

Management of Diabetic Ketoacidosis in Remote and Resource-constrained Settings in India

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Abstract

Diabetic ketoacidosis (DKA) remains a major endocrine emergency in India, particularly in remote and resource-constrained settings where standard intensive care-based protocols are often difficult to implement. This narrative review examines the challenges of DKA management in rural Indian healthcare systems and evaluates the feasibility of pragmatic adaptations to existing treatment recommendations. Available evidence suggests that delayed presentation, infection, interrupted insulin access, limited laboratory support, inadequate monitoring facilities, and shortages of trained personnel significantly influence DKA outcomes in India. Selected patients with mild-to-moderate DKA may be managed safely using structured subcutaneous insulin protocols, although Indian prospective data remain limited. Future Indian DKA guidelines should incorporate resource-stratified recommendations that distinguish ideal care from minimum safe care. Context-sensitive management pathways, simplified monitoring protocols, improved diabetes education, and strengthened healthcare infrastructure are essential for improving DKA outcomes in underserved regions.

Keywords: Diabetic ketoacidosis, India, management, resources

Résumé

L'acidocétose diabétique (ACD) demeure une urgence endocrinienne majeure en Inde, particulièrement dans les zones rurales et les contextes à ressources limitées, où la prise en charge conventionnelle fondée sur les soins intensifs peut être difficile à mettre en œuvre. Cette revue narrative examine les difficultés liées à la prise en charge de l'ACD dans les systèmes de santé ruraux indiens et évalue la faisabilité d'adaptations pragmatiques des recommandations thérapeutiques établies. Les données disponibles indiquent que le retard de prise en charge, les infections, les interruptions de l'accès à l'insuline, les capacités limitées en matière d'analyses biologiques, les possibilités insuffisantes de surveillance et le manque de personnel de santé formé influencent considérablement la prise en charge et le pronostic de l'ACD en Inde. Chez certains patients présentant une ACD légère à modérée, des protocoles structurés d'insulinothérapie sous-cutanée peuvent constituer une alternative réalisable lorsque les ressources de soins intensifs ne sont pas disponibles, bien que les données prospectives provenant de l'Inde restent limitées. Les futures recommandations indiennes relatives à l'ACD devraient intégrer des stratégies adaptées aux différents niveaux de ressources, distinguant clairement les soins optimaux des soins minimaux permettant d'assurer la sécurité des patients. Des parcours de prise en charge adaptés au contexte, des protocoles de surveillance simplifiés, une meilleure éducation thérapeutique, un accès fiable à l'insuline et le renforcement des infrastructures de santé sont essentiels pour améliorer la sécurité et l'efficacité de la prise en charge de l'ACD dans les régions défavorisées.

Mots-clés: Acidocétose diabétique ; Inde ; soins de santé ruraux ; contextes à ressources limitées ; insulinothérapie ; prise en charge de l'ACD

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INTRODUCTION

Diabetic ketoacidosis (DKA) continues to represent one of the few endocrine emergencies where outcome is determined as much by health-system efficiency as by disease severity itself.^[1] In high-income settings, mortality from DKA has progressively declined over the past few decades, largely because patients reach hospitals early, laboratory support is continuous, insulin delivery systems are standardized, and monitoring is intensive.^[2-4] Across low- and middle-income countries, including parts of South Asia and Africa, many health facilities lack the staff, equipment, and medicines needed for ideal DKA management.^[5-7] This contributes to higher morbidity and mortality compared with high-income settings. In India, adult DKA mortality of about 4.8%–11.6% has been reported in tertiary intensive care units (ICUs) and medical wards,^[8,9] with infections, noncompliance, pancreatitis, older age, renal dysfunction, hypokalemia, and altered sensorium linked to worse outcomes.^[10,11]

In an Ethiopian referral hospital, DKA in-hospital mortality was 12%, largely related to hypoglycemia and severe hypokalemia, reflecting constrained monitoring and replacement capacity.^[10] During a humanitarian crisis in Sudan, almost all diabetic patients presenting to hospitals had DKA, with severe metabolic derangement, attributed to medication scarcity and system collapse.^[12] The Indian experience with DKA differs in important ways from descriptions originating from western ICUs. Patients frequently present late,^[5,13,14] often after several days of osmotic symptoms, vomiting, febrile illness, or treatment interruption. In many rural settings, the first point of contact is not a trained physician but a small clinic, pharmacy practitioner, or peripheral healthcare worker. Initial treatment may consist only of intravenous fluids, empirical antibiotics, or intermittent insulin administration without biochemical monitoring.^[13,14] Referral frequently occurs only after altered sensorium or hemodynamic instability develops.^[5,13,14] Consequently, the “typical” DKA patient encountered in Indian tertiary hospitals may already represent the advanced end of a prolonged and fragmented disease trajectory.^[14] The problem is further complicated by socioeconomic realities that remain insufficiently discussed in most international recommendations.^[15-18] Out-of-pocket cost is a dominant reason for refusing or delaying insulin in low-income urban settings; 74% of slum-dwelling patients who needed insulin but refused cited financial constraints, as insulin is bought out-of-pocket and often not insured.^[19] National reviews highlight access to affordable medicines as a core barrier to diabetes control in India.^[20-22] Patients discontinue insulin because refrigeration is unavailable, travel costs prevent follow-up, daily wages are lost during hospital visits, or insulin stocks become intermittently inaccessible in public facilities.^[22-27] Infections remain major precipitants, but unlike Western cohorts where urinary tract infections and pneumonia predominate, Indian studies continue to report tuberculosis, skin and soft-tissue infections, and undifferentiated febrile illnesses as important triggers.^[8,28,29] Malnutrition, chronic anemia, and delayed sepsis

recognition frequently coexist, altering both presentation and physiological reserve.^[30,31]

Current DKA guidelines are largely derived from studies conducted in resource-rich critical care environments. These protocols presume availability of hourly glucose monitoring, frequent electrolyte analysis, continuous cardiac monitoring, trained nursing ratios, and intensive care supervision.^[32,33] While scientifically robust, many of these recommendations become difficult to operationalize in district and subdistrict hospitals.^[32,34] In practice, clinicians in remote Indian settings are often forced to improvise. Potassium may be unavailable for several hours.^[35-37] Urine ketones may substitute for serum beta-hydroxybutyrate.^[37,38] Intravenous insulin infusion may be impossible because infusion pumps are unavailable or nursing supervision is inadequate.^[39] These adaptations are rarely acknowledged in formal guidelines despite being routine components of real-world care.

An important consequence of this disconnect is that DKA management in India frequently oscillates between two extremes: aggressive protocolization in tertiary centers and largely experience-based treatment in peripheral hospitals.^[6,11,34,40] Neither approach is ideal. Excessive dependence on rigid ICU-oriented algorithms may delay treatment initiation where resources are constrained, whereas unstructured empiricism increases the risk of preventable complications.^[6,7,11,41] This review critically examines the management of DKA in remote and resource-limited Indian settings. Rather than reiterating standard recommendations, the emphasis is on evaluating which aspects of current evidence are genuinely transferable to low-resource environments, where they fail, and how pragmatic adaptations may be developed without compromising patient safety.

LITERATURE EVIDENCE

The epidemiology of DKA in India remains incompletely defined. Most available studies emerge from urban tertiary hospitals and therefore provide limited insight into disease burden in rural populations.^[5,8,42] This introduces a significant selection bias. Patients who survive long enough to reach referral centers are overrepresented, whereas mortality occurring during transport or at peripheral facilities is poorly captured.^[43,44] Consequently, the true burden of severe DKA in India is likely underestimated. Several Indian tertiary-center studies have reported DKA mortality ranging between 2% and 11%,^[8,42] substantially higher than figures commonly reported from high-income countries where mortality is often below 1%. However, these estimates likely underrepresent the actual burden because most available Indian data originate from referral centers and do not capture deaths occurring during transport or at peripheral facilities.^[41] Indian cohorts have also consistently demonstrated prolonged symptom duration before presentation, frequently exceeding 24–48 h, reflecting delayed recognition and referral barriers.^[45] Indian studies consistently identify infection and insulin omission as

the two dominant precipitants of DKA.^[46] However, the term “non-compliance” used in many reports deserves scrutiny. In several Indian cohorts, treatment interruption appears closely linked to economic barriers, interrupted drug supply, poor counseling, or inability to maintain follow-up rather than deliberate refusal of therapy.^[19,22,29] The tendency to classify such patients simply as “non-compliant” risks oversimplifying a structurally mediated problem. In public-sector hospitals, interrupted insulin availability and irregular follow-up remain important contributors.^[47] In rural populations, financial constraints, travel distance, loss of daily wages, and inability to maintain cold-chain storage continue to influence adherence patterns.^[48-50] Another recurring observation is the increasing proportion of DKA occurring in individuals with type 2 diabetes mellitus.^[8] This phenomenon has important implications in India, where ketosis-prone diabetes and mixed phenotypes are relatively common.^[51] Peripheral physicians frequently encounter adults with previously undiagnosed diabetes presenting with severe ketosis during infection or physiological stress.^[52] Distinguishing these cases from hyperosmolar states or sepsis-associated metabolic acidosis may be difficult without laboratory support.^[53-55] Diagnostic limitations remain central to the rural DKA problem, not only in India but also in other low- and middle-income nations.^[12,56] Standard definitions rely on hyperglycemia, ketonemia, and metabolic acidosis.^[57,58] Yet many hospitals continue to function without round-the-clock arterial blood gas analysis.^[59] Serum ketone estimation is unavailable in large parts of the public sector. Urine ketone testing therefore remains widely used despite its known limitations.^[57,60] Acetoacetate-based urine assays may remain positive even after metabolic recovery and correlate poorly with severity. Nevertheless, in many peripheral centers, they continue to guide treatment because no alternative exists.^[61,62] This gap between ideal and feasible diagnostics has important consequences. Clinicians frequently initiate treatment based primarily on bedside assessment: dehydration, tachypnea, abdominal pain, altered sensorium, and uncontrolled hyperglycemia.^[63] Such pragmatic decision-making is often necessary, although it increases diagnostic uncertainty. Sepsis with lactic acidosis, acute pancreatitis, toxic ingestion, and starvation ketosis may all mimic DKA^[63] in poorly monitored settings. Fluid therapy illustrates a similar tension between guideline recommendations and practical feasibility. Standard protocols advocate isotonic saline with frequent reassessment of electrolytes and acid-base status.^[64,65] In reality, electrolyte results may be delayed for several hours in remote hospitals, particularly during night shifts. Potassium replacement therefore becomes largely empirical. This is not a trivial issue. Hypokalemia in DKA is frequently underestimated in undernourished populations with prolonged osmotic diuresis. Peripheral administration of insulin before potassium assessment remains common practice and probably contributes to avoidable arrhythmic complications;^[65,66] that are rarely documented systematically in the Indian rural set-up. There is also increasing debate regarding the indiscriminate use of large-volume normal

saline. Hyperchloremic acidosis is well recognized,^[67] although its clinical significance in resource-limited settings remains uncertain. Balanced crystalloids may theoretically offer advantages,^[68] but recommendations favoring them often ignore procurement realities in government hospitals where even basic consumables are inconsistently available. Perhaps the most important practical question concerns insulin delivery. Intravenous insulin infusion is widely regarded as the standard of care for moderate and severe DKA.^[69] However, this recommendation assumes availability of infusion pumps, close nursing supervision, and frequent monitoring.^[70] Many district hospitals in India do not possess such infrastructure consistently. In peripheral wards, insulin infusion may be administered through gravity-based systems with substantial variability in delivery.^[71] Under these circumstances, the continued insistence on universal intravenous insulin infusion deserves reconsideration. Evidence from several studies suggests that carefully selected patients with mild-to-moderate DKA can be managed using subcutaneous rapid-acting insulin analogues with outcomes comparable to intravenous infusion in monitored settings.^[72-75] Although most supporting data originate from non-Indian populations, the implications for resource-constrained systems are significant.^[76] A simplified protocol that can be safely implemented may ultimately prove more valuable than an ideal protocol that cannot be operationalized reliably.^[77,78] At present, however, evidence specific to Indian secondary-level hospitals remains sparse. Most published Indian studies evaluating DKA management are retrospective, involve small sample sizes, and originate from tertiary institutions.^[5,9,11,32,79-81] There are remarkably little prospective data examining simplified DKA pathways in district hospitals even though these facilities manage a substantial proportion of the national disease burden.

DISCUSSION

A persistent weakness of contemporary DKA literature is its tendency to universalize recommendations generated within highly monitored critical care environments. This becomes problematic when such protocols are incorporated into health systems with profoundly different constraints.^[82,83] In India, the challenge is not merely whether guidelines are scientifically correct, but whether they remain implementable across diverse levels of care. The prevailing ICU-centric approach to DKA management may not always represent the most rational strategy for low-resource settings.^[41,82,83] Mild DKA is frequently admitted to tertiary ICUs primarily because standardized alternatives are lacking. This contributes to unnecessary ICU occupancy in already overburdened systems.^[84] Conversely, severe DKA may continue to receive suboptimal treatment at peripheral centers because referral thresholds are unclear and transport systems inadequate. What India arguably requires is not simplification alone, but stratification. Not every patient with DKA requires identical intensity of monitoring. Patients with preserved mentation, stable hemodynamics, and mild acidosis may potentially be managed using structured

ward-based protocols with scheduled subcutaneous insulin administration and focused monitoring.^[85] Such models could reduce dependence on scarce critical care infrastructure while preserving patient safety. The reluctance to formally endorse such approaches partly reflects the limited quality of available evidence.^[36] Yet insisting exclusively on ICU-level standards risks perpetuating a system where evidence-based care remains inaccessible outside tertiary hospitals. In this context, pragmatic protocols may represent not a compromise, but a necessary adaptation. An equally neglected issue is manpower. Much of DKA management depends on vigilant nursing observation rather than sophisticated intervention.^[86] In many Indian public hospitals, nurse-to-patient ratios remain severely inadequate.^[87,88] Junior residents frequently supervise multiple critically ill patients simultaneously. Under these conditions, protocols requiring hourly adjustments become difficult to sustain consistently. The resulting variability in care is rarely acknowledged in formal recommendations. The language of many guidelines also deserves scrutiny. Terms such as “careful monitoring” or “frequent reassessment” are clinically appropriate but operationally vague. In practice, their meaning differs dramatically between a tertiary endocrinology ICU and a rural emergency ward staffed by a single duty medical officer overnight.^[46,59] Future Indian guidelines must therefore incorporate explicit resource stratification rather than assuming homogeneous infrastructure.^[89,90] Another important but insufficiently discussed issue is the limited critical care capacity available for diabetes emergencies in India.^[91] Many district hospitals continue to function without dedicated endocrinology services or specialty,^[92] and even tertiary government institutions frequently face shortages of monitored ICU beds. Consequently, DKA is often managed in general medical wards with variable nurse-to-patient ratios and inconsistent biochemical monitoring.^[64] The practical implications of this reality are rarely reflected in international guideline documents. Table 1 shows the standard DKA feasibility in rural Indian settings.

The discrepancy between recommended and feasible care pathways is not merely logistical but conceptual. Current DKA guidelines largely define optimal management under conditions of resource adequacy. In contrast, clinicians working in peripheral Indian settings are often compelled to prioritize treatments that are operationally sustainable rather than protocol-perfect. Recognizing this distinction is essential if future Indian recommendations are to remain clinically relevant across different tiers of healthcare delivery. Prevention remains another underemphasized dimension.^[93] Recurrent DKA in India is often a marker of chronic health-system failure. Patients discharged after DKA episodes frequently return with similar precipitating factors: inability to procure insulin, inadequate understanding of sick-day management, missed follow-up, or unresolved infections.^[94] Educational interventions remain fragmented and poorly standardized. The healthcare system continues to invest disproportionately in acute rescue while underinvesting in continuity of diabetes care.^[94-96] Telemedicine may offer partial solutions, particularly for peripheral stabilization and referral triage. Even basic specialist support through district networks could improve decision-making regarding insulin initiation, potassium replacement, or transfer urgency.^[97] However, technological interventions alone will not overcome structural deficiencies in staffing and supply chains.^[98]

FUTURE DIRECTIONS

There is a clear need for Indian data generated outside metropolitan tertiary centers. District hospitals, subdistrict facilities, and secondary-care institutions remain underrepresented in current literature despite carrying much of the practical burden of DKA management.

Future research priorities should include:

1. Prospective validation of subcutaneous insulin protocols for mild-to-moderate DKA in district hospitals
2. Development of simplified monitoring algorithms for low-resource settings

Table 1: Standard diabetic ketoacidosis recommendations versus practical feasibility in remote Indian settings

Standard recommendation	Operational challenge in remote Indian settings	Common real-world adaptation
Hourly blood glucose monitoring	Limited nursing manpower; glucometer shortages in peripheral wards	Monitoring every 2–4 h depending on staffing availability
Arterial/venous blood gas analysis	ABG facilities unavailable in many district hospitals, especially after routine hours	Clinical assessment combined with serum bicarbonate or urine ketones
Continuous intravenous insulin infusion	Lack of infusion pumps and inadequate nurse supervision	Intermittent intravenous or subcutaneous insulin regimens
Frequent electrolyte estimation, especially potassium	Delayed laboratory reporting; night-time laboratory limitations	Empirical potassium replacement based on clinical risk assessment
ICU admission for moderate DKA	Scarcity of ICU beds in public hospitals	Management in high-dependency units or general medical wards
Serum beta-hydroxybutyrate measurement	Point-of-care ketone testing often unavailable or unaffordable	Reliance on urine ketone testing
Continuous cardiac monitoring during potassium correction	Limited telemetry availability	Periodic ECG assessment where feasible
Multidisciplinary diabetes education before discharge	Overcrowding and early discharge pressures	Brief counselling focused mainly on insulin continuation

DKA=Diabetic ketoacidosis, ICU=Intensive care unit, ECG=Electrocardiogram, ABG=Arterial blood gas

- Evaluation of low-cost point-of-care electrolyte and ketone testing strategies^[99]
- Operational studies examining delays in referral and transport-related mortality
- Structured diabetes education models tailored to low-literacy populations^[100]
- Nationally adapted DKA guidelines stratified according to healthcare resource availability.

Importantly, future Indian guidelines should distinguish between “ideal care” and “minimum safe care.”^[101] Failure to make this distinction risks producing recommendations that remain scientifically sound but practically inaccessible.

CONCLUSION

DKA in India cannot be understood purely as a metabolic emergency. In many patients, it represents the final common pathway of delayed diagnosis, interrupted insulin access, infection, financial vulnerability, and fragmented healthcare delivery. The conventional image of DKA management derived from Western intensive care practice captures only part of this reality. Current protocols remain heavily dependent on assumptions that are inconsistently valid across remote Indian settings. Continuous biochemical monitoring, infusion-based insulin delivery and intensive nursing supervision are frequently unavailable outside tertiary centers. Yet peripheral hospitals continue to manage substantial numbers of DKA patients, often with limited guidance tailored to their operational realities. Unless guidelines begin to acknowledge the realities of unequal healthcare access, the gap between recommended care and delivered care is likely to persist. In the Indian context, improving DKA outcomes will require not only better protocols, but also a more honest recognition of the systems within which those protocols are expected to function.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

- Lizzo JM, Goyal A, Kaur J. Adult Diabetic Ketoacidosis; 2026. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/31142480>. [Last accessed on 2026 Jan 26].
- Desai D, Mehta D, Mathias P, Menon G, Schubart UK. Health Care Utilization and Burden of Diabetic Ketoacidosis in the U.S. Over the Past Decade: A Nationwide Analysis. *Diabetes Care* 2018;41:1631-8.
- Jones HC, Kiburg KV, Lee MH, O'Neal DN, MacIsaac RJ. Trends in diabetic ketoacidosis in Victoria, Australia 2002-2016. *BMC Endocr Disord* 2024;24:128.
- Benoit SR, Zhang Y, Geiss LS, Gregg EW, Albright A. Trends in diabetic ketoacidosis hospitalizations and in-hospital mortality – United States, 2000-2014. *MMWR Morb Mortal Wkly Rep* 2018;67:362-5.
- Dhatariya KK, Glaser NS, Codner E, Umpierrez GE. Diabetic ketoacidosis. *Nat Rev Dis Primers* 2020;6:40.
- Eledrisi MS, Beshyah SA, Malik RA. Management of diabetic ketoacidosis in special populations. *Diabetes Res Clin Pract* 2021;174:108744.
- Matthews S, Coates MM, Bukhman A, Trujillo C, Ferrari G, Dagnaw WW, *et al.* Health system capacity to manage diabetic ketoacidosis in nine low-income and lower-middle income countries: A cross-sectional analysis of nationally representative survey data. *EClinicalMedicine* 2023;55:101759.
- Paul S, Debnath S, Singh AK, Mishra S, Rajotiya S, Singh M, *et al.* Epidemiologic pattern and factors associated with adverse outcomes of diabetic ketoacidosis in medical intensive care units of a tertiary care centre in India. *Endocr Metab Sci* 2024;16:100204.
- Athar AM, George J, Duddagi RG, Maria MJ, Begum GA. Clinical profile and in-hospital outcome of diabetic ketoacidosis in adults. *Acta Medica Int* 2025;12:1099-102.
- Taye GM, Bacha AJ, Taye FA, Bule MH, Tefera GM. Diabetic ketoacidosis management and treatment outcome at medical ward of shashemene referral Hospital, Ethiopia: A retrospective study. *Clin Med Insights Endocrinol Diabetes* 2021;14:1-7.
- Mahesh P, Ramaiah B, Thomas MS. A prospective observational study on clinical profile, precipitating factors and management in patients presenting with diabetic ketoacidosis in a tertiary care hospital. *Int J Res Trends Innov* 2025;10:1-15.
- Ahmed AA, Mounfali MA, Yassin T, Ibrahim H, Ahmed RA, Ahmed RA, *et al.* Prevalence and patterns of diabetic ketoacidosis (DKA) among diabetic patients presenting to hospitals in northern state, Sudan: a cross-sectional study during the 2025 humanitarian crisis. *BMC Endocr Disord* 2025;25:292.
- Varadarajan P, Suresh S. Delayed diagnosis of diabetic ketoacidosis in children – A cause for concern. *Int J Diabetes Dev Ctries* 2015;35:66-70.
- Jayashree M, Sasidharan R, Singhi S, Nallasamy K, Baalaji M. Root cause analysis of diabetic ketoacidosis admissions at a tertiary referral pediatric emergency department in North India. *Indian J Endocrinol Metab* 2017;21:710-4.
- Ewen M, Joosse HJ, Beran D, Laing R. Insulin prices, availability and affordability in 13 low-income and middle-income countries. *BMJ Glob Health* 2019;4:e001410.
- Chow CK, Ramasundarathettige C, Hu W, AlHabib KF, Avezum A Jr., Cheng X, *et al.* Availability and affordability of essential medicines for diabetes across high-income, middle-income, and low-income countries: A prospective epidemiological study. *Lancet Diabetes Endocrinol* 2018;6:798-808.
- Chan JC, Deerochanawong C, Khunti K, Hassanein M, Mohan V. Glycaemic control remains central in type 2 diabetes mellitus management: Key learnings from the latest International Diabetes Federation guidelines. *Diabetes Res Clin Pract* 2026;234:113173.
- Babar ZU, Ramzan S, El-Dahiyat F, Tachmazidis I, Adebisi A, Hasan SS. The availability, pricing, and affordability of essential diabetes medicines in 17 low-, middle-, and high-income countries. *Front Pharmacol* 2019;10:1375.
- Raghavendran S, Inbaraj LR, Norman G. Reason for refusal of insulin therapy among type 2 diabetes mellitus patients in primary care clinic in Bangalore. *J Family Med Prim Care* 2020;9:854-8.
- Pradeepa R, Mohan V. Epidemiology of type 2 diabetes in India. *Indian J Ophthalmol* 2021;69:2932-8.
- Ke C, Narayan KM, Chan JC, Jha P, Shah BR. Pathophysiology, phenotypes and management of type 2 diabetes mellitus in Indian and Chinese populations. *Nat Rev Endocrinol* 2022;18:413-32.
- Beran D, Lazo-Porras M, Mba CM, Mbanya JC. A global perspective on the issue of access to insulin. *Diabetologia* 2021;64:954-62.
- Bayked EM, Kahissay MH, Workneh BD. Barriers and facilitators to insulin treatment: A phenomenological inquiry. *J Pharm Policy Pract* 2022;15:45.
- Willner S, Whittemore R, Keene D. “Life or death”: Experiences of insulin insecurity among adults with type 1 diabetes in the United States. *SSM Popul Health* 2020;11:100624.
- Mona Hussain AH. Enhancing insulin supply chain resilience: A critical importance for diabetes management. *Glob J Obesity Diabetes Metab Syndr* 2023;10:9-13.
- Alsaidan AA, Alsaidan OA, Mallhi TH, Khan YH, Alzarea AI, Alanazi AS. Assessment of adherence to insulin injections among diabetic patients on basal-bolus regimen in primary and secondary healthcare centers in Al-Jouf Region of Saudi Arabia; A descriptive analysis. *J Clin Med* 2023;12:3474.

27. Lamptey E. Building sustainable capacity for better access to diabetes care in low-resource settings: A critical review of global efforts and integrated strategies. *Health Care Sci* 2024;3:131-9.
28. Singh K, Singh UP, Soni DK. To study risk factors and biochemical profile of diabetic ketoacidosis patients with special emphasis on serum amylase. *Asian J Med Sci* 2023;14:65-72.
29. Singh H, Saroch A, Pannu AK, Sachin HJ, Sharma N, Dutta P. Clinical and biochemical profile, precipitants and prognostic factors of diabetic ketoacidosis: A retrospective study from a tertiary care center of North India. *Diabetes Metab Syndr* 2019;13:2357-60.
30. Kichloo A, Shaka H, El-Amir Z, Wani F, Singh J, Velazquez GR, *et al.* In-patient outcomes of patients with diabetic ketoacidosis and concurrent protein energy malnutrition: A national database study from 2016 to 2017. *Postgrad Med* 2021;133:854-9.
31. Casipit C, Barnett M, Lam J, Rivadeneira Rodriguez A, Casipit B. SUN-597 impact of malnutrition among hospitalized patients with diabetic ketoacidosis : A United States population-based cohort study. *J Endocr Soc* 2025;9 Suppl 1:1-2.
32. Rao P, Jiang SF, Kipnis P, Patel DM, Katsnelson S, Madani S, *et al.* Evaluation of outcomes following hospital-wide implementation of a subcutaneous insulin protocol for diabetic ketoacidosis. *JAMA Netw Open* 2022;5:e226417.
33. Griffey RT, Schneider RM, Girardi M, LaRossa G, Yeary J, Lehmkuhl M, *et al.* SQuID (subcutaneous insulin in diabetic ketoacidosis) II: Clinical and operational effectiveness. *Acad Emerg Med* 2025;32:61-71.
34. Jozwiak M, Hayes MM, Canet E, Lautrette A, Duroyon MM, Molinari N, *et al.* Management of diabetic keto-acidosis in adult patients admitted to intensive care unit: An ESICM-endorsed international survey. *Crit Care* 2024;28:408.
35. Ssemmondo E, Wong HH, Moteca S, Abobaker A, Pawlak T. A reaudit testing the adherence to the local trust protocol detected delay in potassium replacement during acute management of diabetic ketoacidosis. *Int J Clin Pract* 2021;75:e14647.
36. Tran TT, Pease A, Wood AJ, Zajac JD, Mårtensson J, Bellomo R, *et al.* Review of evidence for adult diabetic ketoacidosis management protocols. *Front Endocrinol (Lausanne)* 2017;8:106.
37. Zhang Y, Li J, Deng S, Zhang Y, Guo M, Jiang F, *et al.* Real-world insights from acute management of potassium disorders in diabetic ketoacidosis. *Front Endocrinol (Lausanne)* 2025;16:1-12.
38. Kilpatrick ES, Butler AE, Ostlundh L, Atkin SL, Sacks DB. Controversies around the measurement of blood ketones to diagnose and manage diabetic ketoacidosis. *Diabetes Care* 2022;45:267-72.
39. Bacha T, Shiferaw Y, Abebaw E. Outcome of diabetic ketoacidosis among paediatric patients managed with modified DKA protocol at Tikur Anbessa specialized hospital and Yekatit 12 hospital, Addis Ababa, Ethiopia. *Endocrinol Diabetes Metab* 2022;5:e363.
40. Zheng DJ, Iskander S, Vujcic B, Amin K, Valani R, Yan JW. Comparison of adult diabetic ketoacidosis treatment protocols from Canadian emergency departments. *Can J Diabetes* 2022;46:269-76.e2.
41. Fatima S, Rehman N, Hashmi M, Khan A, Shahzaib M, Akram MT, *et al.* Threshold-based compliance with diabetic ketoacidosis management protocols and its association with inpatient mortality: A retrospective single-centre study in a tertiary hospital in Karachi, Pakistan. *BMJ Open* 2025;15:e102173.
42. Praveen PA, Hockett CW, Ong TC, Amutha A, Isom SP, Jensen ET, *et al.* Diabetic ketoacidosis at diagnosis among youth with type 1 and type 2 diabetes: Results from SEARCH (United States) and YDR (India) registries. *Pediatr Diabetes* 2021;22:40-6.
43. Enzenbach C, Wicklein B, Wirkner K, Loeffler M. Evaluating selection bias in a population-based cohort study with low baseline participation: The LIFE-adult-study. *BMC Med Res Methodol* 2019;19:135.
44. Goldstein ND, Kahal D, Testa K, Burstyn I. Inverse probability weighting for selection bias in a Delaware community health center electronic medical record study of community deprivation and hepatitis C prevalence. *Ann Epidemiol* 2021;60:1-7.
45. Kuriakose DM, Francis DJ, George DD, Babu DA. Clinical profile and outcome of children with diabetic ketoacidosis admitted in a tertiary care centre in Kerala during the pre and post COVID period. *Int J Paediatr Geriatr* 2023;6:1-6.
46. Ahmad R, Narwaria M, Singh A, Kumar S, Haque M. Detecting diabetic ketoacidosis with infection: combating a life-threatening emergency with practical diagnostic tools. *Diagnostics (Basel)* 2023;13:2441.
47. Shrestha S, Sapkota S, Acharya K, Chaulagain S, Sayami M, Dahal A, *et al.* Perspectives of patients with type 1 and type 2 diabetes on barriers to diabetes care: A qualitative study. *BMC Health Serv Res* 2024;24:1420.
48. Basu S, Sharma N. Diabetes self-care in primary health facilities in India – Challenges and the way forward. *World J Diabetes* 2019;10:341-9.
49. Oberoi S, Kansra P. Economic menace of diabetes in India: A systematic review. *Int J Diabetes Dev Ctries* 2020;40:464-75.
50. Nanda M, Sharma R. Financial burden of seeking diabetes mellitus care in India: Evidence from a Nationally Representative Sample Survey. *Health Care Sci* 2023;2:291-305.
51. Waddankeri SS, Swaraj Waddankeri M, Gurushantappa Mangshetty B. Clinical and biochemical characteristics and treatment outcomes of ketosis-prone diabetes: The remission prone diabetes. *Int J Endocrinol Metab* 2021;19:e106799.
52. Kovacs A, Bunduc S, Veres DS, Palinkas D, Gagyí EB, Hegyi PJ, *et al.* One third of cases of new-onset diabetic ketosis in adults are associated with ketosis-prone type 2 diabetes-a systematic review and meta-analysis. *Diabetes Metab Res Rev* 2024;40:e3743.
53. Yan F, Chen X, Quan X, Wang L, Wei X, Zhu J. Association between the stress hyperglycemia ratio and 28-day all-cause mortality in critically ill patients with sepsis: A retrospective cohort study and predictive model establishment based on machine learning. *Cardiovasc Diabetol* 2024;23:163.
54. Beloborodova NV, Olenin AY, Pautova AK. Metabolomic findings in sepsis as a damage of host-microbial metabolism integration. *J Crit Care* 2018;43:246-55.
55. Mustafa OG, Haq M, Dashora U, Castro E, Dhataria KK, Joint British Diabetes Societies (JBDS) for Inpatient Care Group. Management of hyperosmolar hyperglycaemic state (HHS) in adults: An updated guideline from the joint British diabetes societies (JBDS) for Inpatient Care Group. *Diabet Med* 2023;40:e15005.
56. Ndebele NF, Naidoo M. The management of diabetic ketoacidosis at a rural regional hospital in KwaZulu-Natal. *Afr J Prim Health Care Fam Med* 2018;10:e1-6.
57. Umpierrez GE, Davis GM, ElSayed NA, Fadini GP, Galindo RJ, Hirsch IB, *et al.* Hyperglycemic crises in adults with diabetes: A consensus report. *Diabetes Care* 2024;47:1257-75.
58. Aynalem MW, Nigusse B, Legesse Y, Abebe DG, Ayele T, Getachew H, *et al.* Clinical profile of diabetic ketoacidosis and its severity in adults: Evidence from ALERT comprehensive specialized hospital. *BMC Endocr Disord* 2026;26:110.
59. Abdul-Aziz AA, Desikan P, Prabhakaran D, Schroeder LF. Tackling the burden of cardiovascular diseases in India. *Circ Cardiovasc Qual Outcomes* 2019;12:e005195.
60. Sacks DB, Arnold M, Bakris GL, Bruns DE, Horvath AR, Lermmark Å, *et al.* Guidelines and Recommendations For Laboratory Analysis In The Diagnosis And Management Of Diabetes Mellitus. *Diabetes Care* 2023;46:e151-99.
61. Bhaladhare R, Rishipathak P. Hospital readiness for emergency and critical care in India: A nationwide cross-sectional study. *Int J Emerg Med* 2026;19:50.
62. Sharma J, Leslie HH, Regan M, Nambiar D, Kruk ME. Can India's primary care facilities deliver? A cross-sectional assessment of the Indian public health system's capacity for basic delivery and newborn services. *BMJ Open* 2018;8:e020532.
63. Kostopoulou E, Sinopidis X, Fouzas S, Gkentzi D, Dassios T, Roupakias S, *et al.* Diabetic ketoacidosis in children and adolescents: diagnostic and therapeutic pitfalls. *Diagnostics (Basel)* 2023;13:2602.
64. Barski L, Golbets E, Jotkowitz A, Schwarzfuchs D. Management of diabetic ketoacidosis. *Eur J Intern Med* 2023;117:38-44.
65. Campos Magallón P, Royo Sesma I, Vázquez Gómez JA, Ruiz Del Campo M, Ruiz Del Prado MY. Types of fluid therapy for pediatric patients with diabetic ketoacidosis: A systematic review. *Diabetes Res Clin Pract* 2025;229:112926.
66. Deshmukh H. Navigating hypokalaemia in diabetic ketoacidosis: A call for pragmatic insulin initiation guidelines. *Intern Med J* 2026;56:328.

67. Sinatra N, Cuttone G, Testa TS, Via L, Rubulotta FM, Abrignani MG, *et al.* Chloremia disturbances in critical care: A narrative review of pathophysiology, clinical impact and management strategies. *Life (Basel)* 2026;16:151.
68. Self WH, Evans CS, Jenkins CA, Brown RM, Casey JD, Collins SP, *et al.* Clinical effects of balanced crystalloids versus saline in adults with diabetic ketoacidosis: A subgroup analysis of cluster randomized clinical trials. *JAMA Netw Open* 2020;3:e2024596.
69. Alshurtan KS, Alnizari O, Aldarwish H, Al-Tufaif AA. Efficacy and safety of intravenous insulin in treatment of patient with diabetic ketoacidosis: A systematic review and meta-analysis. *Cureus* 2022;14:e30721. Available from: <https://www.cureus.com/articles/120830-efficacy-and-safety-of-intravenous-insulin-in-treatment-of-patient-with-diabetic-ketoacidosis-a-systematic-review-and-meta-analysis>. [Last accessed on 2026 Jan 26].
70. Genay S, Décaudin B, Ethgen S, Alluin A, Babol E, Labreuche J, *et al.* Effect of insulin infusion line on glycaemic variability in a perioperative high dependency unit (HDU): A prospective randomised controlled trial. *Ann Intensive Care* 2017;7:74. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/28699150>. [Last accessed on 2026 Jan 26].
71. Omar Salem Kanzwl SM, Alhajri AH, Abdelbagi Mohammed YJ, AhmedAbdalaziz MA, Mohammed Ramadan MA, Abdalla Abdelgadir AE, *et al.* A comparative effectiveness of intravenous fluids and insulin regimens in the acute management of diabetic ketoacidosis (DKA) and hypoglycemia: A systematic review. *Cureus* 2025;17:e94902.
72. McGrath P. Subcutaneous Insulin Use in Diabetic Ketoacidosis. *Lynchbg J Med Sci* 2026;2:1-23. Available from: <https://digitalshowcase.lynchburg.edu/jms/vol2/iss1/6>. [Last accessed on 2026 Jan 26].
73. Defante ML, de Souza MM, Mendes BX, De Hollanda Morais BA, Prizão VM, Parolin SA, *et al.* Subcutaneous rapid-acting insulin analogues in mild to moderate diabetic ketoacidosis: A meta-analysis of randomized controlled trials. *J Diabetes Complications* 2024;38:108882.
74. Ibarra F Jr, Bae R, Haghighat B. Review of subcutaneous insulin regimens in the management of diabetic ketoacidosis in adults and pediatrics. *Ann Pharmacother* 2025;59:277-88.
75. Mazer M, Chen E. Is subcutaneous administration of rapid-acting insulin as effective as intravenous insulin for treating diabetic ketoacidosis? *Ann Emerg Med* 2009;53:259-63.
76. van Olmen J, Marchal B, Van Damme W, Kegels G, Hill PS. Health systems frameworks in their political context: Framing divergent agendas. *BMC Public Health* 2012;12:774.
77. Andrade MV, Noronha K, Cardoso CS, Oliveira CD, Calazans JA, Souza MN. Challenges and lessons from a primary care intervention in a Brazilian municipality. *Rev Saude Publica* 2019;53:45.
78. Schünemann HJ, Fretheim A, Oxman AD. Improving the use of research evidence in guideline development: 13. Applicability, transferability and adaptation. *Health Res Policy Syst* 2006;4:25.
79. Basavanthappa SP, Srinivasa V, Sivachand T. Comparison of outcome of milwaukee regimen and 48 hours regimen in diabetic ketoacidosis in a tertiary care hospital in Chitradurga, Karnataka, India. *Int J Contemp Pediatr* 2020;7:1123-5.
80. Thakare PS, Ankar R. To assess the knowledge regarding signs and symptoms of diabetic ketoacidosis and its prevention among diabetes patients in Wardha District, Maharashtra, India. *J Evol Med Dent Sci* 2021;10:1413-6.
81. Thakur R, Jha V, Mukherjee S, Bhadada SK, Dhibar DP. Diabetic and nondiabetic endocrine emergencies: Clinical spectrum and outcomes from a tertiary care center in North India. *AACE Endocrinol Diabetes* 2025;13:46-54.
82. Eledrisi MS, Elzouki AN. Management of diabetic ketoacidosis in adults: A narrative review. *Saudi J Med Med Sci* 2020;8:165-73.
83. Hassan S. Nursing shortage in Pakistan. *NURSEARCHER J Nurs Midwifery Sci* 2023;3:24-5. Available from: <https://www.nursearcher.com/index.php/nrs/article/view/39>. [Last accessed on 2026 Jan 26].
84. Mendez Y, Surani S, Varon J. Diabetic ketoacidosis: Treatment in the intensive care unit or general medical/surgical ward? *World J Diabetes* 2017;8:40-4.
85. Nyenwe E, Loganathan R, Blum S, Ezuteh D, Erani D, Palace M, *et al.* Admissions for diabetic ketoacidosis in ethnic minority groups in a city hospital. *Metabolism* 2007;56:172-8.
86. Dhataria KK, Joint British Diabetes Societies for Inpatient Care. The management of diabetic ketoacidosis in adults-An updated guideline from the Joint British Diabetes Society for Inpatient Care. *Diabet Med* 2022;39:e14788.
87. Strengthening Healthcare Workforce in India: The 2047 agenda. Klynveld Peat Marwick Goerdeler (KPMG); 2022. Available from: <https://home.kpmg/in/en/home/insights/2022/10/strengthening-healthcare-workforce-in-india-the-2047-agenda.html>. [Last accessed on 2026 Jan 26].
88. Sharma SK, Rani R. Nurse-to-patient ratio and nurse staffing norms for hospitals in India: A critical analysis of national benchmarks. *J Family Med Prim Care* 2020;9:2631-7.
89. Sharma S, Pandit A, Tabassum F. Potential facilitators and barriers to adopting standard treatment guidelines in clinical practice. *Int J Health Care Qual Assur* 2017;30:285-98.
90. Haines A, Kuruvilla S, Borchert M. Bridging the implementation gap between knowledge and action for health. *Bull World Health Organ* 2004;82:724-31.
91. Unnikrishnan R, Anjana RM, Mohan V. Diabetes mellitus and its complications in India. *Nat Rev Endocrinol* 2016;12:357-70.
92. Das AK, Saboo B, Maheshwari A, Nair VM, Banerjee S, Jayakumar C, *et al.* Health care delivery model in India with relevance to diabetes care. *Heliyon* 2022;8:e10904.
93. Ata F, Khan AA, Khamees I, Iqbal P, Yousaf Z, Mohammed BZ, *et al.* Clinical and biochemical determinants of length of stay, readmission and recurrence in patients admitted with diabetic ketoacidosis. *Ann Med* 2023;55:533-42.
94. Ji H, Hwang SK. Risk factors for the readmission of patients with diabetic ketoacidosis: A systematic review and meta-analysis. *J Korean Acad Nurs* 2025;55:634-50.
95. Sinha A, Jain A, Batra U, Kivolowitz P. Comprehensive Analysis of the Accelerating Diabetes Epidemic in India: Impacts and Strategic Interventions. In: 2025 International Conference on Digital Innovations for Sustainable Solutions (ICDISS). IEEE; 2025. p. 1-8. Available from: <https://ieeexplore.ieee.org/document/11320701/>. [Last accessed on 2026 Jan 26].
96. Elias MA, Pati MK, Aivalli P, Srinath B, Munegowda C, Shroff ZC, *et al.* Preparedness for delivering non-communicable disease services in primary care: Access to medicines for diabetes and hypertension in a district in South India. *BMJ Glob Health* 2018;2:e000519.
97. Lall D, Engel N, Devadasan N, Horstman K, Criel B. Challenges in primary care for diabetes and hypertension: An observational study of the Kolar district in rural India. *BMC Health Serv Res* 2019;19:44.
98. Muralidharan S. Diabetes and current Indian scenario: A narrative review. *Diabetol* 2024;15:12-7. Available from: https://journals.lww.com/10.4103/jod.jod_93_23. [Last accessed on 2026 Jan 26].
99. Pezzuto F, Scarano A, Marini C, Rossi G, Stocchi R, Di Cerbo A, *et al.* Assessing the reliability of commercially available point of care in various clinical fields. *Open Public Health J* 2019;12:342-68. Available from: <https://openpublichealthjournal.com/VOLUME/12/PAGE/342/>. [Last accessed on 2026 Jan 26].
100. Borzuoi TB, Kordestani F, Ashktorab T, Delgoshaei Y, Kebria BS. Designing a health literacy model for patients with diabetes. *BMC Health Serv Res* 2024;24:894.
101. Pati MK, Swaroop N, Kar A, Aggarwal P, Jayanna K, Van Damme W. A narrative review of gaps in the provision of integrated care for noncommunicable diseases in India. *Public Health Rev* 2020;41:8.