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Retrospective evaluation of the treatment of term newborns with hypernatraemic dehydration over the last decade

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ABSTRACT

Objectives Hypernatraemic dehydration in newborns is a significant cause of mortality and morbidity without general consensus on administering fluid therapy. The objective of the study is to evaluate the efficacy and safety of fluid therapy at different concentrations for term dehydrated hypernatraemic newborns requiring intravenous fluid therapy.

Methods Observational, retrospective cohort study was conducted in primary and secondary neonatal intensive care units of a centre between 2014 and 2023. The study included 138 eligible newborns who had a serum sodium level above 146 mmol/L. Isotonic (0.9% NaCl) and hypotonic (0.45% and 0.2% NaCl) fluids were given as a rehydration therapy. The primary outcomes were the development of hyponatraemia and/or increased hypernatraemia. The secondary outcomes were hourly sodium changes between these groups.

Results Fluid containing 0.9% NaCl was administered to 44 infants, 0.45% NaCl to 54 and 0.2% NaCl to 40 infants. The mean serum sodium levels before and after treatment were 151.7±3.3 and 149.0±5.6, 150.7±3.2 and 145.6±2.4 and 149.5±3.0 and 142.5±4.2 (mmol/L; p<0.001), respectively. The hourly sodium decrease rates were 0.08, 0.24 and 0.42 mmol/L/hour, respectively (p<0.001). The rate of clinically significant sodium decrease (>0.5 mmol/L/hour) was 6.8%, 13.0% and 42.5%, respectively (p<0.001). There was no difference between the groups in terms of mortality or morbidity.

Conclusions The study shows that hypotonic fluids were associated with a more rapid decline in serum sodium and higher proportion of infants exceeding the recommended correction rate of 0.5 mmol/L/hour than isotonic fluids, although no difference in morbidity or mortality was observed between groups.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Various fluids with different sodium concentrations are used to hydrate hypernatraemic neonates.
⇒ There is no consensus on the ideal fluid concentration for hypernatraemic dehydration in neonates.

WHAT THIS STUDY ADDS

⇒ Compared with hypotonic fluids, isotonic fluids were associated with a slower decline in serum sodium and fewer infants exceeding 0.5 mmol/L/hour in hypernatraemic newborns.
⇒ No significant difference was observed in the development of severe hypernatraemia.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Our results will provide a basis for the development of more standardised guidelines through prospective, multicentre studies on fluid therapy in infants with hypernatraemic dehydration, a frequently encountered condition.

INTRODUCTION

Maintaining fluid and electrolyte balance from the intrauterine to the postnatal period is crucial in neonatal intensive care for sustaining normal cell and organ function. One of the many important issues in the intensive care process is understanding the physiological changes related to fluid and electrolyte balance and providing appropriate support.[1 2]

Infants who have difficulty feeding may take longer to adapt to their new environment and may be more susceptible to illnesses after birth. However, there is insufficient evidence-based research on the use of maintenance intravenous fluid therapy for these infants. Studies of children older than 1 month have shown that the use of traditional hypotonic fluids may cause hyponatraemia.[3 4]

Hypernatraemia is defined as a serum sodium level of 146 mmol/L or higher. Levels between 146 and 149 mmol/L are considered mild, between 150 and 169 mmol/L are considered moderate and 170 mmol/L or higher are considered severe. Hypernatraemia is a serious condition that can result in severe, permanent neurological damage in term and preterm infants. Many physiological changes in sodium homeostasis occur

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immediately after birth. Understanding this process, predicting hypernatraemia early on and knowing how to manage it in newborns can prevent the mortality and long-term morbidity associated with this condition.[5]

Hypernatraemia-related hypertonicity shifts water from the intracellular to the extracellular space, which partially preserves intravascular volume. Therefore, in chronic hypernatraemia, typical signs of intravascular volume loss and dehydration, such as decreased blood pressure and urine output, usually do not become apparent until the late stage. These signs include restlessness, irritability, weakness, lethargy, high-pitched crying, hyperpnoea and fever. Hyperglycaemia and mild hypocalcaemia may also be observed. Due to dehydration and hypercoagulability, stroke and other thrombotic complications, such as dural sinus thrombosis, peripheral thrombosis and renal vein thrombosis, may develop. The clinical presentation can result in mortality due to venous sinus thrombosis associated with hypertonicity and cerebral oedema associated with rehydration therapy.[6]

Newborns who develop hypernatraemia in the early postnatal period mostly are associated with suboptimal breastfeeding and other nutritional issues. These infants are typically present with symptoms such as weight loss of more than 10% within 7–10 days, severe indirect hyperbilirubinaemia, irritability and insatiable hunger and thirst. However, there is no clear consensus on the appropriate fluid concentration for these newborns with hypernatraemic dehydration. According to guidelines published by the UK's National Institute for Health and Care Excellence, isotonic fluids containing 131–154 mmol/L of sodium and 5%–10% glucose are recommended for term newborns after the eighth postnatal day.[7]

Studies have shown that the incidence of hyponatraemia within the first 24 hours is higher in normonatraemic patients who receive hypotonic fluids than in those who receive isotonic fluids. Also, according to current guidelines, isotonic fluids are not expected to cause a significant increase in serum sodium levels or hypernatraemia in normonatraemic patients.[8 9] However, no studies have compared the effectiveness of hypotonic and isotonic fluids in treating hypernatraemic patients. This retrospective study aimed to evaluate the efficacy and safety of administering hypotonic and isotonic fluids to hypernatraemic infants receiving intravenous fluid therapy.

METHODS

The study was designed as a retrospective, single-centre, observational cohort study. It evaluated patients born at 37 weeks of gestation or older who were admitted to the neonatal intensive care unit (NICU) of a hospital between January 2014 and December 2023. These patients received rehydration therapy due to hypernatraemic dehydration. Hypernatraemia was defined as a serum sodium of 146 mmol/L or higher.

Written consent was obtained from patients on admission for treatment and follow-up. Daily observation notes and files are recorded in the hospital information system for patients. The information recorded includes the day, mode of delivery, birth weight, feeding method, gender, weight at admission, percentage of weight loss, systolic and diastolic blood pressure, pulse, laboratory data, serum blood urea nitrogen (BUN) (mg/dL), serum creatinine (Cr) (mg/dL), serum sodium (Na) (mmol/L), serum potassium (K) (mmol/L), serum chloride (Cl) (mmol/L), blood glucose (mg/dL), total protein (mg/dL), total cholesterol (mg/dL), blood and urine osmolality (mosm/L), urine density (g/cm^3) and spot urine Na/Cr (mg/g) ratio.

The following patients were excluded from the study: those with hypoxic-ischaemic encephalopathy, metabolic disease, severe dehydration with shock, heart or liver failure, portal hypertension with ascites, syndrome of inappropriate antidiuretic hormone secretion, renal failure, adrenal insufficiency, diabetes mellitus, diabetes insipidus, congenital anomalies, diuretic therapy, significant oedema, preoperative and postoperative conditions, total parenteral nutrition therapy, non-standard fluid content and volumes, and those not receiving fluid therapy without a second sodium measurement within the first 24 hours postnatally. Patients were grouped according to the sodium content of the fluids they received (0.9%, 0.45% and 0.2% NaCl). The total amount of intravenous fluids, patients' sodium change rates after fluid therapy, sodium changes exceeding 0.5 mmol/L/hour and treatment-related morbidity and mortality were compared between groups.

Sample size

Based on the rates of hyponatraemia detected in term infants receiving isotonic and hypotonic fluid therapy, the sample size was determined to be 42 participants per group when the effect size was set at 0.05, the power was set at 80% and the CI was set at 80%.[10]

Statistical analysis

The statistical analyses were performed using SPSS (V.26.0). The Pearson χ^2 test and Fisher's exact test were used to compare categorical variables between groups. For post hoc analysis of significance in categorical comparisons involving more than two groups, the Bonferroni correction was applied. Test results for categorical variables are presented as numbers (n) and percentages (%). The presence of a normal distribution for the continuous variables used in the study was assessed using the Kolmogorov-Smirnov and Shapiro-Wilk tests. The Mann-Whitney U test was used to compare binary groups with non-normally distributed continuous variables, and the Student's t-test was used to compare normally distributed continuous variables. The Kruskal-Wallis test was used to make nonparametric comparisons between three groups. One-way analysis of variance and the Games-Howell test were used for post hoc analyses of normally distributed

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continuous variables. The results of the tests used to evaluate continuous variables are presented as mean±SD and median (minimum–maximum). In all statistical tests, p<0.05 was considered statistically significant.

Patient and public involvement

Patients and the public were not involved in the design, conduct, reporting, or dissemination plans of this study. The research was based on retrospective analysis of clinical data from two patient groups receiving different fluid therapy regimens for hypernatraemia. As the study used routinely collected clinical data without direct patient interaction, involvement of patients or the public in setting research priorities, defining outcomes or study design was not feasible. No patients were asked to advise on interpretation or dissemination of results.

RESULTS

The study included 314 patients who received intravenous rehydration fluids for hypernatraemic dehydration in the NICU at Dokuz Eylül University Hospital between January 2014 and December 2023. These patients had a gestational age above 37 weeks and a blood sodium level above 146 mmol/L. Of these patients, 131 did not receive intravenous fluids, 27 had no second sodium measurement and 13 had congenital anomalies. Four patients had metabolic diseases and one patient had hypoxic ischaemic encephalopathy, so they were excluded from the study. Of the 138 newborn infants participating in the study, 44 received 0.9% NaCl, 54 received 0.45% NaCl and 40 received 0.2% NaCl solutions (table 1). Of those patients, 26 had jaundice and 10 were diagnosed with sepsis. There was no significant difference in these diagnoses between groups (p=0.389). No additional morbidity or mortality was detected.

The median age of the patients was determined to be 3 days (72–96 hours postnatal). Most patients were fed exclusively breast milk, while the rest received a mixture of breast milk and formula. No patients were fed formula alone. There were no differences in birth or clinical characteristics among patients at initial presentation. However, statistically significant differences in sodium values were found among groups receiving fluids containing 0.9%, 0.45% or 0.2% NaCl (151.8±3.3, 150.7±3.2 and 149.5±3.0 mmol/L, respectively). There were no differences in other laboratory data between the groups (table 1).

The study found no significant differences between groups in the median duration or amount of fluid therapy administered to infants. After treatment, serum sodium and chloride levels were significantly higher in fluids with higher NaCl concentrations. However, no significant differences were found in other electrolytes. A comparison of the hourly change in serum sodium levels at the end of treatment with the levels at the start of treatment revealed that the reduction in sodium was more rapid with hypotonic fluids, which was significant (p<0.01) (table 2).

Hyponatraemia (Na <135 mmol/L) was observed in two patients (4.5%) receiving 0.9% NaCl and one patient (2.5%) receiving 0.2% NaCl during treatment. However, no statistically significant difference was found (p=0.379).

Among patients with decreased sodium levels during treatment, those with an hourly sodium decrease rate >0.5 mmol/L/hour had the following numbers: 3 (6.8%) in the 0.9% NaCl group, 7 (13.0%) in the 0.45% NaCl group and 17 (41.5%) in the 0.2% NaCl group (p<0.001). However, among patients with increasing sodium levels during treatment, those with an hourly increase in sodium ≥0.5 mmol/L/hour showed an increase in serum

Table 1 Patients' demographic and clinical characteristics at hospital admission

Fluid type	% 0.9 NaCl, n=44	% 0.45 NaCl, n=54	% 0.2 NaCl, n=40	P value
Age (in days)	3 (2–9)	3 (2–9)	3 (2–7)	0.058
C section, n (%)	30 (68)	38 (70)	26 (65)	0.858
Birth weight (g)	3335±484	3408±466	3496±443	0.288
Male	20 (45.5)	26 (48.1)	14 (35.0)	0.416
Exclusively breastfeeding	31 (70.5)	34 (63.0)	27 (67.5)	0.730
Body weight (g)	2954±411	3043±413	3147±440	0.115
Weight loss percent after birth	11.0±3.1	10.4±2.7	9.8±3.7	0.203
HR (/min)	136±14	139±13	138±12	0.512
Serum Na (mmol/L)	151.8±3.3	150.7±3.2	149.5±3.0	0.006
Serum BUN (mg/dL)	16.8 (4.4–56.1)	17.1 (5.6–73.0)	16.4 (5.0–60.7)	0.636
Serum Cr (mg/dL)	0.82 (0.45–1.90)	0.75 (0.49–1.70)	0.77 (0.30–1.28)	0.207
Serum K (mmol/L)	4.61±0.49	4.69±0.58	4.63±0.48	0.713
Serum Cl (mmol/L)	115.57±3.20	114.17±2.81	114.08±3.10	0.060

BUN, blood urea nitrogen; Cl, chloride; Cr, creatinine; HR, heart rate; K, potassium; Na, sodium.

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Table 2 Patients' clinical characteristics at cessation of the fluid therapy

Fluid type	% 0.9 NaCl, n=44	% 0.45 NaCl, n=54	% 0.2 NaCl, n=40	P value
Initiative fluid therapy duration (hours)	20.5 (6.0–71.0)	21.0 (9.0–48.0)	19.0 (6.0–48.0)	0.235
Administered fluid volume (mL/kg/day)	120.0 (45.0–180.0)	100.0 (45.0–180.0)	90.0 (45.0–150.0)	0.057
Body weight (g)	3199±464	3231±445	3320±447	0.452
Serum Na (mmol/L)	149.02±5.60 (134.0–160.0)	145.62±2.47 (140.0–152.0)	142.50±4.16 (134.0–152.0)	<0001
Serum BUN (mg/dL)	14.2 (3.7–57.2)	16.2 (2.6–43.6)	9.3 (3.0–60.0)	0.669
Serum Cr (mg/dL)	0.63 (0.35–1.39)	0.53 (0.24–0.99)	0.69 (0.31–1.12)	0.476
Serum K (mmol/L)	4.30±0.63	4.27±0.62	4.64±0.64	0.023
Serum Cl (mmol/L)	118.63±4.84 (107.0–127.0)	115.07±3.92 (107.0–125.0)	111.94±4.56 (103.0–121.0)	<0001
Serum sodium change during therapy	0.08 (–0.50 to 1.13)	0.24 (0.02–0.78)	0.42 (–0.50 to 1.75)	<0001

BUN, blood urea nitrogen; Cl, chloride; Cr, creatinine; K, potassium; Na, sodium.

sodium ≥0.5 mmol/L/hour. When compared between groups, 1 (2.3%) and 1 (2.5%) of the patients receiving 0.2% NaCl had a serum sodium increase >0.5 mmol/L/hour, which was not significant (p=0.519).

DISCUSSION

The most common cause of hypernatraemic dehydration in newborns is inadequate nutrition and subsequent fluid loss. This study investigated the efficacy and safety of different fluid therapies in this patient group by comparing the rate of change in sodium, a key prognostic factor. In this retrospective cohort study, isotonic fluid was associated with a slower hourly decline in serum sodium and a lower proportion of infants exceeding the recommended correction rate of 0.5 mmol/L/hour (6.8% vs 13% vs 41.5% for 0.9%, 0.45% and 0.2% NaCl, respectively) However, we did not observe any difference in neurological or other morbidity, or in mortality, between groups.

Water homeostasis is maintained in the body without net movement of water between the extracellular and intracellular fluid compartments. However, fluid therapy administered in cases of hypernatraemia can rapidly decrease the sodium levels of patients. Due to the osmotic gradient, water movement also occurs between these compartments.[11 12] The increased water movement from the extracellular to the intracellular compartment can lead to oedema and associated neurological dysfunction. Therefore, sodium reduction is recommended at a rate of <0.5 mmol/L per hour and <12 mmol/L per day. In this study, sodium decrease rates exceeding 0.5 mmol/L/hour were observed 6.8% vs 13% vs 41.5%; for 0.9%, 0.45% and 0.2% NaCl, respectively. However, we did not observe any difference in neurological or other morbidity, or in mortality, between groups. These findings are consistent with isotonic fluid being associated with a more controlled decline in serum sodium, although they do not by themselves establish a difference in clinical risk.

Studies comparing the development of hyponatraemia in isotonic and hypotonic fluids have emphasised that hyponatraemia develops more commonly in hypotonic fluids, especially during the first 24 hours of fluid therapy. This difference is considered significant.[10 13 14] A study investigating the safety of isotonic fluids in children under 2 years of age with hypernatraemia reported that isotonic fluids safely decreased sodium levels within 12 hours, with a median rate of decrease of 0.33 mmol/L/hour. In our study, the median duration of fluid therapy for patients receiving isotonic fluids was 20.5 hours, with a median sodium reduction rate of 0.08 mmol/L/hour. The lower sodium decrease in our study compared with the previously published study was thought to be related to the longer treatment duration.[15] The current findings are consistent with the literature and support the idea that fluid therapy causes a faster sodium shift in the first hours and a slower shift thereafter.[8]

Amer *et al* conducted a meta-analysis of 33 randomised controlled trials evaluating the safety of isotonic and hypotonic maintenance fluids for children aged 0–18 years. The researchers found that patients who received isotonic fluids had a lower risk of experiencing mild hyponatraemia within the first 24 hours.[16] This finding supports the idea that fluid therapy poses a greater risk of dysnatraemia in this patient group during the initial stage, and that renal adaptation mitigates this risk.

The term neonatal kidney has limited concentration ability and reduced sodium handling capacity compared with that of older infants and children. Findings from older paediatric populations therefore cannot be directly extrapolated to term newborns, and the present results should be interpreted within the context of neonatal renal physiology and the predominantly breastfeeding-associated aetiology of hypernatraemia in this cohort.

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This study has several limitations. It was retrospective and non-randomised. Even though the local clinical protocol had been used for choice of fluid, it was not assigned by a standardised clinical trial protocol. Although there was no difference from clinical aspects between baseline serum sodium levels, they differed between groups, which limits attribution of the observed differences solely to fluid tonicity. Serum sodium was not measured at fixed hourly intervals from the start of therapy, so the hourly rate of change was estimated between two time points. Finally, the absence of differences in morbidity and mortality may reflect limited statistical power rather than true clinical equivalence.

In the study, sodium levels increased in 3 out of 44 patients who received isotonic fluids, but this increase was not statistically significant (6.8%, p=0.133). Examination of these patients revealed that their sodium levels were mildly hypernatraemic prior to treatment. It was also observed that the early increase in sodium was not at a rate that presented a neurological risk, and that the hypernatraemia resolved without progressing to a moderate-to-severe level.

During the early neonatal period, renal maturation and the glomerular filtration rate are low. However, as postnatal age increases, the glomerular filtration rate, as well as hormonal and renal maturity, also increase. These factors maintain sodium homeostasis.[17 18] The absence of clinically significant hypernatraemia in patients receiving isotonic fluids and the similarity in sodium changes after the 24th hour of treatment with different fluid types suggest this physiological adaptation. However, as the study excluded patients with renal and metabolic diseases that affect the physiological adaptation mechanisms maintaining fluid-electrolyte balance, these findings should not be generalised to the entire patient population. Isotonic fluids are considered safe for malnourished patients who primarily experience fluid loss.

In the study, the difference in observed sodium changes between groups may be attributed to the amount of fluid administered to patients. However, although the amount of fluid therapy administered to the groups was the same, the difference in sodium administration suggests that this difference is more likely due to sodium concentration than fluid volume. Moritz *et al* emphasised that, when administered in the presence of hypovolaemia, isotonic fluid is retained until volume loss is corrected and does not cause a significant decrease in serum sodium. Once volume loss has been corrected, further fluid administration will result in natriuresis, producing free water to prevent hypernatraemia.[19] These results support the notion that sodium concentration, rather than fluid volume, plays a role in regulating sodium changes.

The patients in this study had mild to moderate hypernatraemia and experienced no adverse effects from isotonic fluid therapy. Prospective, randomised, controlled, multicentre trials, stratified by sodium levels, are needed to predict how physiological adaptation occurs in newborns with different levels of hypernatraemia.

CONCLUSION

The use of isotonic fluids is limited due to concerns that hypernatraemia may develop more rapidly in newborns, potentially leading to complications related to the physiological adaptation mechanisms that occur during the early period. However, this study demonstrates that, contrary to conventional wisdom, hypotonic fluids traditionally used to treat neonatal hypernatraemic dehydration can cause clinically significant decreases in serum sodium levels. Therefore, isotonic fluids are more appropriate for these infants.

Contributors UU, CA and HO conceived and designed the study. UU and CA performed the data analysis, and CA interpreted the results. CA drafted the manuscript. ND and FE critically revised the manuscript for important intellectual content. HO provided final approval of the manuscript. All authors read and approved the final version of the manuscript. CA is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the analysis. AI (ChatGPT) was used only to translate into English.

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Patient consent for publication Not applicable.

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Data availability statement Data are available upon reasonable request.

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REFERENCES

1 Malbrain MLNG, Langer T, Annane D, *et al*. Intravenous fluid therapy in the perioperative and critical care setting: Executive summary of the International Fluid Academy (IFA). *Ann Intensive Care* 2020;10:64.
2 HOLLIDAY MA, SEGAR WE. The maintenance need for water in parenteral fluid therapy. *Pediatrics* 1957;19:823–32.
3 Foster BA, Tom D, Hill V. Hypotonic versus isotonic fluids in hospitalized children: a systematic review and meta-analysis. *J Pediatr* 2014;165:163–9.
4 Wang J, Xu E, Xiao Y. Isotonic Versus Hypotonic Maintenance IV Fluids in Hospitalized Children: A Meta-Analysis. *Pediatrics* 2014;133:105–13.
5 Durrani NUR, Imam AA, Soni N. Hypernatremia in Newborns: A Practical Approach to Management. *Biomed Hub* 2022;7:55–69.
6 Bischoff AR, Dornelles AD, Carvalho CG. Treatment of Hypernatremia in Breastfeeding Neonates: A Systematic Review. *Biomed Hub* 2017;2:1–10.
7 Intravenous fluid therapy in children and young people in hospital NICE guideline, 2020. Available: https://www.nice.org.uk/guidance/ng29 [Accessed 26 Nov 2023].
8 Ozkan H, Duman N, Tuzun F, *et al*. The efficacy and safety of isotonic and hypotonic fluids in intravenous maintenance fluid therapy in term newborns: national multicenter observational "neofluid" study. *Front Nutr* 2024;11:1410571.

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9 Tuzun F, Akcura Y, Duman N, *et al*. Comparison of isotonic and hypotonic intravenous fluids in term newborns: is it time to quit hypotonic fluids. *J Matern Fetal Neonatal Med* 2022;35:356–61.
10 Balasubramanian K, Kumar P, Saini SS, *et al*. Isotonic versus hypotonic fluid supplementation in term neonates with severe hyperbilirubinemia – a double-blind, randomized, controlled trial. *Acta Paediatr* 2012;101:236–41.
11 Kelly LK, Seri I. Renal Developmental Physiology. *Neoreviews* 2008;9:e150–61.
12 Vieux R, Hascoet JM, Merdariu D, *et al*. Glomerular filtration rate reference values in very preterm infants. *Pediatrics* 2010;125:e1186–92.
13 Dathan K, Sundaram M. Comparison of isotonic versus hypotonic intravenous fluid for maintenance fluid therapy in neonates more than or equal to 34 weeks of gestational age - a randomized clinical trial. *J Matern Fetal Neonatal Med* 2022;35:6338–45.
14 Neville KA, Verge CF, Rosenberg AR, *et al*. Isotonic is better than hypotonic saline for intravenous rehydration of children with gastroenteritis: a prospective randomised study. *Arch Dis Child* 2006;91:226–32.
15 Ben-Shalom E, Toker O, Schwartz S. Hypernatremic Dehydration in Young Children: Is There a Solution? *Isr Med Assoc J* 2016;18:95–9.
16 Amer BE, Abdelwahab OA, Abdelaziz A, *et al*. Efficacy and safety of isotonic versus hypotonic intravenous maintenance fluids in hospitalized children: an updated systematic review and meta-analysis of randomized controlled trials. *Pediatr Nephrol* 2024;39:57–84.
17 Joppich R, Weber P, Kiemann U, *et al*. Effects of ADH on the activity and function of the renin-angiotensin-aldosterone system in infants and in children. *Eur J Pediatr* 1976;122:303–8.
18 Wang H, He Z, Li J, *et al*. Early Plasma Osmolality Levels and Clinical Outcomes in Children Admitted to the Pediatric Intensive Care Unit: A Single-Center Cohort Study. *Front Pediatr* 2021;9.
19 Moritz ML, Manole MD, Bogen DL, *et al*. Breastfeeding-associated hypernatremia: are we missing the diagnosis? *Pediatrics* 2005;116:e343–7.

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