Data, Data Everywhere…

How to analyze, interpret and apply information from continuous glucose monitors.

By Gary Scheiner MS, CDE

A1c. HDL. LDL. Fasting blood sugars. Postprandial blood sugars. Grams of carb. Insulin-to-carb ratios. Correction factors.

Ever feel like you're drowning in your own numbers? Diabetes care is chock-full of numerical data, all designed (presumably) to help us manage our blood glucose levels, prevent complications, and live life to the fullest. Judging by the problems diabetes still causes, perhaps we need to find a better way.

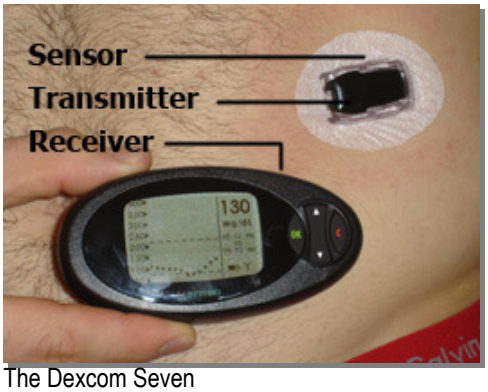
Voila! Along comes Continuous Glucose Monitoring (CGM). When working properly, CGM systems are supposed to generate the kind of information that will allow us to fine-tune our diabetes management program and stay out of harm's way. Trouble is, even with the plethora of charts, graphs and data points (up to 288 per day) produced by CGMs, most people haven't got a clue as to what to do with all that information. And that's a shame, because even with their shortcomings, CGM systems can be an extremely valuable resource for guiding daily decision-making.

CGM Basics

We now have two systems available that provide real-time blood glucose estimations and warning systems to guard against pending highs and lows: The Dexcom Seven and the Medtronic Guardian System (and sensor-augmented pump). A third system, the Navigator from Abbott Diabetes Care, is awaiting FDA approval. All three systems utilize a thin metallic filament inserted just below the skin to detect glucose in the interstitial fluid (fluid between the cells) in the subcutaneous tissue. Spring-loaded insertion devices make sensor insertion quick and relatively painless.

The Medtronic Sensor Augmented Pump

The Medtronic Guardian



The Dexcom Seven

The information from the sensor is transmitted via radio signals to a receiver/monitor, which displays an estimate of the current glucose concentration. While the transmitter and receiver/monitor are "durable", the life expectancy for the glucose sensors varies from 3 to about 14 days. In case you're wondering, the sensors

do not tend to cause skin irritation the way pump infusion sets can.

The Dexcom and Medtronic receiver/monitors provide an updated glucose reading every 5 minutes and can be set to alarm if the value goes above or below a target range set by the user. The Guardian system also has predictive capability, which can warn the user of *pending* highs or lows. Both systems require calibration by way of fingerstick blood glucose readings a minimum of twice daily, and both are generally accurate to within 15-20% of most fingerstick readings. Both provide "line graphs" depicting glucose trends over the past several hours, and software permits detailed analysis over longer time intervals. For a more detailed look at CGM Basics, refer to the article in the March/April issue of Diabetes Self Management.

Immediate Numbers

Go back to the paragraph above. See that "15-20%" figure that we casually glossed over? That means that the data generated by the CGM is usually only a rough estimate. Too rough, in fact, to use in making most insulin-dosing decisions. That's not to say that CGM users never use their data to determine insulin doses, but it takes a sound knowledge of the nuances of the system before doing so.

For example, I find that my CGM data tends to be unreliable during the first 12-24 hours after a new sensor is inserted. It often takes time for a sensor to become acclimated to being below the skin, and for calibration readings to allow the sensor to "hone in" properly. Ironically, the CGM data seems to become *more* precise and reliable the longer a sensor has been in place. Until I start to see a couple of sensor values that are very close to simultaneous fingerstick readings, I just don't trust the CGM for immediate decision-making.

Likewise, the accuracy of CGM values must be questioned if there have been frequent or prolonged data gaps on the monitor/display. Signal interference or erratic/inconsistent signals may cause erroneous and unreliable information.

There is also an issue known as "lag effect" that must be considered. CGM systems take multiple data points over a 5-minute period and average them to generate a single data point. This means that, on average, data is 2 ½ minutes old. And because CGMs are measuring interstitial fluid (and not blood), there is an inherent 5-10 minute delay between fingerstick values and what appears on the CGM display. Thus, if blood glucose levels are rising quickly, the CGM data point can be significantly lower than a concurrent fingerstick value. Likewise, if the blood glucose level is dropping quickly, the CGM data point can be significantly higher.

As a result, I only recommend using the CGM's blood glucose data for immediate dosing purposes if:

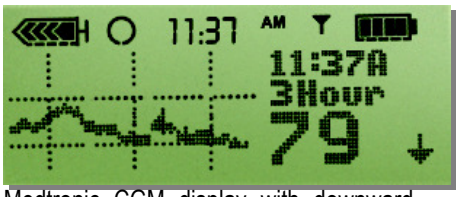
1. the last couple of calibration (fingerstick) values have matched the sensor values closely (within 10%).
2. your current blood glucose is not rising or dropping rapidly (a quick look at the sensor trend graph can tell you if this is the case)
3. the sensor has not generated any error messages or significant data gaps for at least the past hour.

Whether you use your CGM data for dosing purposes or verify the data with fingerstick readings, the simple act of *looking* at your monitor has its rewards. Research has shown that checking the monitor 10-20 times per day and wearing the system most of the time (rather than intermittently) tends to produce improvements in HbA1c and reductions in hypoglycemia.

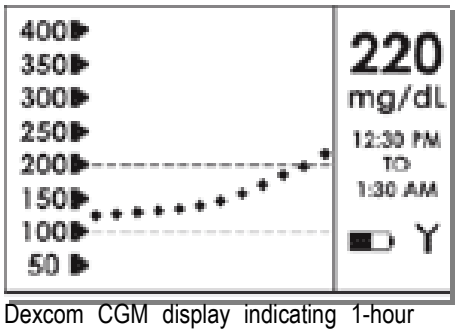
Short-term trends

Perhaps more valuable than the immediate blood glucose value is the direction it is headed. If you checked your blood glucose at bedtime and found it to be 95mg/dl, you would certainly react differently if you knew it was on the rise rather than if it was dropping. Similarly, a value of 188 prior to exercise would mean more to you if you knew whether it was rising, falling or steady.

The Medtronic CGM systems display up or down arrows to denote both the *direction* and *magnitude* of blood sugar changes over the past 20 minutes. The Dexcom Seven system displays a 1-hour trend graph that reveals similar information. USE THIS INFORMATION TO YOUR ADVANTAGE! The ability to forecast where your blood sugar will be over the next hour or two can help to keep you from straying too far out of your desirable blood sugar range.



Medtronic CGM display with downward trend arrow.



Dexcom CGM display indicating 1-hour upward trend.

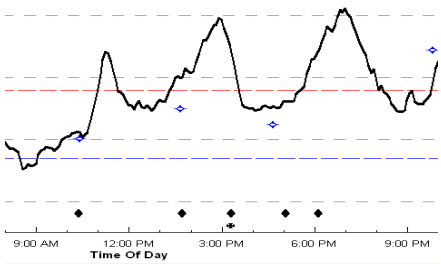
For instance, If your blood glucose is close to or slightly above normal but dropping quickly, either take a snack or be prepared to take a snack soon. Similarly, if your blood glucose is near or slightly below normal and dropping gradually, take a snack and check again soon.

With a rapidly rising blood glucose level, you may choose to offset the rise with rapid-acting insulin (taking active/unused insulin from previous doses into account), and check the monitor often to make sure you don't wind up dropping too much. If the blood glucose continues rising, a ketone check may be in order. It is this type of frequent fine-tuning that can keep you within your target blood glucose range more often.

Intermediate Trends

Both the Dexcom and Medtronic systems display 3-hour trend graphs on-screen (the Medtronic Guardian also displays a 6-hour trend screen). Although looking back at the past three hours of data will not help you to fix a prior problem, they can provide you with information for preventing a recurrence.

For example, checking the 3-hour trend graph a couple of hours after meals can reveal the *postprandial effect* of various types of foods. When downloading the Medtronic CGM to their Carelink website, the *Sensor Overlay By Meal* chart indicates these trends very clearly. Did your blood glucose level spike very high soon after the meal? If so, perhaps you need to give your insulin earlier, get some physical activity after eating, or choose foods that digest more slowly. Did your blood glucose drop soon after the meal and then rise a few hours later? Perhaps you need to delay your injection or extend the delivery of your bolus (if using an insulin pump).



Examples of postprandial "spikes"

For those who use Symlin or Byetta, the 3-hour trendgraphs can show whether or not the medication is effective at minimizes postmeal spikes without causing hypoglycemia immediately post-meal. A

blood sugar drop soon after eating, followed by a rise over the next couple of hours, indicates a need to either delay or extend delivery of the mealtime insulin.

The 3-hour trend graph can also reveal blood glucose patterns related to exercise. Checking the graph during and after exercise will show when and how much your blood sugar rises or falls. Insulin and snack adjustments can be made based on the patterns seen on-screen. For competitive as well as casual athletes, these types of adjustments can certainly enhance performance.

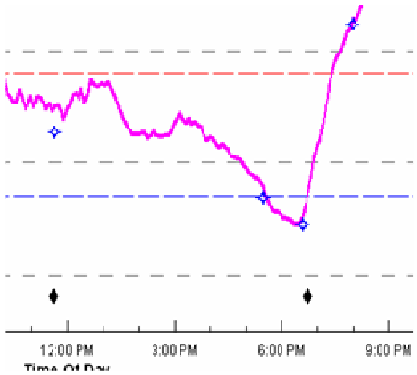
Stress is another concern for many of us. In some instances, stress will cause an abrupt or prolonged blood sugar rise. At other times, it can make blood sugar drop. The very inconsistency of the stress response can cause… well… more stress. I have found that the 3-hour trend graph provides a nice "inside look" at the effects of various forms of stress on blood sugar levels. Not only can you see if the stress is making you rise or fall (and thus requiring extra insulin or an immediate snack, respectively), but it can also indicate how long the effects last so that you'll be better prepared at the next go-round.

Long-Term Trends

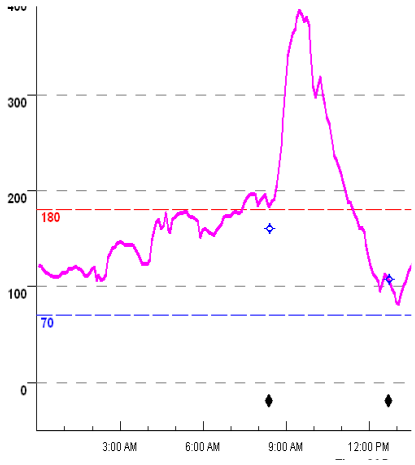
The 9-hour graph on the Dexcom system and the 12 & 24-hour graphs on the Guardian system (24-hr only on the sensor-augmented pump) play a role in the regulation of *basal* insulin, particularly overnight. Whether you take insulin by way of injections or a pump, the basal aspect of your insulin program is designed match your liver's normal secretion of glucose into the bloodstream. In other words, the basal insulin should hold your blood sugar steady in the absence of food, exercise, stress, and rapid-acting insulin.

By looking at the CGM's long-term trend graphs starting approximately 4 hours after a meal is eaten and rapid-acting insulin is taken, you can evaluate the effectiveness of your basal insulin. If the blood sugar level is gradually rising or falling after the food and mealtime insulin have worn off, the basal insulin probably needs adjustment.

In the example below taken from an insulin pump user, with a meal eaten (and bolus given) at 11:30am, the blood sugar level begins to take a downturn at around 4pm. This indicates that the basal insulin level is too high in the late afternoon.

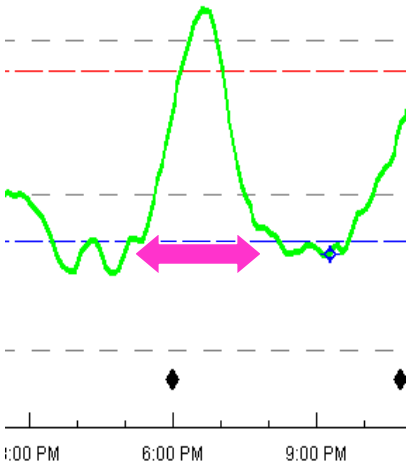


In the next example, taken from a person using Lantus as their basal insulin, the blood sugar level is rising through the night from 2am until 8am. This indicates the need for a higher dose of Lantus.



In addition to helping fine-tune basal insulin doses, long-term trend graphs can be used to determine the *action curve* for your rapid-acting insulin. That is, how long it takes for your insulin to finish working (this is valuable in determining "insulin-on-board" or "active/unused insulin". Action curves can vary from person to person, with times ranging from 2½ to 5 hours. To determine your action curve, simply check to see how

long it takes for your blood sugar to stop dropping after giving insulin for a meal or to correct a high blood sugar level. Once the line graph "flattens out", the insulin has pretty much run its course. For instance, in the example below, the insulin action curve is approximately 3 hours.



Long-term trend graphs are also useful for seeing the delayed effects of high-fat foods and intense/prolonged exercise, as well as blood sugar patterns during illness. The **downloading programs** that can be used with CGM systems (Medtronic's Carelink website; Dexcom DM2 software) can be used to examine long-term trend graphs over multiple days. The *Sensor Daily Overlay* at **www.carelink.minimed.com** lets you see up to 7 days of 24-hour trend graphs superimposed and color coded. The *Hourly Statistics* report on Dexcom's software provides statistical averages and graphic displays for virtually unlimited blocks of time. Both systems can reveal overall peaks and valleys in blood sugar levels during the course of the day, as well as patterns linked to off vs. work/school days, menstrual cycles, and other unique variables.

Those Lovely Alarms

Perhaps the most valuable aspect of CGM systems is their ability to alert the user when blood sugar levels may be approaching dangerously high or low levels. To me, they act sort of like "highway rumble strips" that keep us from veering off the road and into a ditch. By allowing enough margin for error, the low blood sugar alarm in particular can detect *pending* lows long before any symptoms appear.

Although they may not detect every low, CGMs will provide an early warning for the vast majority – and much earlier than most of us would detect them on our own. In 2004, Dr. Bruce Bode, a reknowned diabetes clinician and researcher, published one of the first studies on the effectiveness of CGM. He showed that using a CGM with the low blood sugar alarm *turned on* reduced the amount of time spent in a hypoglycemic range by nearly 50%, compared to those who used the systems without the alarm option turned on. The "low alarm" makes it considerably safer to work, drive, exercise, and generally aim for tighter glycemic control. Likewise, the high blood sugar alarms allow us to be more aggressive at managing after-meal blood sugar spikes and preventing ketoacidosis.

High and low alarm thresholds are not the same as your target blood sugar levels. You don't want to be experiencing alarms for every mild excursion out of a normal range (we call these "nuisance alarms"), but you still want to be notified in time to correct significant excursions. When setting the threshold levels for your alerts, keep the "lag effect" in mind. When blood sugars are dropping, the CGM value is likely to be a bit higher than your actual blood sugar. And when they are rising, the CGM will probably read a bit lower. For this reason, it is a good idea to set the low alert threshold at 80 or higher, and the high alert in the 200-250 range. To avoid nuisance alarms, many people choose to set their high threshold a bit higher and their low threshold a bit lower during the night.

Now get a good night's sleep. Tomorrow, you have a lot of analyzing to do!

Editor's note: Gary Scheiner is a Certified Diabetes Educator with a private practice near Philadelphia. He provides diabetes self-management education and blood

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