatric gastroenteritis. The severity of dehydration, a critical aspect of gastroenteritis, was stratified within the cohort. It was observed that 23 children faced severe dehydration, necessitating intensive care, while the remaining 62 exhibited some degree of dehydration. This nuanced classification underscores the spectrum of disease severity within our study group, allowing for a more nuanced analysis of the clinical course and outcomes associated with varying degrees of dehydration. The summarized findings are encapsulated in Table 1, offering a comprehensive snapshot of the general characteristics of our study population. This table serves as a valuable reference point for subsequent analyses, providing a foundation for exploring the intricate interplay of demographic factors and clinical features influencing the prevalence and severity of gastroenteritis in the pediatric cohort under scrutiny. The wealth of information gleaned from these initial observations lays the groundwork for a deeper

understanding of the multifaceted nature of pediatric gastroenteritis.

Table 1: General characteristics of the study population

Parameter	Value
Total no. of children enrolled	74
Male: Female ratio	1.45: 1
Age in years	2
Weight in Kg	10
Serum Sodium level at admission in mEq/L	138.5
Duration of diarrhoea in days	3.16
Number of loose stools per day	11.66
Duration of vomiting episodes in days	2.32
Number of vomiting episodes per day	3.08
Duration of hospital stay in days	3.67

Despite the mean serum sodium level falling within the normal range at 138.5 mEq/L, an insightful analysis of the sodium disturbances within the study cohort revealed compelling patterns. The majority of children exhibited isonatremic dehydration, constituting 60.1% of the cases. This was followed by hyponatremic dehydration, which manifested in 30.4% of the children, and hypernatremic dehydration, observed in 9.5% of the cases. This distribution underscores the diversity of sodium disturbances in pediatric patients with acute gastroenteritis (AGE), challenging the conventional notion that normal mean values necessarily correspond to uniform clinical presentations. Table 2, a valuable reference point for our analysis, further elucidates the intricate relationship between serum sodium alterations and key demographic factors such as age and gender. Interestingly, the incidence of hypernatremia was found to be significantly higher in infants compared to older children, a finding

substantiated by a p-value of 0.006. This observation underscores a distinct vulnerability of infants to hypernatremic dehydration, possibly attributed to their unique physiological and nutritional needs during this developmental stage. Importantly, despite these variations, there was no discernible sex predilection for the different types of sodium disturbances, indicating that gender did not emerge as a significant factor influencing the prevalence of hyponatremia, hypernatremia, or isonatremic dehydration in these pediatric cases. These findings not only contribute to our understanding of the clinical spectrum of sodium disturbances in AGE but also highlight the importance of considering age-specific vulnerabilities in the assessment and management of pediatric patients with gastroenteritis. The nuanced insights gleaned from this analysis pave the way for tailored interventions and further research to elucidate the underlying factors contributing to the observed patterns of sodium imbalances in this specific population.

Table 2: Sodium alteration in relation to age

Age	Hyponatremia		Hypernatremia		Isonatremia	
	Number	Percentage	Number	Percentage	Number	Percentage
6months- 1 year	12	35.38	5	16.92	15	47.69
1-5 YEARS	11	26.5	3	3.61	29	69.87

Figure1: Sodium alteration in relation to gender

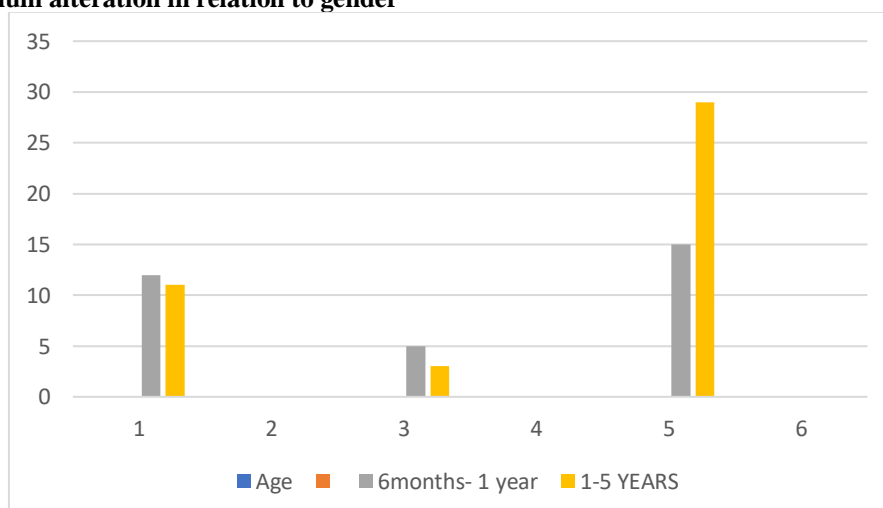


Table 3: Sodium changes in relation to dilution of ORS

	Hyponatremia	Hypernatremia	Isonatremia
	Number	Number	Number
Appropriate dilution (n=9)	1	0	8
Diluted ORS (n=11)	9	0	2
Concentrated ORS (n=5)	0	4	1

DISCUSSION

Acute gastroenteritis (AGE) serves as a prominent health concern, encompassing a spectrum of infectious and non-infectious causes leading to gastrointestinal distress, notably marked by symptoms such as vomiting and diarrhea. This study, undertaken with a cohort of 74 children experiencing AGE and varying degrees of dehydration, delves deeper into the intricate clinical and demographic facets of this condition. The age distribution within the study cohort illuminates a higher incidence of AGE in the age group of 1 to 4 years, constituting 56.1% of cases, in comparison to infants aged 6-12 months, who accounted for 43.9%.¹⁰ This demographic trend aligns with broader epidemiological patterns observed in similar studies, such as the research conducted by Smok B et al., which reported a distribution of 18% in infancy and 82% in children older than 1 year. While this aligns with global trends, regional variations, as evidenced by some Indian studies reporting slightly higher prevalence rates during infancy, underscore the nuanced nature of AGE epidemiology. Gender distribution within the study cohort revealed a higher prevalence of diarrhea in males (65.5%) compared to females (34.5%). This gender-based disparity in AGE incidence echoes findings from previous investigations, including studies conducted by researchers such as Gopchade A, who noted that almost two-thirds of AGE cases occurred in male children. However, it is crucial to acknowledge the potential influence of societal biases or preferences that may contribute to a higher rate of admission for male children, impacting the observed gender distribution.¹¹ The incidence of sodium disturbances in the study cohort adds another layer of complexity to the understanding of AGE. Hyponatremia was observed in 30.4% of cases, hypernatremia in 9.45%, and isonatremia in 60.15%. Notably, isonatremic dehydration emerged as the most prevalent type, aligning with consensus in the scientific community that this is the commonest form of dehydration. This finding is consistent with reports from various researchers in India. Further exploration of hyponatremic cases highlighted that 51.11% occurred in infants aged 6-12 months, emphasizing the vulnerability of this age group to sodium imbalances in the context of gastroenteritis. In essence, this study provides a comprehensive panorama of the demographic and clinical intricacies associated with pediatric AGE and dehydration. The delineated patterns in age distribution, gender prevalence, and sodium disturbances contribute valuable insights for clinicians, public health professionals, and researchers

alike. The multifaceted nature of AGE is underscored, emphasizing the importance of tailored interventions and further research endeavors to refine our understanding and enhance the management of this prevalent pediatric condition.

The persistent global incidence of diarrhea, despite the reduction in mortality rates, remains a substantial healthcare challenge, driving millions of pediatric visits to healthcare professionals annually.¹² While the mortality associated with diarrheal diseases has decreased considerably, its prevalence underscores the need for ongoing attention and effective management. Key to this reduction in mortality is the widespread adoption of oral rehydration solution (ORS), a critical factor that has played a pivotal role in saving lives. The efficacy of ORS lies in its ability to sustain the sodium-coupled solute co-transport mechanism even in the face of severe diarrhea, preventing life-threatening complications and offering a lifeline in the treatment of diarrheal diseases in children.

The clinical presentation of uncomplicated diarrhea in children typically manifests as an increase in stool frequency and a change in consistency, often accompanied by symptoms such as vomiting and abdominal pain.¹³ Without prompt and appropriate treatment, these seemingly benign symptoms can escalate into severe complications secondary to dehydration, including hypovolemic shock and renal failure. Additionally, electrolyte imbalances may ensue, leading to neurological manifestations such as lethargy, irritability, and convulsions, underscoring the potential severity of pediatric diarrheal cases.

Against this backdrop, the present study takes a focused approach, aiming to assess the clinical profile and discern patterns of water and sodium disturbances in children suffering from diarrhea with dehydration. By undertaking this investigation, the study seeks to contribute valuable insights into the nuanced clinical presentations and electrolyte imbalances associated with pediatric diarrhea. The ultimate goal is to enhance our understanding of these complexities, thereby informing more effective management strategies and interventions that can further contribute to the reduction of morbidity and mortality associated with diarrheal diseases in the pediatric population.

The study by Samadi AR et al introduced valuable insights into the age-related dynamics of hyponatremia, revealing a nuanced pattern with increasing incidence across different age groups. Conversely, the current investigation uncovered a distinctive trend, showcasing a significantly higher prevalence of hypernatremia in infants compared to older children (78.6% vs. 21.4%, $p < 0.01$). This

divergence in findings underscores the complexity of sodium imbalances in pediatric populations, highlighting the need for a nuanced understanding of age-specific factors that contribute to variations in electrolyte disturbances.¹⁴ The observed higher incidence of hypernatremia in infants was postulated to be associated with factors such as the use of overconcentrated oral rehydration solution (ORS) or formula milk. Additionally, the heightened evaporative water loss through the delicate skin of young infants could further exacerbate the risk of hypernatremia.¹⁵ This finding emphasizes the critical importance of tailoring dehydration management strategies to the specific vulnerabilities of different age groups, particularly recognizing the unique physiological and nutritional needs of infants.

Gender, however, did not exhibit a preferential association with either hyponatremia or hypernatremia in the current study. Instead, the type of ORS administered emerged as a significant factor influencing sodium disturbances. The higher incidence of hyponatremia in children receiving diluted World Health Organization (WHO) ORS (82.60%) and the increased prevalence of hypernatremia in those administered concentrated WHO ORS (80%) underscore the importance of adhering to appropriate ORS dilution protocols. These findings emphasize the critical role of healthcare providers in ensuring accurate and safe administration of oral rehydration therapy to prevent electrolyte imbalances in pediatric patients with diarrhea.¹⁶ The socioeconomic dimension revealed that more than half of the children in the study belonged to lower socioeconomic groups, reflecting the broader societal challenges associated with poor sanitation, unhygienic practices, and limited access to education and resources. This observation underscores the multifaceted nature of diarrheal disease determinants, urging comprehensive public health interventions that address social and economic disparities to mitigate the prevalence of diarrhea in underprivileged communities. Malnutrition emerged as a prevalent concern in the study, affecting 34.5% of the children. This finding resonates with the broader global health challenge of malnutrition in vulnerable populations. Malnourished children not only experienced a prolonged hospital stay but also exhibited a higher incidence of both hyponatremia and hypernatremia.¹⁷ This correlation reinforces the intricate interplay between nutritional status and susceptibility to complications in children with diarrheal diseases. It emphasizes the imperative of integrating nutritional interventions as a crucial component of comprehensive care for pediatric patients with diarrhea. In conclusion, the expanded insights from this study further elucidate the intricate factors contributing to sodium imbalances in pediatric diarrhoea. The age-specific patterns, implications of ORS administration, socioeconomic considerations, and the intersection with malnutrition

provide a comprehensive framework for understanding and managing diarrheal diseases in diverse pediatric populations. These findings underscore the importance of tailored and holistic approaches to pediatric diarrhoea care that consider the multifaceted nature of the contributing factors.

CONCLUSION

The study findings underscore the substantial incidence of sodium disturbances, encompassing both hyponatremia and hypernatremia, in children grappling with Acute Gastroenteritis (AGE) and dehydration, reaching a notable prevalence of nearly 40%. This high frequency highlights the critical need for heightened awareness and proactive management strategies, particularly given the potential complications associated with electrolyte imbalances in this vulnerable population. Malnourished children emerged as a particularly susceptible group, carrying a significantly higher risk of developing hyponatremia in the context of AGE. This association underscores the intricate interplay between nutritional status and the physiological responses to gastrointestinal illnesses, emphasizing the need for tailored interventions in malnourished pediatric patients. In addition to malnutrition, the choice of oral rehydration solution (ORS) played a pivotal role in determining the risk of both hyponatremia and hypernatremia. Children administered diluted WHO ORS were found to be at a significantly higher risk of developing hyponatremia, while those receiving concentrated WHO ORS faced an increased risk of hypernatremia. This emphasizes the importance of precise and appropriate ORS administration in preventing electrolyte imbalances, advocating for adherence to established guidelines to ensure optimal patient outcomes. The clinical implications of AGE with hyponatremia or hypernatremia were also elucidated, revealing an association with a heightened risk of seizures, prolonged hospital stays, and an increased risk of mortality when compared to cases with isonatremia. These findings underscore the critical nature of electrolyte disturbances in influencing the clinical course and outcomes of pediatric patients with AGE, necessitating vigilant monitoring and timely interventions. In conclusion, the study underscores the multifaceted nature of sodium disturbances in children with AGE and dehydration. The identified risk factors, including malnutrition and ORS choice, provide valuable insights for healthcare practitioners, emphasizing the importance of tailored care strategies and vigilant monitoring to mitigate complications and enhance the overall management of pediatric patients facing AGE-associated electrolyte imbalances.

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