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RESEARCH

Bridging the Gap in Pediatric Diabetic Ketoacidosis: Insights from Indonesia and Pathways to Sustainability

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ABSTRACT

PURPOSE: To evaluate the clinical characteristics, outcomes, and key biomarkers associated with paediatric diabetic ketoacidosis (DKA) in Indonesia and propose evidence-based pathways towards sustainable care.

DESIGN/METHODOLOGY/APPROACH: A retrospective cross-sectional analysis was conducted at a tertiary hospital in Medan, Indonesia. Clinical and laboratory data were extracted from the medical records of all paediatric patients (aged 1–18 years) diagnosed with DKA over a 5-year period. Clinical data collection included demographic characteristics, clinical presentation (symptoms, vital signs), and laboratory investigations (blood gas analysis, blood glucose, serum electrolytes, and C-peptide levels). Severity classification was based on pH and bicarbonate levels. The analytical approach included descriptive characterisation of clinical patterns and statistical analysis of biomarker associations with DKA severity categories.

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FINDINGS: Our findings indicate that delayed presentation, as well as the underutilisation of point-of-care and early diabetes testing, contributes to more severe metabolic derangements at admission.

ORIGINALITY/VALUE: We propose an integrative framework that emphasises capacity building in rural health facilities, implementation of standardised management protocols, and community-based education. These interventions are expected to reduce DKA incidence, improve clinical outcomes, and support sustainable paediatric diabetes care within Indonesia's diverse healthcare landscape.

KEYWORDS: *Children; Diabetic Ketoacidosis; Biomarkers; Diabetes testing.*

INTRODUCTION

Diabetic ketoacidosis (DKA) remains one of the most serious and potentially life-threatening acute complications of diabetes mellitus in children and adolescents. Despite major advances in insulin therapy, glucose monitoring technologies, and standardised clinical guidelines, DKA continues to contribute substantially to paediatric morbidity and mortality worldwide (Elendu *et al.*, 2023). The burden is particularly pronounced in low- and middle-income countries (LMICs), where delayed diagnosis, limited access to insulin, fragmented health systems, and socioeconomic barriers increase the risk of severe presentation and poor outcomes (Varadarajan, 2014; Abdraimova *et al.*, 2022; Abdalrahman *et al.*, 2025). A significant proportion of children in resource-limited settings are still diagnosed with type 1 diabetes only after presenting with DKA, reflecting persistent gaps in early recognition and healthcare access (Gomber *et al.*, 2022).

Global epidemiological data reveal striking disparities in DKA prevalence that reflect underlying differences in healthcare system capacity rather than differences in disease biology (Jensen *et al.*, 2021). In developed countries with robust primary care systems and widespread diabetes screening, DKA at initial type 1 diabetes mellitus (T1DM) diagnosis occurs in approximately 30-40% of cases. In contrast, developing, and underdeveloped countries report significantly higher rates, with DKA occurring in approximately 70% of newly diagnosed T1DM cases. (Usher-Smith *et al.*, 2012). Resource-limited settings like Indonesia exemplify this disparity, with data from 2017 showing that 71% of children with newly diagnosed type 1 diabetes presented with DKA (Pulungan *et al.*, 2021). Notably, many cases remain unreported or are misdiagnosed, suggesting that the true burden may be even greater.

From a clinical perspective, paediatric DKA is a complex metabolic emergency (Passanisi *et al.*, 2023). Severe DKA is associated with life-threatening complications such as cerebral oedema, acute kidney injury, shock, and electrolyte imbalances (Padma

and Antony, 2017; Aşık *et al.*, 2024) The International Society for Paediatric and Adolescent Diabetes (ISPAD) regularly updates evidence-based guidelines on DKA management, emphasising early diagnosis, careful fluid resuscitation, appropriate insulin therapy, and meticulous monitoring to prevent complications (Varadarajan, 2014; Wolfsdorf *et al.*, 2018). However, adherence to these protocols varies widely in real-world practice, particularly in settings with limited paediatric intensive care resources, shortages of trained personnel, and inconsistent availability of laboratory monitoring (Varadarajan, 2014).

Beyond acute management, recurrent DKA episodes reflect deeper systemic and psychosocial challenges, including suboptimal glycaemic control, poor treatment adherence, gaps in caregiver education, mental health issues, and structural barriers such as cost and geographic access to care (Lee *et al.*, 2017; Palmer *et al.*, 2022). Translating clinical data into actionable strategies is critical for improving paediatric DKA outcomes. This manuscript aims to analyse the clinical profile, outcomes, and significant biomarkers of paediatric DKA in Indonesia and to outline evidence-based strategies for sustained management.

LITERATURE REVIEW

Paediatric DKA represents a severe metabolic emergency and remains the primary cause of morbidity and mortality for children and adolescents with type 1 diabetes mellitus (T1DM). Characterised by the biochemical triad of hyperglycaemia, ketosis, and metabolic acidosis, the condition results from a critical absolute or relative deficiency of insulin (Passanisi *et al.*, 2023). The resulting metabolic derangement leads to an accelerated catabolic state, characterised by uncontrolled glucose production and the breakdown of fats into acidic ketones. If not promptly addressed, this cascade produces profound osmotic diuresis, leading to severe dehydration and dangerous electrolyte imbalances (Foti Randazzese *et al.*, 2025).

Effective management of DKA requires the precise monitoring of specific biomarkers to track the severity of the illness and the effectiveness of treatment. While venous pH and bicarbonate remain the primary indicators of metabolic acidosis and are central to defining DKA resolution, other electrolytes provide critical prognostic information (Glaser *et al.*, 2022). Monitoring these markers, alongside other indicators such as blood osmotic pressure and creatinine, is vital for identifying high-risk patients and adjusting management pathways to improve clinical outcomes (Wei *et al.*, 2020). Standardised protocols emphasise a triad of management: careful fluid resuscitation,

timely insulin administration, and the vigilant monitoring of electrolytes to prevent lethal complications (Glaser *et al.*, 2022). Despite the existence of clear international frameworks, substantial evidence reveals a significant gap between these guidelines and their real-world application.

Global trends since the early 2000s show an increasing incidence of the disease. While DKA frequency at T1DM onset ranges from 15% to 70% in Europe and North America, it accounts for more than 50% of all deaths in children with established diabetes, predominantly through acute complications (Kostopoulou *et al.*, 2023). Significant disparities in clinical outcomes exist between high-income countries and low- and middle-income countries. In high-income countries advances in management have lowered mortality rates to between 0.15% and 0.35%, while in developing nations, rates remain alarmingly high at 3.4% to 13.4% (Passanisi *et al.*, 2023), and can reach 24-26%(Varadarajan, 2014). Delayed diagnosis by both parents and physicians has been identified as the "root cause" of these preventable fatalities in resource-limited regions (Varadarajan, 2014). In many resource-limited regions, DKA is frequently misdiagnosed as more common paediatric conditions such as bronchopneumonia, meningitis, or acute gastroenteritis. This diagnostic inertia is often driven by the non-specific nature of early symptoms (such as vomiting and abdominal pain) and a widespread lack of awareness regarding paediatric diabetes among both caregivers and primary care clinicians (Kostopoulou *et al.*, 2023).

The Indonesian landscape presents a substantial public health challenge regarding the timely identification of paediatric diabetes. This high prevalence at presentation is largely attributed to low community and professional awareness, leading to symptoms being frequently misdiagnosed as common infections. Structural barriers, including a critical shortage of specialised care, with only 51 paediatric endocrinologists serving a population of over 83 million children, and geographic inequities in access to diagnostic tools, further complicate management (Pulungan *et al.*, 2021). Rather than being framed as a failure, these figures underscore an essential public health priority that requires sustained attention and the systematic enhancement of primary care infrastructure.

A profound challenge for many health systems is the transition from reactive acute metabolic crises to a sustainable, data-driven model of care. Reducing DKA incidence is a core requirement for achieving "Health Sustainability" and meeting the Sustainable Development Goals (SDGs), specifically the target to reduce premature deaths from non-communicable diseases by one-third by 2030 (Pulungan *et al.*, 2021). Frequent acute crises place an immense strain on limited healthcare resources, often requiring

costly and intensive paediatric intensive care unit (PICU) admissions (Nakhla *et al.*, 2018). Beyond the immediate crisis, a single DKA episode at diagnosis has profound long-term implications, being associated with persistently higher HbA1c levels, increased insulin requirements, and adverse neurocognitive outcomes, including impaired memory and verbal intelligence, for years following the event (Dovc *et al.*, 2025). Therefore, establishing sustainable management pathways that prioritise early detection and universal access to care is essential for improving long-term patient outcomes and ensuring the efficient use of healthcare resources.

RESEARCH METHODOLOGY

We conducted a retrospective cross-sectional study from medical records of paediatric patients diagnosed with DKA to examine clinical characteristics, biomarkers, and outcomes. The study was conducted at Adam Malik Hospital Medan, a tertiary referral centre located in Medan City, North Sumatra, Indonesia. This hospital serves as a regional referral centre receiving paediatric DKA cases from across North Sumatra and surrounding regions between January 2023 and December 2025.

Inclusion criteria were as follows: (1) age 0 to 18 years at admission; (2) a confirmed diagnosis of diabetic ketoacidosis, defined by the presence of all three of the following criteria: blood glucose >11 mmol/L (≈200 mg/dL), a venous pH <7.3 or serum bicarbonate <18 mmol/L, and ketonaemia (blood β-hydroxybutyrate ≥3 mmol/L) or large ketonuria; and (3) complete medical records containing at minimum: baseline characteristics (age, sex, nutritional status, family history, prior diabetes history, and precipitating factors), electrolyte analysis, C-peptide level, HbA1c level, and complications (if any). Patients were excluded if they had incomplete medical records lacking any of the essential data elements listed above.

The minimum sample size was calculated using the Lemeshow formula: $n = (Z\alpha^2 \times P \times Q)/d^2$. Using a 95% confidence level (z-score = 1.96), an estimated proportion of 6% based on previous literature, and an absolute precision of 10%, the calculated minimum sample size was 22 subjects. To account for potential data quality issues, missing values, and potential selection bias inherent in retrospective studies, an additional 20% buffer was added to the minimum sample size, resulting in a final target sample size of 26 subjects. Data security and confidentiality were maintained throughout the study in accordance with institutional data protection policies and ethical guidelines. Descriptive statistics were calculated for all variables followed by bivariate analyses. A p-value of <0.05 was considered statistically significant for all analyses.

Ethical Statement

Ethical approval for this study was obtained from the Institutional Ethics Committee of Adam Malik Hospital Medan prior to data collection (No. 4322/UN5.2.1.1. D1/SPB/2024). All authors declare no conflict of interest.

RESULTS

This study analysed 30 paediatric patients diagnosed with DKA at Adam Malik Hospital Medan between January 2023 and December 2025. The cohort was stratified by DKA severity classification: 7 mild cases (23.3%), 9 moderate cases (30%), and 14 severe cases (46.7%). This distribution demonstrates that severe DKA remains the predominant presentation in this tertiary referral centre, accounting for nearly half of all admissions. All baseline characteristics are summarised in Table 1.

Table 1: Baseline Characteristics and DKA Severity

Variable	DKA Severity			P-Value
	Mild, n=7	Moderate, n=9	Severe, n=14	
Age (n,%)				
0-10 years	2 (40%)	2 (40%)	1(20%)	0.401
>10-18 years	5 (20%)	7 (28%)	13 (52%)	
Gender (n,%)				
Female	4 (21%)	5 (26.4%)	10 (52.6%)	0.269
Male	3 (27.2%)	4 (36.4%)	4 (36.4%)	
Nutritional Status (n,%)				
Malnourished	1 (14.3%)	0 (0%)	6 (85.7%)	0.152
Underweight	1 (12.5%)	3 (37.5%)	4 (50%)	
Normal	4 (30.8%)	6 (46.2%)	3 (23.1%)	
Obese	1 (50%)	0 (0%)	1 (50%)	
Type of DM (n,%)				
Type 1 DM	2 (9.1%)	8 (36.4%)	12 (54.5%)	0.013*
Type 2 DM	5 (71.4%)	1 (14.3%)	1 (14.3%)	
Other type DM	0 (0%)	0 (0%)	1 (100%)	
Family History (n,%)				
Present	4 (25%)	3 (18.8%)	9 (56.2%)	0.339
Absent	3 (21.4%)	6 (42.9%)	5 (35.7%)	
DKA Precipitating Factors (n, %)				
Infection	2 (50%)	0 (33,3%)	2(50%)	0.162

Variable	DKA Severity			P-Value
	Mild, n=7	Moderate, n=9	Severe, n=14	
Infection and non-compliance with treatment	0 (0%)	0 (%)	2 (100%)	
Infection and Delayed diagnosis	0 (0%)	2 (100%)	0 (0%)	
Delayed diagnosis	0 (0%)	2 (28.6%)	5 (83,3%)	
Non-compliance with treatment	4 (30.8%)	4 (30.8%)	5 (38.5%)	
Unknown/Other	1 (50%)	1 (50%)	0 (0%)	
History of DKA (n, %)				
1x previous DKA	0 (0%)	0 (0%)	1(100%)	0.139
2-3x previous DKA	1 (33.3%)	2 (66.7%)	0 (0%)	
>3x previous DKA	0 (0%)	2 (100%)	0 (0%)	
No previous history	6 (25%)	5 (20.8%)	13 (54.2%)	
P-Value = Chi square Test; *p<0.05				

Source: Author's own data from Adam Malik Hospital Medan (2023-2025)

Clinical features of DKA differed by severity, with altered mental status showing a clear link to more severe disease (See Table 2). Of 11 patients with loss of consciousness, 64.7% were classified as severe DKA, compared to 5.9% in the mild group, showing a significant association (p=0.020). This highlights impaired consciousness as an important marker of serious metabolic disturbance requiring urgent care.

Table 2: DKA Severity and Clinical Symptoms of DKA

Symptoms of DKA	DKA Severity			P-Value
	Mild, n=7	Moderate, n=9	Severe, n=14	
Polyuria (n,%)				
Present	5 (26.3%)	4 (21.1%)	10 (52.6%)	0.372
Absent	2(18.2%)	5 (45.5%)	4 (36.4%)	
Polydipsia (n,%)				
Present	6 (31.6%)	3 (15.8%)	10 (52.6%)	0.067
Absent	1 (9.1%)	6 (54.5%)	4 (36.4%)	
Polyphagia (n,%)				
Present	6 (31.6%)	3 (15.8%)	10 (52.6%)	0.067
Absent	1 (9.1%)	6 (54.5%)	4 (36.4%)	
Weight loss (n,%)				
Present	4 (26.7%)	3 (20%)	8 (53.3%)	0.490
Absent	3(20%)	6 (40%)	6 (40%)	

Symptoms of DKA	DKA Severity			P-Value
	Mild, n=7	Moderate, n=9	Severe, n=14	
Loss of Consciousness (n,%)				
Present	1 (5.9%)	5 (29.4%)	11 (64.7%)	0.020*
Absent	6 (46.2%)	4 (30.8%)	3 (23.1%)	
Lethargy (n,%)				
Present	5 (21.7%)	9 (39.1%)	9 (39.1%)	0.132
Absent	2 (28.6%)	0 (0%)	5 (71.4%)	
Nausea and Vomiting (n,%)				
Present	4 (22.2%)	5 (27.8%)	6 (50%)	0.903
Absent	3 (25%)	4 (33.3%)	5 (41.7%)	
Abdominal pain (n,%)				
Present	5 (31.3%)	5 (31.3%)	6 (37.5%)	0.459
Absent	2 (14.3%)	4 (28.6%)	8 (57.1%)	
Seizure (n,%)				
Present	1 (33.3%)	0 (0%)	2 (66.7%)	0.490
Absent	6 (22.2%)	9 (33.3%)	12 (44.4%)	
Fever (n,%)				
Present	1 (11.1%)	1 (11.1%)	7 (77.8%)	0.081
Absent	6 (28.6%)	8 (38.1%)	7 (33.3%)	
Kussmaul Breathing (n,%)				
Present	4 (22.2%)	6 (33.3%)	8 (44.4%)	0.888
Absent	3 (25%)	4 (25%)	3 (50%)	
P-Value: Chi square Test; *p<0.05				

Source: Author's own data from Adam Malik Hospital Medan (2023-2025)

As shown in Table 3, admission blood glucose varied widely across severity groups, with medians of 449 mg/dL in mild, 421 mg/dL in moderate, and 554 mg/dL in severe DKA, without significant difference (p=0.299). This indicates that blood glucose level alone does not predict severity. HbA1c values were also similar across groups, 13.0 ± 3.97% in the mild group, 13.04 ± 3.19% in the moderate group, and 4.94 ± 3.76% in the severe group (p=0.371), suggesting that chronic glycaemic control is not strongly linked to acute severity, despite a trend towards higher levels in severe cases. C-peptide showed the strongest association with severity (p=0.003). Median levels declined from 1.38 ng/mL in mild cases to 0.34 ng/mL in moderate cases and 0.15 ng/mL in severe DKA, reflecting reduced residual beta-cell function in more severe disease and supporting its role as a potential marker for risk stratification.

Markers of acidosis closely aligned with clinical severity. Blood pH decreased significantly from 7.29 ± 0.11 in mild cases to 7.21 ± 0.07 in moderate cases and 7.04 ± 0.15 in severe cases ($p<0.001$). Serum bicarbonate showed the most pronounced difference, with median levels of 14.5 mmol/L in mild, 8 mmol/L in moderate, and 4.7 mmol/L in severe DKA ($p<0.001$), confirming progressive metabolic acidosis and supporting its use as a key severity indicator.

Sodium and potassium levels did not differ significantly between groups ($p=0.419$ and $p=0.455$, respectively), though both showed wide variability, reflecting fluid shifts and total body electrolyte depletion. Chloride levels were significantly higher in moderate and severe cases, with the median of 107 mmol/L compared with 103 mmol/L in mild DKA ($p=0.019$), suggesting a component of hyperchloraemic acidosis and emphasising the need for monitoring during management. Calcium levels remained stable across groups ($p=0.783$), with occasional low values in severe cases but no significant association with severity.

Complications were observed in 73% of patients and became more common with increasing DKA severity (See Table 4). Acute kidney injury was the most frequent complication, highlighting the significant renal impact of severe metabolic disturbance. More complex complications were concentrated in severe DKA. AKI combined with cerebral oedema occurred in 5 patients (16.7% of cases), AKI with pulmonary oedema was seen in 3 patients (10% of all cases) and was evenly distributed across severity groups.

Table 3: DKA severity and Lab Parameters

Lab Parameters	DKA Severity			P-Value
	Mild, n=7	Moderate, n=9	Severe, n=14	
Blood Glucose (mg/dL) *	449 (353-732)	421 (292-714)	554 (338-802)	0.299
Sodium (mmol/L)	132.42 ± 3.26	138.89 ± 13.75	136.36 ± 8.32	0.419
Potassium (mmol/L) *	4.3 (2.3-4.4)	4.5 (2.8-6.8)	4.2 (3.2-5.9)	0.455
Chloride (mmol/L) *	103 (94-104)	107 (103-125)	107 (90-119)	0.019**
Calcium (mEq/L) *	8.22 (7.3-10.1)	8.55 (5.51-12.2)	8.62 (1.5-9.6)	0.783
HbA1c (%)	13 ± 3.97	13.04 ± 3.19	14.94 ± 3.76	0.371
C-Peptide (ng/mL) *	1.38 (0.44-2.81)	0.34 (0.06-0.70)	0.15 (0.01-2.72)	0.003**
Blood PH	7.29 ± 0.11	7.21 ± 0.07	7.04 ± 0.15	<0.001**
HCO_3^- *	14.5 (10.2-17.3)	8 (5.8-22)	4.7 (3-6.2)	<0.001**

P-Value = One-way ANOVA Test, data presented as mean ± SD
*Abnormally distributed data presented as median (min-max) analysed with Kruskall-Wallis Tes
** p<0.05

Source: Author's own data from Adam Malik Hospital Medan (2023-2025)

Table 4: Complications of DKA

Complications	DKA Severity			P-Value
	Mild, n=7	Moderate, n=9	Severe, n=15	
Acute Kidney Injury (AKI)	1 (11.1%)	2 (22.2%)	6 (66.7%)	0.282
AKI and Cerebral oedema	0 (0%)	1 (20%)	4 (80%)	
AKI and Pulmonary oedema	1 (33.3%)	1 (33.3%)	1 (33.3%)	
None	5 (38.5%)	5 (38.5%)	3 (23.1%)	
P-Value = Chi Square Test				

Source: Data are collected by the authors from Adam Malik Hospital Medan (2023-2025)

DISCUSSION

The high prevalence of severe DKA at presentation in our cohort demonstrates that the challenge facing paediatric diabetes care in Indonesia is fundamentally a systemic problem, not a clinical competence problem. These data are critical for informing effective decision-making and policy implementation (Hammad, 2025). The biomarker patterns identified in this study (particularly the strong associations between HbA1c, C-peptide, chloride levels, and DKA severity) provide an evidence base for developing targeted interventions. Our findings support the development of an integrative framework emphasising three complementary strategies: capacity building in rural health facilities, implementation of standardised management protocols, and community-based education interventions (Goliath *et al.*, 2016; Lamptey, 2024). Each pillar addresses specific barriers identified in this study and leverages the biomarker and clinical findings to improve outcomes.

Capacity Building in Rural Health Facilities

Nearly half of cases were severe DKA, at 46.7%, and altered consciousness was strongly linked to severity (p=0.020), a finding that may point to delays in diagnosis and referral from primary or secondary care facilities. Notably, 84.6% of patients had no prior diabetes diagnosis, meaning the most presented with their first diabetic emergency. This highlights missed opportunities for earlier detection at primary or rural care levels.

The implementation of effective DKA management in rural settings requires addressing fundamental healthcare access barriers. Rural regions face multifaceted infrastructure challenges that extend beyond healthcare alone, including limited access to education, water, sanitation, and electricity (Ahmed, 2025). Within this constrained

environment, several priorities for rural capacity building emerge. First, early detection through point-of-care glucose and HbA1c testing in primary and community settings is critical, along with training health workers to recognise diabetes symptoms and screen high-risk individuals before a metabolic crisis develops (Heidt *et al.*, 2020; (Heidt *et al.*, 2020; Gourlay *et al.*, 2023; Kushner *et al.*, 2025).

Second, prompt recognition and triage of DKA must be strengthened (Lee *et al.*, 2017; Padma and Antony 2017). Health workers should be trained to identify key warning signs such as polyuria, polydipsia, Kussmaul breathing, and especially altered consciousness, which occurred in 64.7% of severe cases and signals the need for urgent referral.

Third, basic acid-base assessment capability is essential. Since glucose levels alone do not reflect severity, access to pH and bicarbonate measurement through blood gas or point-of-care testing would allow proper severity classification and guide referral decisions, even if C-peptide testing is unavailable (Wei *et al.*, 2020; Koyama *et al.*, 2024). Fourth, rural facilities should implement initial stabilisation protocols. Early fluid resuscitation, electrolyte monitoring, and insulin initiation can be lifesaving and should begin before transfer to tertiary care, with appropriate staff training to reduce complications and improve outcomes (Glaser *et al.*, 2022).

Standardised Management Protocols

The findings from this study provide clear guidance for standardised DKA management protocols. The dramatic variation in acid-base parameters across severity categories validates the use of pH and bicarbonate for severity classification and management intensity (Koyama *et al.*, 2024). Protocols should specify different management approaches for mild, moderate, and severe DKA (See Figure 1) as proposed in the newest ISPAD guidelines (Glaser *et al.*, 2022).

Protocols should also incorporate C-peptide measurement where feasible, as this biomarker provides valuable prognostic information and could inform decisions about insulin therapy intensity and specialist consultation. The dramatic decline in C-peptide with increasing severity suggests that patients with very low C-peptide levels warrant heightened vigilance for complications and more intensive management. Protocols must address electrolyte management, including recognition of hyperchloraemia in severe cases and consideration of lower-chloride fluid solutions (Suresh *et al.*, 2024). Protocols should also specify monitoring for complications, particularly AKI and cerebral oedema, with clear thresholds for escalation of care (Aşık *et al.*, 2024; Sehgal *et al.*, 2022).

Community-Based Education Interventions

The finding that the majority of patients lacked a prior diabetes diagnosis represents a profound failure of the community health literacy and early detection systems (Peng *et al.*, 2021; Aşık *et al.*, 2024). Community-based education should target multiple audiences: (1) families with a history of diabetes, who should receive education about early warning signs and the importance of prompt medical evaluation (Nakhla *et al.*, 2018; Peng *et al.*, 2021; Passanisi *et al.*, 2023); (2) parents and caregivers of children with newly diagnosed diabetes, who require intensive education about insulin administration, blood glucose monitoring, recognition of hypoglycaemia and hyperglycaemia, and the importance of medication adherence (Pulungan, *et al.*, 2021; Heyns *et al.*, 2025); (3) community health workers, who can provide ongoing support and monitoring (Heyns *et al.*, 2025); and (4) school-based programmes to increase awareness among peers and educators about diabetes symptoms and the importance of early evaluation (Peng *et al.*, 2021; Passanisi *et al.*, 2023).

LIMITATIONS AND FUTURE DIRECTIONS

This study is limited by its observational design and reliance on routine clinical documentation, which may introduce misclassification and missing data. Future work should incorporate prospective registries, standardised data capture, and implementation trials evaluating bundled interventions (protocol adherence, discharge education, tele-follow-up) on DKA incidence and recurrence. Incorporating patient-reported outcomes and geospatial access measures could also deepen understanding of the social drivers and inform equity-focused interventions.

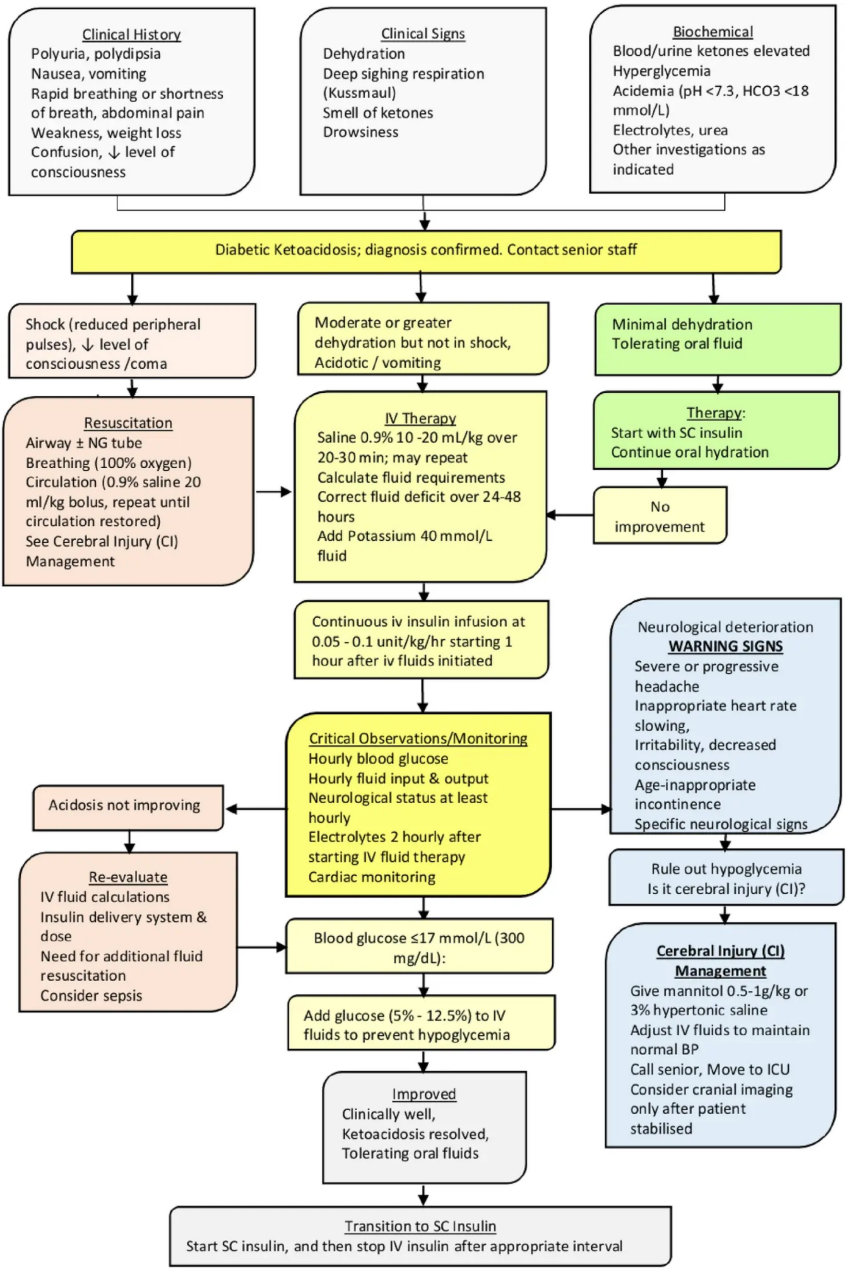

Figure 1: DKA Management Algorithm
Source: ISPAD Guidelines (Glaser *et al.*, 2022)

CONCLUSIONS

The results of this study are relevant not only to Indonesia but also to other low resource settings dealing with similar gaps in paediatric diabetes care. The large proportion of patients presenting with severe DKA appears to reflect limitations in health system capacity and low community awareness, rather than a lack of clinical expertise, as it indicates that meaningful progress can be made through focused, evidence-based strategies. Protocolised acute care, early detection, continuity of follow-up, and psychosocially informed interventions represent pragmatic pathways towards sustainable DKA prevention and better long-term outcomes for children with diabetes.

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