Although only involving a small group of individuals, this pilot study has demonstrated that use of blood ketone testing along with a structured education programme about DKA has reduced related-hospital admissions and improved individual confidence and self management.

In the author's locality, initial concerns over cost implications for extra strip usage have been shown to be offset by cost savings from reduced related hospital admissions. This has allowed the protocol to be developed for county-wide initiation and is currently being ratified by the local implementation group for diabetes.

Further work is required in the development of clear clinical coding of DKA within the secondary care environment to allow clinical audit of DKA admissions and judge the impact of the programme at both the individual and strategic levels.

This pilot study demonstrates how DSNs are in a unique position to initiate the use of available technology to improve the experience of people with diabetes and positively influence the wider community protocols used within their area of practice. ■

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Box 3. Ketone testing advice – local guidelines.

Ketone levels	What to do
Below 0.6 mmol/l	This level is normal – carry on with your usual blood glucose testing.
0.6–1.5mmol/l	Test your blood glucose after 1 hour. Continue regular insulin regimen. Consider increasing insulin after 1 hour. If blood glucose and ketones are falling retest hourly until ketones are below 1.1mmol/l.
1.5–3 mmol/l	Take additional short- or rapid-acting insulin. If you do not have this type of insulin use your usual premix insulin. Take the amount shown below or take $^1/_5$ of YOUR total daily dose. If this is above 10 units only take 10 units. • Insulin type: …….. • Amount: …… • Drink 1 cup of sugar free clear liquid every 15 minutes (500 ml per hour) • Retest ketones and blood sugar in 1 hour • If blood ketones not falling contact professional advice.
Above 3 mmol/l and/or continued vomiting and unable to tolerate fluids	SEEK SPECIALIST ADVICE IMMEDIATELY Take additional short- or rapid-acting insulin. If you do not have this type of insulin use your usual premix insulin. Take amount shown below or $^1/_5$ of YOUR total daily dose. If this is above 10 units only take 10 units. • Insulin type: …….. • Amount: …….. • Drink 1 cup of sugar free clear liquid every 15 minutes (500 ml per hour)

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Ketone testing for diabetes management

A pilot programme of proactive education

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Despite advancements in education and support, sudden illness and subsequent episodes of diabetic ketoacidosis (DKA) are still a reality for many individuals with type 1 diabetes. DKA remains a potentially fatal complication of diabetes precipitated by the combination of two factors: lack of circulating insulin and elevated levels of counter-regulatory hormones (Wallace and Matthews, 2004). Frequently the episode will necessitate the intervention of medical professionals and admission to hospital. DKA is preventable in many cases as only around 10% of people treated for it have undiagnosed diabetes (Krentz and Nattrass, 2002).

Repeated admissions with DKA can increase the emotional and psychological burden on an individual living with a complex long-term condition. Coupled with this is the financial burden of DKA admissions to the health service: each admission costs an estimated £4000–£6000 (South West Public Health Observatory, 2006).

In response to the National Service Framework goals of 'Empowering people with diabetes' and being able to 'Manage diabetic emergencies' (DoH, 2001), the DSN team in Cornwall have piloted an education programme among people with type 1 diabetes cared for in the community setting. The principal aim of this programme was to shift the treatment of DKA from a reactive to a proactive process.

In a pilot study in Cornwall, the ready availability of monitoring equipment that allows capillary blood glucose and blood ketone testing (Optium Xceed, Abbott Diabetes Care, Maidenhead) has allowed a targeted structured education process to be implemented, facilitating the early intervention of self-care strategies, thereby attempting to reduce the need for hospital admission. The background to this study, the results and implications are discussed herein.

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Diabetic ketoacidosis is usually the result of absolute or relative insulin deficiency in combination with the presence of counter-regulatory hormones such as glucagon, catecholamine, cortisol and growth hormones. This leads to lypolisis and the release of acetyl-CoA from fatty acids that is then converted by the liver into ketone bodies (acetoacetate, β-hydroxybutyrate and acetone). It is the elevated levels of acetoacetate and ß-hydroxybutyrate that leads to metabolic acidosis (Tantiwong et al, 2005).

Self monitoring of blood glucose is an established part of diabetes self-care, with type 1 treatment regimens still relying heavily on the individual's 'blood sugar diary' as a marker of adherence to therapy and attainment of glycaemic targets. However, blood glucose readings alone are not a sound clinical indicator of potential DKA. Other causes need to be ruled out, such as: consumption of large volumes of carbohydrate, stress, exercise and drug interactions (Orsini-Federici et al, 2006).

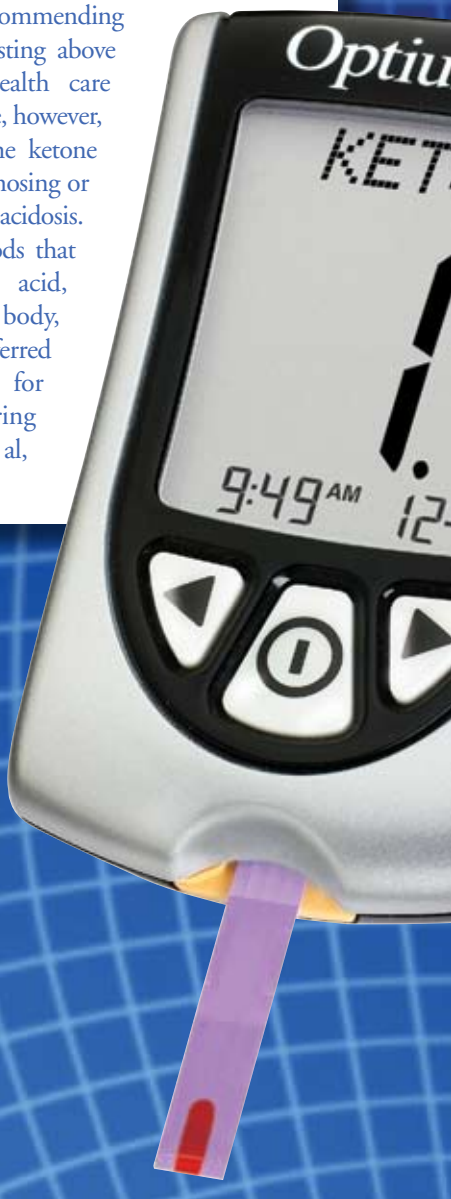
Laffel et al (2006) suggest that ketone monitoring has remained largely unchanged since the 1970s, with the standard test method involving ketone-reactive test strips for detecting ketone bodies in urine. Testing relies upon the semiquantative results from a nitroprusside reaction, in which acetoacetate in the urine reacts with the nitroprusside in the test strips, causing a colour change. This test does not detect β-hydroxybutyrate (the predominant ketone body involved in DKA; Goldstein et al, 1995).

False-positives have been reported with urine ketone test strips in the presence of sulphydryl drugs and when the test strips have been exposed to air for extended time spans – a possible occurrence in the home and clinical setting (Goldstein et al, 1995). See *Box 1* for a fuller list of potential problems with this method.

People with diabetes are frequently prescribed urine ketone test strips on initial diagnosis, but do not have cause to use them until later in the course of the condition. Within the clinical setting, the individual with diabetes should be encouraged to take responsibility for ordering replacement test strips within the allotted time scale. This aids empowerment as well as helping to reduce the risk of false-positives and the subsequent cascade of events that may follow – these include the administration of additional rapid- or short-acting insulin and admission to hospital.

The reduction of urine ketone levels is dependent on correction of the ketogenesis, obtaining an optimal fluid balance and the ability of the body to convert β-hydroxybutyrate to acetoacetate (Laffel et al, 2006). The persistence of blood β-hydroxybutyrate can be reduced to a half-life of 90 minutes following initiation of appropriate insulin regimens (Wallace and Matthews, 2004).

Equipment that allows testing for capillary levels of β-hydroxybutyrate offers a clinically superior testing system for both individual and wider clinical usage (Porter et al, 1997). The American Diabetes Association (ADA) goes as far as recommending the use of blood ketone testing above urine testing, stating: 'Health care professionals should be aware, however, that currently available urine ketone tests are not reliable for diagnosing or monitoring treatment of ketoacidosis. Blood ketone testing methods that quantify β-hydroxybutyric acid, the predominant ketone body, are available and are preferred over urine ketone testing for diagnosing and monitoring ketoacidosis.' (Goldstein et al, 1995).



Box 1. Potential problems with urine ketone testing.

- False-positives can occur when test strips are exposed to air for long periods.
- Sulphydryl medications can cause interference with the test results.
- Highly acidic urine samples can impact upon results.
- The test result is qualitative, relying on the user to differentiate between colours.
- The process depends on the ability to pass urine and urine ketone levels often lag 2 to 4 hours behind the blood ketone levels.
- Urine ketone levels may remain positive for up to 24 hours after resolution of ketoacidosis.

Ketone testing for diabetes management

A pilot programme of proactive education

The diabetes population of Cornwall is 20,002, with 1000 registered as having type 1 diabetes. The identification of accurate DKA admission rates is recognised nationally as being difficult as there are currently no standard diagnosis or coding systems in place. Data obtained for Cornwall for 2005/6 suggests there were 248 admissions for DKA (South West Public Health Observatory, 2006). The problem with these data are that they do not recognise cases of repeat admissions where the individual is at the highest risk, or those who had DKA at diagnosis. Secondly, following the county's population distribution, hospitals are often long distances apart. This can result in individuals delaying seeking attention from accident and emergency departments or minor injuries units due to travel difficulties.

The high admission rate in Cornwall identified an area of care in which the diabetes team could proactively identify individuals at risk and improve education for people newly diagnosed with diabetes accessing the system for the first time.

Traditionally, education for DKA has always been given during the initial diagnosis period using written materials outlining 'sick day rules'. The method and degree of follow up and re-assessment of this knowledge was unique to each DSN's consultation process. In order to encourage equality of services across the county and to reduce admissions for DKA, a pilot programme involving structured education and blood ketone testing equipment was carried out over 3 months.

The target population were people with type 1 diabetes known to the diabetes team as having had a hospital admission for DKA in the past 6 months or who were considered at high risk due to unstable glycaemic control. If not already using this meter to test blood glucose each individual was issued with an Optium Xceed meter (Abbott Diabetes Care, Maidenhead) and taught how to carry out blood ketone testing. The participant's GP was requested to prescribe β-hydroxybutyrate testing strips (Optium Xceed β-ketone Test Strips, Abbott Diabetes Care, Maidenhead). In addition to the equipment, each individual received a personalised care plan outlining when to carry out ketone testing (*Box 2*), the testing intervals and points at which to administer additional insulin (*Box 3*).

Twenty-seven candidates were enrolled in the study (16 female, 11 male; mean age 22.7 years; mean duration of diabetes 9.2 years). Initial data from this pilot study indicates a reduction in DKA-related admission rates of up to 45% among those involved. Anecdotal feedback from the participants involved in this study suggests an increase in confidence in dealing with diabetes and insulin management.

Box 2. Advice on when to test for blood ketones.

Fasting blood glucose level	What to do
A little bit high (7–10 mmol/l)	Continue with your usual insulin and blood glucose testing. Contact your diabetes team to discuss your levels if this is often your range.
High (10–16 mmol/l)	Consider taking extra insulin. Check glucose every 2–4 hours until it is below 10 mmol/l. If it goes on rising or you feel ill check ketones. Contact your diabetes team if this is often your range.
Very high (over 16 mmol/l)	Check ketones and follow given advice. Continue checking blood glucose as well as ketone levels.