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Systematic Review

Balanced crystalloids versus normal saline for fluid therapy in pediatrics diabetic ketoacidosis: a systematic review

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ABSTRACT

Fluid therapy is a cornerstone of management in paediatric diabetic ketoacidosis (DKA). Although normal saline has traditionally been the preferred resuscitation fluid, concerns regarding hyperchloremic metabolic acidosis have led to increasing interest in balanced crystalloids such as Ringer's lactate and Plasma-lyte. However, evidence regarding their efficacy and safety in children with DKA remains limited and has not been comprehensively synthesized. A systematic review of the literature was conducted to evaluate balanced crystalloids versus normal saline for fluid therapy in paediatric DKA. PubMed/MEDLINE, Embase, Scopus, Web of Science, and the Cochrane central register of controlled trials were searched from database inception to March 2026. Randomized controlled trials and comparative observational studies involving children and adolescents with DKA were included. Outcomes of interest included time to DKA resolution, resolution of acidosis, incidence of hyperchloremia, serum bicarbonate recovery, incidence of acute kidney injury (AKI), cerebral edema and duration hospital stay. Four comparative studies involving 49,920 paediatric patients were included in this systematic review. Out of these studies three were randomized controlled trials and one was retrospective observational study. Balanced crystalloids were consistently found to be associated with lower chloride accumulation, decreased incidence of hyperchloremia and improved bicarbonate recovery as compared to cases treated by normal saline. DKA and acidosis resolution demonstrated a trend toward earlier metabolic recovery with balanced crystalloids. No clear difference was observed in the incidence of AKI, intensive care unit stay, or hospital stay between treatment groups. One large observational study reported a lower rate of cerebral edema among children receiving Ringer's lactate compared with normal saline. Balanced crystalloids appear to be safe and effective alternatives to normal saline for fluid therapy in paediatric DKA. They are associated with favorable clinical and biochemical outcomes specially with respect to chloride homeostasis and bicarbonate recovery. Larger multicenter randomized controlled trials are required to confirm these findings and determine their impact on clinically important outcomes.

Keywords: Diabetic ketoacidosis, Pediatrics DKA, Balanced crystalloids, Ringer's lactate, Plasma-lyte, Normal saline, Hyperchloremia, Acute kidney injury

INTRODUCTION

Diabetic ketoacidosis (DKA) remains one of the most serious acute complications of type 1 diabetes mellitus (T1DM) in children and adolescents and continues to be associated with significant morbidity and mortality in some cases.[1] Despite advances in diabetes care, DKA accounts for a substantial proportion of paediatric intensive care admissions and is frequently the initial presentation of T1DM particularly in developing countries. Pediatrics DKA is characterized by severe dehydration, hyperglycemia, ketosis and metabolic acidosis.[2] All these metabolic derangements require prompt fluid resuscitation and meticulous metabolic correction. Delayed diagnosis and inadequate management of DKA can result in serious complications including life-

threatening complications such as cerebral edema, acute kidney injury (AKI), arrhythmias and even mortality. Fluid therapy therefore remains the cornerstone of DKA management. It is not only aimed at restoring circulatory volume but also at improving tissue perfusion, correcting electrolyte abnormalities and facilitating clearance of ketone bodies.[3]

Normal saline (NS; 0.9% sodium chloride) has traditionally been used as the preferred intravenous fluid for resuscitation and deficit correction in children presenting with DKA. Current international guidelines, including those from the international society for pediatrics and adolescent diabetes (ISPAD), continue to support the use of isotonic saline during the initial phase of DKA management.[4] However, concerns regarding the high chloride content of NS and its contribution to hyperchloremic metabolic acidosis have increasingly attracted the attention of researchers in recent years. Administration of large volumes of chloride-rich crystalloids may aggravate acidosis, delay normalization of bicarbonate levels and prolong insulin infusion requirements.[5] All these factors may potentially extend paediatric intensive care unit (PICU) stay. Hyperchloremia has additionally been implicated in renal vasoconstriction, reduced glomerular filtration and increased risk of AKI in critically ill children. Since children with DKA usually present with severe dehydration that requires correction by substantial fluid replacement, the type of crystalloid administered may significantly influence metabolic recovery and clinical outcomes.[6]

Balanced crystalloids such as Ringer's lactate (RL) have emerged as potential alternatives to NS in critically ill children presenting with DKA because of their lower chloride concentration and more physiologic electrolyte composition.[7] RL contains lactate ions that are metabolized in the liver to bicarbonate, which contributes to correction of metabolic acidosis. Compared with NS, RL has a lower chloride concentration (110 mEq/l versus 154 mEq/l), thereby reducing the risk of hyperchloremia and acid-base disturbances. Several adult critical care studies have demonstrated favorable renal and metabolic outcomes with balanced crystalloids when compared to chloride-rich solutions. In patients with DKA, balanced crystalloids have been associated with earlier resolution of acidosis.[8] Balanced crystalloids have also been associated with a lower incidence of hyperchloremia and a shorter duration of intravenous insulin therapy. The physiologic rationale supporting the use of RL in DKA management is therefore compelling, particularly in paediatric patients who are more susceptible to electrolyte shifts and cerebral complications.[9]

Some randomized trials have demonstrated reduced frequency of hyperchloremia and faster correction of acidosis with balanced fluids, while others did not report significant differences in time to DKA resolution. More recently, studies from developing countries have suggested that RL may reduce PICU stay and improve biochemical recovery in children with severe DKA. In resource-limited settings, where delayed presentation and severe metabolic derangements are common, minimizing treatment-related hyperchloremia may be particularly important.[10] In addition to ringer's lactate, other balanced crystalloids such as Hartmann's solution and Plasma-lyte have also been evaluated in paediatric DKA and have demonstrated potential benefits with respect to acid-base balance and renal outcomes. Many paediatric studies have indicated possible reductions in complications such as AKI and cerebral edema with balanced crystalloid use. Nevertheless, the available literature in children remains relatively sparse, and there is no universal consensus regarding the ideal crystalloid for fluid resuscitation in paediatric DKA.

Because of possibility of hyperchloremic acidosis associated with normal saline and the increasing interest in balanced crystalloids for paediatric DKA management there is a need to evaluate available evidence. Although several randomized and observational studies have compared balanced crystalloids with normal saline in children with DKA the findings have been inconsistent d. Furthermore, important clinical outcomes such as time to DKA resolution, incidence of acute kidney injury and duration of intensive care stay have not been systematically synthesized in the paediatric population. Therefore, the present systematic review was undertaken to evaluate the efficacy and safety of balanced crystalloids compared with normal saline in children with DKA.

METHODS

Study design and reporting guidelines

This systematic review was conducted for evaluating the efficacy as well as safety of balanced crystalloids as compared to normal saline for fluid therapy in paediatric DKA. The methodology included a comprehensive literature search followed by study selection based on predefined eligibility criteria, risk of bias assessment and qualitative synthesis of the available published evidence. The review protocol was developed a priori to ensure methodological rigor and to minimize the risk of selection and reporting bias.

Eligibility criteria

Studies were considered eligible for inclusion if they enrolled children and adolescents (aged <18 years) diagnosed with DKA according to established diagnostic criteria and compared balanced crystalloids, including Ringer's lactate, Hartmann's solution, or Plasma-lyte, with 0.9% normal saline for intravenous fluid therapy. Randomized controlled trials and comparative observational studies reporting at least one relevant clinical or biochemical outcome were included. Eligible outcomes comprised time to DKA resolution, time to resolution of acidosis, incidence of hyperchloremia, change in serum bicarbonate levels, acute kidney injury,

cerebral edema, duration of paediatric intensive care unit stay, and length of hospital stay. Studies conducted exclusively in adults, non-comparative studies, case reports, case series, review articles, editorials, letters, and animal studies were excluded. Conference or research abstracts were considered eligible for inclusion if they provided sufficient methodological details and extractable outcome data for qualitative synthesis.

Literature search strategy

A comprehensive literature search was conducted to identify studies that evaluated balanced crystalloids versus normal saline in paediatric DKA. The electronic databases PubMed/MEDLINE, Embase, Scopus, Web of Science, and the cochrane central register of controlled trials (CENTRAL) were searched from database inception to March 2026. The search strategy incorporated combinations of medical subject headings (MeSH) terms and free-text keywords including "diabetic ketoacidosis," "DKA," "children," "paediatric," "Ringer's lactate," "Hartmann's solution," "Plasma-lyte," "balanced crystalloids," and "normal saline". Boolean operators (AND, OR) were used as appropriate to optimize retrieval. In addition, the reference lists of all eligible studies and relevant review articles were manually screened to identify any additional studies not captured during the electronic database search. No restrictions were placed on publication status, and conference abstracts were considered for inclusion when sufficient data were available for extraction.

Study selection

All records identified through the database search and manual reference screening were imported into a reference management software, and duplicate records were removed. Two reviewers independently screened the titles and abstracts of all retrieved studies for potential eligibility. Full-text articles of potentially relevant studies were subsequently assessed against the predefined inclusion and exclusion criteria. Disagreements were resolved through discussion and consensus between reviewers. Conference abstracts were also evaluated for eligibility and were included when sufficient methodological details as well as outcome data were available for analysis. The study selection process was documented using PRISMA 2020 flow diagram.

Data extraction

Data extraction was performed independently by two reviewers using a standardized data collection form. The following information was extracted from each eligible study: first author, year of publication, country of origin, study design, sample size, participant characteristics, type of balanced crystalloid used, comparator fluid, diagnostic criteria for diabetic ketoacidosis, and reported clinical and biochemical outcomes. Outcome data extracted included time to DKA resolution, time to resolution of acidosis, incidence of hyperchloremia, change in serum bicarbonate levels, acute kidney injury, cerebral edema, duration of paediatric intensive care unit stay, and length of hospital stay. Any discrepancies in data extraction were resolved through discussion and consensus.

Quality assessment and risk of bias assessment

The methodological quality and risk of bias of the included studies were meticulously assessed by two reviewers independently. Randomized controlled trials were evaluated using the Cochrane Risk of Bias 2 (RoB 2) tool, which mainly assesses bias arising out of randomization process, deviations from intended interventions and selection of reported results. Comparative observational studies were assessed using the Newcastle-Ottawa scale (NOS). Based on the predefined criteria of the respective assessment tools, studies were categorized as having low, moderate, or high risk of bias. Any disagreements during quality assessment were resolved through discussion and consensus.

Statistical analysis

A descriptive synthesis of the included studies was performed. Clinical and methodological characteristics of the included studies were summarized in tables and narratively reviewed. Owing to the limited number of studies, variability in outcome definitions, and differences in reporting formats, quantitative pooling of results was not feasible. Outcomes including time to DKA resolution, resolution of acidosis, hyperchloremia, change in serum bicarbonate levels, acute kidney injury, cerebral edema, and duration of intensive care unit and hospital stay were therefore summarized descriptively.

RESULTS

A total of 846 records were identified through database search. After removal of 285 duplicate records, 561 unique records underwent title and abstract analysis. Following exclusion of 508 records, 53 full-text articles were assessed for eligibility. Forty-nine articles were excluded for predefined reasons. Four studies met the inclusion criteria and were included in the systematic review (Figure 1).

A total of four comparative studies involving paediatric patients with diabetic ketoacidosis were included in the systematic review. Among these, three were randomized controlled trials and one was found to be retrospective observational study. The studies were published between 2018 and 2025. Two studies compared Ringer's lactate with normal saline, one study compared Plasma-lyte-a with normal saline, and one observational study evaluated the use of Ringer's lactate versus normal saline in routine clinical practice. The sample size of the included studies varied considerably, ranging from 50 participants in randomized controlled trials to 49,737 participants in the retrospective observational study. The reported outcomes

included time to DKA resolution, resolution of acidosis, hyperchloremia, serum bicarbonate levels, acute kidney injury, cerebral edema, and duration of PICU and hospital stay. The detailed characteristics of the included studies are presented in Table 1.

The risk of bias of the included studies was assessed using the Cochrane risk of bias 2 tool for randomized controlled trials and the Newcastle–Ottawa scale for the observational study. Overall, the randomized controlled trials were judged to have a low to moderate risk of bias, while the observational study was considered to be of good methodological quality. The detailed risk of bias assessment is presented in Figure 2.

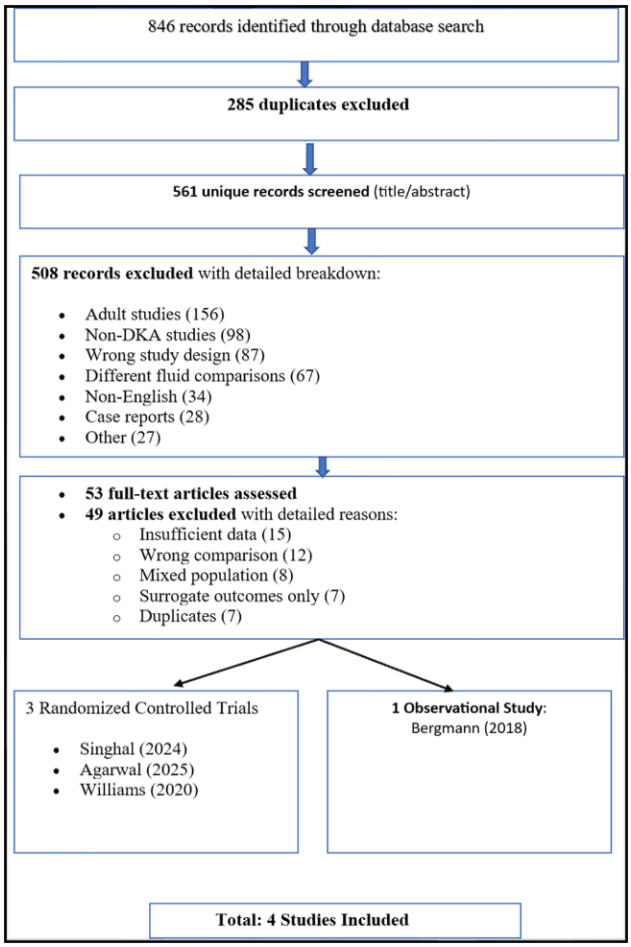

Figure 1: PRISMA flow diagram illustrating the study selection process for the systematic review.

Data regarding time to DKA resolution were available from two of the four included studies. Agarwal et al reported a shorter mean time to DKA resolution in children treated with Ringer's lactate compared with normal saline. Similarly, Williams et al observed a numerically shorter median time to DKA resolution in the Plasma-lyte-A group than in the normal saline group. The remaining two studies did not report time to DKA resolution as an outcome. Due to differences in the format of reported data and limited availability of comparable outcome measures, the available evidence was summarized narratively (Table 2).

Figure 2: Summary of risk of bias assessment of the included studies. Randomized controlled trials were assessed using the Cochrane risk of bias 2 tool, while the observational study was evaluated using the Newcastle-Ottawa scale.

Time to acid resolution

Time to acidosis resolution was reported by Singhal et al in a randomized controlled trial comparing ringer's lactate with normal saline in children with DKA.[13] The median time to resolution of acidosis was 8 (4-10) hours in the ringer's lactate group compared with 12 (4-18) hours in the normal saline group. Although the difference did not reach statistical significance (p=0.16), a trend toward earlier correction of acidosis was observed with ringer's lactate. The remaining included studies did not specifically report time to acidosis resolution as a separate outcome; therefore, the available evidence was summarized narratively.

Hyperchloremia

Hyperchloremia was evaluated in two included studies. Singhal et al reported a significantly higher incidence of hyperchloremia among children receiving normal saline compared with those receiving Ringer's lactate.[13] Similarly, Agarwal et al demonstrated a greater rise in serum chloride concentrations in the normal saline group at both 4- and 8-hours following initiation of therapy.[14] At 4 hours, the mean increase in chloride concentration was 8.7±5.6 mmol/l in the normal saline group compared with 3.9±5.1 mmol/l in the ringer's lactate group. At 8 hours, the corresponding increases were 10.8±7.7 mmol/l and 4.4±8.3 mmol/l, respectively.

Collectively, these findings suggest that balanced crystalloids are associated with reduced risk of hyperchloremia compared as compared to normal saline in cases of paediatric DKA.

Change in bicarbonate levels

Change in serum bicarbonate levels was reported by Agarwal et al.[14] In this study, the rise in bicarbonate concentration at 8 hours was 11.8±3.1 mmol/l in the Ringer's lactate group and 10.6±3.3 mmol/l in the normal saline group. At 12 hours, the rise in bicarbonate was significantly higher in the Ringer's lactate group compared with the normal saline group, 14.7±1.6 mmol/l versus 12.9±3.1 mmol/l, respectively. The remaining included studies did not provide extractable bicarbonate change data suitable for comparison (Table 5).

Acute kidney injury

Acute kidney injury was evaluated in three of the included studies. Williams et al reported that there was no significant difference in the incidence of new or progressive AKI between the Plasma-lyte-A and normal saline groups. The authors reported AKI occurring in 13 of 34 patients and 15 of 32 patients, respectively. Singhal et al also assessed AKI and reported comparable rates between the Ringer's lactate and normal saline groups.

Agarwal et al reported that new-onset or progressive AKI occurred in 2 of 34 children (6%) in the normal saline group and in none of the 33 children receiving ringer's lactate. All cases of AKI resolved with hydration, and no child required renal replacement therapy. It can be concluded that available evidence does not suggest a clear difference in the incidence of AKI between balanced crystalloids and normal saline in paediatric diabetic ketoacidosis (Table 6).

Cerebral edema

Only Bergmann et al evaluated cerebral edema as an outcome. In this large retrospective observational study, the rate of cerebral edema was 12.7 per 1000 episodes among patients receiving Ringer's lactate compared with 34.6 per 1000 episodes among those receiving normal saline.

Although these findings suggest a lower incidence of cerebral edema with balanced crystalloids, comparable data were unavailable from the remaining studies (Table 7).

Intensive care unit and hospital stay

Data regarding intensive care unit (ICU/PICU) stay and overall hospital stay were reported in selected studies. Singhal et al reported a significantly longer PICU stay among children receiving normal saline compared with those treated with Ringer's lactate. Williams et al reported a median ICU stay of 48 (48-60) hours in the Plasma-lyte-A group and 47 (24-54) hours in the normal saline group. The same study reported a median hospital stay of 9 (8-12) days in the Plasma-lyte-A group compared with 10 (8.25-11) days in the normal saline group. Bergmann et al evaluated hospital length of stay in a large observational cohort and found no significant difference between patients receiving Ringer's lactate and those receiving normal saline. Due to differences in study design, outcome definitions, and reporting formats, the available evidence was summarized narratively (Table 8).

Table 1: Characteristics of included studies.

Study	Country	Study design	Age group	Sample size (n)	Intervention	Compar-ator	Main outcomes reported
Bergmann et al (2018)[11]	USA	Retrospective observational study	0–17 years	49,737	Ringer's lactate	Normal saline	Length of stay, cerebral edema, hospital cost
Williams et al (2020)[12]	India	Double-blind randomized controlled trial	>1 month–12 years	66	Plasma-lyte-A	Normal saline	AKI, DKA resolution, PICU stay, hospital stay
Singhal et al (2024)[13]	India	Triple-blind randomized controlled trial	6 months–18 years	50	Ringer's lactate	Normal saline	Resolution of acidosis, hyperchloremia, AKI, PICU stay
Agarwal et al (2025)[14]	India	Double-blind randomized controlled trial	9 months–12 years	67	Ringer's lactate	Normal saline	DKA resolution, chloride change, bicarbonate change, AKI

Table 2: Time to DKA resolution in included studies.

Study	Balanced crystalloid group	Normal saline group	Outcome
Agarwal et al (2025)[14]	12.9±7.9 hours	16.8±9.0 hours	Shorter time to DKA resolution with Ringer's lactate

Continued.

Study	Balanced crystalloid group	Normal saline group	Outcome
Williams et al (2020)[12]	14.5 (12-20) hours	16 (8-20) hours	Numerically shorter time to DKA resolution with plasma-lyte-A
Singhal et al (2024)[13]	-	-	Time to DKA resolution not reported (study reported time to acidosis resolution)
Bergmann et al (2018)[11]	-	-	Time to DKA resolution not evaluated

Table 3: Time to acidosis resolution in included studies.

Study	Balanced crystalloid group	Normal saline group	Outcome
Singhal et al (2024)[13]	8 (4-10) hours	12 (4-18) hours	Trend toward earlier acidosis resolution with Ringer's lactate
Agarwal et al (2025)[14]	-	-	Time to acidosis resolution not reported separately
Williams et al (2020)[12]	-	-	Time to acidosis resolution not reported separately
Bergmann et al (2018)[11]	-	-	Outcome not evaluated

Table 4: Hyperchloremia and changes in serum chloride among included studies.

Study	Balanced crystalloid group	Normal saline group	Findings
Singhal et al (2024)[13]	Lower incidence of hyperchloremia	Higher incidence of hyperchloremia	Significantly greater hyperchloremia with normal saline
Agarwal et al (2025)[14]	Chloride rise at 4 hours: 3.9±5.1 mmol/l; chloride rise at 8 hours: 4.4±8.3 mmol/l	Chloride rise at 4 hours: 8.7±5.6 mmol/l; chloride rise at 8 hours: 10.8±7.7 mmol/l	Greater chloride accumulation with normal saline

Table 5: Change in serum bicarbonate levels.

Study	Balanced crystalloid group	Normal saline group	Findings
Agarwal et al (2025) [14]	8 hours: 11.8±3.1 mmol/l; 12 hours: 14.7±1.6 mmol/l	8 hours: 10.6±3.3 mmol/l; 12 hours: 12.9±3.1 mmol/l	Greater bicarbonate rise with Ringer's lactate, especially at 12 hours

Table 6: Acute kidney injury in included studies.

Study	Balanced crystalloid group	Normal saline group	Findings
Williams et al (2020)[12]	13/34 patients with AKI	15/32 patients with AKI	No significant difference between groups
Singhal et al (2024)[13]	Exact event data not available	Exact event data not available	AKI incidence reported to be comparable between groups
Agarwal et al (2025)[14]	0/33 patients with new-onset/progressive AKI	2/34 patients with new-onset/progressive AKI	Numerically fewer AKI events with Ringer's lactate
Bergmann et al (2018)[11]	-	-	Outcome not reported

Table 7: Cerebral edema reported by Bergmann et al.

Study	Balanced crystalloid group	Normal saline group	Findings
Bergmann et al (2018)[11]	12.7 per 1000 episodes	34.6 per 1000 episodes	Lower rate of cerebral edema with Ringer's lactate

Table 8: Intensive care unit and hospital stay in included studies.

Study	Outcome	Balanced crystalloid group	Normal saline group	Findings
Singhal et al (2024)[13]	PICU stay	Shorter PICU stay	Longer PICU stay	Significantly longer PICU stay with normal saline
	ICU stay	48 (48-60) hours	47 (24-54) hours	No significant difference reported

Continued.

Study	Outcome	Balanced crystalloid group	Normal saline group	Findings
Williams et al (2020) [12]	Hospital stays	9 (8-12) days	10 (8.25-11) days	Comparable hospital stays between groups
Bergmann et al (2018)[11]	Hospital stays	-	-	No significant difference in length of stay

DISCUSSION

The present systematic review evaluated the available evidence comparing balanced crystalloids with normal saline for fluid therapy in paediatric DKA. Four comparative studies were included, comprising three randomized controlled trials and one large observational study. Overall, the available evidence suggests that balanced crystalloids, including Ringer's lactate and Plasma-lyte, provide clinical outcomes comparable to normal saline while offering potential biochemical advantages, particularly with respect to acid-base balance and chloride homeostasis. Across the included studies, balanced crystalloids were associated with lower chloride accumulation, improved bicarbonate recovery, and a trend toward earlier resolution of ketoacidosis.[11-14] The current findings are also consistent with contemporary DKA management guidelines and previous investigations evaluating balanced crystalloid solutions in critically ill patients.[15,16]

Resolution of DKA and correction of metabolic acidosis remain the primary therapeutic goals in the management of paediatric DKA. In the present review, Agarwal et al reported a shorter mean time to DKA resolution among children treated with ringer's lactate compared with normal saline, while Williams et al observed a numerically shorter median time to DKA resolution with Plasma-lyte-A.[12,14] Similarly, Singhal et al demonstrated a trend toward earlier resolution of acidosis in children receiving Ringer's lactate.[13] Although quantitative synthesis was not feasible because of differences in outcome reporting, the overall direction of effect was consistent across studies. These findings are biologically plausible because balanced crystalloids more closely resemble plasma electrolyte composition and avoid the excessive chloride load associated with normal saline. Previous studies in adult DKA have similarly demonstrated faster correction of acidosis and earlier metabolic recovery with balanced crystalloid solutions.[17,18]

One of the most consistent findings of this review was the reduced occurrence of hyperchloremia with balanced crystalloids. Singhal et al reported higher incidence of hyperchloremia among children receiving normal saline.[13] Additionally, Agarwal et al demonstrated substantially greater increases in serum chloride concentrations at both four and eight hours in the normal saline group.[14] Hyperchloremia has emerged as an important concern during DKA management because it may contribute to persistent metabolic acidosis despite adequate suppression of ketogenesis. Administration of large volumes of chloride-rich fluids can result in hyperchloremic metabolic acidosis, potentially delaying biochemical recovery and prolonging insulin therapy. Similar observations have been reported in critically ill adults, where balanced crystalloids have consistently been associated with lower chloride accumulation and improved acid-base status compared with normal saline.[19,20,22]

The findings regarding serum bicarbonate recovery further support the physiologic advantages of balanced crystalloids. Agarwal et al demonstrated a greater rise in serum bicarbonate levels among children treated with ringer's lactate, particularly at 12 hours following initiation of therapy.[14] Restoration of bicarbonate concentration is an important marker of recovery from ketoacidosis and reflects correction of the underlying metabolic disturbance. The lactate component of Ringer's lactate undergoes hepatic metabolism to bicarbonate, thereby contributing to correction of acidosis without exposing patients to excessive chloride loads. These observations are consistent with established pathophysiologic principles and current guideline recommendations regarding fluid management in DKA.[15,16]

AKI is a common complication of paediatric DKA and is primarily related to severe dehydration, renal hypoperfusion, and metabolic derangements. Three studies in the present review evaluated AKI outcomes. Williams et al reported that there was no significant difference in the incidence of AKI between Plasma-lyte-A and normal saline.[12] Singhal et al similarly reported comparable AKI rates between treatment groups.[13] Agarwal et al reported no cases of new-onset or progressive AKI in children receiving ringer's lactate, compared with two cases in the normal saline group.[14] Although balanced crystalloids have been associated with improved renal outcomes in several critical care settings, the currently available paediatric DKA evidence remains insufficient to demonstrate a clear renal benefit. Large observational and randomized studies in critically ill adults have suggested that chloride-restrictive fluid strategies may reduce the risk of kidney injury; however, whether these findings can be extrapolated to children with DKA remains uncertain.[20-23]

Cerebral edema remains the most feared complication of paediatric DKA because of its association with substantial morbidity and mortality.[24,25]Among the studies included in this review, only Bergmann et al evaluated cerebral edema as a predefined outcome.[11] The authors reported a lower rate of cerebral edema among patients receiving ringer's lactate compared with those receiving normal saline. Although these findings are encouraging, the

observational design of the study limits causal inference. Furthermore, cerebral edema is a relatively uncommon event, and none of the randomized trials were adequately powered to evaluate differences in this outcome.

As far as hospital and ICU stay was concerned Singhal et al reported a significantly shorter PICU stay among children treated with ringer's lactate, whereas Williams et al found no meaningful difference in ICU stay or overall hospital stay between balanced crystalloids and normal saline.[12,13] Similarly, Bergmann et al reported that there was no statistically significant difference in length of hospital stay between groups.[11] Variability in severity of DKA as well as discharge protocol may account for these inconsistent findings. Therefore, it must be emphasized that while balanced crystalloids may improve biochemical recovery in cases of DKA current evidence does not conclusively demonstrate reductions in intensive care or hospital utilization.

The present review has several strengths. It focused exclusively on paediatric patients presenting with DKA and incorporated evidence from both randomized controlled trials as well as observational studies. Nevertheless, certain limitations should be acknowledged. The number of available paediatric studies was small, and two included studies were available only as abstracts. Variability in outcome definitions and reporting methods limited opportunities for quantitative synthesis. In addition, several outcomes were reported by only a single study, reducing the certainty of available evidence. These limitations highlight the need for larger multicenter randomized controlled trials comparing balanced crystalloids with normal saline in paediatric DKA.

CONCLUSION

The findings of this systematic review suggest that balanced crystalloids including Ringer's lactate and Plasma-lyte are safe as well as effective alternatives to normal saline for fluid therapy in cases of paediatric DKA. As compared to normal saline balanced crystalloids were consistently associated with lower chances of chloride accumulation, reduced incidence of hyperchloremia and improved bicarbonate recovery. There was a trend toward earlier resolution of ketoacidosis in children receiving Ringer's lactate and Plasma-lyte as compared to normal saline. Available evidence did not demonstrate a clear difference in the incidence of acute kidney injury, intensive care unit stay or duration of hospital stay between the two fluid strategies. A lower rate of cerebral edema was reported in one large observational study however current evidence remains insufficient to establish a definitive protective effect. Overall, balanced crystalloids were found to offer biochemical advantages over normal saline without compromising clinical outcomes. Therefore, balanced crystalloids may represent a reasonable alternative to normal saline for fluid management in paediatric DKA. However, the limited number of paediatric studies and heterogeneity in outcome reporting makes it imperative that larger, high-quality multicenter randomized controlled trials be undertaken to confirm these findings and determine their impact on clinically important outcomes.

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