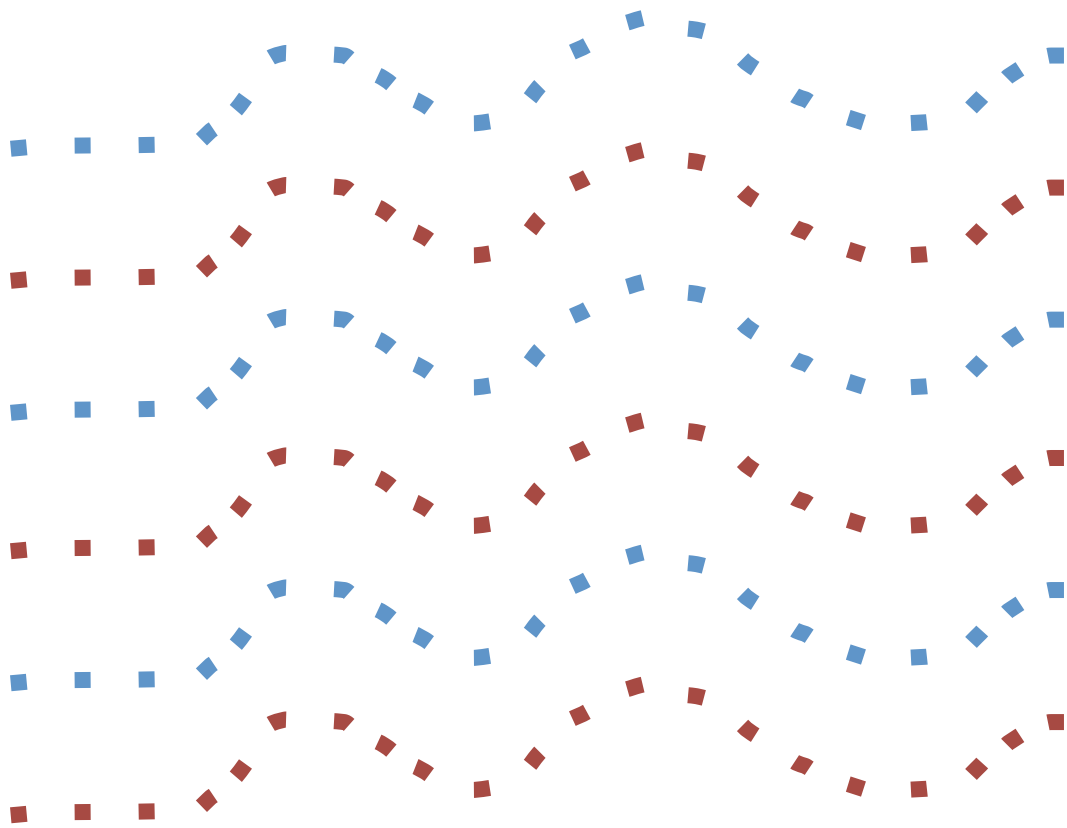


Using continuous glucose monitoring (CGM) to improve control in type 1 diabetes



DISCLAIMER

BE AWARE THAT THE ADVICE CONTAINED IN THIS BOOKLET IS INTENDED AS A GENERAL GUIDE FOR PEOPLE USING CGM SYSTEMS. BECAUSE OF SIGNIFICANT DIFFERENCES BETWEEN INDIVIDUALS, IT IS IMPORTANT TO CAREFULLY ASSESS THE EFFECTS OF ANY CHANGE IN INSULIN THERAPY AND, WHERE YOU ARE UNCERTAIN, DISCUSS THIS WITH YOUR DIABETES TEAM.

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What does CGM tell you that finger prick testing can't?

A finger prick blood glucose gives a snap-shot of what your capillary blood glucose level is at that moment – it cannot tell you what it was in the minutes and hours before, or provide any information on whether it is stable, rising or falling. CGM measures glucose in the interstitial fluid (fluid between the cells in your skin) and, by constantly sampling, informs you what has happened over the preceding hours as well as providing an indication of how quickly the glucose level is changing.

CGM is particularly useful in helping assess:

- Blood glucose levels through the night
- Blood glucose trends after meals (different types of food)
- Effects of exercise on blood glucose (both during and after)
- Effects of stress on blood glucose
- Response to treatment of hypoglycaemia (over or under-treatment)
- How well your basal insulin is working

The options

Current options for CGM are described on our website, which also has links to the manufacturers' sites. The Freestyle Libre is not technically a continuous glucose monitoring system as it does not display glucose results in 'real time' and does not have alarm functions (for high and low glucose). Nonetheless, you can apply the principles of CGM to the Libre and almost all of what follows in this document is relevant for Libre users.

We would encourage you to familiarise yourself with the instruction manuals and instructional videos specific to the device you are using.

The most important thing

This may seem obvious but CGM only works when it is used regularly. In addition, it is essential to regularly review and respond to the patterns and results. Where a problem developed – why did it happen? What strategies can be employed to avoid problems in future? These issues are discussed in greater detail later on.



The basics of working out basal insulin doses, insulin to carb ratios and correction factors are discussed in our 'Ten steps to improve control in type 1 diabetes' booklet (pump and injection versions are available on our website to download). It is important to deal with the basics before moving on to some of the more complicated 'fine-tuning' that CGM can help with.

What do the arrows tell you?

The arrows on CGM indicate the current rate of change of glucose – is it steady, going up (slowly or quickly) or going down (slowly or quickly)? The arrows mean slightly different things on different devices - see the table below:

	Dexcom	Libre	Guardian
↑↑	Going up more than 0.17 mmol/L per minute		Going up more than 0.11 mmol/L per minute
↑	Going up between 0.11 and 0.17 mmol/L per minute	Going up more than 0.11 mmol/L per minute	Going up between 0.06 and 0.11 mmol/L per minute
↗	Going up between 0.06 and 0.11 mmol/L per minute	Going up between 0.06 and 0.11 mmol/L per minute	
→	Stable	Stable	Stable
↘	Going down between 0.06 and 0.11 mmol/L per minute	Going down between 0.06 and 0.11 mmol/L per minute	
↓	Going down between 0.11 and 0.17 mmol/L per minute	Going up more than 0.11 mmol/L per minute	Going down between 0.06 and 0.11 mmol/L per minute
↓↓	Going down more than 0.17 mmol/L per minute		Going up more than 0.11 mmol/L per minute

If glucose is changing by 0.17 mmol/L per minute this means a change of at least 2.6 mmol/L in 15 minutes and 5.1 mmol/L in 30 minutes.

If glucose is changing by 0.11 mmol/L per minute this means a change of at least 1.7 mmol/L in 15 minutes and 3.3 mmol/L in 30 minutes.

If glucose is changing by 0.06 mmol/L per minute this means a change of at least 0.9 mmol/L in 15 minutes and 1.8 mmol/L in 30 minutes.

You can use the arrows to predict highs and lows and, therefore, take action to prevent problems developing....

Remember if glucose is falling fast – blood glucose will be lower than the CGM value.



Look at your receiver/reader regularly

The more you look at your CGM, the greater the opportunity to learn what foods and/or insulin dosing works best for you. Being aware of the direction your glucose is heading allows you to avoid highs and lows by taking corrective action. CGM can be used **retrospectively** to learn from previous decisions (what worked well – what didn't) but can also be used **proactively** to make real-time adjustments. The proactive approach is quite different from the standard model of diabetes management, takes a lot of practice (trial and error) and is discussed in more detail in later sections.

Calibration and the limitations of CGM

Dexcom and Medtronic CGM devices require regular calibration with blood glucose results to maintain the accuracy of the CGM trace – this should ideally be done when the glucose trace is near your target and stable (➔). Freestyle Libre does not require calibration with finger prick capillary glucose testing. With any CGM device it is important to check a blood glucose where you feel the results do not make sense; it is also advisable to base insulin dosing on a capillary blood glucose result. At present, the DVLA still require blood glucose testing prior to driving. Because CGM does not measure blood glucose there is a 'lag' between any change (up or down) in blood glucose and the CGM result. This means when glucose is rising, the CGM will underestimate and when glucose is falling CGM will overestimate.

Be aware that **paracetamol** can falsely elevate CGM glucose readings.

Alerts and alarms: friend not enemy!

Dexcom and Medtronic CGM devices (but not Freestyle Libre) can be set up to alarm when glucose levels are too high and too low. Typical high and low alerts are 11 mmol/L and 4.5 mmol/L, respectively, although these should be discussed with your diabetes team. You can also set repeat low and repeat high alerts: consider setting 15 to 30 minutes for repeat low alert and 120 minutes for repeat high alerts.

When high or low alerts occur, reflect on what led to the alert (could it be avoided in future?) and what corrective action is required.

Often people find alerts irritating, particularly when they are occurring frequently. Rather than giving up on them please contact your diabetes team to consider strategies to avoid recurrent highs/lows or to adjust the alert settings.

Reflect on past decisions and actions

Use Diasend (or Carelink for Medtronic) to review your CGM traces and the ambulatory glucose profile. This will help uncover recurring patterns which may require a change in approach. Think about the decisions which worked well and what you could do differently, in future, to prevent highs and lows.



Know your targets and take action to reach them

Recent guidance from NICE (National Institute for Health and Care Excellence) suggests the following targets for people with type 1 diabetes:

- 5 – 7 mmol/L on waking
- 4 – 7 mmol/L before meals at other times of day
- 5 – 9 mmol/L after eating (measured at least 90 minutes after meals)

Please confirm your targets with your diabetes team.

Responding to low glucose

If hypoglycaemia develops, consume 15g of rapid acting carbohydrate (4 glucose tablets / half can of coke). Because of the lag between blood and interstitial glucose, the CGM trend may not begin to rise for 15 minutes. Watch for changes in the trend arrow.

Aim to take action before hypoglycaemia develops (low glucose alert) if the glucose is in target but falling rapidly (↓ or ↓↓). Consider whether exercise or stacking insulin (multiple doses of quick-acting insulin) have contributed to the development of a low glucose. See our website for a detailed overview of how best to manage glucose levels in the context of exercise.

CGM will show you whether your usual response to hypoglycaemia results in over-treatment. If this is the case, you can adjust your approach to avoid future over-correction.

Use your CGM trends to improve meal insulin dosing

Learn to adjust your insulin dose using both your blood glucose and the trend arrow. Consider the following scenarios:

Trend arrow: →

Do what you would normally do. Try to take your mealtime insulin 15 minutes before eating.

Trend arrow: ↗ or ↑ or ↑↑

Consider increasing your mealtime insulin dose and allowing more time between your dose and meal. Consider starting your meal with proteins and fats rather than carbohydrates. Look back: should you have taken extra insulin with a snack or did you over-treat a previous hypo?

Trend arrow: ↘ or ↓ or ↓↓

Consider reducing your mealtime dose and reduce the time between your dose and meal. Start the meal with carbohydrate.



Respond to high glucose between meals but avoid “stacking” insulin. Don’t overreact!

One of the major advantages of CGM, over finger-prick tests, is the ability to intervene between meals when you have clear evidence that glucose levels are rising after insulin action has peaked. Rapid-acting insulin can take 90 – 120 minutes to peak and may still be working 4 hours after your injection (bolus). If it is 2 hours or more after a meal and glucose is rising (↗ or ↑ or ↑↑) you should consider giving a dose of quick-acting insulin to correct down. Reflect on what you would do differently next time in relation to your mealtime insulin timing or dose.

If you give extra insulin whilst your earlier dose is still peaking you will be at risk of hypoglycaemia!

Use CGM to work out your correction doses and active insulin time*

You can use CGM to establish the effect a given dose of quick-acting insulin has on your glucose levels and, in addition, the active insulin time (how long the quick acting insulin works). Choose a time when your glucose is stable (*i.e.* no recent food consumed) and in the upper part of your target range (to avoid dropping too low). Give a bolus of quick-acting insulin (perhaps 1 unit) and assess the effect this has on your glucose levels - ideally you should do this on a number of occasions and with different doses of insulin (although always aiming to avoid going low). The time it takes from giving the dose until the glucose level stops falling is the active insulin time. The amount the glucose falls should help inform your future correction doses.

*You need to be confident that your basal (background) insulin is appropriate before doing this.

‘Sugar Surfing’

It is important to get the basics right – basal (background) insulin dose, insulin to carb ratios and correction factors *etc.* However even when everything seems to have gone to plan, there are so many potential variables, that glucose levels rarely respond as predicted. ‘Sugar Surfing’ involves responding early to prevent highs and lows by using trends from CGM. Typically this means setting upper (10**), mid (6**) and lower (4**) targets and glancing at your CGM frequently to anticipate any problems. Where glucose levels are slowly heading below the lower target, ‘micro-carbing’ (4g quick acting carb – glucose tablet) or a temporary reduction in pump basal rate, may be sufficient to prevent hypoglycaemia. Conversely, where glucose levels are heading above the upper target (and the previous insulin dose has already peaked), ‘micro-dosing’ based on your correction factor will help bring your levels back towards your mid-target.

The practice of using CGM to ‘pivot’ around a central target requires regular CGM review and a huge amount of ‘trial and error’. This concept is explored in much greater detail in the book ‘Sugar Surfing’ by Ponder and McMahon (available online for approximately £7).

**Targets will vary between individuals and can get ‘tighter’ with experience.

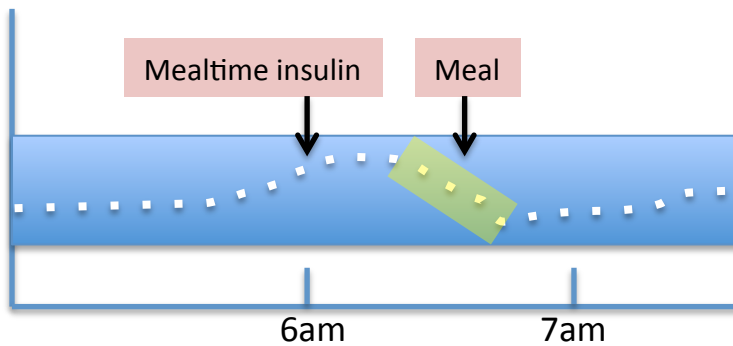


‘Hollow highs’

‘Hollow highs’ are high blood glucose trends that have been caused by stress. Using CGM, you will begin to see the effect that stressful events (e.g. difficult meetings at work, exams *etc.*) can have on your glucose. The reason they have been designated ‘hollow’, is that they often require less insulin to correct when compared to highs caused by food. Consider taking half the insulin correction you would normally give in these situations – everyone is different, so carefully assess the effect this has.

‘Waiting for the bend’

One of the major problems with mealtime insulin dosing is getting the timing wrong. Insulin takes at least 15 minutes to start working and doesn’t peak for at least an hour (even with pumps). After a meal, glucose levels tend to rise within 5 to 10 minutes. If you take insulin after a meal or even immediately before, glucose levels will rise out of target. Some CGM users advocate ‘waiting for the bend’ – meaning take your bolus of insulin and watch the CGM until the glucose starts to tail down:



Using CGM you know your insulin dose is now active and will help prevent a big rise in glucose.

Basal rates on the pump

Just because it is possible to set multiple basal rates on an insulin pump doesn’t mean this is the best approach. Any change in basal rate takes a couple of hours to fully take effect and multiple basal rates can end up introducing a great deal more variability. Some CGM users, with excellent diabetes control, use only a single basal rate and it is always worth reviewing your basal insulin and considering whether fewer rates may be better. When you identify a slow trend down in glucose (towards your lower limit), you should consider whether a temporary reduction (or short interruption) of your basal insulin may be appropriate to avoid hypoglycaemia.



The effect of fat – delayed/prolonged glucose peaks

One major benefit of CGM use is highlighting the massive variation in onset and duration of glucose peaks depending on the type of meal consumed. Fat delays carbohydrate absorption and can result in prolonged (difficult to deal with) glucose peaks. Foods such as pizza, some pasta dishes, fried food and Mexican food fall in to this category (there are many more). If you are on a pump you can consider using a split bolus – estimates vary about how much should be given immediately and how much over a longer duration (anywhere from 2 to 5 hours). This is obviously different for different foods and between individuals but one study suggested 50% immediate bolus and the remainder over 2 to 5 hours for pizza. The key here is to review what happens to you and aim to modify what you do in future.

If you are on insulin injections you may need to consider taking an initial quick-acting dose with your meal, review your CGM at around 2 hours and, if glucose is still rising or is substantially above target, consider an additional dose (taking in to account the glucose level, rate of change arrows and your known correction factor).

It can take a lot of practice to get this right!

Super-bolus

This is a special technique for pump users to help deal with foods with a very high glycaemic index (i.e. carbohydrate that is absorbed very quickly), which are prone to cause rapid rises in glucose. In essence it means stopping your basal insulin for 2 or 3 hours and adding that amount of insulin to your bolus. The theory is that you give more insulin early to deal with the quick rise but avoid later hypoglycaemia by interrupting the basal insulin infusion. There is a detailed explanation of this online (Google: 'John Walsh Superbolus'). It is important to be careful when experimenting with new approaches – check your glucose regularly or ask your diabetes team for advice.

Night-time correction

It is important to be careful when considering whether to correct a high blood glucose before bed, particularly if you are using a system which does not alarm for hypoglycaemia. However, CGM does provide the confidence of knowing what typically happens to your glucose overnight and if you have a high pre-bed result with a → or ↗ or ↑ or ↑↑ trend, you may wish to consider correcting down. One recommendation for pump users is to deliver half your usual correction over a prolonged period (perhaps 5 hours). People using insulin injections should exercise great care and consider reviewing the response to your lowest possible correction dose and perhaps only when ↗ or ↑ or ↑↑.

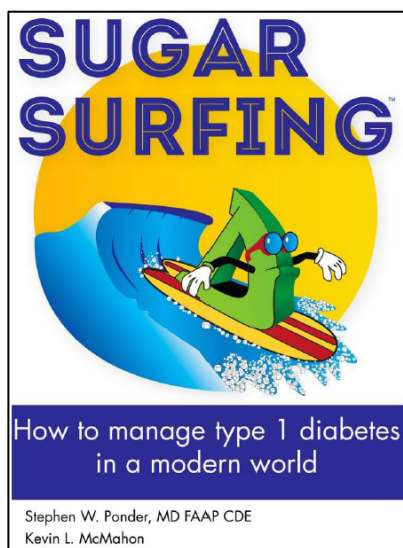


Acknowledgments

Much of the content of this booklet has been adapted from ‘Improving Glucose Control Using Your Continuous Glucose Monitor (CGM): Tips for Type 1 Diabetes’ by Schafer Boeder, Jeremy Pettus, Steven Edelman and David Price from the University of California San Diego.

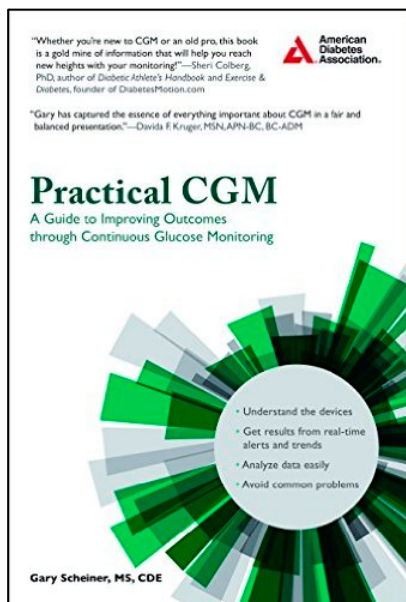
References

If you would like to learn more about CGM please consider reading the following books:



Sugar Surfing: How to manage type 1 diabetes in a modern world. Stephen W Ponder and Kevin L McMahon.

<http://www.mediself.co/#!/sugarsurfing/cm5d4>



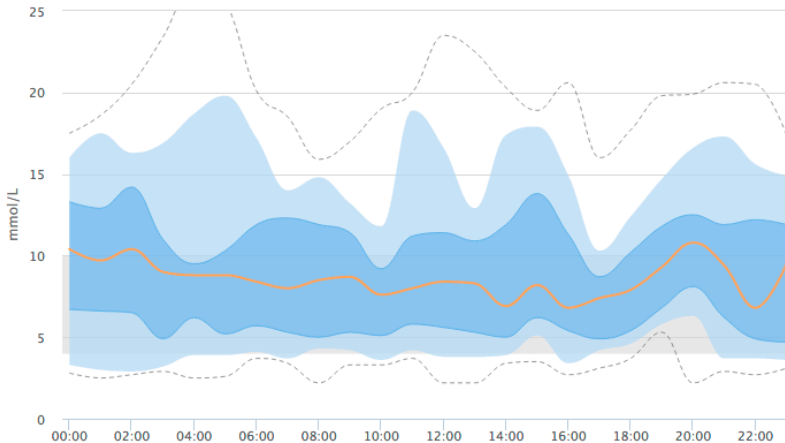
Practical CGM: A guide to improving outcomes through continuous glucose monitoring. Gary Scheiner.

Review your data (and share it with us)

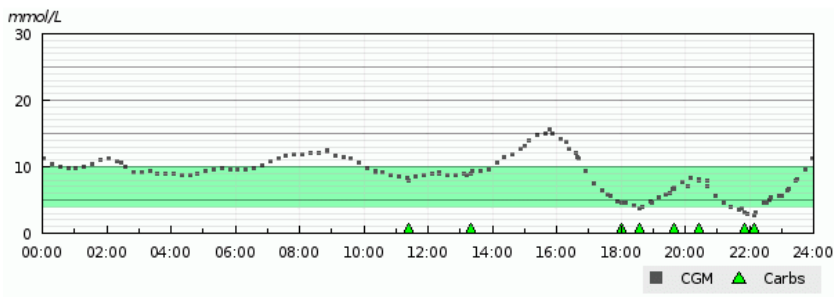


Please consider signing up to Diasend.com and linking your account to our clinic by adding our clinic code (17-17161) during registration.

You can then review your CGM in a number of ways:



Ambulatory glucose profile: a summary of the last 2 weeks to pick out recurring trends.



Day-by-day traces: look over each day's results to identify what worked well (and what didn't)

Get in touch with us at: DiabetesClinic.RIE@nhslothian.scot.nhs.uk if you have any questions or would like us to review your CGM data.

Medtronic CGM users should sign up to Carelink (as your device is not compatible with Diasend).



