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National survey of the management of Diabetic Ketoacidosis (DKA) in the UK in 2014

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Abstract

Aim To examine, in a national survey, the outcomes of adult patients presenting with DKA in 2014, mapped against accepted UK national guidance.

Methods Data were collected in a standardized form covering clinical and biochemical outcomes, risk and discharge planning. The form was sent to all UK diabetes specialist teams (n = 220). Anonymized data were collected on five consecutive patients admitted with DKA between 1 May 2014 and 30 November 2014.

Results A total of 283 forms were received (n = 281 patients) from 72 hospitals, of which 71.4% used the national guidelines. The results showed that 7.8% of cases occurred in existing inpatients, 6.1% of admissions were newly diagnosed diabetes and 33.7% of patients had had at least one episode of DKA in the preceding year. The median times to starting 0.9% sodium chloride and intravenous insulin were 41.5 and 60 min, respectively. The median time to resolution was 18.7 h and the median length of hospital stay was 2.6 days. Significant adverse biochemical outcomes occurred, with 27.6% of patients developing hypoglycaemia and 55% reported as having hypokalaemia. There were also significant issues with care processes. Initial nurse-led observations were carried out well, but subsequent patient monitoring remained suboptimal. Most patients were not seen by a member of the diabetes specialist team during the first 6 h, but 95% were seen before discharge. A significant minority of discharge letters to primary care did not contain necessary information.

Conclusion Despite widespread adoption of national guidance, several areas of management of DKA are suboptimal, being associated with avoidable biochemical and clinical risk.

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Introduction

DKA is a common and significant contributor to mortality and morbidity in people with Type 1 diabetes [1]. Clinicians commonly find that much of the in-hospital morbidity experienced by patients with diabetes is related to DKA treatment, and that there is wide variability in the definition of DKA and in the use of guidelines among teams. To date, only one study has looked in detail at outcomes of DKA that mapped outcomes against a standardized guideline [2].

In 2010, the UK Joint British Diabetes Societies for Inpatient Care (JBDS-IP) published national guidance on the management of DKA, and revised these in 2013 [3,4]. These guidelines have achieved high levels of adoption in the UK and suggest a formal diagnosis be based on a pH level of <7.3, a blood glucose level of >11.0 mmol/l or a previous diagnosis of diabetes, and a blood ketone level of >3.0 mmol/l. The guidelines emphasize the importance of normalization of ketone levels, using bedside ketone monitors to aid treatment, and a weight-based, fixed-rate intravenous (i.v.) insulin infusion in the initial management until the DKA has resolved. Fluid and potassium replacement guidance is also given. Several small-scale audits within individual diabetes and acute medicine departments had been presented in regional and national meetings as abstracts, suggesting there is enthusiasm to assess the management of DKA nationally.

To address gaps in our understanding of modern outcomes in DKA, we conducted a national survey on its management and assessed these against the standards in the nationally adopted JBDS guidelines [4].

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What's new?

- In 2013, a revised version of national guidance on the management of DKA was published, but there are no data to show that these recommendations actually work.
- This is the largest national survey on the management of DKA.
- Most patients developed hypokalaemia and >25% developed hypoglycaemia. There were also significant issues with care processes.
- The management of DKA will need to change to prevent hypokalaemia but this will necessitate a shift in the location in which patients are treated. As a result of moving to a high-dependency or intensive care environment, however, care processes may improve.

Patients and methods

A data collection questionnaire was developed using the 2013 JBDS guidelines as a template (Appendix S1). This questionnaire was sent out by email to all 220 UK specialist diabetes teams.

We accessed the databases of Diabetes UK, the Association of British Clinical Diabetologists and the Diabetes Inpatient Specialist Nurse UK Group. This was the network that was also used to conduct the 2012 survey.

One clinician from each Trust was asked to fill in and return a single form for each of the subsequent five patients admitted to their institution between May and November 2014 with a diagnosis of DKA. This number was chosen to try to gain as much meaningful information from individual units as possible without burdening them.

Data were analysed using SPSS software (IBM Ltd, Portsmouth, UK).

The Clinical Audit and Improvement Department of the Norfolk and Norwich University Hospitals NHS Foundation Trust deemed this survey to be a service improvement exercise and that the project did not require multi-site ethical, research governance or audit approval.

Results

Clinical details

A total of 283 forms were received from 72 hospitals; 281 individual patient forms were received, with two patients having two admissions each. The participating hospitals are listed in Appendix S2. The demographics of the patients and where they received treatment are shown in Table 1.

Admissions for DKA were least frequent between 20:00 and 07:00 h, with only 29.4% of admissions during the night, and the remainder were spread equally throughout the rest of the day. There were no differences in the pH or bicarbonate levels in those admitted during the night compared with those admitted during the day. The median [interquartile range (IQR)] length of stay for the whole cohort was 2.6 (1.5, 4.8) days and the mean (SD) was 4.2 (5.6) days. A total of 7.8% of all episodes had developed in existing inpatients, and 33.7% of patients had had at least one previous admission for DKA in the preceding 12 months (median 2, range 1–100).

Table 1 Baseline demographics of patients included in the study (n = 283)

Gender, %	
Male	51.9
Female	46.3
Missing data	1.8
Mean (± SD) age, years	37.8 (±18.5)
Ethnicity, %	
White	81.6
Mixed white/ Asian or white /black Caribbean	0.8
Indian/Asian	1.4
African /black	1.5
Other	0.4
Missing data	14.5
Treatment area	
Level 1 (general ward)	15.9
Level 2 (high dependency)	14.2
Level 3 (intensive care)	9.5
Acute medical unit	39.2
Accident and emergency	10.2
Combination	7.9
Missing data	2.8

Management in the first hour

The diagnosis of DKA was made at a median (IQR) of 35.5 (18, 81) min after initial presentation to the emergency department. The median (IQR) time at which 0.9% sodium chloride solution was first started was 41.5 (21, 90) min and the median (IQR) time for the fixed rate i.v. insulin infusion being started was 60 (29, 105) min. Table 2 shows the diagnosis and management of the patients during the first hour after admission. Senior review occurred immediately in 34.3% and after the initial management in a further 50.9% of cases. No senior review was carried out in 2.1% of cases.

Biochemical changes in first 24 h

The patients' mean (± SD) pH was at time of admission was 7.16 (± 0.15), glucose concentration was 28.7 (±10.9) mmol/l, blood ketone concentration was 5.68 (±1.5) mmol/l, and bicarbonate concentration was 11.3 (±5.1) mmol/l. The mean (± SD) potassium concentration on admission was 4.8 (±1.0) mmol/l. Figures 1a, b and c show the changes in pH, bicarbonate and potassium values during the course of the 24 h following admission. In 55.1% of cases, potassium

Table 2 Management of the patient in the first hour after diagnosis of DKA was made (n = 283)

Variable	Yes, %	No, %	Missing data, n (%)
Was the diagnosis made according to local criteria?	67.1	3.2	84 (29.7)
Was the diagnosis made using JBDS criteria?	71.4	18.7	28 (9.9)
Seen by intensive care unit staff or a senior?	85.9	7.1	19 (6.7)
Was the care given in an appropriate area?	94	2.1	10 (3.5)
Was a 'STAT' insulin dose given?	14.8	84.1	3 (1.1)
Was 0.9% sodium chloride solution used?	96.5	3.2	1 (0.4)
Was an fixed rate i.v. insulin infusion used?	91.5	8.5	0 (0)
Potassium replacement in accordance with local protocol?	79.9	12.9	20 (7.2)
Early Warning Score recorded?	91.2	3.2	16 (5.7)
Respiratory rate recorded?	96.5	0.4	9 (3.2)
Temperature recorded?	95.4	0	13 (4.6)
Pulse rate recorded?	97.2	0	8 (2.8)
Oxygen saturations recorded?	97.2	0	8 (2.8)
Glasgow Coma Scale score recorded?	89.8	6.7	10 (3.5)
Full history recorded?	95.8	3.2	3 (1.1)
Full examination recorded?	92.6	3.2	11 (3.9)
Foot examination recorded?	33.9	47.7	52 (18.4)
Blood ketones recorded?	80.9	15.9	9 (3.2)
Capillary blood glucose recorded?	97.5	0.7	5 (1.8)
Venous plasma glucose recorded?	93.3	4.2	7 (2.5)
Urea and electrolytes recorded?	98.9	0	3 (1.1)
Venous blood gases recorded?	92.9	5.7	4 (1.4)
Full blood count performed?	92.2	3.2	13 (4.6)
Electrocardiogram performed?	79.9	14.1	17 (6.0)
Chest X-ray performed?	69.3	23.7	20 (7.1)
Urine analysis performed?	74.9	13.1	34 (12)

The number and percentage of missing data for each variable is shown.
JBDS, Joint British Diabetes Societies for Inpatient Care Group.

levels were outside the range of 4.0–5.5 mmol/l. As Fig. 1c shows, the mean potassium level dropped, with 18.6 and 67.1% of patients having a potassium concentration <4.0 mmol/l at 1 and 24 h, respectively. The mean (± SD) lowest recorded potassium value during the admission was reported as 3.65 (±0.66) mmol/l, suggesting that the majority of the out-of-range potassium values were attributable to hypokalaemia.

The mean (± SD) lowest recorded glucose concentration was 4.7 (±2.3) mmol/l, with 27.6% of patients developing overt hypoglycaemia. The median (IQR) time to developing hypoglycaemia was 14.7 (10.5, 25.0) h after admission. In all, 29.6% of patients in whom the long-acting insulin was not continued developed hypoglycaemia, with 36.6% developing hypoglycaemia if it was continued.

Adherence to guidelines

The continued management of the patients during and after the first hour and up to 24 h are shown in Table 3. A total of 20.1% of respondents felt that potassium replacement was not carried out in accordance with their guidelines. In addition, 0.9% sodium chloride solution and a fixed-rate i.v. insulin infusion were also not used according to local protocols in 9.9 and 7.8% of patients, respectively. There was no statistical difference between glucose or potassium levels between the patients in hospitals that reported following the guidelines and those that did not.

Resolution and on-going in-hospital management

The median (IQR) length of time to resolution of DKA was 18.7 (11.3, 27.8) h. This is in contrast to previous data that suggested that resolution was achieved in 12.1 h [2]. Whilst 83.1% of teams said that the resolution of DKA had been confirmed, only 11% of respondents said they used pH to diagnose resolution, 17.3% used ketone measurement, 95% used glucose and 5.3% used bicarbonate. Further data regarding ongoing management in hospital are shown in Table 4.

Patients were discharged from hospital a median (IQR) of 2.6 (1.5, 4.8) days after admission.

Discharge planning

Table 5 shows the steps taken before discharge of patients.

Discussion

This large national survey (30% of UK hospitals participated) found that most centres have adopted or adapted the national guidelines produced by the JBDS group for the management of patients presenting with DKA [4]. Before the publication of the national guidance and the present analysis, there was no way of knowing if the standards of care used to treat DKA were effective. Previous work has shown that the use of a standardized management protocol is associated

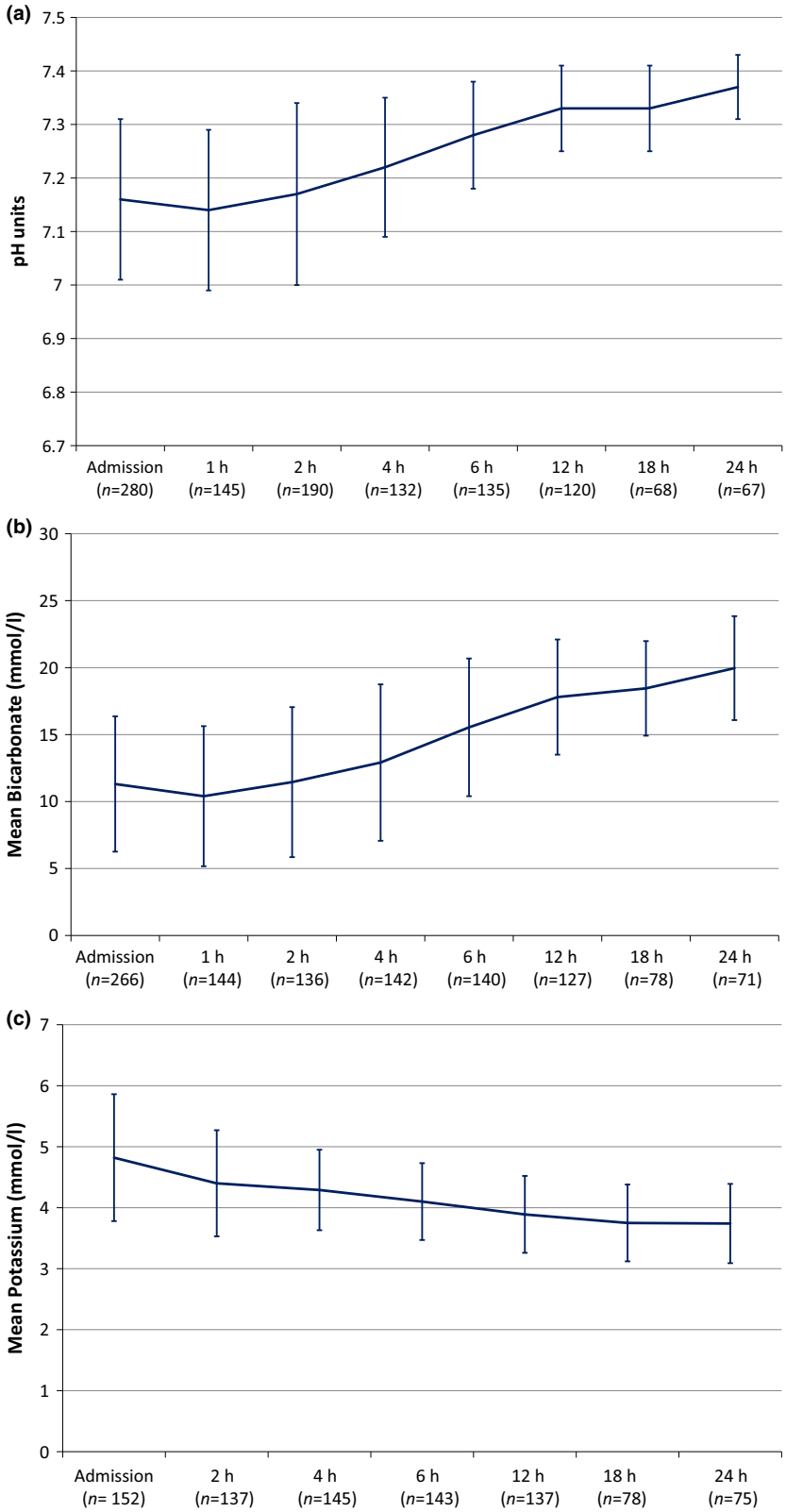

FIGURE 1 Changes in (a) pH (b) bicarbonate (mmol/l) and (c) potassium levels over time (mmol/l). Error bars are ±1 SD.

Table 3 Ongoing patient management between 1 and 24 h after the diagnosis of DKA was made (n = 283)

Variable	Yes, %	No, %	Missing data, n (%)
Was i.v. 0.9% sodium chloride solution replacement given as per local guidance?	89.4	9.9	2 (0.7)
Was potassium replaced as per local guidance?	77.4	20.1	7 (2.5)
Did potassium levels remain between 4.0 and 5.5 mmol/l?	43.1	55.1	5 (1.8)
Was a fixed-rate i.v. insulin infusion used as per local guidance	90.5	7.8	5 (1.8)
Was an appropriate monitoring regimen established?	70.3	25.1	13 (4.6)
Capillary glucose levels measured hourly?	81.6	13.1	15 (5.3)
Ketone levels measured hourly?	57.6	37.1	15 (5.3)
Observations of vital signs taken hourly?	67.8	26.9	15 (5.3)
Early Warning Score measured hourly?	67.1	32.5	21 (7.4)
Urine output documented?	74.2	22.6	9 (3.2)
Was 10% glucose started when the glucose dropped to <14 mmol/l?	82.7	15.2	6 (2.1)
Review of fluid balance with the rate of normal saline amended if appropriate?	68.9	20.8	29 (10.2)
Was a long-acting insulin continued?	58.3	38.5	8 (2.8)
Was there a review of metabolic response to treatment?	85.9	5.7	22 (7.8)
If yes, were appropriate changes in treatment made?	58.7	10.2	86 (30.4)
Did the patient ever develop hypoglycaemia?	27.6	67.5	14 (4.9)
If progress was not satisfactory, did a senior review occur?	33.2	52.3	41 (14.5)
Was a precipitating cause found?	77.0	13.8	25 (8.8)
Was a referral to diabetes team made?	92.6	4.2	9 (3.2)

i.v., intravenous.

Table 4 Data showing the management of DKA beyond 24 h, once the resolution of DKA had been confirmed (n = 283)

Variable	Yes, %	No, %	Missing data, n (%)
Was resolution of DKA confirmed?	83.1	9.2	22 (7.8)
Treatment and monitoring reviewed by specialist registrar /consultant on-call?	11.0	67.5	61 (21.6)
Was the specialist diabetes team involved during the acute phase?	13.4	53.0	95 (33.6)
Where necessary, was a variable-rate i.v. insulin infusion used according to local policy?	50.9	43	17 (6.1)
When eating and drinking and no ketones, was patient transferred to s.c. insulin?	87.6	7.1	16 (5.7)
Was this transition to s.c. insulin managed appropriately?	83.4	12.4	12 (4.2)
After DKA resolution, was the patient reviewed by the Diabetes Inpatient Specialist Team?	95.1	3.9	3 (1.1)

i.v., intravenous; s.c., subcutaneous.

with improved outcomes, in particular, reducing length of stay [5], but there are few data looking at modern national outcomes in the management of DKA [6–8].

This survey was undertaken using the framework of this national guidance; we found that despite widespread adoption of the guidelines, the majority of patients develop hypokalaemia and >27% develop hypoglycaemia during their treatment. These data do not show any differences between the risk of developing hypoglycaemia or hypokalaemia and whether the guideline for potassium replacement or the i.v. insulin regimen was used or not; however, given that there are no previous data on this scale, it is not known if there has been an improvement in overall standards of care since individual hospitals adopted or adapted the guideline. What the current data suggest is that several areas of management were carried out well, in particular 'process issues', carried out in the first few hours after presentation. These were most likely to be carried out by nursing staff in the emergency department. Tables 2 to 5 show where practice was carried out well; however, these data also show that there is some room for continued improvement in many areas and that the guidelines need amending to ensure that more aggressive potassium replacement and an adjustment of the i.v. insulin regimen are carried out. There remain significant shortfalls in management, in particular process issues with regard to monitoring, e.g. capillary glucose or ketone and urine output measurements, that need to be addressed.

There are few recent data on the incidence and prevalence of DKA, and in particular the morbidity and mortality caused by this condition. Data from the Centers for Disease Control in the USA reported that between 1988 and 2009 the age-adjusted discharge rate for DKA as the first listed diagnosis rose from 3.2 to 4.6 per 10 000 population [9]. In England and Wales, the National Diabetes Audit in 2011/2012 data show that there were 7608 adults with at least one episode of DKA during that year, representing a crude prevalence of 3.57% [10].

In the present dataset there was one reported death, which occurred 33 days after admission with DKA that had resolved within 24 h of admission, in a 72-year-old man with hospital-acquired pneumonia and osteomyelitis. Data from Birmingham, UK show that mortality decreased from 3.9% between 1971 and 1991 to 1.8% between 2000 and 2009 [11,12]. More recently, some authors have suggested

Table 5 Data showing the management of DKA once resolution had been confirmed (n = 283)

Variable	Yes, %	No, %	Missing data, n (%)
Did the patient receive education support before discharge?	86.8	8.8	13 (4.6)
Did the patient receive psychological support before discharge?	8.1	82.7	26 (9.2)
Did the discharge letter contain all the correct clinical information?	91.2	2.5	17 (6.0)
Did the discharge letter contain the correct insulin dose?	76.3	15.5	23 (8.1)
Did the discharge letter contain the correct delivery device?	56.9	32.5	30 (10.6)
Did the discharge letter contain the correct insulin name?	83.7	8.8	20 (7.1)
Did follow-up by Diabetes Inpatient Specialist Team take place within 30 days?	54.1	31.1	41 (14.5)
Were there any post-discharge complications?	9.2	83.0	22 (7.8)
Was there a written care plan between patient and Diabetes Inpatient Specialist Team?	46.6	41.3	34 (12.0)
Was a copy of the care plan sent to GP?	53.4	38.2	24 (8.5)
Did the patient have access to ketone testing on discharge?	55.5	26.1	52 (18.4)

GP, general practitioner.

that with improvements in overall care, deaths from hyperglycaemic crises and DKA have been declining [13], but it remains a condition with significant mortality of between 0.7 and 5% in adults [12,14,15].

Our data show that 7.8% of patients had developed DKA during their inpatient stay. This is in marked contrast to the data from the National Diabetes Inpatient Audit, which suggested that only 0.4% of patients who developed DKA and who took part in that audit developed the DKA during that admission [1]. The data collection strategy in that audit was different, and the patient population was different, but the large number is still striking. A total of 32.8% of patients had had at least one episode of DKA in the previous 12 months (range of previous admissions for DKA in the previous 12 months, 1–100). The causes of inpatient DKA were not given in four cases, in nine cases the patients had developed infections (urinary tract, gastroenteritis or dental), two patients developed vomiting (one post-partum), and in six cases, there were insulin administration errors. That so many people developed DKA while they were hospital inpatients is clearly of great concern. The failure to administer insulin correctly has been identified as a 'never event' by NHS England [16]. As a result of these data it would be prudent for hospitals to have mechanisms for every case of in-hospital DKA to be investigated, and interventions put in place to prevent these from recurring.

In all, 10 people (3.5%) presented with blood glucose levels of ≤12 mmol/l, suggesting that 'euglycaemic DKA' remains an important differential diagnosis. Furthermore, given that 14.8% of all patients required a 'STAT' dose of insulin within the first hour after diagnosis, this suggests there may have been a delay in treatment in these individuals, even though the median times to starting fluids and insulin were 41.5 and 60 min, respectively, after initial presentation to the emergency department.

The fact that almost all patients were treated with 0.9% sodium chloride solution ('normal saline') suggests that most acute medical teams and diabetes specialist teams use this as the first-line fluid of choice. This issue has previously been discussed elsewhere [17]. Data to show that alternative fluids are associated with better outcomes are lacking [18].

The move to a fixed-rate i.v. insulin infusion has been very quickly taken up across the UK and is a clear change of practice since the introduction of the JBDS guidelines. In addition, the use of venous blood gases analysis is now very frequent. This has been advocated because the perceived difference between arterial and venous bicarbonate is small enough to be clinically insignificant when making management decisions in DKA [19].

Nurse-led initial observations were carried out in most cases; however, factors that may have more traditionally fallen to the doctors were less well performed. Notably, only 33.9% of patients had a record of their feet being looked at, despite recommendations that the feet of all patients with diabetes admitted to hospital should be examined [20].

A total of 80.9% of patients had their blood ketone levels measured. There has been an argument against the use of handheld, point-of-care ketone testing meters in hospital because of their potential inaccuracy and lack of well conducted clinical trials [21]; however, to date, these fears do not seem to have resulted in any measurable patient harms and have become an integral part of the management of DKA [22].

The lack of a chest X-ray in one in four admissions and an electrocardiogram in 14% of admissions warrants further investigation. Potassium remains the most significant electrolyte disturbance in DKA. As a result of both metabolic acidosis and osmotic diuresis, it has been estimated that even in 'mild' DKA, at the time of presentation, an individual may have a deficit of 3–5 mmol/kg [23]. Adequate potassium replacement is therefore paramount, but this has its problems because of the potential for acute cardiac toxicity if given too fast. National guidelines suggest replacement regimens [4,23], but it is clear that these need to be altered, because most patients developed hypokalaemia. From the current database, there is no evidence of harm from the lowered potassium levels. In addition, to replace potassium more aggressively may mean the insertion of a central venous catheter, and/or being cared for in a level 2/3 (high-dependency/intensive care unit) environment where a cardiac

monitor is available. This shift would have potentially major consequences on resources, given that just 55% of patients are cared for in the acute medical unit, or a level 1 (general) medical ward where monitored beds are less likely to be available than on a high-dependency or intensive care unit. This may cause more controversy, because a survey of 13 intensive care units across the East of England showed that most did not adhere to any form of national guidance [24].

The changes over time in, pH, bicarbonate and potassium levels are shown in Fig. 1a, b and c, respectively. Potassium levels continued to drop as shown, despite 77.4% of teams saying that they followed their potassium replacement guidelines. Figure 1a shows how pH levels rise to 7.35 by just under 19 h after admission, with Fig. 1b showing the changes in bicarbonate levels, rising to >15 mmol/l by 6 h.

The most commonly identified precipitants were infection (44.6%), and non-compliance (19.7%). Other causes included newly diagnosed diabetes (6.1%) and alcohol/drug-related precipitants (5.8%). In 18.7% of current cases, no precipitant was identified. These data contrast with recent work in the paediatric population which suggested that up to 25% of cases were attributable to newly diagnosed diabetes [25].

A quarter of patients did not have an appropriate monitoring regimen instituted. More than one in seven patients did not have their capillary glucose measured hourly, despite receiving i.v. insulin infusion. This issue was also previously identified in the UK National Diabetes Inpatient Audit 2013 [1]. In addition, even though DKA is a recognized medical emergency, and patients are usually very ill, 26.9% did not have hourly observations taken, and more than one patient in five did not have hourly assessment of urine output. It would seem that if an appropriate monitoring regimen was not in place, then it is unlikely that the potassium or glucose was also correctly managed; thus, the data reporting that monitoring frequency was inadequate are likely to be underestimates.

Together, these failures in process issues and patient management after the initial assessments on admission may be a reflection of how busy nursing and medical staff are in the ward areas where patients with DKA are cared for (Table 1). Further work needs to be done to assess if this lack of appropriate monitoring leads to any patient harm.

Hypoglycaemia developed in 27.6% of all patients, at a median time of 14.7 h after treatment was started. It is possible that the currently used insulin infusion regimen is too aggressive when glucose levels drop, and it may be necessary to adjust the insulin infusion rate. Our data differ from those of Crasto *et al.* [2] who found that their median time to developing hypoglycaemia (just under 12.9 h) was longer than their median time to resolution (12.1 h), suggesting that the i.v. insulin infusion was used for too long. In the present study, there was no relationship between developing hypoglycaemia and not receiving 10% dextrose when the blood glucose dropped to <14 mmol/l. This may be attributable to the relatively small numbers in these groups. The fact that more than a third of patients developed hypoglycaemia whilst continuing with a long-acting insulin is of concern. Previous work has shown that continuing basal insulin is associated with a reduction in rebound hyperglycaemia [26]. Given the data to show that hypoglycaemia is a strong predictor of longer length of hospital stay and higher mortality [27,28], more work will need to be done to determine the optimum approach.

In two thirds of patients, treatment and monitoring was reviewed by junior medical staff alone, with no further senior involvement being recorded. This is concerning because of data showing that confidence amongst junior doctors in managing diabetes remains low [29]. Similarly, 53% of all admissions for DKA did not involve the diabetes specialist team during the acute phase of the illness, despite evidence that input from the diabetes team helps to reduce the length of hospital stay [30]. In addition, in the UK, diabetes specialist team involvement is integrated into recommendations from the National Institute for Clinical and Healthcare Excellence (NICE) [20].

Perhaps unsurprisingly, almost 83% of all admitted patients did not receive psychological support before discharge. There are data to show that eating disorders are more common in this population and early identification and intervention is likely to help further deterioration [31]. The provision of this service is known to be lacking in many teams, despite being advocated by NICE as an important part of a diabetes team [32].

In many cases, the discharge letter to the primary care team did not contain the correct name of the insulin, the right dose of insulin or the correct insulin delivery device. Discharge summaries are most often filled out by the most junior members of the medical team; that is, by doctors who are only 1 or 2 years post-qualification. As mentioned, the data show that a large number of admissions had no contact with the diabetes specialist team, and with the previous work showing low confidence among junior staff when managing diabetes, it may well be that this combination led to these omissions [29].

Further areas of concern highlighted were that >30% of patients did not have any form of follow-up by the diabetes specialist team within 30 days of discharge, and that communication with the primary care team was poor. In the UK, there is a recommendation that a written care plan be drawn up between the patient and the diabetes specialist team, and that a copy of the care plan be sent to the primary care team; however, this was not carried out in 41.3 and 38.2% of cases, respectively.

Access to ketone testing on discharge was limited. More than one in four patients had no access to ketone testing on discharge, despite almost a third of patients having had a previous admission with DKA in the previous year. Previous work, albeit of low quality, has shown that early identification of ketonaemia and hyperglycaemia may allow appropriate treatment to be started (even at home) if patients have hand-held ketone monitors [33].

There are several limitations to our data. We asked for voluntary contributions from teams across the UK, and for sequential cases admitted to hospital, but some case selection may have occurred. There may have been particular reason for respondents to choose patients who developed DKA as an inpatient to try and highlight poor practices in their place of work, or to submit data where the outcomes were deemed better than in most cases. There is no way of knowing if such case selection took place, and the data are presented in the assumption that across the UK the data were reported in 'good faith'. Furthermore, because of the nature of the data collection exercise in which the authors did not perform a direct review of the medical records, the authors were unable to verify the accuracy of the information submitted. In addition, whilst individuals reported that they had adopted the guidelines it is possible that the medical and nursing staff were not using them correctly.

An important omission from the study was the glucose data after admission, so we were unable to provide predictors of severity. We did not ask for a definition of hypoglycaemia (although this is widely accepted to be blood glucose levels <4 mmol/l) or the frequency of occurrence of hypoglycaemic episodes. In addition, only 72 (out of a possible 220) hospitals returned any data. Despite this, we feel that the forms returned are likely to be a reasonable representation of patients presenting daily to emergency teams across the UK and elsewhere.

It is not known whether the areas where deficiencies were highlighted (e.g. foot examination) were the result of the procedures not being carried out or not being recorded.

Importantly, because of the nature of the survey, we collected no personal information on individual patients, so we have no way of linking the data to the UK National Diabetes Audit and correlating the current data with frequency of previous admissions, hospital clinic attendance rates, previous HbA_{1c} values, socio-economic data, or the presence of other comorbidities. Previous work has shown that poor glycaemic control and frequent clinic non-attendance, female gender, the presence of psychological problems and comorbidities all increase the risk of DKA [12,34]. Other factors reported in the USA include low household income, having a low education level and having no health insurance [34]. Linkage of local data on DKA to nationwide databases is needed to allow investigators to look at predictors of DKA, and to calculate the prevalence, something were unable to do because we had no denominator.

In summary, we believe that these data represent the largest-ever nationwide survey on the management of DKA. The data show that the large majority of Health Trusts have adopted the UK national guidelines, and we also report several novel and important findings including the low mortality, swift biochemical resolution, and the relatively short length of hospital stay. We also show no differences in outcomes between those who follow the national guidelines and those who do not, although this conclusion may be limited by the small numbers. There remain important areas, however, where further work is needed. In particular to determine whether the development of low potassium and glucose levels is attributable to the poor adherence to the current guidelines or because the guidelines are wrong. In addition, there remain a significant number of process issues that individual hospitals must address, which may include more education for staff. Furthermore, there may be a small number of patients who are cared for by inexperienced, junior staff and who do not come into contact with more senior members of the medical team, or the diabetes specialist team. Patients may be discharged with the incorrect name and/or dose of insulin on the discharge letters. These issues highlight the need for Trusts to make education and training mandatory for all medical and nursing staff. Future work needs to include prospective randomized studies to assess the efficacy and safety of each part of the pathway. It is likely that these will require very large patient numbers because of the heterogeneity of the population. We feel that the existence of national guidelines at multiple sites in the UK allows the valuable process of audit against hard quantitative endpoints, and a cycle of improvement. To this end, each hospital that contributed data for this survey (listed in Appendix S2) will be sent their own results with a summary of the aggregated national results to aid self-improvement.

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Competing interests

None declared.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Questionnaire sent to adult diabetes teams in all UK hospitals.
Appendix S2. List of all contributing hospitals, contributors and the numbers of forms they submitted.