Title:

The cost of treating diabetic ketoacidosis in the UK: a national survey of hospital resource use.

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Keywords: Diabetic ketoacidosis; management; survey, costs, economic

Novelty Statement

a) Diabetic ketoacidosis is a commonly encountered metabolic emergency, but the costs of treating the condition remain unknown in the UK

b) Using individual patient data from the 2014 national survey we conducted a ‘bottom-up’ approach to cost analysis

c) The average cost of an episode of diabetic ketoacidosis in the UK in 2014 was £2064 per patient (95% CI: £1800, 2563)

Abstract

Aims

Diabetic ketoacidosis (DKA) is a commonly encountered metabolic emergency. In 2014 a national survey was conducted looking at the management of DKA in adult patients across the UK. The survey reported the clinical management of individual patients as well as institutional factors that teams felt were important in helping to deliver that care. However, costs of treating DKA were not reported.

Methods

We used a ‘bottom up’ approach to cost analysis to determine the total expense associated with treating DKA in a mixed population sample. The data were derived from the source data from the national UK survey of 283 individual patients collected via questionnaires sent to hospitals across the country.

Results

Because the initial survey collection tool was not designed with a health economic model in mind, several assumptions were made when analysing the data. The mean and median time in hospital was 5.6 and 2.7 days, respectively. Based on the individual patient data and using the Joint British Diabetes Societies Inpatient Care Group guidelines, the cost analysis shows that for this cohort, the average cost for an episode of DKA was £2064 per patient (95% CI: £1800, 2563).

Conclusion

Despite relatively short stays in hospital, costs for managing episodes of DKA in adults were relatively high. Assumptions made in calculations did not take into account prolonged hospital stay due to co-morbidities nor costs incurred as a loss of productivity. Therefore the actual costs to the healthcare system and society in general are likely to be substantially higher.

Keywords
Diabetic ketoacidosis; Management; Cost; Economic

Introduction

Diabetic ketoacidosis (DKA) is one of the most commonly encountered metabolic emergencies, but incidence varies geographically. In the UK the crude one-year incidence has been reported as 3.6%, equating to 4.8 episodes per 100 patient years [1,2]. In North America the one year incidence is between 1% and 5% of people with type 1 diabetes [3,4], equating to about 145,000 cases per year [5]. In the Western Pacific region, the rate amongst children is 10 per 100 patient years [6] but is much lower in some parts of Northern Europe [7,8]. Most cases of DKA occur in type 1 diabetes, but up to 50% of cases in some regions occur in those with type 2 diabetes, depending on ethnicity and family history [9,10]. However, those with type 1 diabetes tend to have the greatest metabolic derangement, with a lower pH compared to those with type 2 diabetes [11]. Whilst there are few datasets, DKA remains an expensive condition to treat with individual admissions estimated to cost ~US$17,500 in the USA. Very little work on how much an episode of DKA costs the health service has been carried out until recently in the UK, and those data that have been produced have relied on relatively crude methods.

In 2014 a national survey was carried out in the UK looking at the management of DKA. Briefly, this survey consisted of two parts, one looking at outcomes of a convenience sample of up to 5 consecutive patients presenting with DKA over a 7 month period. 72 out of 220 UK hospitals returned data on 283 admissions in 281 patients looking at all aspects of their care during the acute hospital admission [12]. The demographic data of these patients have been described previously [12]. In addition, 67 hospitals returned questionnaires on the institutional factors that assessed their ability to provide comprehensive care for adult patients presenting with DKA [13]. We used these datasets to conduct an analysis to assess how much it cost to treat DKA in adults in the UK in 2014

Methods

The cost analysis was based on an aggregation of individual-level factors collected as part of the questionnaire, and informed by the Joint British Diabetes Societies (JBDS) Inpatient Care Group guidelines [14]. The key components of our estimate of cost included diagnostic and laboratory assessments, nurse and physician contacts and drug dosages during the acute DKA phase of the admission, and per diem ward costs following the resolution of DKA. The quantity of diagnostic tests was recorded in the questionnaire, along with time from admission to DKA resolution and time to discharge. Healthcare staff times were based on expert opinion. Our key costing assumptions are detailed below, and unit prices are shown in Table 1.

- Each patient was assessed for 15 minutes by a junior doctor upon admission.
- Blood and urine samples were collected at admission and required 15 minutes of nurse time.
- All patients received intravenous insulin according to JBDS guidelines every hour from admission to DKA resolution. This required 15 minutes of nurse time and 5 minutes of junior doctor time per hour.
- For dosing purposes, patients were assumed to weigh an average of 70kg.
- Assessment by members of the diabetes specialist team took 30 minutes of nurse time.

- Location of care during the DKA phase was recorded in the questionnaire (see Table 2) and we assumed patients were transferred to a general ward upon DKA resolution for the remainder of their inpatient stay.
- Where more than one treatment location was recorded in the questionnaire (9% of responses), we assumed treatment occurred in the more intensive location.
- For patients treated in A&E, we assumed a maximum time of 4 hours (as per government targets) after which they were equally likely to be transferred to HDU or ITU until DKA resolution.
- Time on the acute wards was costed according to published per diems and time in the general ward was costed at the best practice tariff for extended days following DKA [15,16].
- A follow-up visit from the specialist diabetes team was costed as requiring 30 minutes of nurse time.

Total costs were estimated as the sum of individual components. Specifically, total cost included the costs of an initial physician assessment, nursing time and diagnostic/laboratory tests, insulin and other drugs during the acute DKA phase, ward per diems during active treatment, and recovery (post-DKA), as well as a follow-up visit post admission if recorded. We did not include costs associated with any follow-up beyond an initial visit from a member of the diabetes specialist team, or the consequences of any precipitating factors, treating comorbidities, or on the cost of diabetes to society in general.

Missing data and imputation

A summary of the questionnaire data are shown in Table 3 in the online supplementary material. Because a number of variables had a high proportion of missing values, we used multiple imputation methods to infer values for missing values, assuming values were missing completely at random (MCAR). We performed predictive mean matching (PMM) using the Multivariate Imputation by Chained Equations Package in R statistical software (version 3.3.2) [17]. Briefly, PMM estimates a regression model for each variable with missing values, and replaces each missing value with the value of the record with the closest match on the regressed predictors [18]. The regression model is used to estimate the similarity of the record with other non-missing observations rather than the missing value itself. Table 3 in the online supplementary material shows the variables with imputed values. We did not impute non-continuous variables such as flags indicating a particular blood test or imaging procedure. Instead, we imputed the continuously distributed sub-totals for the individual components noted above (physician assessment, nursing time, diagnostic/laboratory tests, insulin and other drugs, ward per diems), and used the sum of these components to estimate total cost. This allowed the estimated total cost to be based on observed values as much as possible while avoiding strong assumptions about the distribution of non-normal parameters. A comparison of the observed and imputed total costs is shown in Figure 1.

Following data imputation, we tested the fit of different theoretical distributions to inform future modelling efforts. We tested gamma and log-normal distributions using the fitdistrplus package and selected the preferred distribution on the basis of the Bayesian Information Criterion (BIC).

Predictors of cost and length of stay

We used linear regression to test a number of predictors of cost and length-of-stay (LOS). These included age, gender, the number of previous DKA admissions, and flags indicating hypoglycaemia following resolution of DKA and whether DKA treatment followed JBDS guidelines.

Clinical care staff

To determine the amount of time spent by clinical care staff such as nurses and doctors in managing the patients, we sought expert opinion from a consultant in diabetes medicine. We determined the following minimum times that would be spent by clinical staff. A full list of allocated time, procedure and clinical staff is provided in Appendix 1 in the on line supplementary material. This was constructed by a one of the authors (KD) using the JBDS DKA guideline [19].

Similarly, to be able to determine the costs associated with clinical care staff time we determined the hourly wage rages of a range of different staff. Sources of salaries and other costs are provided in Table 1.

Costs of DKA were only considered from a hospital perspective and the admission of the patient to the resolution of DKA. Cost analysis however was done for the duration of DKA treatment and not the whole duration of the patients stay to provide an accurate picture of the impact of DKA and the associated costs with patient treatment. This allows us to determine the impact of DKA on the NHS but does not take into the account patient circumstance or comorbidities. These circumstances could be medical or social and many cases led to lengthier hospital stays and subsequently higher costs than would be the case of DKA alone.

Results

The mean cost per episode of DKA was £2064 per patient [95% confidence interval (CI): £1800, 2563], including physician and nursing time, laboratory and diagnostic assessments, intravenous insulin, and ward per diems. The mean time to DKA resolution was 22.3 hours (95% CI: 20.3, 24.3) and the mean total length of stay was 5.6 days (95% CI: 3.9, 7.2).

We found that a theoretical log-normal distribution, with a log mean of 7.206 and standard error of 0.05, had the best fit with the observed (imputed) distribution of total costs (BIC 4791.8) compared to a gamma distribution (BIC 5031.8). The empirical and theoretical distributions are shown in Figure 1.

The distribution of patients by treatment area is shown in Table 2. The majority of patients were treated in acute medical units and general wards, with only one-third treated in higher intensity areas.

Predictors of cost and length of stay

An episode of hypoglycaemia following DKA had statistically significant impact, reducing the mean cost of an event by £935 (p=0.03). Males had a significantly shorter time to DKA resolution (-6.2 hours, p=0.003). The other parameters were not statistically significant at 5 per cent.

Transfer to HDU

Initially according to the guidelines we determined the number of patients who should have been transferred to a high dependency unit (HDU). By observing three important factors 1) Bicarbonate concentration 2) pH and 3) potassium concentration, we determined that, according to the JBDS guidelines, 35% of the patients should have been treated in HDU or ITU. However only 4% of patients were actually treated in these areas. Not transferring them would most likely have resulted in higher cost for DKA treatment. A range of plausible reasons could influence whether the patient was moved to HDU or ITU, the most significant being the shortage or unavailability of beds [20]. Hence costs may have been influenced by institutional arrangements and capacity constraints.

Hypoglycaemia

Another factor which could impact on the length of stay was whether or not the patient had an episode of hypoglycaemia after their DKA treatment. Twenty eight percent of patients in our cohort had a hypoglycaemic episode. Somewhat surprisingly however, our data showed that an episode of hypoglycaemia was associated with a significant reduction in costs by £935. These data contradict previous work that show that hypoglycaemia is associated with a longer length of stay and increased mortality [21]. We are unable to explain this difference and clearly this is an area where more work needs to be done.

Cost impact of precipitating causes

As part of the analysis we also looked at precipitating factors that were associated with DKA. The nationally collected data used in this analysis showed that 77% of the patients provided information on their precipitating factors. Of those, 21% patients were not complying with their diabetes treatment; 5% had new-onset diabetes; and the remaining 51% were due a combination of other acute and non-acute illnesses. These data differentiated the present work from previous studies because of the granularity of the information that was obtained from individual patient level data.

Discussion

This study has shown that in 2014, the average cost of treating an episode of diabetic ketoacidosis in an adult patient in the UK was £2064 (95% CI: £1800, 2563)

The data collected as part of the national survey were not specifically collected for a health economic analysis to be conducted upon. However we were able to identify a pathway of treatment based on the JBDS DKA guideline which was used by the majority of hospitals who returned data. We were also able to determine the staff type and time required in each treatment step as well as being able to determine the impact of a range of physiological results upon the resolution of DKA. This allowed us to determine the cost associated with the treatment of DKA in a more granular fashion than has been done previously. The costs identified in this study however do not account for hospital overheads which are often included in Healthcare Resource Groups (HRG) codes and their associated cost calculation per event. HRG codes are groups of clinically similar treatments which use similar quantities of resource [22].

Cost of DKA

Direct healthcare costs

The current study is one of the first to present the costs of DKA from a secondary care perspective. A previous study involved requesting data from primary care organisations on the costs associated with DKA admissions [23]. The authors stated that only 32% of the primary care organisations provided such information which showed that the average total cost of DKA was £1,438 per patient. The report also stated median overall cost of treating DKA among the primary care organisations was £125,440 [23]. A more recent study (presented in abstract form only) reported data from a high risk sub-population of individuals who suffered from recurrent DKA events over a retrospective three-year period [24]. The resultant cost analysis of the data from that single centre study showed that the average cost per patient per year was £1,803.

Productivity losses

Previous work on the costs associated due to lost productivity in people with type 1 diabetes estimated that 37,000 work years are lost from premature death [25]. Furthermore, they showed that more than 830,000 sick days were taken by people with type 1 diabetes. From the prevalence figures we can estimate the work years lost and time taken off work due to sickness to be approximately 12,000 and 27,000 years respectively. However, no work has been done which looks at the costs associated with productivity loss from DKA.

By using forecasts of the population of people with diabetes increasing over the coming years and data on incidence rates of DKA, it is possible to assign values to future costs of DKA treatment. This is particularly possible using the crude prevalence rate of type 1 diabetes mentioned earlier; the crude prevalence rate of DKA events in the UK and the predicted yearly increase in the diabetes population. From this figure we can multiply the average patient cost for DKA and obtain a figure allowing us to determine the economic burden of the disease for the years to come.

It may well be that the differences between costs in the UK and the USA are in part due to the higher number of people looked after in Level 2 (HDU) or Level 3 (ITU) environments. These are more expensive areas within the hospital. Had the sicker patients been treated in these - more appropriate - clinical environments, then the overall costs would have been higher.

There are several limitations to our data. The data used came from a retrospective convenience sample. The data collected were not in a form that was easily usable for health economic analysis and many assumptions had to be made. In addition, we did not add on further salary costs (e.g. employers 'on costs') or costs associated with the treatments of co-morbidities because these were very disparate. Our sample size was too small to make general assumptions about these co-morbidities. In addition, we could not cost for recurrent readmissions because the 283 cases of DKA represented 281 individual patients. However, the major strengths of our data are that it was collected from across the UK, and that data were available for a large number for all stages of the patient journey from which appropriate calculations could be made.

In summary, to treat an episode of DKA in an adult patient in the UK in 2014 cost, on average, £2064 (95% CI: £1800, 2563). Many assumptions were made to allow these calculations, but as the number of people with diabetes increases, it is likely that the number of people admitted with DKA will also increase. In addition, given the many assumptions made it is likely that the true costs of an episode of DKA are much higher. These data should be used to enable funders to plan for future costs associated with this potentially life-threatening medical emergency.

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Legends to Tables, Figure and Appendices

Table 1 - Cost components - unit prices

Table 2 - Patient distribution by treatment area

Figure 1 - A comparison of the observed and imputed total costs

Online supplementary data

Table 3 – Data collection with percentage of missing data and imputed data

Table 4 – Costs by component

Appendix 1 - A full list of allocated time, procedure and clinical staff needed to treat an episode of DKA

Table 1

Cost Component	**Unit Cost (£)**
Hospital facilities	
Level 1: General Ward – per day	428.49*
Level 2: HDU – per day	889.14*
Level 3: ITU – per day	2004.45*
Acute Medical Unit (AMU) - per day	428.49*
A&E – per day	2552.00*
Other wards – per day	428.49*
Variable	
Healthcare staff (per hour)	
Staff Nurse (Band 6)	13.32**
Specialist Registrar (Middle band)	23.76Ƭ
Junior Doctor	14.39Ƭ
Diabetes Specialist Nurse (Band 6)	16.70**
Variable	
Investigations	
X-Ray	25.00§
Laboratory blood tests	1.00§
Electrocardiogram (ECG)	32.00§
Urine test strip	0.43¥
Intravenous insulin	5.24∞
1 litre 0.9% sodium chloride solution with potassium	2.20¶

* Data taken from Reference [15]
** Data taken from Reference [26]
Ƭ Data taken from [27]
§ Data taken from [28]
¥ Data taken from [29]
∞ Data taken from [30]

¶ Data taken from [31]

Table 2

TREATMENT AREA	**DISTRIBUTION (%)**
General ward	16
High Dependency Unit	14
Intensive Care Unit	10
Acute Medical Unit	39
Accident & Emergency	10
Other	2
Assumption made	9

Figure 1: Observed vs Imputed Total Costs

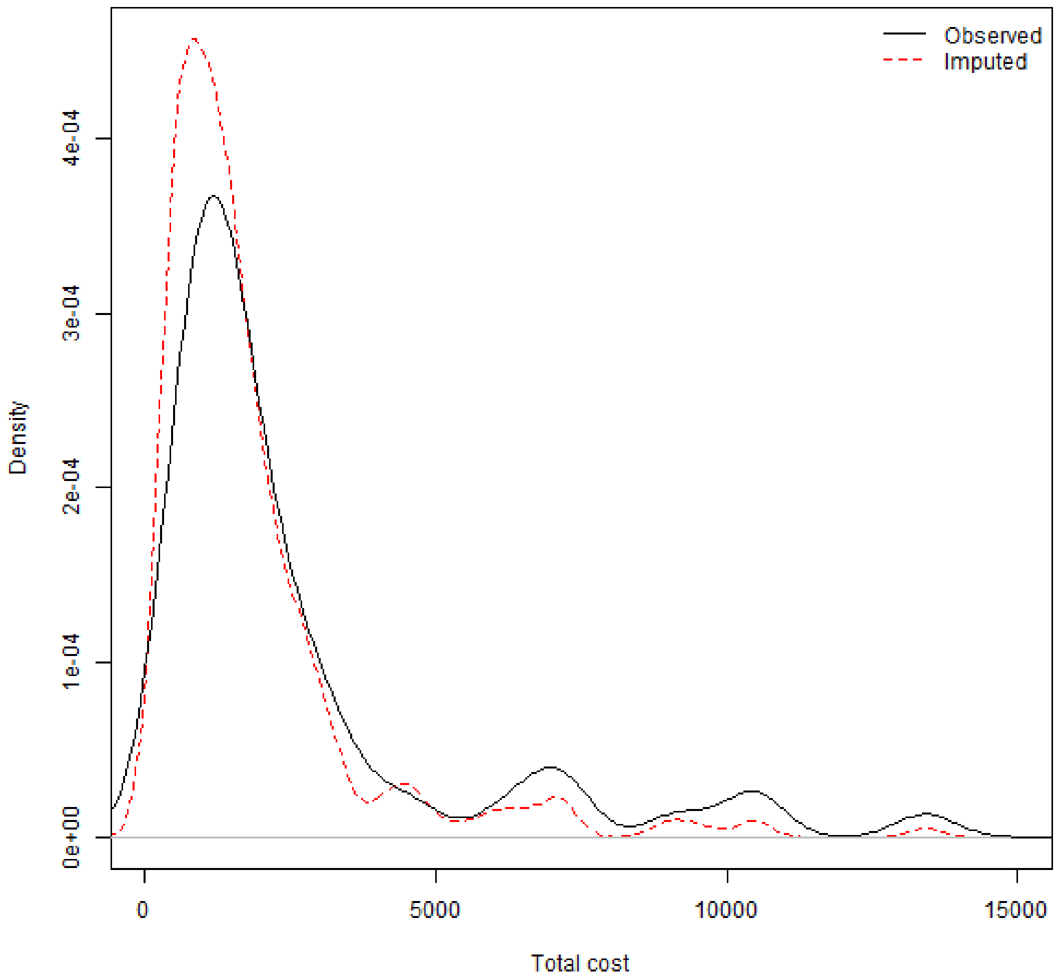

Figure 2: Empirical vs Theoretical Total Costs