

Diabetic ketoacidosis is a potentially life-threatening complication of diabetes, making it a medical emergency. Nurses need to know how to identify and manage it

Management of diabetic ketoacidosis in adults

In this article...

- 1 Epidemiology and pathophysiology of diabetic ketoacidosis
- 2 Guidance on diagnosis, management and complications
- 3 The nurse's role in caring for patients with DKA

Authors Georgia Noble-Bell and Alison Cox are diabetes specialist nurses at King's College Hospital, London.

Abstract Noble-Bell G, Cox A (2014) Management of diabetic ketoacidosis in adults. *Nursing Times*; 110: 10, 14-17.

Ketoacidosis is a serious complication of diabetes. It is commonly precipitated by poor adherence to medication, stress and concurrent illness; it can be life threatening if it is not addressed quickly and effectively. This article discusses the pathophysiology, diagnosis and management of the condition, and highlights the nurse's role in this.

D iabetic ketoacidosis (DKA) is a serious and potentially life-threatening complication of diabetes (Joint British Diabetes Societies, 2013). It is a complex disordered metabolic state characterised by hyperglycaemia (elevated blood glucose), acidosis (pH imbalance) and ketonaemia (excess ketones in the blood).

Although the majority of patients presenting with DKA have type 1 diabetes, those with type 2 diabetes can also develop the condition, especially during acute illness (Umpierrez et al, 2002). People from non-Caucasian ethnic groups are more likely to develop DKA in the presence of type 2 diabetes (Yehia et al, 2008).

While the incidence of DKA is difficult to establish, population-based studies suggest an annual incidence of 4.6-8.0 episodes per 1,000 patients with diabetes (Faich et al, 1983); the worldwide mortality rate is 2-10% (Yehia et al, 2008). Over the past 20 years, mortality rates in developed countries have fallen from 7.96% to 0.67% (Lin, 2005) due to a better understanding

of the pathophysiology of DKA and advances in the clinical management. Many cases could be prevented by better access to medical care, education and effective communication between patients and health professionals during concurrent illness (Kitabchi et al, 2004).

Pathophysiology

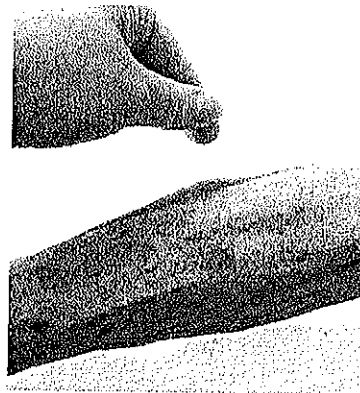
DKA results from a dysregulation of carbohydrates, protein and lipid metabolism (Yehia et al, 2008) and usually occurs as a consequence of absolute or relative insulin deficiency accompanied by an increase in counter-regulatory hormones (glucagon, catecholamine, cortisol, growth hormones and epinephrine), which contribute to increased blood glucose levels and insulin resistance.

The combination of insulin deficiency and increased counter-regulatory hormones leads to alteration in glucose production and use, increased lipolysis (breakdown of fatty acids to form alternate source of energy) and production of ketone bodies (Umpierrez et al, 2002). An increase in hepatic gluconeogenesis (production of glucose from non-carbohydrate sources) and glycogenolysis (breakdown of glycogen to glucose), renal glucose production and impaired glucose use in peripheral tissues leads to severe hyperglycaemia (JBDS, 2010). An increase in free fatty acids in circulation as a result of lipolysis enhances hepatic production of ketone bodies, which result in ketonaemia and metabolic acidosis (Kitabchi et al, 2004).

Dehydration and electrolyte imbalances occur in DKA as a result of several mechanisms. Hyperglycaemia causes fluid and electrolytes to shift from the

5 key points

- 1 The majority of patients presenting with diabetic ketoacidosis have **type 1 diabetes**
- 2 Patients with **type 2 diabetes** can develop DKA, especially during **acute illness**
- 3 **Infection** is the most common precipitating factor for DKA
- 4 Clinical signs of DKA include **polyuria, polydipsia, weakness, fatigue, weight loss, vomiting and abdominal pain**
- 5 DKA is a **medical emergency**



Signs of dehydration, including decreased skin turgor, are often seen in DKA



"People write thank-you letters for the care received, not for meeting targets"

Richard Knowles ▶ p26

BOX 1. CRITERIA FOR DIAGNOSING DKA

- Ketonaemia $\geq 3\text{mmol/L}$ (normal values < 0.6) or significant ketonuria ($> 2+$ on standard urine dipstick)
- Blood glucose $> 11\text{mmol/L}$ (normal values: $3.5\text{--}7.8\text{mmol/L}$) or known diabetes
- Bicarbonate blood levels (HCO_3^-) $< 15\text{mmol/L}$ (normal values: $22\text{--}26\text{mmol/L}$) and/or venous pH < 7.3 (normal values: $7.35\text{--}7.45$)

Source: JBDS (2013)

intracellular to the extracellular space, leading to cellular dehydration and electrolyte imbalance. Both hyperglycaemia and high ketone levels also cause osmotic diuresis, resulting in further dehydration; vomiting is commonly associated with DKA and contributes to fluid depletion and electrolyte imbalances (JBDS, 2013).

Precipitating factors

About one in five adults with type 1 diabetes initially present with DKA (Umpierrez et al, 2002). Common precipitating factors for DKA in those with established diabetes are infection, poor adherence to medication, psychological stress and concurrent illnesses (Umpierrez et al, 2002; Delaney et al, 2000).

Infection is the most common precipitating factor for DKA and occurs in about 30-50% of adult cases; other acute conditions that may precipitate DKA include cerebral vascular accident, alcohol/drug misuse, pancreatitis, myocardial infarction and trauma (Umpierrez et al, 2002).

Recent studies have identified the significance of medication non-adherence and psychological factors in DKA (Umpierrez et al, 2002). High incidences of DKA related to medication non-adherence have been identified in subgroups with type 1 diabetes, including young women with psychological problems such as eating disorders (Umpierrez et al, 2002).

Other risk factors include poor glycaemic control, clinic non-attendance and lower socioeconomic status (Wright et al, 2009). The JBDS (2010) has also highlighted a lack of self-management skills as another risk factor associated with recurrent DKA.

Clinical presentation and diagnosis

The metabolic abnormalities associated with DKA develop rapidly (usually within

BOX 2. CRITERIA FOR HIGH DEPENDENCY CARE

Patients exhibiting one or more of these signs should be assessed by a consultant physician and considered for referral to a high dependency unit:

- Blood ketones $> 6\text{mmol/L}$
- Bicarbonate level $< 5\text{mmol/L}$
- Venous/arterial blood gas < 7.0
- Hypokalaemia (low potassium) on admission (3.5mmol/L)
- Glasgow Coma Scale ≤ 12 or abnormal AVPU assessment scale
- Oxygen saturation $< 92\%$ on air (assuming normal baseline respiratory function)
- Systolic BP $< 90\text{mmHg}$
- Pulse rate > 100 or $< 60\text{bpm}$

Source: JBDS (2013)

24 hours), but the signs and symptoms of poor glycaemic control may be evident for several days before this (Kitabchi et al, 2006). These include polyuria, polydipsia, weakness, fatigue and weight loss. Vomiting and abdominal pain are frequently the presenting symptoms in DKA (Kearney and Dang, 2007).

On physical examination, signs of dehydration are often present, including dry mucus membranes, decreased skin turgor, tachycardia and hypotension. In addition the smell of acetone on the breath and deep and laboured breathing (Kussmaul breathing) may be observed, particularly in patients with severe acidosis. This change in breathing is an attempt by the body to correct the metabolic acidosis and compensatory respiratory alkalosis (Yehia et al, 2008; Umpierrez et al, 2002). Mental

BOX 3. KEY MANAGEMENT POINTS

- Fluid resuscitation with 0.9% sodium chloride
- Insulin infusion (fixed-rate intravenous insulin infusion) at 0.1unit/kg/hr
- Close monitoring of vital signs, blood glucose, ketones, electrolytes and blood gases
- Continue FRII until DKA has resolved before converting to subcutaneous insulin
- Give background insulin alongside IV to prevent rebound hyperglycaemia
- Involve the diabetes specialist team as soon as possible

state can vary from full alertness to profound lethargy (Umpierrez et al, 2002).

Laboratory investigations

Although DKA can be suspected on clinical observations, confirmation of the diagnosis is based on laboratory findings. The "syndrome" of DKA consists of the biomedical triad of hyperglycaemia, ketonaemia and metabolic acidosis (JBDS, 2013; Umpierrez et al, 2002). The laboratory investigation in DKA includes measurement of:

- » Venous blood glucose;
- » Electrolytes, urea, creatinine, osmolality and ketones;
- » Urinalysis for ketones;
- » Blood tests for infection markers;
- » Venous blood gas values.

Further investigations may be carried out to identify potential infection or myocardial infarction as precipitating factors for DKA; these tests may include complete blood count, blood cultures, cardiac enzymes and ECG (Kitabchi et al, 2004).

Clinical presentation and laboratory investigations usually provide the information needed to diagnose DKA. It is important to remember that not all patients who present with ketoacidosis have DKA (Umpierrez et al, 2002) so when diagnosing DKA, other causes of ketosis should be considered, including starvation ketosis and alcohol ketoacidosis (Yehia et al, 2008; Umpierrez et al, 2002). Other differential diagnoses include lactic acidosis, renal failure and drug intoxication (Yehia et al, 2008). Box 1 outlines the JBDS (2013) criteria for diagnosing DKA.

DKA is a medical emergency and should be managed promptly (JBDS, 2013). It is important to assess for severity to determine the clinical setting in which the patient is to be managed; criteria are outlined in Box 2.

Management

The management of patients presenting with DKA includes a full clinical assessment, while regular monitoring of vital signs and consciousness levels using the Glasgow Coma Scale is essential (JBDS, 2013). Key areas in the management of DKA include:

- » Restoring circulatory volume;
- » Insulin therapy (fixed-rate intravenous insulin infusion);
- » Correcting metabolic acidosis and electrolyte imbalances;
- » Identifying and treating precipitating factors;
- » Early involvement of the diabetes specialist team (JBDS, 2013).

Nursing Practice Review

Key management points are summarised in Box 3.

Restoring circulatory volume

Fluid replacement is one of the most important initial therapeutic interventions in the management of DKA. Patients are usually dehydrated and correcting this deficit will result in significant metabolic improvement (Kitabchi et al, 2004). The aims of fluid resuscitation are to:

- » Restore circulatory volume;
- » Clear ketones;
- » Correct electrolyte imbalance (JBDS, 2010).

Pulse and blood pressure should be used to assess the severity of dehydration, as hypotension (systolic BP <90mmHg) is likely to be due to low circulatory volume. Other causes such as heart failure, sepsis and factors such as age, sex and medication history should also be taken into consideration (JBDS, 2013).

Normal saline (0.9% sodium chloride) is recommended for fluid resuscitation (JBDS, 2013). Rapid fluid replacement is usually required in the first few hours of treatment; most patients require between 500ml and 1L to be given rapidly (JBDS, 2013). However, the rate of fluid replacement must be tailored to patients' clinical situation. Special attention must be paid to fluid balance in patients at high risk of complications – these include older people, pregnant women, children and young people (18–25 years), and those with heart and kidney failure (JBDS, 2010).

Insulin therapy

The aim of insulin therapy in DKA management is to suppress ketogenesis, reduce blood glucose and correct electrolyte imbalance. Insulin therapy increases peripheral glucose use and decreases hepatic glucose production, thereby lowering blood glucose concentration. It inhibits the release of free fatty acids from adipose tissues and decreases ketogenesis (Umpierrez et al, 2002).

A continuous fixed-rate intravenous insulin infusion (FRII) of 0.1 units/kg/hr is recommended (JBDS, 2013). The recommendation for preparation of insulin infusion is 50 units of human soluble insulin made up with 50ml normal saline (0.9% sodium chloride) (JBDS, 2013). FRII should continue until DKA is resolved. When the blood ketones are <0.6mmol/L, pH >7.3 and the patient is able to eat and drink, an appropriate subcutaneous insulin regimen should be recommended (JBDS, 2013). The JBDS (2013) recommends that background insulin should be continued

along with the IV insulin infusion to reduce the risk of rebound hyperglycaemia when the IV insulin infusion is discontinued. If background insulin is discontinued, a subcutaneous dose must be given before the IV insulin infusion is discontinued (JBDS, 2013). The conversion to the subcutaneous insulin regimen should be planned around a mealtime; subcutaneous short-acting insulin should be given at the meal and then IV insulin discontinued one hour later (JBDS, 2013).

Correcting metabolic acidosis and electrolyte imbalance

The JBDS (2010) recommends the following metabolic treatment targets for DKA:

- » Reduction in blood ketones of at least 0.5mmol/L/hr;
- » Increase in venous bicarbonate by 3mmol/L/hr;
- » Reduction in capillary blood glucose by 3mmol/L/hr;
- » Maintenance of serum potassium at 4–5.5 mmol/L.

Blood glucose, ketones, electrolytes, including bicarbonate, and venous pH, should be monitored closely at or near the bedside. If the above targets for blood ketones and/or bicarbonate are not reached, the rate of the IV insulin infusion should be increased by 1 unit every hour until metabolic targets are achieved (JBDS, 2013).

Potassium

Maintaining normal serum potassium and prevention of hypoglycaemia are important in the management of DKA as hypokalaemia (low potassium level) and hyperkalaemia (high potassium level) are both life-threatening conditions and common complications.

Serum potassium is often high on admission but falls rapidly with insulin treatment, so regular monitoring is essential and potassium should be added to IV infusions if serum potassium is <5.5mmol/L (JBDS, 2013).

Capillary blood glucose

Prevention of hypoglycaemia is vital, so bedside blood glucose monitoring should be performed every 1–2 hours (JBDS, 2010). It is sometimes necessary to give dextrose infusions to stabilise blood glucose levels; this should be given concurrently with the sodium chloride infusions used to correct circulatory volume (JBDS, 2010).

To avoid complications related to rapid infusion it is important to monitor fluid balance and electrolytes closely. Regular assessment for complications such as

cerebral oedema and fluid overload is vital (JBDS, 2013).

The diabetes specialist team

The JBDS (2010) stipulates that the diabetes specialist team must be involved in the management of every patient admitted with DKA, and referral should be made as soon as possible during the acute phase.

The team's involvement is necessary to improve safety and reduce length of stay (Sampson et al, 2006). Team members play an important role in assessing the precipitating cause of DKA, acute management, discharge planning, education and follow-up care including psychological support (JBDS, 2010).

The best-practice tariffs stipulate that people admitted with DKA must be referred to the diabetes team and be seen by a member of the team within one working day of admission (Price et al, 2013).

The nurse's role

All health professionals involved in caring for patients with DKA have a responsibility to ensure safe delivery of patient care in accordance with local and national clinical guidelines.

Some of the roles and responsibilities for nurses include:

- » Ongoing clinical assessment of the patient: this involves regular (at least hourly) monitoring of vital signs and level of consciousness during the acute phase (JBDS, 2013). The early warning score system should be used as a guide to determine the patient's clinical condition and response to treatment, and escalated to senior or specialist colleagues or medical team as appropriate;
- » Accurate monitoring of fluid balance: this includes accurate intake and output charts (JBDS, 2013). Prescribed fluids should be administered and patients monitored for signs of complications related to fluid overload, dehydration and electrolyte imbalance;
- » Insulin therapy: this should be administered as prescribed;
- » Regular monitoring of capillary blood glucose and ketones: this is required at least hourly (JBDS, 2013) during the acute phase. Nurses should liaise with the medical team for appropriate adjustment to insulin doses as required;
- » Monitoring of metabolic acidosis and electrolytes: this involves liaising with the medical team to ensure blood gases and appropriate blood tests are carried out regularly, results interpreted and

TABLE 1. COMMON COMPLICATIONS IN DKA MANAGEMENT

Complications	Causes	Comments
Hypoglycaemia	Insulin administration	<ul style="list-style-type: none"> ● Low-dose Insulin infusion ● Check blood glucose hourly and add 10% dextrose IV when level falls below 14mmol/L
Hyperglycaemia	Interruption of insulin coverage	<ul style="list-style-type: none"> ● Continue subcutaneous background insulin with IV insulin infusion and ● Give pre-meal-dose of subcutaneous short-acting insulin at least one hour before discontinuing IV insulin infusion
Hypokalaemia	Insulin administration	<ul style="list-style-type: none"> ● Monitor potassium at least two-hourly and if less than 5.5mmol/L add potassium supplement to IV fluids
Fluid overload	Intravenous fluid	<ul style="list-style-type: none"> ● Maintain accurate fluid balance chart
Cerebral oedema	Possible due to rapid correction of hyperosmolarity	<ul style="list-style-type: none"> ● Check serum sodium and osmolarity at least two-hourly ● Replace fluid gradually
Thromboembolism	Hypercoagulable state and dehydration	<ul style="list-style-type: none"> ● Limited evidence to support prophylactic anticoagulation
Hypoxia/acute respiratory syndrome	Decreased osmotic pressure leads to increase lung water content (pulmonary oedema)	<ul style="list-style-type: none"> ● Add 10% dextrose when glucose is <14mmol/L ● Monitoring serum sodium and osmolarity regularly

Source: JBDS (2010); Yehia et al (2008)

action taken, for example potassium being added to IV infusions if required.

- » Support early referral to the diabetes team: this involves liaising with the medical team to ensure the diabetes team is contacted as soon as possible after admission.
- » Provide psychological support for patients: this includes keeping the patient and relatives fully informed about the patient's clinical condition and the care given.
- » Diabetes specialist nurse: this nurse has a key role in providing patient education including sick-day management (see below) and arranging follow-up support for patients after discharge.

Complications

There are many potential areas for error in the management of DKA, so standardised protocols and guidelines are important to reduce risk for complications and management errors (Quevedo et al, 2001). Table 1 highlights common complications.

Patient education

Patients should be taught how to manage blood glucose during periods of illness (sick-day management). This should include specific information about frequency of blood glucose monitoring, blood glucose targets, checking for ketones, taking extra quick-acting insulin, appropriate adjustment of insulin doses, identifying early signs and symptoms of DKA and knowing when to contact the diabetes specialist team (Kitabchi et al, 2004).

Follow-up diabetes review

Patients should always have a follow-up review with the diabetes specialist team after an episode of DKA. This should include assessment of overall diabetes control and assessment of risk for a recurrence of DKA.

Risk reduction measures may include referrals to support services such as psychological services or structured education such as Dose Adjustment for Normal Eating (DAFNE) to increase diabetes knowledge, self-management skills and overall control.

Best-practice tariffs for DKA and hypoglycaemia recommend that all patients admitted to hospital with DKA should have access to structured education within three months of discharge (Price et al, 2013).

Conclusion

Management of DKA reduces the risk of mortality and improves clinical outcomes; this includes restoring circulatory volume, insulin therapy, correcting metabolic acidosis and electrolyte imbalance, identifying and treating precipitating factors and the early involvement of the diabetes specialist team.

The availability of standardised protocols and guidelines in clinical areas are important to reduce the risk of management errors.

Patient education about sick-day management and communication with diabetes specialist team are necessary to reduce the risk of DKA recurring. **NT**

References

Delaney MF et al (2000) Diabetic ketoacidosis and hyperglycemic hyperosmolar nonketotic syndrome. *Endocrinology Metabolic Clinics of North America*; 29: 683-705.

Faich GA et al (1993) The epidemiology of diabetic ketoacidosis: population-based study. *American Journal of Epidemiology*; 137: 551-558.

Joint British Diabetes Societies (2013) *The Management of Diabetic Ketoacidosis in Adults*. Malmesbury: JBDS. tinyurl.com/JBDS-2013-adults

Joint British Diabetes Societies (2010) *The Management of Diabetic Ketoacidosis in Adults*. Malmesbury: JBDS. tinyurl.com/JBDS-2010-adults

Kearney T, Dang C (2007) Diabetic and endocrine emergencies. *Postgraduate Medical Journal*; 83: 79-86.

Kitabchi AE et al (2006) Hyperglycemic crisis in adult patients with diabetes: a consensus statement from the American Diabetes Association. *Diabetes Care*; 29: 2739-2748.

Kitabchi AE et al (2004) American Diabetes Association: position statement: hyperglycemic crisis in diabetes. *Diabetes Care*; 27: S94-S102.

Lin SF et al (2005) Diabetic ketoacidosis: Comparison of patient characteristics, clinical presentations and outcomes today and 20 years ago. *Chang Gung Medical Journal*; 28: 24-30.

Price H et al (2013) Developing best practice tariffs for diabetic ketoacidosis and hypoglycemia. *Practical Diabetes*; 30: 1, 6-8.

Quevedo SF et al (2001) Improving diabetes care in the hospital using guideline-directed order. *Diabetes Spectrum*; 14: 226-233.

Sampson MJ et al (2006) Trends in bed occupancy for inpatients with diabetes before and after the introduction of a diabetes inpatient specialist nurse service. *Diabetic Medicine*; 23: 1008-1015.

Umpierrez GE et al (2002) Diabetic ketoacidosis and hyperglycemic hyperosmolar syndrome. *Diabetes Spectrum*; 15: 28-36.

Wright J et al (2009) Diabetic Ketoacidosis (DKA) in Birmingham, UK, 2000-2009: an evaluation of risk factors for recurrence and mortality. *Journal of Diabetes and Vascular Disease*; 9: 278-282.

Yehia BR (2008) Diagnosis and management of diabetic ketoacidosis in adults. *Hospital Physician*; 35: 21-26.