BMJ Open Diabetes Research & Care

Identifying interhospital variation in hyperosmolar hyperglycemic syndrome (HHS) care: development and outcomes of the DEKODE HHS model

Tania M Kew ,[1] Aspasia Manta ,[2] Jhanvi Pravesh Sawlani ,[1] Amanda Ling Jie Yee ,[3] Amar Mann ,[1] Lakshmi Narayanan ,[1] Eleni Armeni,[2,4] Gerry Rayman,[5] Ketan Dhatariya ,[6,7] Punith Kempegowda ,[1,2] DEVI Collaboration

To cite: Kew TM, Manta A, Sawlani JP, *et al*. Identifying interhospital variation in hyperosmolar hyperglycemic syndrome (HHS) care: development and outcomes of the DEKODE HHS model. *BMJ Open Diab Res Care* 2025;**13**:e005489. doi:10.1136/bmjdrc-2025-005489

► Additional supplemental material is published online only. To view, please visit the journal online (https://doi.org/10.1136/bmjdrc-2025-005489).

Parts of this study were presented at the Royal College of Medicine (RCP) 2025 Conference, London, 2 – 3rd June 2025.

Received 31 July 2025
Accepted 20 October 2025

For numbered affiliations see end of article.

Correspondence to
Dr Punith Kempegowda;
p.kempegowda@bham.ac.uk

ABSTRACT

Introduction Hyperosmolar hyperglycemic state (HHS) is a life-threatening metabolic emergency with high mortality rate. Yet, there is no national system in the UK to monitor clinical practice or outcomes. To address this, we implemented and evaluated a multicenter surveillance system for HHS, assessing interhospital variations in management, outcomes, and barriers to guideline implementation.

Research design and methods This mixed-methods observational study was conducted across 12 NHS hospitals between 2021 and 2024. A standardized data collection tool was developed, capturing demographics, biochemistry, treatment, and outcomes of HHS care. Adults meeting the Joint British Diabetes Societies criteria for HHS were included. Quantitative analyses were conducted to investigate care variations compared with guidelines among centers and identify predictors of HHS outcomes. In parallel, stakeholder interviews were analyzed thematically to explore implementation experiences. The Reach, Effectiveness, Adoption, Implementation, Maintenance framework guided evaluation.

Results In our cohort, a total of 218 HHS episodes were included. Median patient age was 77 years; 84.4% had type 2 diabetes, with a high comorbidity burden. The median hospital stay was 10.3 days, and the mortality rate was 16.1%. Significant interhospital variation was observed in insulin dosing, glucose monitoring, and time to discharge. Multivariate analysis identified older age and elevated sodium as independent predictors of mortality. The Digital Evaluation of Ketosis and Other Diabetes Emergencies (DEKODE)-HHS model demonstrated feasibility, high user engagement, and potential for integration into routine quality improvement structures. Qualitative findings revealed barriers, including diagnostic misclassification and resource constraints, to the adoption of the DEKODE-HHS model. However, they also highlighted the educational impact and system usability once the model was adopted.

Conclusions The DEKODE-HHS model represents the first UK multicenter surveillance initiative for HHS. It identifies variation in practice and outcome predictors while highlighting systemic barriers to guideline adherence. This model provides a scalable framework for continuous quality improvement in HHS management and may inform future updates to national guidance.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Hyperosmolar hyperglycemic state (HHS) is a life-threatening diabetic emergency, yet no national surveillance system exists and guideline adherence is unknown.

WHAT THIS STUDY ADDS

⇒ We developed a surveillance model to monitor real-time trends in patient outcomes and adherence to clinical guidelines. Age, serum sodium, urea, and osmolality emerged as key predictors of mortality, supporting their role in risk stratification, and interhospital variation in guideline adherence identified current lapses in performance standards.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE, OR POLICY

⇒ This study demonstrates a scalable and reproducible model for standardizing HHS surveillance, with data that can inform future guidelines and strengthen a sparse evidence base on HHS management.

INTRODUCTION

Hyperosmolar hyperglycemic state (HHS) is a life-threatening acute metabolic complication most commonly observed in individuals with type 2 diabetes mellitus, though it can occur across the diabetes spectrum.[1–3] It is characterized by profound hyperglycemia, marked hyperosmolarity, and severe dehydration resulting from sustained osmotic diuresis secondary to relative insulin deficiency.[1 2] In contrast to diabetic ketoacidosis (DKA), HHS typically presents with minimal or absent

ketonemia and acidosis. Despite a lower prevalence than DKA, HHS carries a significantly higher mortality rate—up to 10 times greater in some reports—due to its insidious onset, delayed recognition, and more severe biochemical derangements.[1 4]

While population-level data from the USA suggest a declining trend in inpatient HHS mortality, with recent estimates as low as 0.77%, the generalizability of these findings to other healthcare systems is unclear.[5] In the UK and Europe, contemporary evidence on the epidemiology, clinical management, and outcomes of HHS remains scarce. Existing studies are frequently limited to single-center or regional datasets, rely on retrospective designs, and are largely descriptive in nature.[6–9] Consequently, a critical gap remains in the literature to inform high-quality, evidence-based care pathways for HHS within the UK context.

Current clinical guidance in the UK, issued by the Joint British Diabetes Society (JBDS), provides structured recommendations for managing HHS.[10] However, these guidelines are predominantly consensus-driven and lack a strong empirical foundation due to the paucity of large-scale, multicenter data. Moreover, there is no dedicated national surveillance mechanism to monitor real-world adherence to these guidelines or to assess variation in care delivery across institutions.[10 11] The National Diabetes Inpatient Safety Audit, while valuable, does not capture the granularity required to evaluate HHS-specific processes and outcomes.[12] This limits the ability of healthcare systems to benchmark performance, identify areas of suboptimal care, or implement evidence-informed improvements.

Variability in the implementation of guideline-based care for HHS is well documented, often reflecting systemic and behavioral barriers at both individual and organizational levels.[13] Such variation in practice can lead to suboptimal outcomes, including prolonged hospital stay, preventable complications, and increased mortality.[5 14] Our prior work has demonstrated that routine feedback on key process and outcome measures can significantly enhance adherence to best-practice guidelines and reduce unwarranted variation in inpatient diabetes care.[15] In this context, there is an urgent need to develop and implement a structured, multicenter surveillance system to systematically evaluate HHS care and drive continuous quality improvement. Therefore, we conducted this study:

1. To develop and implement a standardized multicenter surveillance system for the systematic collection of data on clinical presentation, management practices, and outcomes in patients with HHS.
2. To assess interhospital variation in adherence to national HHS management guidelines and its association with patient outcomes.
3. To explore the barriers and facilitators influencing adoption and sustained implementation of the HHS surveillance model across diverse clinical settings.

METHODS

This was a multicenter, mixed-methods observational study conducted across 12 acute National Health Service (NHS) hospitals in the UK between January 2021 and November 2024. The study aimed to establish and evaluate a standardized surveillance system for the management of HHS. Each participating site secured local institutional approval and registered the project in line with clinical governance frameworks (registration numbers: Hereford Hospital (HHS-QIP 011), Ipswich Hospital (SE-MEDIPS23-1553), Norfolk and Norwich University Hospital (DIAB-22–23 A08), Russells Hall Hospital (Diab/QI/2023-24/04), Royal Free Hospital London (RFHBU_79623/24), Sandwell and West Birmingham Hospitals (SG1913), University Hospitals Birmingham (CARMS 20986), Walsall Manor Hospital (QI20-21/LTC/01), Warwick Hospital (2593)). Data collection adhered to Caldicott principles and institutional data governance protocols to ensure patient confidentiality and compliance with national data protection regulations.[16]

Development of the HHS surveillance system

The HHS surveillance model was developed using the Digital Evaluation of Ketosis and Other Diabetes Emergencies (DEKODE)-DKA framework established by the DEVI collaboration at the University of Birmingham, which facilitates structured data collection to monitor adherence to national guidelines and identify variation in care delivery.[17] We codesigned a standardized data collection tool—a secure, structured Google Form—through an expert consultation process involving contributors to the JBDS HHS guidelines. The form was piloted at a lead site to assess usability, data completeness, and interpretability. Based on iterative feedback from clinicians, revisions were made to enhance clarity, particularly in recording temporally sequenced clinical interventions. Final domains captured included: demographics (age, sex, ethnicity, diabetes type, Body Mass Index, Charlson Comorbidity Index (CCI), HbA1c, preadmission insulin requirements in 24 hours, diabetes pharmacotherapy and residential status), precipitating factors (intercurrent illness, dehydration, poor adherence, steroid-induced hyperglycemia, alcohol-related causes, or new-onset diabetes), biochemical parameters (pH, bicarbonate, osmolality, ketones, glucose, lactate, urea, electrolytes), management (fluid volumes, administration of 0.450% saline, insulin dosing, frequency of capillary blood glucose and ketone monitoring), and outcomes (time to resolution of HHS, time to medically fit for discharge, delays in discharge, complications (eg, hypoglycemia, intensive care unit admission), and in-hospital mortality. Data were pseudonymized at the point of entry using site-specific identifiers, with no patient-identifiable information shared externally.

Case identification and inclusion criteria

Adult inpatients (≥18 years) admitted with suspected HHS were identified using combined informatics-based methods: (1) diagnostic coding via ICD-10-CM (E11.00), and (2) pharmacy records indicating initiation of fixed-rate intravenous insulin infusions. All potential cases underwent screening against diagnostic criteria defined by the JBDS guidelines, which included serum osmolality ≥320 mOsm/kg, serum glucose ≥30 mmol/L, absence of significant ketonemia (≤3.0 mmol/L), and absence of acidosis (pH ≥7.3 and bicarbonate ≥15 mmol/L).[10] Patients with mixed DKA-HHS presentations or those not meeting the above criteria were excluded to maintain diagnostic fidelity.

Implementation and roll-out across sites

Following pilot refinement, the surveillance tool was disseminated to all centers engaged in the DEKODE initiative. Structured training sessions were delivered to individuals expressing interest in participating in the DEKODE HHS surveillance model by experienced DEKODE team members, ensuring a uniform understanding of JBDS-aligned diagnostic criteria, data definitions, and form usage.[10] Training materials and walkthroughs were shared digitally and reinforced through follow-up consultations to maintain fidelity to protocol.

Comparative analysis of clinical practice

To assess intersite variation, individual hospital-level data were benchmarked against median values aggregated across all participating centers. Comparative analyses were also stratified by hospital size and population demographics to control for contextual variability. Each site received anonymized, tailored feedback highlighting areas of congruence or divergence from national guideline recommendations.

Evaluation of implementation: barriers and facilitators

To gain insight into the implementation experience, we administered structured surveys to the clinical teams involved at each site. Survey domains included perceived utility of the surveillance system, ease of integration into existing workflows, organizational readiness, and barriers to data collection. Respondents were invited to participate in semistructured interviews to explore these domains further in depth.

Implementation success was evaluated using the Reach, Effectiveness, Adoption, Implementation, Maintenance (RE-AIM) framework.[18] This structured model enabled multidimensional assessment of feasibility, sustainability, and potential for scale-up.

Data analysis

Quantitative analysis

Descriptive statistics were computed for all clinical and outcome variables. Continuous variables were reported as medians with IQRs and compared using Wilcoxon rank-sum tests following assessment for normality via the Shapiro-Wilk test. Categorical variables were reported as counts (N) with frequencies and compared using χ^2 or Fisher's exact tests, as appropriate. Multivariable logistic regression was performed to identify independent predictors of in-hospital mortality. Variables were selected based on clinical relevance and univariate significance. Calculated osmolality was excluded from the final model due to conceptual collinearity with included variables (sodium and urea). Multicollinearity was assessed using variance inflation factors (VIFs), with all predictors demonstrating acceptable levels (VIFs <1.2). Model performance was assessed using the Hosmer-Lemeshow goodness-of-fit test and Nagelkerke's R^2. Results are presented as adjusted ORs (aORs) with 95% CIs and p values. All statistical analyses were conducted using IBM SPSS Statistics for Mac, V.29.0.1.1 (IBM, Armonk, New York, USA). A two-tailed p value of <0.05 was considered statistically significant.

Qualitative analysis

Interview data were transcribed verbatim and analyzed inductively using thematic analysis. Coding was conducted independently by two researchers using NVivo V.14.24.3 (QSR International, 2025). Discrepancies were resolved through discussion to achieve consensus. Emergent themes were mapped to the RE-AIM framework and synthesized to generate actionable insights for system refinement and wider implementation.[18]

RESULTS

Implementation of the DEKODE-HHS surveillance model

The DEKODE-HHS surveillance system was successfully implemented across 12 acute NHS trusts in England, aligning with audit principles from the National Institute for Health and Care Excellence (NICE) and the Healthcare Quality Improvement Partnership (HQIP) (online supplemental file 1).[19 20] The surveillance model demonstrated feasibility for identifying, monitoring, and evaluating the management and outcomes of HHS across a range of hospital settings.

From 245 patients initially identified through coding and pharmacy records, 218 episodes met JBDS-IP diagnostic criteria for HHS and were included in the final analysis.[10] Excluded cases included miscoded diagnoses (n=17), mixed DKA/HHS presentations (n=6), and incomplete records (n=4).

Improvement initiatives driven by DEKODE-HHS feedback

At Hospital A, early engagement of diabetes specialist nurses, use of real-time feedback loops, and adaptation of JBDS guidance into a streamlined, color-coded A4 protocol were facilitated by the feedback from DEKODE HHS surveillance.[10] Barriers to improving HHS care included workforce shortages, intermittent access to point-of-care testing equipment, and variable interdepartmental communication. Clinicians reported challenges with the practical application of fluid resuscitation and

insulin titration protocols, particularly in out-of-hours settings. To address these challenges, the local guideline was revised to include simplified biochemical monitoring intervals and highlighted early referral to diabetes specialist teams. Updates to local guidelines were informed by the 2024 American Diabetes Association (ADA) consensus on hyperglycemic emergencies to align with current international standards and were piloted successfully at Hospital A, with plans for scaling up across other sites.[21]

Characteristics of the HHS cohort

The median age of included patients was 77.0 years (IQR 64.0–85.0), and 84.4% (n=184/218) had type 2 diabetes. New diagnoses of diabetes accounted for 8.7% (n=19/218) of cases, while 2.4% (n=5/218) had secondary forms of diabetes (eg, post-transplant, steroid-induced). Preadmission glycemic control was suboptimal, with a median HbA1c of 81 mmol/mol (IQR 61.5–116). 41.7% (n=91/218) of patients required insulin therapy, with a median daily dose of 30 units (IQR 16–57.5) prior to admission. Metformin was the most commonly used oral antiglycemic agent (37.2%, n=81/218), and 41.3% (n=90/218) of patients were not receiving any glucose-lowering therapy prior to admission for HHS. The burden of multimorbidity was high, with a median CCI score of 6 (IQR 4–7). The ethnic profile broadly reflected regional diversity: White (57.8%, n=126/218), Asian (19.3%, n=42/218), and Black (10.5%, n=23/218). Most patients (37.2%, n=81/218) were living at home prior to admission, while the remainder resided in long-term care facilities, such as nursing or care homes (table 1).

Intercurrent illness was the most commonly documented precipitant (49.5%, n=108/218), followed by infections (16.0%, n=35/218). Biochemical parameters at presentation were consistent with severe HHS: median glucose 33.0 mmol/L (IQR 30.1–38.9), sodium 147.0 mmol/L (IQR 139.2–154.0), and serum osmolality 354.5 mOsm/kg (IQR 338.3–375.4) (table 1). The median time to formal HHS diagnosis was 1.95 hours (IQR, 0.77–6.00), although 7.8% (n=17/218) were diagnosed more than 24 hours post admission. Median intravenous fluid volume administered during the acute phase was 6.5 L (IQR 4.0–9.7), and median time to resolution was 48.2 hours (IQR 24.9–74.2) (tables 1 and 2). Length of stay was 10.3 days (IQR 6.0–17.0), with common delays in discharge attributed to ongoing investigations or care coordination (table 2).

Interhospital variation in clinical practice and outcomes

Across participating sites, notable variation in management practices and outcomes was observed. In comparative analyses, Hospital A exhibited distinct patterns in several domains. Compared with the overall cohort, patients in Hospital A were younger (median 73.0 years vs 77.0 years; p=0.006), received higher total insulin doses (median 107 units vs 69 units; p=0.001), and demonstrated significantly better adherence to hourly capillary glucose monitoring (86.3% vs 65.9%; p<0.001) (table 1).

Despite a longer time from HHS resolution to medically fit-for-discharge status at Hospital A (11.4 days vs 7.13 days; p=0.012), in-hospital mortality was significantly lower compared with the overall cohort (2.3% vs 16.1%; p=0.011) (table 2). These differences persisted in a direct comparison with Hospital B, which had similar baseline characteristics but lower insulin dosing and adherence to monitoring (tables 3 and 4).

Univariate logistic regression identified older age, higher sodium, urea, and serum osmolality at presentation as significant predictors of in-hospital mortality. In the final multivariable logistic regression model, older age (aOR 1.049 per year; 95% CI 1.012 to 1.087; p=0.015), higher serum sodium at presentation (aOR 1.043 per mmol/L; 95% CI 1.009 to 1.081; p=0.016), and higher serum urea (aOR 1.051 per mmol/L; 95% CI 1.006 to 1.097; p=0.024) remained independent predictors of in-hospital mortality. The mortality difference between Hospitals A and B did not retain significance after adjustment (OR 5.255; 95% CI 0.589 to 46.897; p=0.137). The model showed good calibration (Hosmer-Lemeshow χ^2 = 6.431, p=0.599) and moderate explanatory power (Nagelkerke R^2 = 0.236), with no evidence of multicollinearity (all VIFs <1.2) (table 5).

Stakeholder feedback: training, utility, and motivators

17 stakeholders from participating sites completed the DEKODE-HHS Participant Involvement Questionnaire. The majority had contributed to data collection (76.5%, n=13/17) and audit activities (58.8%, n=10/17), with motivations centered on academic development (76.5%, n=13/17) and quality improvement (64.7%, n=11/17). Participants rated the data collection tool positively for clarity (mean score 8.2/10) and usability (7.1/10). Challenges included incomplete electronic health records, variability in guideline interpretation, and frequent misclassification of HHS as DKA. Engagement was high, with 88.2% (n=15/17) indicating interest in contributing to future protocol development and dissemination.

Eight participants from five NHS trusts participated in follow-up interviews. Thematic analysis (κ=0.68) revealed four core domains:

1. *Implementation logistics*: familiarity with DEKODE initiatives facilitated rapid approval processes. As participant 3 explained: *"So there was absolutely no challenge in getting approval. Everybody was happy. (DEKODE) is quite known, I must say throughout England, so no objection from anyone in setting up the project*". However, logistical barriers, including rotating staff, non-intuitive Electronic Health Records, and Virtual Private Network limitations for remote data entry, impeded data collection.
2. *Educational impact:* the project enhanced clinicians' understanding of HHS, with feedback facilitating struc-

Table 1 Baseline characteristics, precipitating factors, biochemical parameters at diagnosis and management of the overall cohort and comparison with Hospital A

Characteristics	Overall (n=218)	Hospital A (n=44)	P value
Age, median (IQR)	77.0 (64.0–85.0)	73.0 (60.25–83.75)	**0.006**
Gender, n (%)			0.07
Male	104 (47.7)	27 (61.4)	
Female	114 (52.3)	17 (38.6)	
Ethnicity, n (%)			0.326
White	126 (57.8)	32 (72.7)	
Asian	42 (19.3)	6 (13.6)	
Black	23 (10.5)	5 (11.4)	
Other ethnic group	3 (1.4)	0 (0.0)	
Not stated	24 (11.0)	1 (2.3)	
BMI, median (IQR)	25.7 (22.0–29.2)	26.3 (22–30.9)	0.496
Type of diabetes, n (%)			0.193
Type 1	10 (4.6)	7 (15.9)	
Type 2	184 (84.4)	34 (77.3)	
Type 3c	3 (1.4)	0 (0.0)	
First presentation	19 (8.7)	2 (4.5)	
Steroid-induced	1 (0.5)	0 (0.0)	
Post-renal transplant	1 (0.5)	1 (2.3)	
Preadmission HbA1c in mmol/mol, median (IQR)	81 (61.5–116)	70 (59–93)	0.343
Medications, n (%)			
None	90 (41.3)	21 (47.7)	0.238
Insulin	91 (41.7)	19 (43.2)	0.481
Metformin	81 (37.2)	16 (36.4)	0.5
Dipeptidyl peptidase-4 inhbitors (DPP4i)	47 (21.6)	10 (22.7)	0.5
Sulfonylureas	30 (13.8)	3 (6.8)	0.130
Sodium-glucose co-transporter-2 inhibitors (SGLT2i)	11 (5.0)	2 (4.5)	0.418
Preadmission insulin requirements in 24 hours, median (IQR)	30 (16–57.5)	28 (14.5–55.5)	
Residential status before admission, n (%)			0.004
Own home	81 (37.2)	18 (40.9)	
Care/residential home	19 (8.7)	7 (15.9)	
Nursing home	13 (6.0)	7 (15.9)	
Assisted living	1 (0.5)	0 (0.0)	
Sheltered accommodation	1 (0.5)	0 (0.0)	
Unknown	103 (47.2)	12 (27.3)	
CCI, median (IQR)			
Overall	6 (4-7)	5.5 (4-7)	0.194
Discharged alive	6 (4-7)	5 (4-7)	0.194
In-hospital death	5 (4-6)	–	–
Precipitating factors, n (%)			0.131
Intercurrent illness	108 (49.5)	26 (59.1)	
Infectious diseases	35 (16.0)	3 (6.8)	
Suboptimal compliance to treatment	26 (11.9)	5 (11.4)	

Continued

Table 1 Continued

Characteristics	Overall (n=218)	Hospital A (n=44)	P value
Dehydration/reduced oral intake	12 (5.5)	5 (11.4)	
First presentation	11 (5.0)	0 (0)	
Steroid-induced	5 (2.3)	0 (0)	
Alcohol-related	1 (0.5)	1 (2.3)	
Unknown	20 (9.2)	4 (9.1)	
Biochemical parameter at diagnosis, median (IQR)			
pH	7.35 (7.31–7.40)	7.37 (7.30–7.41)	0.542
Bicarbonate (mmol/L)	23.05 (20.7–26.4)	23.0 (19.1–25.8)	0.772
Glucose (mmol/L)	33.0 (30.1–38.9)	33.0 (31.3–33.3)	0.184
Serum osmolality (mOsm/L)	354.5 (338.3–375.4)	354 (328.8–364.8)	0.357
Sodium (mmol/L)	147.0 (139.2–154.0)	145 (137–154)	0.894
Potassium (mmol/L)	4.6 (4.02–5.3)	4.6 (4.14–4.95)	0.990
Urea (mmol/L)	19.35 (13.6–25.25)	19.5 (14.4–25.3)	0.717
Lactate (mmol/L)	2.8 (2.17–3.80)	3.2 (2.2–4.8)	0.073
Ketones (mmol/L)	0.8 (0.3–2.5)	0.7 (0.1–2.4)	0.104
Management, median (IQR)			
Total fluids (L)	6.5 (4.0–9.7)	6.5 (4.5–10.1)	0.122
Total insulin (units)	69.0 (30.8–116.0)	107 (50–161.7)	**0.001**
Adherence to hourly glucose monitoring (%)	65.9 (47.5–88.0)	86.33 (68.61–105.01)	**<0.001**
Adherence to hourly ketone monitoring (%)	28.9 (14.9–49.7)	21.5 (13.0–31.9)	0.079
Administration of 0.45% saline, n (%)	70 (32.1)	29 (67.4)	<0.001

Significant p values (<.05) are highlighted in bold.
BMI, Body Mass Index; CCI, Charlson Comorbidity Index; HHS, hyperosmolar hyperglycemic state.

tured teaching, improving confidence in biochemistry interpretation, and clarifying fluid and insulin management. Participants also became more involved in updating trust-specific guidelines. As participant 7 shared: *"…to recognize which patients are just hyperglycemia or whether they are DKA and HSS are just differentiating between the kind of biochemistry on presentation and then also just appreciating. The different types of fluids, depending on how the patient responds to the initial management, because I think sort of an A&E, the initial few steps…".*

3. *Engagement and motivation*: sustained engagement was driven by opportunities for academic gain and leadership opportunities, with suggestions to embed surveillance activities into foundation training and medical school placements. Participant 4 commented, *"So I'd already been collecting data for the DKA part of it for quite a while. Most, which was mostly because I wanted to learn more about diabetes, … that I didn't have as much knowledge in that as I would have liked really."*
4. *Evaluation and future directions:* participants cited the Google form's clarity and user-friendly design as a key strength of data collection, assuming baseline clinical knowledge. Regular monthly meetings helped maintain momentum and foster collaboration across centers. Communication with consultant leads was efficient and responsive. However, participants expressed a need for more regular feedback on project progress and findings at the local level. Nevertheless, the project helped identify institutional gaps in HHS management and areas requiring focused education. As one participant observed: *"It really brought out where we were lacking in terms of management and where we had to focus more in educating the resident doctors."* (Participant 1)

Evaluation using the RE-AIM framework

The DEKODE-HHS model demonstrated success across all RE-AIM domains (online supplemental file 3)[18]:

- Reach: involved 12 NHS sites with a nationally representative HHS cohort.
- Effectiveness: identified modifiable variations in care and predictors of adverse outcomes.
- Adoption: secured rapid uptake across DEKODE-affiliated trusts via structured training and protocol standardization.
- Implementation: achieved high fidelity through the use of a uniform audit tool, embedded training, and support structures.
- Maintenance: iterative refinements and site-specific feedback loops were integrated, with several sites initiating plans to embed HHS surveillance within routine audit and governance cycles.

Table 2 Outcomes, complications, and discharge types of the overall cohort and comparison with Hospital A

Characteristics	Overall (n=218)	Hospital A (n=44)	P value
Outcomes, median (IQR)			
Time from admission to diagnosis (hours)	1.95 (0.77–6.0)	1.78 (0.85–4.13)	0.165
HHS >24 hours after admission, n (%)	17 (7.8)	1 (2.3)	0.146
HHS duration (hours)	48.2 (24.9–74.15)	53.4 (27.6–68.0)	0.458
Time from HHS resolution to MFFD (days)	7.13 (2.98–12.89)	11.4 (4.6–16.5)	**0.012**
Time from MFFD to discharge (days)	1.0 (0.15–1.86)	0.99 (0.34–1.88)	0.989
Length of stay (days)	10.3 (6.03–16.98)	13.0 (5.77–19.05)	0.145
Complications, n (%)			
Hypoglycemic episodes	32 (14.7)	10 (23.3)	0.085
ITU admission	12 (5.5)	2 (4.7)	0.5
Death	35 (16.1)	1 (2.3)	**0.011**
Factors affecting discharge			
Until MFFD, n (%)			0.513
Ongoing investigations and treatment	61 (28.0)	22 (66.7)	
Glycemic control	34 (15.6)	6 (18.2)	
DSN review	15 (6.9)	3 (9.1)	
Allied health professional review	6 (2.8)	1 (3.0)	
Medical specialist review	2 (0.9)	0 (0.0)	
Awaiting IP Rehab	2 (0.9)	1 (3.0)	
After MFFD, n (%)			0.538
Ongoing investigations and treatment	19 (8.7)	5 (15.6)	
Glycemic control	3 (1.4)	0 (0.0)	
DSN review	11 (5.0)	3 (9.4)	
Allied health professional review	4 (1.8)	0 (0.0)	
Discharge letter or TTO awaited for >3 hours	18 (8.3)	10 (31.3)	
Awaiting placement/POC	23 (10.6)	7 (21.9)	
Awaiting transport	8 (3.7)	4 (12.5)	
No delay	8 (3.7)	3 (9.4)	

Significant p values (<.05) are highlighted in bold.
DSN, diabetes specialist nurse; HHS, hyperosmolar hyperglycaemic state; IP, inpatient; ITU, intensive therapy unit; MFFD, medically fit for discharge; POC, package of care; TTO, to take out medications.

This structured, scalable approach demonstrated both feasibility and impact, offering a replicable model for improving care quality in other rare and complex inpatient diabetes emergencies.

DISCUSSION

This study represents the first successful implementation of a standardized, multicenter surveillance system for HHS in the UK. It led to the most extensive UK dataset to date on the epidemiology, clinical presentation, management, and outcomes of HHS, and demonstrates how structured surveillance can reveal modifiable variation in care and inform improvements in practice. The model aligns with national audit standards from NICE and HQIP and establishes a foundation for embedding continuous quality improvement into routine clinical pathways for rare but high-risk diabetes emergencies.[19 20]

Our findings demonstrate that the DEKODE-HHS model facilitates both clinical insight and institutional benchmarking. By enabling hospitals to evaluate their local data against aggregate medians and similar peers, the model supports early identification of adverse outcomes, areas of low compliance, and good practice. These data can inform future iterations of national guidelines and contribute to a stronger evidence base for optimal HHS care.

To our knowledge, this is the first UK study to report national multicenter data on HHS duration and length of hospitalization. The median length of stay in our cohort was 10.3 days, significantly longer than the 3.8 days

Table 3 Comparison of outcomes, complications, and discharge types between Hospital A and Hospital B

Characteristics	Hospital A (n=44)	Hospital B (n=43)	P value
Outcomes, median (IQR) / n (%)			
Time from admission to diagnosis (hours)	1.78 (0.85–4.13)	2.1 (0.76–8.87)	0.562
HHS >24 hours after admission	1 (2.3)	7 (16.7)	**0.03**
HHS duration (hours)	53.4 (27.6–68.0)	55.7 (30.9–73.2)	0.804
Time from HHS resolution to MFFD (days)	11.4 (4.6–16.5)	6.08 (2.3–12.06)	0.103
Time from MFFD to discharge (days)	0.99 (0.34–1.88)	0.83 (0.16–2.87)	0.482
Length of stay (days)	13.0 (5.77–19.05)	10.4 (7.03–20.86)	0.815
Complications, n (%)			
ITU admission	2 (4.7)	0 (0.0)	0.196
Death	1 (2.3)	7 (16.3)	**0.024**
Hypoglycemic episodes	10 (23.3)	10 (27.8)	0.645
Factors affecting discharge			
Until MFFD, n (%)			0.287
Ongoing investigations and treatment	22 (66.7)	18 (60)	
Glycemic control	6 (18.2)	9 (30)	
DSN review	3 (9.1)	0 (0.0)	
Allied health professional review	1 (3.0)	2 (6.7)	
Medical specialist review	0 (0.0)	1 (3.3)	
Awaiting IP Rehab	1 (3.0)	0 (0.0)	
After MFFD, n (%)			0.521
Ongoing investigations and treatment	5 (15.6)	5 (19.2)	
Glycemic control	0 (0.0)	1 (3.8)	
DSN review	3 (9.4)	3 (11.5)	
Allied health professional review	0 (0.0)	1 (3.8)	
Discharge letter or TTO awaited for>3 hours	10 (31.3)	5 (19.2)	
Awaiting placement/POC	7 (21.9)	9 (34.6)	
Awaiting transport	4 (12.5)	1 (3.8)	
No delay	3 (9.4)	1 (3.8)	

Significant p values (<.05) are highlighted in bold.
DSN, diabetes specialist nurse; HHS, hyperosmolar hyperglycaemic state; IP, inpatient; ITU, intensive therapy unit; MFFD, medically fit for discharge; POC, package of care; TTO, to take out medications.

reported in some US studies, suggesting differences in care pathways, discharge planning, or underlying health system structures.[6] Delays following HHS resolution were frequently attributed to non-clinical factors, including care coordination and ongoing investigation needs, indicating the importance of system-level interventions to support timely discharge.

The demographic profile of our cohort is consistent with previously reported population-level estimates.[3 6] Notably, a significant minority, approximately one-third of HHS cases, occurred in individuals under 70 years of age, including 8.3% aged 30–49 years. This likely reflects the rising prevalence of type 2 diabetes across younger age groups and underscores the importance of recognizing HHS risk in a wider age spectrum.[22 23] Consistent with earlier reports, intercurrent illness and infection were the leading precipitants, accounting for over 70% of cases.[4 9] Furthermore, 10.8% of admissions were linked to poor treatment adherence, indicated by a median preadmission HbA1c of 81 mmol/mol, highlighting opportunities for primary and secondary prevention through education and proactive follow-up, particularly in long-term care facilities, since the majority of our cohort resided in nursing or care homes prior to admission.[24 25]

While 84.4% of our cohort had pre-existing type 2 diabetes, 8.7% presented with new diagnoses. This aligns with findings by Rosager *et al*, who reported that nearly one-third of HHS cases lacked a prior diabetes diagnosis.[3 26] This reinforces the importance of diagnosing and managing HHS based on clinical and biochemical criteria rather than relying solely on known diabetes status.

Table 4 Comparison of baseline characteristics, precipitating factors, biochemical parameters at diagnosis and management between Hospital A and Hospital B

Characteristics	Hospital A (n=44)	Hospital B (n=43)	P value
Age, median (IQR)	73.0 (60.2–83.7)	77.0 (69.0–84.0)	0.139
Gender, n (%)			0.391
Male	27 (61.4)	22 (51.2)	
Female	17 (38.6)	21 (48.8)	
Ethnicity, n (%)			**0.003**
White	32 (72.7)	21 (48.8)	
Asian	6 (13.6)	10 (23.3)	
Black	5 (11.4)	1 (2.3)	
Other ethnic group	0 (0.0)	0 (0.0)	
Not stated	1 (2.3)	11 (25.6)	
BMI, median (IQR)	26.3 (22–30.9)	25.8 (22.1–28.7)	0.674
Type of diabetes, n (%)			0.091
Type 1	7 (15.9)	1 (2.3)	
Type 2	34 (77.3)	41 (95.3)	
Type 3c	0 (0.0)	0 (0.0)	
First presentation	2 (4.5)	1 (2.3)	
Steroid-induced	0 (0.0)	0 (0.0)	
Post-renal transplant	1 (2.3)	0 (0.0)	
Preadmission HbA1c in mmol/mol, median (IQR)	70 (59–93)	76 (60–100)	0.598
Medications, n (%)			
None	21 (47.7)	12 (27.9)	0.077
Insulin	19 (43.2)	22 (51.2)	0.522
Metformin	16 (36.4)	17 (39.5)	0.827
DPP4i	10 (22.7)	14 (32.6)	0.345
Sulfonylureas	3 (6.8)	9 (20.9)	0.068
SGLT2i	2 (4.5)	4 (9.3)	0.434
Preadmission insulin requirements in 24 hours, median (IQR)	28 (14.5–55.5)	26 (14 - 54)	0.149
Residential status before admission, n (%)			0.320
Own home	18 (40.9)	19 (44.2)	
Care/residential home	7 (15.9)	5 (11.6)	
Nursing home	7 (15.9)	2 (4.7)	
Assisted living	0 (0.0)	1 (2.3)	
Sheltered accommodation	0 (0.0)	0 (0.0)	
Unknown	12 (27.3)	16 (37.2)	
CCI, median (IQR)			
Overall	5.5 (4-7)	6 (4–7.75)	0.674
Discharged Alive	5 (4-7)	6 (4-8)	0.403
In-hospital Death	–	5 (4-7)	–
Precipitating factors, n (%)			0.627
Intercurrent illness	26 (59.1)	26 (60.5)	
Infectious diseases	3 (6.8)	7 (16.3)	
Suboptimal compliance to treatment	5 (11.4)	3 (7)	
Dehydration/reduced oral intake	5 (11.4)	4 (9.3)	
Steroid-induced	0 (0)	1 (2.3)	

Continued

Table 4 Continued

Characteristics	Hospital A (n=44)	Hospital B (n=43)	P value
Alcohol-related	1 (2.3)	0 (0)	
Unknown	4 (9.1)	2 (4.7)	
Biochemical parameter at diagnosis, median (IQR)			
pH	7.37 (7.30–7.41)	7.37 (7.32–7.40)	0.607
Bicarbonate (mmol/L)	23.0 (19.1–25.8)	22.1 (20.9–25.2)	0.989
Glucose (mmol/L)	33.0 (31.3–33.3)	32.5 (29.5–35.8)	0.852
Serum osmolality (mOsm/L)	354 (328.8–364.8)	357 (345–380.9)	**0.048**
Sodium (mmol/L)	145 (137–154)	149 (143–159)	0.273
Potassium (mmol/L)	4.6 (4.14–4.95)	4.5 (3.86–5.26)	0.805
Urea (mmol/L)	19.5 (14.4–25.3)	19.7 (13.6–30.65)	0.566
Lactate (mmol/L)	3.2 (2.27–4.8)	2.55 (2.18–3.68)	0.452
Ketones (mmol/L)	0.7 (0.1–2.4)	0.6 (0.2–1.8)	0.647
Management, median (IQR)			
Total fluids (L)	6.5 (4.5–10.1)	7 (5.3–8.0)	0.653
Total insulin (units)	107 (50–161.7)	65 (27–101)	**0.016**
Adherence to hourly glucose monitoring (%)	86.33 (68.61–105.01)	64.88 (52.5–74.6)	**<0.001**
Adherence to hourly ketone monitoring (%)	21.5 (13.0–31.9)	27.9 (9.53–41.0)	0.406
Administration of 0.45% saline, n (%)	29 (67.4)	17 (47.2)	0.108

Significant p values (<.05) are highlighted in bold.
BMI, Body Mass Index; CCI, Charlson Comorbidity Index; HHS, hyperosmolar hyperglycaemic state.

Importantly, the study revealed considerable variation in HHS management, particularly in insulin dosing and capillary glucose monitoring. At Hospital A, higher insulin dosing and superior adherence to hourly glucose monitoring were observed alongside lower inpatient mortality. Notably, baseline glycemic control indicated by HbA1c and preadmission insulin use did not differ between hospitals, suggesting that differences in insulin management during HHS likely reflect institutional variations in clinical practice rather than prior diabetes care. These findings are notable given the absence of trial-based guidance on insulin and fluid regimens in HHS, with current protocols often extrapolated from DKA pathways, and reinforces the importance of adherence to a standardized protocol to reduce variations in HHS care.[10] While causality cannot be established, the observed differences in mortality may warrant further evaluation in prospective or interventional studies.

Inpatient mortality in this cohort was 16.1%, comparable to 10–17% observed in international cohorts.[3 5 7] Multivariate analysis revealed patient-level factors rather than management variations predominantly determined patient outcomes. Higher serum sodium and urea at presentation emerged as significant independent predictors of mortality, reflecting greater severity of HHS. These findings corroborate prior evidence and suggest their potential utility in risk stratification models to guide enhanced monitoring or early therapeutic escalation.[9 27 28] Advanced age also remained a significant predictor of mortality in our cohort, likely a reflection of decreased physiological reserve and increased vulnerability to metabolic stress. The lack of association between comorbidity burden (CCI) and mortality in our cohort

Table 5 Multivariable logistic regression analysis for HHS mortality

Variable		aOR	95% CI	P value
Age (years)		1.049	1.012 to 1.087	0.015
Sodium (mmol/L)		1.043	1.009 to 1.081	0.016
Urea (mmol/L)		1.051	1.006 to 1.097	0.024
Hospital	Hospital A (ref)	1	0.589 to 46.897	0.137
	Hospital B	5.255		

aOR, adjusted OR; HHS, hyperosmolar hyperglycemic state.

differs from some previous studies, possibly due to the uniformly high comorbidity burden across the cohort or sample size limitations.[8 29 30] However, this could also suggest that acute physiological derangement may be superior to chronic disease burden in determining patient outcomes in HHS care.

While some intersite variation in adherence to guideline-recommended practices was observed, differences in outcomes were not statistically significant after adjustment, suggesting that institutional characteristics alone may not explain mortality differences. Instead, the DEKODE-HHS model highlights how structured feedback and local ownership can drive targeted quality improvement. For example, Hospital A adapted the ADA international consensus for HHS care into a simplified, color-coded tool, enhanced educational activities, and demonstrated higher monitoring compliance.

Qualitative feedback further emphasized the educational value of the project, with many participants reporting increased confidence in recognizing and managing HHS. Thematic analysis revealed key implementation facilitators including alignment with existing quality improvement (QI) structures and engagement from clinical leadership, as well as persistent barriers such as workforce limitations, misclassification of HHS, and challenges with data entry and case identification.

This study illustrates the value of a mixed-methods evaluation in implementation science. The RE-AIM framework was instrumental in assessing real-world impact, highlighting the model's wide reach, feasibility, and adaptability across varied institutional contexts.[18] Importantly, stakeholder engagement was high, and feedback has already informed refinements to both the surveillance tool and educational resources.

Strengths and limitations

This study presents the largest UK multicenter dataset on HHS, integrating clinical outcomes with implementation insights to offer a comprehensive evaluation of care delivery. Standardized diagnostic criteria and an embedded feedback model enhanced comparability, adaptability, and scalability. However, key limitations include incomplete documentation of critical variables such as hydration and neurological status, limiting prognostic analysis. Additionally, our analysis did not include the granular specifics of insulin management including loading doses and infusion parameters, imposing constraints on the evaluation of treatment effects given the pivotal role of insulin in HHS management. The study was not powered to detect adjusted mortality differences between sites, and voluntary participation may introduce selection bias. Nonetheless, the findings provide valuable data to inform future guidelines and highlight the feasibility of a surveillance-based quality improvement model for rare acute metabolic emergencies.

CONCLUSION

The DEKODE-HHS surveillance system demonstrates a feasible, scalable model for monitoring and improving care for patients with HHS. It supports early identification of unwarranted variation, informs clinical decision-making, and provides a platform for national benchmarking and future research. Age and serum sodium at presentation emerged as key predictors of mortality and should be further explored in risk-stratification efforts. Institutional adaptation, education, and continuous feedback are critical to enabling improvement. This model may serve as a blueprint for similar efforts in other complex inpatient conditions where national data are sparse and variation in care remains a barrier to safety and equity.

Author affiliations
[1]Department of Diabetes and Endocrinology, Queen Elizabeth Hospital Birmingham, University Hospitals Birmingham NHS Foundation Trust, Birmingham, UK
[2]Department of Applied Health Sciences, School of Health Sciences, College of Medicine and Health, University of Birmingham, Birmingham, UK
[3]Birmingham Medical School, University of Birmingham, Birmingham, UK
[4]Department of Diabetes and Endocrinology, Royal Free Hospital, Royal Free London NHS Foundation Trust, London, UK
[5]Department of Diabetes and Endocrinology, Ipswich Hospital, East Suffolk and North Essex NHS Foundation Trust, Colchester, UK
[6]Department of Diabetes and Endocrinology, Norfolk and Norwich University Hospital, Norfolk and Norwich University Hospitals NHS Foundation Trust, Norwich, UK
[7]Norwich Medical School, University of East Anglia, Norwich, UK

Acknowledgements We are grateful to the various healthcare professionals involved in the surveillance model across all participating sites.

Collaborators Abigail Hallum (Sandwell and West Birmingham Hospitals, Birmingham, UK), Abosede Arafat Bankole (Ipswich Hospital, East Suffolk and North Essex NHS Foundation Trust, Ipswich, UK), Alexandra Solomon (Russells Hall Hospital, The Dudley Group NHS Foundation Trust, Dudley, UK), Angelica Sharma (Norfolk and Norwich University Hospital, Norfolk and Norwich University Hospitals NHS Foundation Trust, Norwich, UK), Anmol Mansha Natt (Warwick Hospital, South Warwickshire University NHS Foundation Trust, Warwick, UK), Charlotte Boden (Sandwell and West Birmingham Hospitals, Birmingham, UK), Emmanuel Beltazar (Royal Free Hospital, Royal Free NHS Foundation Trust, London, UK), Hari Panneerselvam (Hereford Hospital, Wye Valley NHS Trust, Hereford, UK), Hetti Nandasiri (Royal Free Hospital, Royal Free NHS Foundation Trust, London, UK), Joseph Dalzell (Sandwell and West Birmingham Hospitals, Birmingham, UK), Justin Lim (Ipswich Hospital, East Suffolk and North Essex NHS Foundation Trust, Ipswich, UK), Katherine Kinnear (Warwick Hospital, South Warwickshire University NHS Foundation Trust, Warwick, UK), Lisa Kelly (Ipswich Hospital, East Suffolk and North Essex NHS Foundation Trust, Ipswich, UK), Marigold Jabulo (Ipswich Hospital, East Suffolk and North Essex NHS Foundation Trust, Ipswich, UK), Muhammad Aizaz (Norfolk and Norwich University Hospital, Norfolk and Norwich University Hospitals NHS Foundation Trust, Norwich, UK), Rasiah Thayakaran (Walsall Manor Hospital, Walsall Healthcare NHS Trust, Walsall, UK), Samuel Mills (Ipswich Hospital, East Suffolk and North Essex NHS Foundation Trust, Ipswich, UK), Senthilkumar Krishnasamy (Walsall Manor Hospital, Walsall Healthcare NHS Trust, Walsall, UK), Sneha Shaji (Royal Free Hospital, Royal Free NHS Foundation Trust, London, UK), Sulmaaz Qamar (Royal Free Hospital, Royal Free NHS Foundation Trust, London, UK), Tristan Page (Warwick Hospital, South Warwickshire University NHS Foundation Trust, Warwick, UK), and Zeenat Banu (Ipswich Hospital, East Suffolk and North Essex NHS Foundation Trust, Ipswich, UK).

Contributors PK, AS, EA, GR, KD, SK, and TP were involved in the conception and supported the design of the study. AM conducted the statistical analysis. AH, AAB, AS, AS, AMN, CB, EA, EB, HP, HN, JS, JD, JL, KK, KD, LN, LK, MJ, MA, SM, SK, SS, SQ, TMK, and TP collected the data. TMK, PK, and ALJY wrote the original draft of the manuscript, and all authors edited, reviewed, and approved the final version of the manuscript. PK is the guarantor of this work. During the preparation of this work, the author(s) used ChatGPT and Grammarly to improve language and readability. After using this tool/service, the author(s) reviewed and

edited the content as needed and take(s) full responsibility for the content of the publication.

Funding PK is supported by the National Institute for Health and Care Research (NIHR) through his Advanced Fellowship (NIHR303671). Additionally, he is supported by the Midlands Patient Safety Research Collaboration (PSRC) and the NIHR Race, Equity, and Diversity in Careers Incubator. The views expressed in this study are those of the author and do not necessarily reflect the official positions of the NIHR or the Department of Health and Social Care.

Competing interests None declared.

Patient consent for publication Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. All data generated and analyzed in this study are included in the published article (and its online supplemental files) and are available from the corresponding author upon reasonable request.

ORCID iDs
Tania M Kew https://orcid.org/0000-0001-9363-3760
Aspasia Manta https://orcid.org/0000-0002-3420-1420
Jhanvi Pravesh Sawlani https://orcid.org/0000-0002-1054-5325
Amanda Ling Jie Yee https://orcid.org/0000-0001-9235-2836
Amar Mann https://orcid.org/0000-0002-7972-4794
Lakshmi Narayanan https://orcid.org/0009-0009-7894-3133
Ketan Dhatariya https://orcid.org/0000-0003-3619-9579
Punith Kempegowda https://orcid.org/0000-0003-0954-6512

REFERENCES

1 Pasquel FJ, Umpierrez GE. Hyperosmolar hyperglycemic state: a historic review of the clinical presentation, diagnosis, and treatment. *Diabetes Care* 2014;37:3124–31.
2 Karslioglu French E, Donihi AC, Korytkowski MT. Diabetic ketoacidosis and hyperosmolar hyperglycemic syndrome: review of acute decompensated diabetes in adult patients. *BMJ* 2019;365:l1114.
3 Rosager EV, Heltø ALK, Fox Maule CU, *et al*. Incidence and Characteristics of the Hyperosmolar Hyperglycemic State: A Danish Cohort Study. *Diabetes Care* 2024;47:272–9.
4 Kitabchi AE, Umpierrez GE, Murphy MB, *et al*. Management of hyperglycemic crises in patients with diabetes. *Diabetes Care* 2001;24:131–53.
5 Shaka H, El-Amir Z, Wani F, *et al*. Hospitalizations and inpatient mortality for hyperosmolar hyperglycemic state over a decade. *Diabetes Res Clin Pract* 2022;185:109230.
6 Pasquel FJ, Tsegka K, Wang H, *et al*. Clinical Outcomes in Patients With Isolated or Combined Diabetic Ketoacidosis and Hyperosmolar Hyperglycemic State: A Retrospective, Hospital-Based Cohort Study. *Diabetes Care* 2020;43:349–57.
7 Fadini GP, de Kreutzenberg SV, Rigato M, *et al*. Characteristics and outcomes of the hyperglycemic hyperosmolar non-ketotic syndrome in a cohort of 51 consecutive cases at a single center. *Diabetes Res Clin Pract* 2011;94:172–9.
8 Chen H-F, Wang C-Y, Lee H-Y, *et al*. Short-term case fatality rate and associated factors among inpatients with diabetic ketoacidosis and hyperglycemic hyperosmolar state: a hospital-based analysis over a 15-year period. *Intern Med* 2010;49:729–37.
9 Wu X-Y, She D-M, Wang F, *et al*. Clinical profiles, outcomes and risk factors among type 2 diabetic inpatients with diabetic ketoacidosis and hyperglycemic hyperosmolar state: a hospital-based analysis over a 6-year period. *BMC Endocr Disord* 2020;20:182.
10 Mustafa OG, Haq M, Dashora U, *et al*. 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.
11 Nyenwe EA, Kitabchi AE. Evidence-based management of hyperglycemic emergencies in diabetes mellitus. *Diabetes Res Clin Pract* 2011;94:340–51.
12 NHS England. National diabetes inpatient audit (NaDIA). 2019. Available: https://digital.nhs.uk/data-and-information/publications/statistical/national-diabetes-inpatient-audit/2019 [Accessed 19 Dec 2024].
13 Zhou P, Chen L, Wu Z, *et al*. The barriers and facilitators for the implementation of clinical practice guidelines in healthcare: an umbrella review of qualitative and quantitative literature. *J Clin Epidemiol* 2023;162:169–81.
14 McCoy RG, Herrin J, Galindo RJ, *et al*. All-cause mortality after hypoglycemic and hyperglycemic emergencies among U.S. adults with diabetes, 2011-2020. *Diabetes Res Clin Pract* 2023;197:110263.
15 Thomas L, Kolenysk A, Melson E, *et al*. Retrospective validation of Digital Evaluation of Ketosis and Other Diabetes Emergencies (DEKODE) algorithm: automated auditing system for diabetic ketoacidosis (DKA) management. *Future Healthc J* 2020;7:s75–6.
16 UK Government. The eight caldicott principles. 2020. Available: https://www.gov.uk/government/publications/the-caldicott-principles [Accessed 19 Dec 2024].
17 Rengarajan LN, Cooper C, Malhotra K, *et al*. DEKODE-A cloud-based performance feedback model improved DKA care across multiple hospitals in the UK. *Diabet Med* 2025;42:e70004.
18 Glasgow RE, Harden SM, Gaglio B, *et al*. RE-AIM Planning and Evaluation Framework: Adapting to New Science and Practice With a 20-Year Review. *Front Public Health* 2019;7:64.
19 National Institute for Care and Excellence. Principles for best practice in clinical audit. 2002. Available: https://www.nice.org.uk/media/default/About/what-we-do/Into-practice/principles-for-best-practice-in-clinical-audit.pdf [Accessed 19 Dec 2024].
20 Healthcare Quality Improvement Partnership. Best practice in clinical audit. 2020. Available: https://www.hqip.org.uk/wp-content/uploads/2020/05/FINAL-Best-Practice-in-Clinical-Audit-2020.pdf [Accessed 19 Dec 2024].
21 Umpierrez GE, Davis GM, ElSayed NA, *et al*. Hyperglycemic Crises in Adults With Diabetes: A Consensus Report. *Diabetes Care* 2024;47:1257–75.
22 Ong KL, Stafford LK, McLaughlin SA, *et al*. Global, regional, and national burden of diabetes from 1990 to 2021, with projections of prevalence to 2050: a systematic analysis for the Global Burden of Disease Study 2021. *The Lancet* 2023;402:203–34.
23 Pal K, Horsfall L, Sharma M, *et al*. Time trends in the incidence of clinically diagnosed type 2 diabetes and pre-diabetes in the UK 2009-2018: a retrospective cohort study. *BMJ Open Diabetes Res Care* 2021;9:e001989.
24 McCoy RG, Galindo RJ, Swarna KS, *et al*. Sociodemographic, Clinical, and Treatment-Related Factors Associated With Hyperglycemic Crises Among Adults With Type 1 or Type 2 Diabetes in the US From 2014 to 2020. *JAMA Netw Open* 2021;4:e2123471.
25 Gianchandani R, Wei M, Demidowich A. Management of Hyperglycemia in Hospitalized Patients. *Ann Intern Med* 2024;177:ITC177–92.
26 Chou W, Chung M-H, Wang H-Y, *et al*. Clinical characteristics of hyperglycemic crises in patients without a history of diabetes. *J Diabetes Investig* 2014;5:657–62.
27 Chung ST, Perue GG, Johnson A, *et al*. Predictors of hyperglycaemic crises and their associated mortality in Jamaica. *Diabetes Res Clin Pract* 2006;73:184–90.
28 MacIsaac RJ, Lee LY, McNeil KJ, *et al*. Influence of age on the presentation and outcome of acidotic and hyperosmolar diabetic emergencies. *Intern Med J* 2002;32:379–85.
29 Desai R, Singh S, Syed MH, *et al*. Temporal Trends in the Prevalence of Diabetes Decompensation (Diabetic Ketoacidosis and Hyperosmolar Hyperglycemic State) Among Adult Patients Hospitalized with Diabetes Mellitus: A Nationwide Analysis Stratified by Age, Gender, and Race. *Cureus* 2019;11:e4353.
30 Soh JGS, Wong WP, Mukhopadhyay A, *et al*. Predictors of 30-day unplanned hospital readmission among adult patients with diabetes mellitus: a systematic review with meta-analysis. *BMJ Open Diabetes Res Care* 2020;8:e001227.