Erratum

Wallymahmed M (2013) Encouraging people with diabetes to get the most from blood glucose monitoring: Observing and acting upon blood glucose patterns. *Journal of Diabetes Nursing* 17: 6–13

In this article, there was an error under the heading "Regulation of blood glucose." The original sentence was "Glucagon is secreted by beta-cells in response to low blood glucose levels." This has now been corrected to read "Glucagon is secreted by alpha-cells in response to low blood glucose levels."

Encouraging people with diabetes to get the most from blood glucose monitoring: Observing and acting upon blood glucose patterns

Maureen Wallymahmed

Citation: Wallymahmed M (2013) Encouraging people with diabetes to get the most from blood glucose monitoring: Observing and acting upon blood glucose patterns. *Journal of Diabetes Nursing* **17**: 6–13

Article points

1. It is well established that good glycaemic control can reduce the risk of microvascular complications in type 1 and type 2 diabetes; however, for many people the goal of good glycaemic control is difficult to achieve.
2. Self-monitoring of blood glucose is an important tool in diabetes management, especially for those treated with insulin injections; frequency should be determined on an individual basis.
3. Educating people with diabetes to recognise blood glucose patterns means they can tailor treatment to achieve optimal glycaemic control.

Key words

- Blood glucose monitoring
- Blood glucose patterns
- Glycaemic control

Author

Maureen Wallymahmed is Nurse Consultant in Diabetes, Diabetes Centre, Aintree Hospital, Liverpool.

The relationship between good glycaemic control and the development and progression of microvascular and macrovascular complications in people with diabetes is now well established; however, target HbA_{1c} levels are difficult to achieve for many people. Self-monitoring of blood glucose, if used as part of a structured education programme, can help to optimise glycaemic control. People with diabetes need training in the appropriate use of blood glucose monitoring equipment, so that they know to observe for blood glucose patterns and what action to take if blood glucose levels are outside of individual target ranges. This article gives a general overview of how to monitor glycaemic control and focuses on the importance of observing for blood glucose patterns to optimise treatment.

Diabetes is a common lifelong condition that affects 366 million people worldwide; its prevalence is expected to rise to 552 million by 2030 (Diabetes UK, 2012). Poorly controlled diabetes can cause distressing symptoms and can severely impair an individual's quality of life; life expectancy can be reduced, with the main causes of death being renal and cardiovascular disease (Morrish et al, 2001; Soedamah-Muthu et al, 2006).

It is well established that good glycaemic control can reduce the risk of microvascular complications in type 1 and type 2 diabetes (Diabetes Control and Complications Trial [DCCT] Research Group, 1993; UK Prospective Diabetes Study Group, 1998; DCCT/Epidemiology of Diabetes Interventions and Complications [EDIC] Study Research Group, 2002; Hammes et al, 2011) and may reduce the risk of cardiovascular events (DCCT/EDIC Study Research Group, 2005; Gaede et al, 2008). Targets for glycaemic control have been defined by NICE (2004, 2009); however, for many people with diabetes the goal of good glycaemic control is difficult to achieve. Thus, the aim of diabetes education is to facilitate self-management skills, including interpreting blood glucose trends and patterns and taking action to optimise glycaemic control.

Regulation of blood glucose

Blood glucose levels in people without diabetes are maintained within relatively narrow limits, at about 5–7 mmol/L (Bilous and Donnelly, 2010). It is insulin and glucagon, produced by the pancreas, that are largely responsible for the regulation of blood glucose. Insulin is synthesised in and secreted from the beta-cells within the Islets of Langerhans. Insulin levels are low during periods of fasting, and rise in response to high blood glucose levels, such as after meals. Glucagon is secreted by the beta-cells in response to low blood glucose levels and is inhibited by high blood glucose levels.

Monitoring glycaemic control

Glycated haemoglobin (HbA_{1c}) and capillary blood glucose readings are used to monitor glycaemic control, and both have their own merits.

HbA_{1c} is perceived as the "gold standard"; it provides information on overall control and serves as a surrogate for diabetes-related complications, although it cannot identify blood glucose patterns.

Capillary blood glucose monitoring is a tool for self-management; it is valuable in identifying hypoglycaemia and can help distinguish between fasting, pre- and post-prandial hyperglycaemia. It can provide useful information to people with diabetes about the effects of particular food choices, physical activity and medication on glycaemic control (Parkin and Davidson, 2009).

Additionally, capillary blood glucose monitoring is particularly useful in guiding self-management strategies during periods of illness.

However, there can be problems with both of these methods, such as assay errors and poor self-monitoring technique; therefore, the importance of clinical assessment, including enquiry about episodes of hypoglycaemia and osmotic symptoms, should not be overlooked.

Glycaemic targets for people with diabetes

Target HbA_{1c} levels of 6.5–7.5% (48–58 mmol/mol) are recommended for people with type 1 and type 2 diabetes (NICE, 2004; 2009). NICE also advises that self-monitoring of blood glucose levels should be used as part of an integrated education package, with pre-prandial target levels of 4.0–7.0 mmol/L and post-prandial targets of <9 mmol/L for people with type 1 diabetes, and post-prandial levels of <8.5 mmol/L for those with type 2 diabetes.

Educating people with diabetes for self-monitoring of blood glucose

Self-monitoring of blood glucose is recognised as an important tool in diabetes management, especially for those people treated with insulin injections. However, blood glucose monitoring alone is unlikely to have a major impact on glycaemic control unless it is part of a structured education programme. Education should involve skills-based, patient-centred education methods such as those employed by national programmes like DESMOND (Diabetes Education and Self-Management for Ongoing and Newly Diagnosed; Davies et al, 2008) and DAFNE (Dose Adjustment For Normal Eating; DAFNE Study Group, 2002).

Additionally, many centres in the UK have designed their own programmes to meet local needs. Programmes are designed to equip people with diabetes with the skills and knowledge they need to manage their diabetes on a day-to-day basis. In terms of blood glucose control, education should include information and practical training on normal physiological blood glucose

control, what happens in diabetes, target blood glucose levels and the effects of different food groups and physical activity on blood glucose. In addition, practical information on the time–action profile of different insulins or other medication and the importance of coordinating meals and diabetes treatment is essential for individuals to make informed decisions on treatment changes.

Specific insulin regimens should be discussed in detail demonstrating when individual insulins are effective, including the onset of action, peak action and duration of action. Simple diagrams can be used as teaching aids to demonstrate these time profiles (*Figure 1*) and their relationship to specific regimens (*Figure 2*).

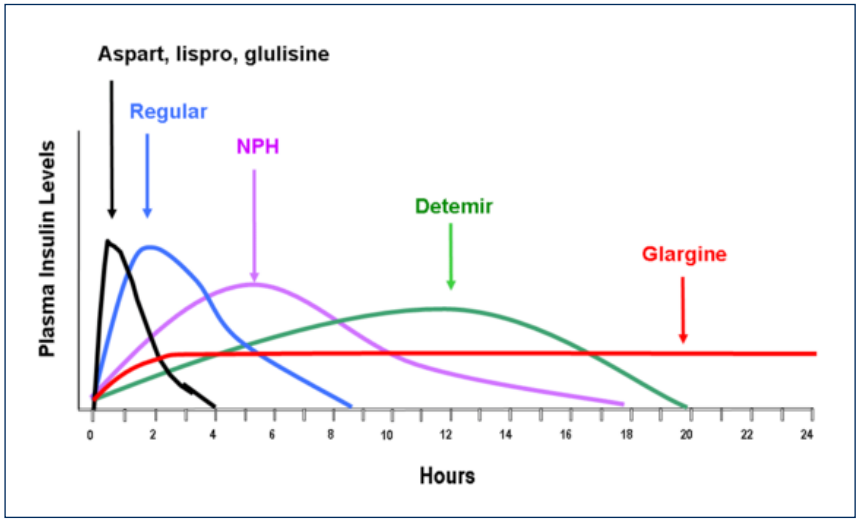

Figure 1. Insulin time profiles following subcutaneous injection. From Hirsch and Skyler (2009). Please note these are approximate times only and that the duration of action of a particular insulin can vary considerably between people, therefore individual assessment is required.

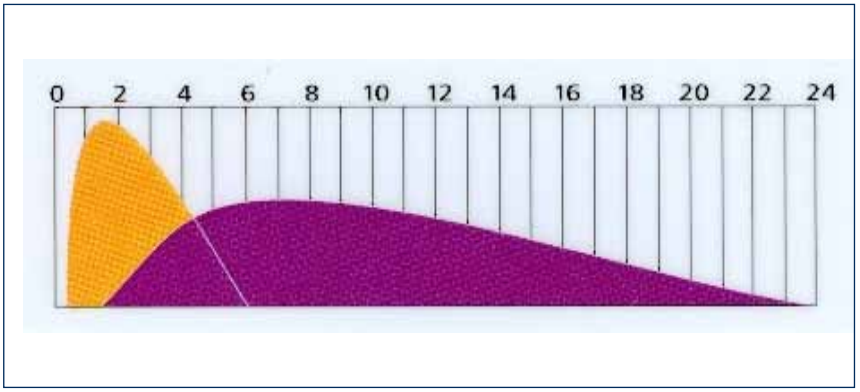

Figure 2. Approximate time profile of 30/70 pre-mixed analogue insulin. Key: orange=rapid-acting insulin; purple=long-acting insulin.

Care should be taken to focus on the basic skills of blood glucose monitoring technique, such as hand washing, collection of the blood sample, expiry date and storage of blood glucose strips, relevant calibration of meters and regular quality control. Additionally, injection technique and adherence to medication should be discussed; injection technique is beyond the remit of this article, but recently updated comprehensive information is available from the Royal College of Nursing (2012). Erratic or poor glycaemic control can often be attributed to poor understanding of these basic issues.

When to test blood glucose

Standard pre-prandial blood glucose monitoring may not be sufficient to optimise glycaemic control in many instances, particularly in people using flexible insulin regimens who are altering insulin doses according to carbohydrate intake (Pearson and Bergenstal, 2001). Increasing evidence supports the importance of targeting all three components of the "glucose triad": fasting blood glucose; post-prandial blood glucose; and HbA_{1c} (Ceriello and Colagiuri, 2008). Several studies, particularly in type 2 diabetes, have demonstrated a relationship between post-prandial hyperglycaemia and cardiovascular disease (DECODE Study Group, 2001; Cavalot et al, 2006).

Frequency of blood glucose monitoring should be determined on an individual basis depending on treatment regimen, lifestyle factors (including driving) and individual choice.

Optimising the effectiveness of blood glucose monitoring

Self-monitoring of blood glucose comes at considerable expense to the NHS, both in terms of prescription costs and staff resources to educate people with diabetes on appropriate management. In some areas people with diabetes, especially those with type 2 diabetes, appear to have difficulty accessing prescriptions for blood glucose monitoring strips. Therefore, to optimise cost and clinical effectiveness people with diabetes, their carers and healthcare professionals should:

- Understand the role of blood glucose testing, including the "glucose triad".

Page points

1. People with diabetes should be advised to review their blood glucose patterns on a regular basis.
2. It is relatively common for people with diabetes to contact their heathcare professional reporting erratic blood glucose control. Following a review of blood glucose readings, mostly from the memory of a blood glucose meter, a pattern can often be found and appropriate changes to treatment made.

- Understand and show competence in the purpose and value of testing.
- Be able to analyse and interpret the results.
- Be able to decide what action to take.
- Be able to take that action.
- Know how to review results, including when to be followed up (Ceriello et al, 2009).

Following appropriate training, many people with diabetes will be able to absorb all of the above into their daily lives, such as those using flexible insulin regimens and insulin pumps who alter their insulin according to blood glucose, carbohydrate intake and level of activity; however, for others this may not be so easy and could lead to increased anxiety. Some people with diabetes, for a variety of reasons, will not be able to alter their own diabetes treatment. However, they may be able to accurately monitor their blood glucose, recognise when blood glucose levels are outside of their target range and contact their healthcare professional to discuss what action to take.

Encouraging people with diabetes to observe for blood glucose trends and patterns

In normal circumstances, changes to treatment regimens should be made following a review of blood glucose readings that have been recorded in a systematic manner. This involves recording blood glucose levels at similar times each day and observing for patterns; for example, for routine monitoring this may involve fasting and pre-prandial blood glucose readings most days with post-prandial readings on several occasions during the week. The frequency and times of blood glucose readings need to be agreed on an individual basis; for example, if the HbA_{1c} is above the agreed target but pre-prandial blood glucose readings are on target then the focus may change to looking for post-prandial patterns.

It is relatively common for people with diabetes to contact their heathcare professional reporting erratic blood glucose control. Following a review of blood glucose readings, mostly from the memory of a blood glucose meter, a pattern can often be found and appropriate changes to treatment made. However, many individuals with diabetes (and some healthcare professionals) are unaware of the importance of observing for patterns and may make rash decisions based on a single blood glucose reading; this can lead to "chasing" blood glucose levels with glucose peaks and troughs, erratic control and an anxious person with diabetes.

There are of course situations where it is not advisable to wait for a pattern to emerge, such as an individual with type 1 diabetes who is unwell and reporting raised blood glucose levels and urinary or capillary ketones; in this situation action needs to be taken quickly to avoid diabetic ketoacidosis.

People with diabetes should be advised to review their blood glucose patterns on a regular basis. This is best done by retrieving results from the memory of a blood glucose meter and recording in a diary or by downloading results. Many diabetes centres have facilities for downloading meter readings, but this is not widely available in general practice. However, people with diabetes can download the results themselves and forward to the relevant healthcare professional. The following questions should then be asked:

- Are there any patterns, or are high or low readings isolated incidents?
- If there are patterns, are they "highs" or "lows", or both?
- Has there been any change in activity or usual routine?
- Have there been any periods of physical or emotional stress?
- Have there been any dietary changes?

Taking all of this into consideration, what can be done to remedy the problem? If there is a mixed picture of hypoglycaemia followed by hyperglycaemia then management of the low blood glucose should take priority; this is because the high blood glucose may be caused by over-treating the episode of hypoglycaemia.

Encouraging people with diabetes to observe for blood glucose patterns has several advantages:

- It can lead to a greater understanding of the effects of specific foods, physical activity and other situations on blood glucose levels.
- It can avoid overzealous alterations to diabetes treatment, which may lead to swings in blood glucose levels.
- It can help identify specific situations when a proactive alteration in treatment is needed, for example during periods of hot weather or when going on holiday.

Page points

1. Observing for blood glucose patterns is not a "quick fix"; rather, it aims to address the cause of the problem and prompt appropriate problem-solving action.
2. People with diabetes need to be given guidance on what action to take if a pattern is noted; this is dependent on individual treatment regimens and the emerging pattern.

Table 1. Guidance for action when a pattern of high blood glucose is noted before evening meals in a person with type 1 diabetes on a multiple injection regimen with analogue insulin.

Possible causes of pre-prandial high blood glucose	Possible action
Dietary causes:	
• More-than-usual carbohydrate at lunchtime	• Consider reducing lunchtime carbohydrate or increasing pre-lunch fast-acting insulin
• Late lunch	• If this is not going to be a regular occurrence, no action may be needed
• Too much carbohydrate with afternoon snack	• Reduce or omit carbohydrate in snack or consider if need fast-acting insulin to cover this snack (if carbohydrate counting)
Lifestyle issues:	
• Change from usual routine	• Is this an ongoing change? If so, need to review changes and insulin regimen
• A reduction in physical activity	• Try to increase activity; if not possible, consider increasing pre-lunch fast-acting insulin
No specific cause identified:	
• Not enough insulin at lunchtime	• Increase pre-lunch fast-acting insulin, usually by 10–20%

Note: Illness and stress can lead to an increase in blood glucose levels. For further information and advice, contact your diabetes healthcare professional.

All of these factors can have a positive effect on individuals' self-confidence in managing their diabetes and may improve glycaemic control. It has been suggested that blood glucose pattern management involves five basic steps (Pearson and Bergenstal, 2001):

- Knowing the target pre- and post-prandial blood glucose range.
- Gathering the information needed, such as blood glucose levels, food intake, insulin doses, level of activity, changes from usual routine.
- Looking for patterns.
- Assessing the influencing factors.
- Taking action.

Observing for blood glucose patterns is not a "quick fix"; rather, it aims to address the cause of the problem and prompt appropriate problem-solving action. This action may involve the following activities:

- A review of lifestyle issues, such as the timing of physical activity.
- A proactive decision to make a change to insulin dose on non-working days compared with working days.
- A general need to increase or reduce insulin at specific times according to the observed pattern.

It may also help people with diabetes to realise that there are often several solutions to a specific problem; for example, it may be identified from blood glucose patterns that a period of intensive physical activity in the early afternoon is related to mid-afternoon hypoglycaemia. If activity is planned, the individual may opt to reduce the pre-lunch insulin; however, if activity is spontaneous then the individual can consider other options such as increasing carbohydrate intake rather than missing out on physical activity because of fear of hypoglycaemia.

In addition, people with diabetes need to be given guidance on what action to take if a pattern is noted; this is dependent on individual treatment regimens and the emerging pattern. An example is given in *Table 1.*

Correction insulin doses

Many people with diabetes who are calculating their insulin doses according to carbohydrate intake are encouraged to use "correction" doses

of insulin. This involves consideration of current blood glucose, carbohydrate intake, target blood glucose and insulin sensitivity. Correction doses are an important element of achieving optimal glycaemic control. However, overuse of correction doses is an indication that the fundamental regimen is not correct (either basal insulin or insulin:carbohydrate ratio). Observing for blood glucose and correction dose patterns can be helpful in identifying the issues.

Blood glucose meter technology

Most blood glucose monitoring meters now have a memory function specifying when the blood glucose was recorded. However, for some individuals, transferring this information to a blood glucose diary or downloading the data and looking for patterns is an inconvenience. Several meters now have advanced functions such as insulin:carbohydrate calculators, facilities for tagging pre- and post-prandial readings and alerting the user to low or high blood glucose patterns. Such functions, when used properly, can help identify blood glucose patterns and prompt the individual to take appropriate action.

Conclusions

Self-monitoring of blood glucose is an important aspect of diabetes care. It is useful in detecting acute complications such as hypoglycaemia, and if used properly may help optimise glycaemic control. People with diabetes should be encouraged to observe for blood glucose patterns, and once a pattern has been identified to act appropriately so that changes to lifestyle or diabetes treatment regimen can be made. ■

Bilous R, Donnelly R (2010) *Handbook of Diabetes*. Fourth edition. Wiley-Blackwell, Oxford

Cavalot F, Petrelli A, Traversa M et al (2006) Postprandial blood glucose is a stronger predictor of cardiovascular events than fasting blood glucose in type 2 diabetes mellitus, particularly in women: Lessons from the San Luigi Gonzaga Diabetes Study. *J Clin Endocrinol Metab* **91**: 813–9

Ceriello A, Colagiuri S (2008) International Diabetes Federation guideline for management of post-meal glucose: A review of recommendations. *Diabet Med* **25**: 1151–6

Ceriello A, Cradock S, Forde R et al (2009) Post-meal blood glucose testing in adults with diabetes: Consensus recommendations. *Journal of Diabetes Nursing* **12**: 311–8

DAFNE Study Group (2002) Training in flexible, intensive insulin management to enable dietary freedom in people with type 1 diabetes: Dose adjustment for normal eating (DAFNE) randomised controlled trial. *BMJ* **325**: 746–9

Davies MJ, Heller S, Skinner TC et al (2008) Effectiveness of the diabetes education and self-management for ongoing and newly diagnosed (DESMOND) programme for people with newly diagnosed type 2 diabetes: Cluster randomised controlled trial. *BMJ* **336**: 491–5

DCCT/EDIC Study Research Group (2005) Intensive diabetes treatment and cardiovascular disease in patients with type 1 diabetes. *N Engl J Med* **353**: 2643–53

DECODE Study Group (2001) Glucose tolerance and cardiovascular mortality: Comparison of fasting and 2-hour diagnostic criteria. *Arch Int Med* **161**: 397–405

Diabetes Control and Complications Trial Research Group (1993) The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. *N Engl J Med* **329**: 977–86

Diabetes Control and Complications Trial/ Epidemiology of Diabetes Interventions and Complications (DCCT/EDIC) Study Research Group (2002) Effect of intensive therapy on the microvascular complications of type 1 diabetes mellitus. *J Am Med Assoc* **287**: 2563–9

Diabetes UK (2012) *Diabetes in the UK 2012. Key Statistics on Diabetes*. Available at: http://bit.ly/Uu13Vz (accessed 04.01.13)

Gaede P, Lund-Andersen H, Parving HH, Pedersen O (2008) Effect of a multifactorial intervention on mortality in type 2 diabetes. *N Engl J Med* **358**: 580–91

Hammes HP, Kerner W, Hofer S et al (2011) Diabetic retinopathy in type 1 diabetes – a contemporary analysis of 8784 patients. *Diabetologia* **54**: 1977–84

Hirsch IB, Skyler JS (2009) *The Management of Type 1 Diabetes*. Available at: http://www.endotext.org/diabetes/diabetes17/diabetesframe17.htm (accessed 04.01.13)

Morrish NJ, Wang S, Stevens LK (2001) Mortality and cause of death in the WHO multinational survey of vascular disease in diabetes. *Diabetologia* **44** (Suppl 2): S14–21

NICE (2004) *Type 1 Diabetes: Diagnosis and Management of Type 1 Diabetes in Children, Young People and Adults*. CG 15. NICE, London. Available at: http://publications.nice.org.uk/type-1-diabetes-cg15 (accessed 04.01.13)

NICE (2009) *Type 2 Diabetes: The Management of Type 2 Diabetes*. NICE, London. Available at: http://guidance.nice.org.uk/CG66 (accessed 04.01.13)

Parkin C, Davidson JA (2009) Value of self-monitoring blood glucose patterns analysis in improving diabetes outcomes. *J Diabetes Sci Technol* **3**: 500–8

Pearson J, Bergenstal R (2001) Pattern management: An essential component of effective insulin management. *Diabetes Spectr* **14**: 75–8

Royal College of Nursing (2012) *Starting Injectable Treatment in Adults with Type 2 Diabetes*. RCN guidance for nurses. Available at: http://www.rcn.org.uk/__data/assets/pdf_file/0009/78606/002254.pdf (accessed 04.01.13)

Soedamah-Muthu SS, Fuller JH, Mulnier HE et al (2006) All-cause mortality rates in patients with type 1 diabetes mellitus compared with a non-diabetic population from the UK general research database, 1992–1999. *Diabetologia* **49**: 660–6

UK Prospective Diabetes Study (UKPDS) Group (1998) Intensive blood glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33). *Lancet* **652**: 837–53

"People with diabetes should be encouraged to observe for blood glucose patterns, and once a pattern has been identified to act appropriately so that changes to lifestyle or diabetes treatment regimen can be made."