An audit of the management of diabetic ketoacidosis at St Luke's Hospital

Alexia-Giovanna Abela, Caroline Jane Magri, Miguel Debono, Neville Calleja, Josanne Vassallo, Joseph Azzopardi

Abstract

Aim: To perform an audit of the protocol used in the management of patients with Diabetic Ketoacidosis, in St Lukes Hospital.

Methods: Patients admitted with 'Diabetes Ketoacidosis', between 14th August 2004 and 14th August 2005, were identified from the Admission book at the Accident and Emergency Department. Data obtained from patients' medical records were collected according to a preset proforma. The criteria assessed by this audit included parameter monitoring, investigations performed, the type and amount of intravenous fluids given, the insulin regime and potassium supplements used.

Key words

Diabetic ketoacidosis, Audit,
St Luke's Hospital, Diabetes mellitus

Alexia-Giovanna Abela* MD, MRCP (UK)
Department of Medicine, St. Luke's Hospital,
G'Mangia, Malta
Email: abelaalexia@hotmail.com

Caroline Jane Magri MD, MRCP (UK)
Department of Medicine, St. Luke's Hospital,
G'Mangia, Malta

Miguel Debono MD, MRCP(UK)
Diabetes & Endocrine Centre, St. Luke's Hospital,
G'Mangia, Malta

Neville Calleja MD, MSc
Department of Health Information, G'Mangia, Malta.

Josanne Vassallo MD, PhD
Diabetes & Endocrine Centre, St. Luke's Hospital,
G'Mangia, Malta

Joseph Azzopardi MD, FRCP
Diabetes & Endocrine Centre, St. Luke's Hospital,
G'Mangia, Malta

* corresponding author

Results: From a total of fifty six patients, forty seven files were traced, of which seventeen satisfied the criteria for Diabetic Ketoacidosis. Two were excluded and fifteen were analysed. In the population studied the mean age was 28 years with a male predominance of 60%. Ten patients suffered from Type 1 Diabetes whilst two patients had Type 2 Diabetes. Three other patients were newly diagnosed. Only one patient had all parameters checked according to protocol. In the majority of patients, fluids given in the first 22 hours, coincided with the amount of fluids stated in the protocol whilst 6/15 (40%) patients were administered the requested amount of insulin via infusion pump. With regards to potassium replacement, 13/15 (87%) patients were started on potassium supplements at a later stage. The factors influencing the total time for conversion to a fixed insulin regime and the duration of stay in hospital were also analysed.

Conclusion: Deviations from the protocol were identified in parameter recording, the type of intravenous fluids given and the doses of insulin and potassium supplementation administered. New Diabetic Ketoacidosis guidelines have now been developed.

Introduction

Diabetic Ketoacidosis (DKA) is a state of uncontrolled catabolism associated with insulin deficiency, counter-regulatory hormone excess and fluid depletion. It is the hallmark of Type 1 Diabetes (DM) and can be its mode of presentation. However, patients with Type 2 DM are also at risk of developing DKA during the catabolic stress of acute illness.[1] Signs and symptoms of DKA include polyuria, polydipsia, lethargy, anorexia, hyperventilation, ketotic breath, dehydration, vomiting, abdominal pain and coma. Precipitants include infections, psychological stress, poor compliance with therapy, cerebrovascular accidents, alcohol/drug abuse, pancreatitis, pulmonary embolism, myocardial infarction, trauma and drugs.[2] DKA continues to be an important cause of morbidity and mortality amongst patients with diabetes. Mortality rates in DKA, quoted at <5%, increase substantially with increasing age and concomitant life-threatening illnesses.[3,4] DKA treatment outcomes are similar in both community and teaching hospitals, and do not vary with the level of expertise of the managing physician, so long as standard written therapeutic guidelines are followed.[1]

Results

From a total of fifty six patients, forty seven files were traced, of which seventeen satisfied the criteria for the diagnosis of DKA. Out of the latter, two, considered as 'outliers', were excluded in view of their prolonged duration of stay (≥ 13.36 days). One of these patients was admitted with gas gangrene of the foot requiring urgent above-knee amputation and admission to the Intensive Therapy Unit. This resulted in a total length of stay of 37 days. The hospital stay of the second patient was complicated by a seizure; ultimately the patient discharged against medical advice 15 days post-admission.

In the population studied (15 patients) the mean age was 28 years with a male predominance of 60% (n=9). Ten patients suffered from Type 1 DM, two patients suffered from Type 2 DM whilst the other three were newly diagnosed with the disease.

Out of the ten patients with Type 1 DM, nine patients were on a fixed insulin regime whilst one patient was on a combination of subcutaneous insulin and an oral hypoglycaemic agent (OHA), metformin. One of the Type 2 DM patients was on glibenclamide whilst the other was on a fixed insulin regime.

Reasons for DKA

Compliance to insulin was documented in nine out of eleven patients. Three patients were documented to have missed their fixed insulin regime, Table 1.

Investigations

The majority of patients (80%, n=12) had all the necessary investigations performed. On admission, two patients did not have their random blood glucose (RBG) checked, whilst four patients did not have their temperature recorded. Only one patient (14 year old) did not have a chest X-ray performed on admission. Other results are shown in Table 2.

Table 1: *Reasons for admission with Diabetic ketoacidosis as documented on the patients' notes*

Reason	Frequency (n)
Gastroenteritis	6
No reason documented	5
Upper respiratory tract infection	3
Incision of abscess	1

Patients admitted to St. Luke's Hospital (SLH) were diagnosed with DKA if they fulfilled the following criteria, as per DKA protocol (issued in the year 1996): (a) hyperglycaemia, (b) ketonuria, and (c) pH less than 7.3. This protocol provided guidelines on parameter monitoring, investigations, and therapeutic intervention. Instructions on fluid balance, insulin infusion rates and potassium supplements were given. The protocol also mentioned indications for antibiotics and sodium bicarbonate use.

The aim of this audit was to analyse the protocol used in the management of patients admitted with DKA to a University Teaching Hospital. This would then help in the development of new guidelines with consequent improved patient care.

Method

The subjects studied were adult patients (≥ fourteen years of age) admitted to SLH with 'DKA' between 14th August 2004 and 14th August 2005 as per Admission book at the Accident and Emergency (A&E) Department. Data of defined criteria were obtained from patients' medical records in line with Data Protection Act and analysed according to a preset proforma.

All data were recorded on Microsoft Excel spreadsheet. Analysis of data was then performed using SPSS version 14.

Table 2: *The mean values and 95% confidence intervals for the investigations taken on admission. In view of the small sample size it was preferable to use bedside blood glucose monitoring (BGM) reading in lieu of random blood glucose (RBG) readings where the latter were missing rather than treating them simply as missing data. All continuous variables were tested for normality using Q-Q Plots and were found to be within acceptable limits*

Investigation	Mean	95% Confidence Interval
Arterial blood gases		
- pH	7.16	(7.11, 7.21)
- pCO$_2$ (mmHg)	18.55	(12.83, 24.27)
- HCO$_3^-$ (mmol/L)	6.92	(4.29, 9.55)
White cell count (x 10^9/L)	17.26	(13.28, 21.30)
Creatinine (μmol/L)	111.93	(91.67, 132.20)
Random blood glucose (mmol/L)	28.85	(23.44, 34.26)
Ketonuria	3.67	(3.20, 4.14)

Table 3: *The frequency and percentage of measurements of serial arterial blood gases (ABGs) taken during admission documented as once, twice, three times or four times.*

Serial ABGs taken	Frequency (n)	Percentage (%)
None	0	0
Once	0	0
Twice	2	13.3
Three times	2	13.3
Four times or more	11	73.3

Serum amylase

According to the DKA protocol, patients who have abdominal pain should have their serum amylase checked. Five patients admitted with DKA had their amylase checked on admission. Of these, four subjects had abdominal pain whilst one was pain free. All patients who complained of abdominal pain had their amylase checked.

White cell count and temperature

Out of a total of fifteen patients, twelve were started on antibiotics. Of these, ten had a high white cell count (taken as $>11 \times 10^9$ /L) whilst two patients had a normal white cell count. All patients with a high white cell count were started on antibiotics.

Four patients did not have their temperature recorded on admission. Two patients were febrile (>37°C) and both were started on antibiotics.

Arterial blood gases (ABGs)

According to the DKA protocol ABGs need to be taken at least 4 times during admission i.e. at 2, 4, 8 and 12 hours after admission. Eleven out of fifteen patients had at least four ABGs taken during admission (Table 3). Table 4 shows the frequency at which ABGs were taken at 2, 4, 8 and 12 hours respectively.

Table 4: *The frequency and percentage of measurements of arterial blood gases (ABGs) taken at 2, 4, 8 and 12hrs after admission*

Time of ABG (hrs)	Frequency (n)	Percentage (%)
2	9	60.0
4	8	53.3
8	8	53.3
12	8	53.3

Urinalysis and microscopy

During admission six patients out of fifteen had their urine sent for urinalysis and microscopy as requested by the DKA protocol.

Serial parameters

Parameters need to be taken regularly for adequate management of the patient with DKA. The frequency at which parameters were taken according to the DKA protocol is documented in Table 5.

Insulin administration

Intravenous insulin infusions were administered as per protocol in 40.0% of the cases (n=6). None of the 15 patients required doubling of the dose. The frequency at which the insulin infusion was stopped, when bedside blood glucose monitoring (BGM) was less than 4, and restarted when BGM was more than 6, was also analysed (Table 6).

Total insulin given *via* insulin pump according to regime was compared to the total insulin requested as per protocol for each patient using the Wilcoxon Signed Ranks Test. The actual mean total insulin administered was 123.33 units whilst the predicted mean total insulin as per protocol was 142.80 units. This difference was found to be significantly lower (p=0.002).

Intravenous fluid administration

In the fifteen patients studied the mean amount of fluids given in the first 22 hours was 7.66 litres (SD 1.55, SME 0.41). This difference was not statistically significant (p=0.141) when compared to the amount of fluids requested in the protocol.

Only two patients with a BGM <11mmol/L had their fluids changed to 5% dextrose in normal saline alternating with 10% dextrose. The other eight patients were changed to 5% dextrose in normal saline without alternating with 10% dextrose (Table 7). Most of these patients were ketone free and not acidotic at the time, thus not requiring 10% dextrose infusion.

Table 5: Frequency of parameters taken		
Parameter	**Frequency (n)**	**Percentage (%)**
Pulse rate (1 hrly)	1	6.7
Blood pressure (2 hrly)	1	6.7
Temperature (4 hrly)	3	20.0
BGM (1 hrly)	11	73.3
Urinalysis for ketones (4 hrly)	8	53.3

Potassium administration

The mean litre of intravenous fluids at which potassium should have been started was calculated for the 15 patients and was found to be 3.40. Using the Wilcoxon Signed Ranks Test, this was found to be significantly different from the mean litre at which potassium was started - 6.31 litre ($p<0.001$) (Figure 1).

Further management
Sodium bicarbonate ($NaHCO_3$)

Only one patient was administered $NaHCO_3$ in view of a deteriorating pH of 7.069 despite adequate Actrapid® and fluids given. This patient required further monitoring at the Intensive Therapy Unit.

Urinary catheter

Seven patients had a urinary catheter inserted. One of these patients had oliguria while in the other six patients no reason was documented.

Nasogastric tube

One patient had a nasogastric tube inserted. No reason was documented.

Factors influencing hours on insulin infusion and length of stay in hospital

The mean number of hours until the patients were changed to subcutaneous (sc) insulin was 51.27 hrs (SE=0.5.77 CI=39.96, 62.58) (Figure 2).

Table 6: Number of times the insulin infusion was being stopped if bedside blood glucose monitoring (BGM) was <4 mmol/L and restarted when BGM was >6 mmol/L (frequency of correct action)		
BGM (mmol/L)	**Frequency (n)**	**Frequency of correct action (n)**
Less than 4	8	6
More than 6	3	3

Correlation analysis was conducted for the total time to conversion to sc insulin and each of the following variables: pH, HCO_3^-, RBG and ketones. Backward stepwise multivariate regression analysis resulted in only pH having a significant contribution ($p=0.048$) (Table 8).

The difference between the insulin administered and the insulin requested according to the DKA protocol per hour (insulin difference/hr) was also found to be significantly correlated with hours until changed to sc insulin ($p=0.02$).

The mean duration of stay in hospital was found to be 4.8 days (SE=0.57; CI=3.68, 5.92). pH, HCO_3^-, RBG and ketones on admission were not found to be significantly correlated to the number of days in hospital (Table 9).

Discussion

This audit attempts to analyse the entire management of the DKA patient, from presentation at the A & E department until discharge.

The majority of patients admitted with DKA suffered from Type 1 DM whilst two subjects suffered from Type 2 DM. This shows that DKA can also affect individuals with Type 2 DM. It is postulated that the balance and interplay of insulin and glucagon predicts the type of acute hyperglycaemic emergencies (DKA

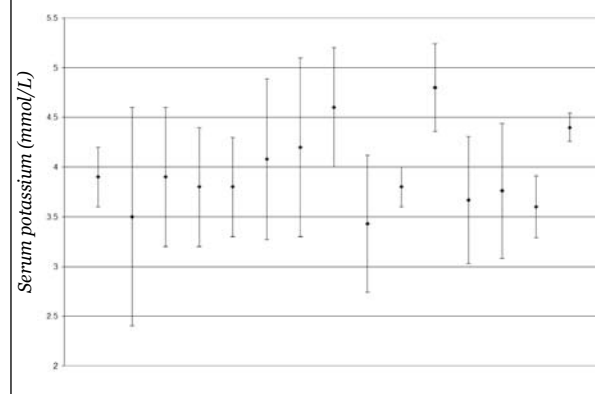**Figure 1:** The range and mean of serum potassium level in mmol/L for each patient while on the DKA protocol

Table 7: *Frequency of the change in intravenous fluids to 5% dextrose in normal saline when bedside blood glucose monitoring (BGM) <11mmol/L and the frequency at which fluids were changed back to normal saline when BGM rose back to >11mmol/L (frequency of correct action)*

BGM (mmol/L)	Frequency (n)	Frequency of correct action (n)
Less than 11	14	10
More than 11	11	2

and Hyperosmolar non-ketotic acidosis (HONK)), such that a reduction of insulin / glucagon ratio to 1:0.9 in patients with Type 2 DM may result in DKA instead of HONK.[5]

Three out of nine subjects were documented to be noncompliant. Compliance was not documented for the remaining two subjects who were on insulin prior to admission. Studies indicate that insulin error (with or without intercurrent illness) is the most common precipitating factor for DKA, accounting for nearly two thirds of cases (excluding those where DKA was the first presentation of diabetes mellitus).[6]

Deviations from the protocol were noted during the patients' admission. Serial parameters (pulse and blood pressure) were taken hourly only in the Intensive Therapy Unit where intensive nursing care is provided. Most of the patients had their blood gases taken more than four times although not at the time requested by the protocol. The subjects with the least number of arterial blood gases taken were noted to be the ones who became ketone free in the shortest period of time. Further, some ABG results may have been lost.

Insulin was generally administered at a lower dose than the amount requested. This could possibly be related to physicians' concerns of either hypoglycaemia or a rapid decline in blood glucose levels. The lower insulin doses administered via pump led to a delay in starting the patients on a fixed insulin regime. The period to conversion to sc insulin was also found to be associated with the degree of acidosis on admission.

Potassium supplements were given at a later stage than requested by the protocol, leading to a lower mean serum potassium level. The delay in giving potassium supplements can be attributed to various reasons, mainly lack of clear instructions in the protocol regarding the maximum dose of potassium per hour that can be administered and the dose of potassium to be administered according to the exact serum potassium level. The target range of serum potassium for the DKA patient was also not adequately highlighted in the protocol. Other possible explanations for this problem include blood investigations either not taken or taken later then the time specified by the protocol, laboratory delay in issuing result and lost results. The majority of the patients were given the correct amount of fluid as requested by the protocol.

The mean duration of stay for the patients analysed was 4.8 days. This is comparable to the length of stay in other countries.[7]

Definition of DKA in the protocol is very restrictive with no mention of bicarbonate, anion gap and serum osmolality. Variability was revealed in the time spent to give one litre saline running, varying from fifteen minutes to one hour. The protocol does not state at which point one should be switched to a fixed insulin regime, leaving this to the discretion of the attending physician.

This audit has its limitations. The population studied was small, some files could not be traced and some blood investigations had been lost. At times, it was difficult to interpret the observation and fluid-balance charts mainly due to inadequate/unclear documentation. Even the patients' notes were sometimes not exhaustive and lacked important information about patients' management.

Nonetheless, this audit has helped to identify some of the problems encountered in the management of the patient admitted with DKA.

The new DKA protocol that has recently been introduced addresses most of the previous limitations. Thus, the definition of DKA is more exhaustive with inclusion of the level of bicarbonate and hyperglycaemia. Clearer and simpler instructions are provided for the rate and type of intravenous fluids to be given. Potassium supplementation is changed to

Table 8: *p values and correlation coefficients for hours until switching the patient to sc insulin and each of the above variables. Statistically significant values are shown in bold*

Variable	Correlation	p value
pH	-0.517	**0.048**
HCO_3^- (mmol/L)	0.505	0.055
Random blood glucose (mmol/L)	0.413	0.126
Ketones	-0.103	0.714

Table 9: *p values and correlation coefficients for number of days in hospital and each of the above variables*

Variable	Correlation	p value
pH	-0.046	0.870
HCO₃⁻ (mmol/L)	-0.265	0.339
Random Blood Glucose (mmol/L)	0.296	0.293
Ketones	-0.098	0.728

Figure 2: *Time distribution for commencement of the DKA protocol to conversion to subcutaneous (sc) insulin.*
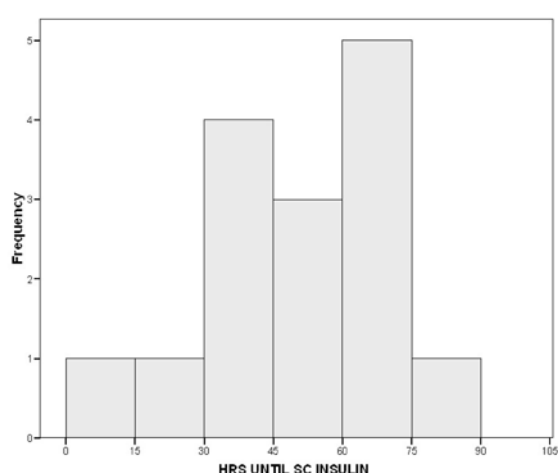
potassium required per litre instead of potassium per hour, and guidelines are provided to indicate when one should switch the patient to a fixed insulin regime and consequently stop the DKA protocol.

In addition, the new protocol aims at improving patient monitoring by providing a data monitoring sheet, resulting in facilitated documentation. The protocol also includes allocation of a nurse for each patient, regular reviews by a medical officer and involvement of the emergency lab.

The new protocol will hopefully reduce the period to conversion to a fixed insulin regime and give more confidence to the attending physician with regards to decision making in the management of the DKA patient. It also provides nursing staff with increasing awareness regarding the serious implications of this diabetic emergency.

Many episodes of DKA can be prevented through better patient education. Sick-day management should be reviewed periodically with all patients and include specific information on (a) when to contact the health care provider, (b) blood glucose goals and use of supplemental short-acting insulin during illness, (c) means to suppress fever and treat infection, and (d) initiation of an easily digestible liquid diet containing carbohydrates and salt. Most importantly, the patient should be advised to never discontinue insulin and seek professional advice early in the course of the illness.

Conclusion

In this audit we have analysed the DKA protocol that had been used at SLH for several years with the aim of improving the ultimate management of the patient admitted with DKA. The authors shall reaudit the new protocol in the forthcoming months.

References

1. Kitabchi AE, Umpierrez GE, Murphy MB, Barrett EJ, Kreisberg RA, Malone JI *et al*. Management of hyperglycaemic crises in patients with diabetes. Diabetes Care. 2001;24:131.
2. Umpierrez GE, Murphy MB, Kitabchi AE. Diabetic ketoacidosis and hyperglycaemic hyperosmolar syndrome. Diabetes Spectr. 2002;15:28.
3. Hamblin PS, Topliss DJ, Chosich N, Lording DW, Stockigt JR. Deaths associated **with** diabetic ketoacidosis and hyperosmolar coma, 1973-1988. Med J Aust. 1989;151:439-44.
4. Basu A, Close CF, Jenkins D, Krentz AJ, Nattrass M, Wright AD. Persisting mortality in diabetic ketoacidosis. Diabet Med. 1992;10:282-9.
5. Wahid M, Naveed AK, Hussain I. Insulin and glucagon ratio in the pathophysiology of diabetic ketoacidosis and hyperosmolar hyperglycaemic non-ketotic diabetes. J Coll Physicians Surg Pak. 2006;16:11-4.
6. Hardern RD and Quin ND. Emergency management of diabetic ketoacidosis in adults. Emergency Medical Journal. 2003; 20:210-3.
7. Freire AX, Umpierrez GE, Afessa B, Latif KA, Bridges L, Kitabchi AE. Predictors of intensive care unit and hospital length of stay in diabetic ketoacidosis. J Crit Care. 2002;17:207-11.