CHAPTER 17:

HOW TO USE CONTINUOUS GLUCOSE MONITORING (CGM) RESULTS

Laurel Messer, RN, BSN

There are two ways to review CGM information. One way is to look at the information on the CGM while it is being worn. This data is called real time information. The other way is to download the device and evaluate the reports for glucose trend information. This is called retrospective analysis. Both ways have unique advantages for improving diabetes control.

REAL-TIME GLUCOSE INFORMATION

People/families that use CGM will immediately recognize the value of having updated glucose information every five minutes displayed on the receiver. Some people/families have told us that they become compulsive about looking at the receiver all the time! This is a natural response at first, and it usually decreases with experience.

Although constantly checking sensor glucose information is not necessary, the information on the receiver can be used in smart ways to improve diabetes control.

Trend graphs: Trend graphs provide excellent information for the CGM user/family. They can be especially useful when correcting a high blood sugar. Without CGM, a person with diabetes must correct a high blood sugar without knowing how quickly it is rising, how long it has been high, or if it is starting to drop. Trend graphs change this process by providing information about the time leading up to the high blood sugar. To take the example from Chapter 15, if a blood sugar check showed a value of 240 mg/dl (13.3 mmol/L), a person might decide to take a correction dose of insulin.

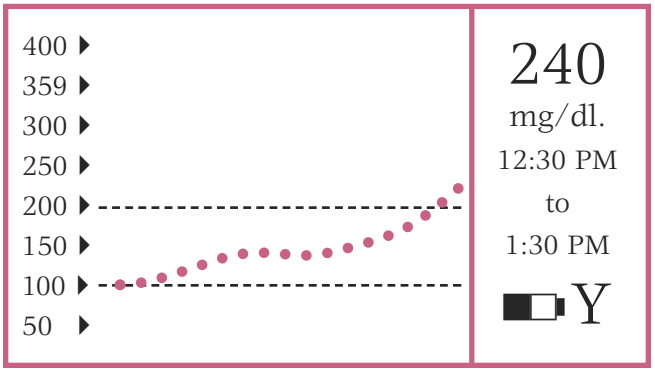
Figure 1 shows two different scenarios that could be occurring. In Graph 1, the glucose levels have been rising steadily, and the person may need to take extra insulin to bring the glucose level back down into range. In Graph 2, the glucose level is already falling, and the person may need less insulin to correct the high glucose level.

Trend graphs allow the family to make decisions based on several hours of information instead of one point in time.

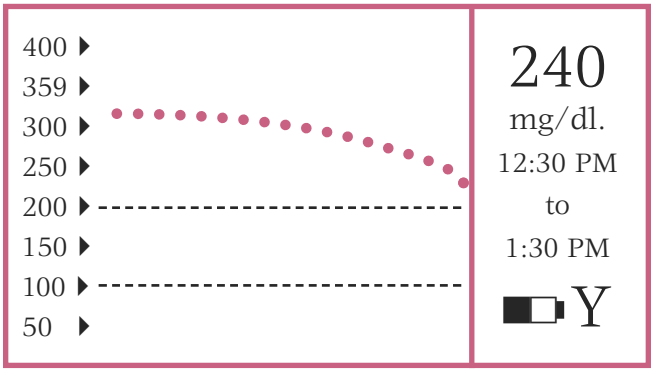
FIGURE 1:

DEXCOM TREND GRAPHS Both graphs show a glucose level of 240 mg/dl (13.3 mmol/L)

Graph 1



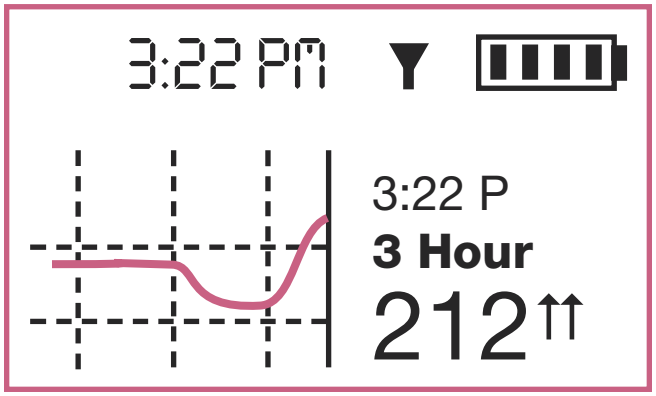
Graph 2



Trend arrows: Some CGMs also show trend arrows on the main screen of the receiver. This is a quick way to predict whether glucose levels are rising or falling. Trend arrows can be used in a similar way to the trend graphs. Trend arrows are calculated by the CGM using the sensor information from the past 15 to 20 minutes. Both the Medtronic and Navigator systems offer this feature.

FIGURE 2:

MEDTRONIC TREND GRAPH AND ARROWS



Because both trend graphs and trend arrows reveal glucose changes, the DirecNet group has suggested using this information to alter insulin dosing. In our pilot studies with CGM, we have suggested that families increase or decrease an insulin dose based on the glucose trend (Table 1). This applies to both meal doses and correction doses of rapid acting insulin (but not to basal insulin rates). These slight changes occur on a dose per dose basis to control specific situations. This may be more beneficial than changing pump settings or altering insulin to carbohydrate (I/C) ratios or sensitivities.

The adjustments in Table 1 are very slight, and can easily fit into a routine. Imagine it is time for a snack and the CGM is reading 212 mg/dl (11.7 mmol/L) (Figure 2). After confirming this value with a blood sugar check, the user/family calculates the rapid acting insulin dose for the carbohydrates and the correction. The trend arrow in this situation indicates that the glucose level is rising. The double arrow means it has been rising at the rate of >2 mg/dl per minute for the past 20 minutes. This information can now be factored into the calculation; in this case the dose is increased by 20%. So if the original dose of insulin was 5 units, the person/family would now choose to give 1 extra unit (20%) for a total of 6 units to quickly halt the increasing glucose level.

TABLE 1:

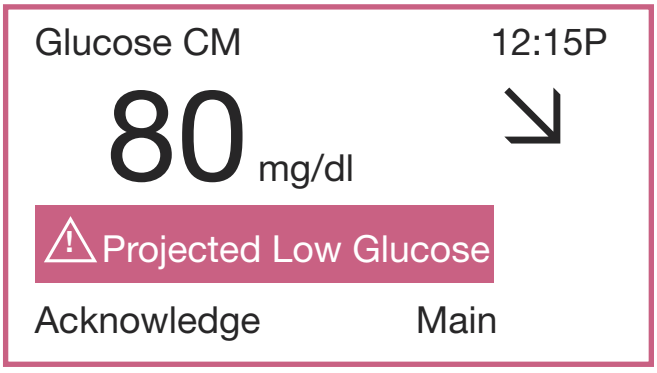
ADJUSTING INSULIN DOSES BASED ON GLUCOSE TREND

Symbol on CGM	What it means	What to do with insulin
Medtronic: ⇈ Navigator: ↑	Glucose rising > 2 mg/dl per min	Increase dose by 20%
Medtronic: ↑ Navigator: ↗	Glucose rising 1-2 mg/dl per min	Increase dose by 10%
Medtronic: none Navigator: →	Glucose level changing <1 mg/dl per min	No change in dose of rapid-acting insulin
Medtronic: ↓ Navigator: ↘	Glucose falling 1-2 mg/dl per min	Decrease dose by 10%
Medtronic: ⇊ Navigator: ↓	Glucose falling > 2 mg/dl per min	Decrease dose by 20%

Predicted low and high glucose alarms: Another feature of CGM is the predicted low and high glucose alarms. These alarms calculate whether a person is at risk for a low or high glucose based on the rate at which glucose levels are changing. They can be set to predict that a low/high glucose will occur in 10, 20 or 30 minutes.

FIGURE 3:

NAVIGATOR PROJECTED LOW GLUCOSE ALARM The glucose level is 80 mg/dl (4.5 mmol/L) and is falling at the moderate rate.



The prediction alarms occur when glucose levels are still in a normal range. In Figure 3, the CGM is detecting a glucose level of 80 mg/dl (4.5 mmol/L), with a warning that the glucose level is falling and may soon be low. If a person/family were to check a blood sugar at this point to confirm it was not actually low, they still should drink a small amount of juice or other fast-acting carbohydrate in order to prevent the blood sugar from becoming low.

In our DirecNet studies, we have suggested that a predicted low glucose can be treated with 10 grams of fast acting carbohydrate for older children and 5-10 grams of carbohydrate for younger children.

This type of treatment cannot be done without CGM, because a person does not know whether glucose levels are rising or falling. With the predicted low alarms, pre-treating a predicted low blood sugar can reduce the number of true low blood sugars that occur.

Real time treatment of hypoglycemia: Hypoglycemia has been discussed in Chapter 10. However, when using a CGM, it is important to stress that a finger stick blood sugar level must be done both for confirmation and treatment. The CGM glucose values lag behind blood sugar levels by 10-15 minutes and can be very different from the true blood sugar when levels are falling or rising rapidly. Thus, CGM values may not reflect how low the blood sugar actually is. Likewise, after treatment of a low blood sugar,

the CGM glucose value may not rise as quickly as the blood sugar. Therefore, it is always important to treat hypoglycemia on the basis of the blood sugar level and not the CGM value.

Real-time treatment of hyperglycemia: As with treatment of low blood sugars, it is wise to rely on finger stick blood sugar levels rather then CGM values. This is both for accuracy and because the decline in CGM values after correcting the high blood sugar may lag behind the decline in blood sugar levels. It usually takes about 30 minutes to see a drop in blood sugar levels. However, rapid acting insulin action does not peak until 100 minutes after the dose is given. It is common for people/families to watch the CGM values and worry that the glucose levels are not falling very quickly, and want to give a second correction dose soon after the first. This is called "insulin stacking", and can be very dangerous by causing a low blood sugar later. It is generally wise to wait two hours before repeating a correction dose of rapid acting insulin (and of course the insulin dose should always be based on a new finger stick blood sugar value). If the person/family has a smart pump, the rules change a little. A smart pump automatically calculates how much insulin is still active from a previous dose (called the insulin on board feature), and will subtract this amount from the second insulin dose. Therefore those with a smart pump can take a second correction dose after one hour, trusting that the pump will subtract the insulin on board and prevent them from having low blood sugar levels later.

These CGM features are just a few of many ways a person/family may use real time data from CGM to change their diabetes management. We have found that the longer people/families use the device, the more creative they get in using the real time information. CGM is particularly helpful in reducing the wide fluctuations in glucose levels that occur in most people with diabetes. It is important to learn and understand the unique features of any particular CGM before using it and to refresh diabetes knowledge with continued use. Before long, the real-time data becomes part of a diabetes routine, contributing to daily management decisions and good glycemic control.

RETROSPECTIVE GLUCOSE DATA ANALYSIS

Like blood sugar meters, CGMs have software that can be installed on a computer and used to evaluate glucose trends. This can be done at home or by a diabetes healthcare provider. The computer software programs feature different types of charts, line graphs and statistical reports to review data over time. All graphs and reports can be configured to set target glucose ranges for personal targets. The following section discusses the most common types of download reports and how to use them.

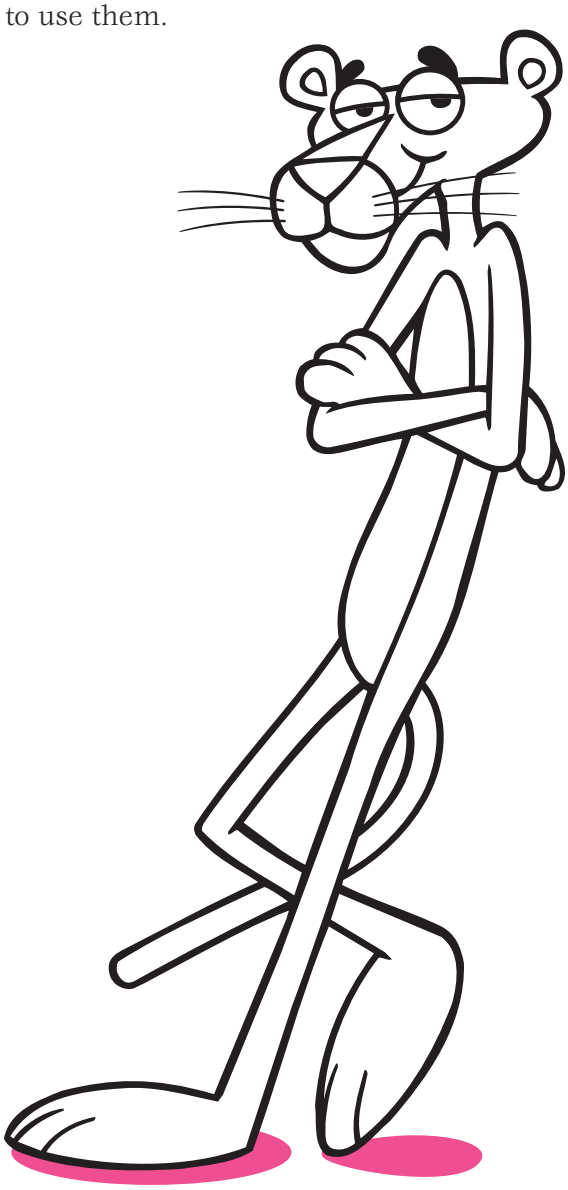
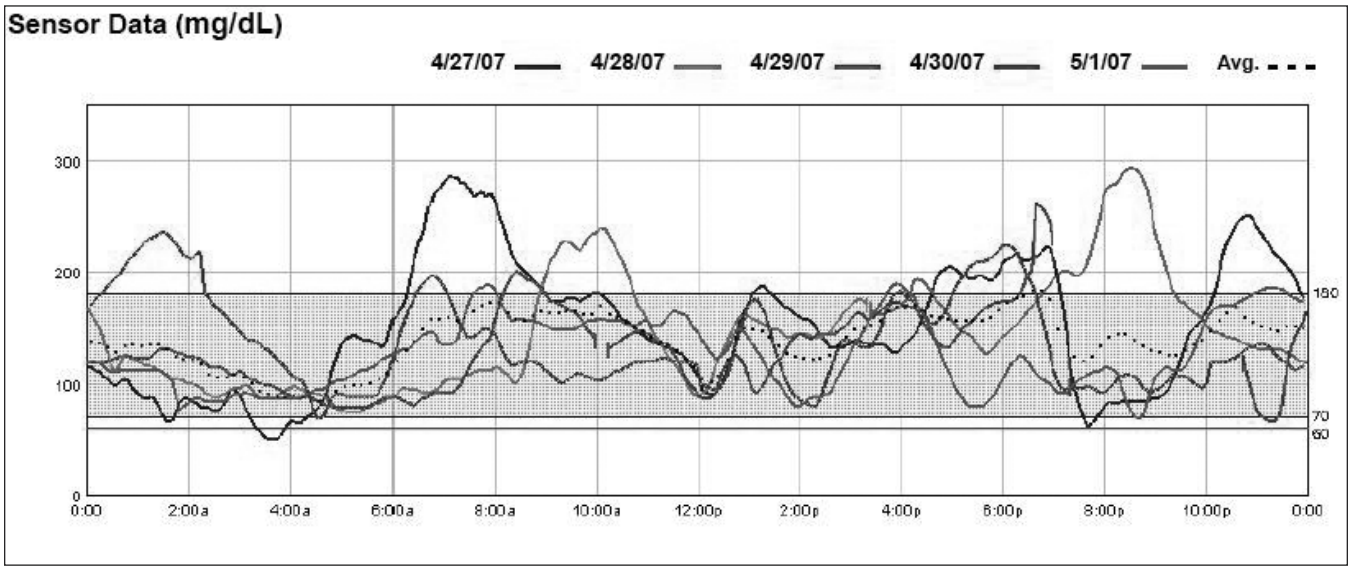


FIGURE 4:

MEDTRONIC MODAL DAY REPORT

Target Glucose range set to 70-180 mg/dl (3.9-10.0 mmol/L)



Modal day report: These reports give valuable trend information in the quickest amount of time. Modal day reports take 24-hour trend graphs and overlap several days worth of data on top of each other for comparison. These graphs are generated in color and have a date legend to differentiate between days. Some programs start the graph with midnight at the far left (Medtronic), and others with 5:00 a.m. (Navigator). The graph can also be configured to show the target glucose ranges in a shaded color.

FIGURE 5:

NAVIGATOR STATISTICS REPORT

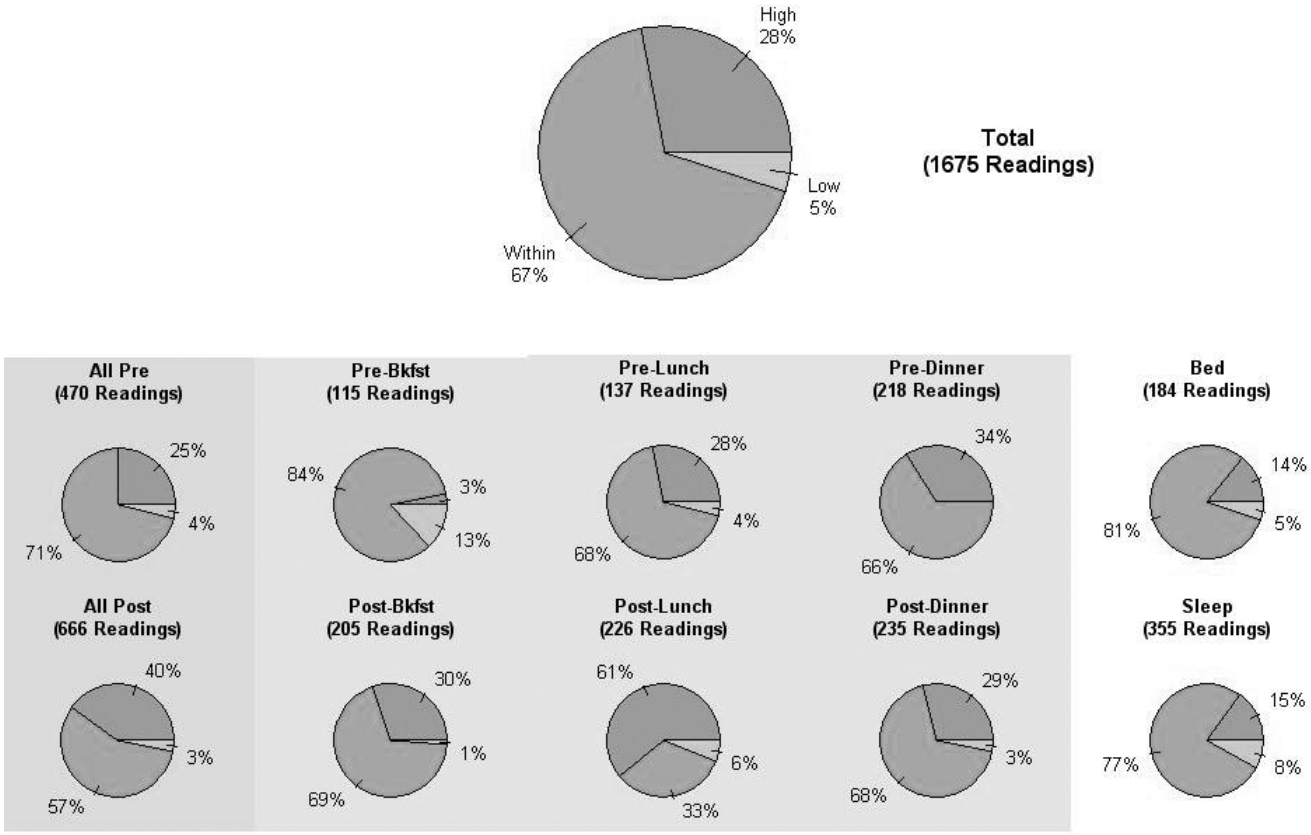
1/29/2007 - 2/12/2007

	Breakfast		Lunch		Dinner		Bed & Sleep		
Glucose Statistics (mg/dL)	Pre	Post	Pre	Post	Pre	Post	Bed	Sleep	Total/Summary
# Readings	123	232	153	237	236	240	183	337	1741
# Days w/Readings	14	15	14	14	15	15	15	16	16
Avg. # Readings/day	8.2	15.5	10.2	15.8	15.7	16.0	12.2	22.5	116.1
Highest	381	363	230	290	235	360	261	349	381
Lowest	105	77	80	66	77	45	61	57	45
Average	171	165	151	142	156	159	156	168	159
Standard Deviation	68.1	59.8	32.4	44.5	38.4	54.3	42.3	52.8	50.8
Above %	16	29	18	14	27	36	34	39	28
Within %	84	71	82	85	73	63	64	60	71
Below %	0	0	0	1	0	1	2	1	1

Statistics report: Statistics are available for every CGM system in slightly different formats. These reports appeal to people who are used to looking at numbers and averages. Some statistics reports look at just one day, and others at several days of data. Figure 5 is a two-week average of sensor data broken down into different time periods. The three rows in the middle display the highest, lowest and average glucose levels for each period of the day. The bottom three rows indicate the percent of time in, below and above range, which are visually represented in the pie charts described next.

FIGURE 6:

NAVIGATOR GLUCOSE PIE CHART



Glucose pie charts: Sensor glucose data can also be read in the form of a pie chart. The user sets thresholds for low and high glucose values, and is able to see how often they are in range at different times throughout the day. Pie charts can be generated for any length of time from the past two weeks to the past few days. The advantage of the pie chart is the ability to quickly spot times of day when glucose values are out of range. It is especially important to try to reduce the amount of time spent in hypoglycemia. The disadvantage of the pie chart is that the user/family cannot tell how far out of range the glucose levels were. For example, in Figure 6, being "high" 28% of the time indicates how often the values exceeded the high threshold. It does not, however, identify if the glucose levels were 210 mg/dl (11.6 mmol/L) or 350 mg/dl (19.4 mmol/L), which would make a difference in how the user interprets the 28% high glucose values.

MAKING SENSE OF RETROSPECTIVE DATA

Retrospective CGM reports provide a tremendous amount of information for the person/family. After learning about each report, the question becomes how to best use the information.

The simplest way to look at CGM data is to concentrate on four or five days at a time. Usually the most recent days of data are the best choice because they represent the current state of diabetes management. The exception might be if the person was ill or had other unusual circumstances during those days.

There are three questions to ask when analyzing four or five days of CGM data:

QUESTION #1 — THE WHAT
What periods of the day are the glucose levels out of range?

QUESTION #2 — THE WHY
Why are these periods of glucose levels out of range?

QUESTION #3 — THE HOW
How could we alter the periods of high or low glucose levels?

ANSWER #1 — THE WHAT
When looking for CGM patterns over a few days, it is important to look for averages and trends. Out of range periods can be defined as times when glucose levels are out of range at least two out of three days. It would not make sense to change insulin doses if just one day was too high or too low. It is likewise important to identify the periods when glucose levels are in range. These are successes that should be celebrated! It means that the insulin regimen is working the way it is intended to work. The most important factor is that there is a pattern to the CGM tracings and that the pattern is repeated over a few days.

When we evaluate CGM trends in our Clinic, we print out the reports to write on them. It is helpful to circle periods of time when glucose levels are out of range, either too high or too low. This provides a starting point for the discussion of WHY and HOW.

ANSWER #2 — THE WHY
When focusing on periods where glucose levels are out of range, the reason must be identified. This can be done by the person/family, or with a diabetes care provider. The most common reasons why glucose levels are out of range are listed here:

• **Doses of insulin were missed:** This is seen most frequently with a missed dose of insulin to cover a meal or snack. When this happens, there will usually be one or two very high glucose spikes that are not consistent with the pattern of other days. This shows up clearly on the modal day report (see Figure 4).

• **The wearer has been sick, under stress, or exercising more then usual:** When a normal routine changes temporarily, glucose levels may change as well. This pattern usually manifests as being out of range for many periods during the day. If the person is sick, glucose levels may be high all the time. Stress will change glucose levels during the hours of the day that are stressful, such as during school. Exercise usually shows up as unexplained late afternoon, evening, or nighttime low glucose values.

• **The insulin doses are not set correctly and need to be changed:** If there are no obvious reasons for high or low glucose patterns, then the most common reason is that the insulin dose is not set optimally and needs to change. These are the patterns that are most easy to spot with CGM data. They show periods of time on a modal day when glucose values consistently go above or below target. On the statistics report the average glucose is out of range as well. On the pie charts, a large percentage of time is out of range.

These questions are best answered with the most recent days of data since it is easier to recall specific events and relate them to the observed glucose levels. It is helpful to write this information next to the circled patterns, so the questions of WHAT and WHY are answered clearly before moving on to the HOW. These insights can also be discussed with a diabetes care provider.

ANSWER #3 — THE HOW
When people are new to CGM, they tend to skip immediately to the HOW without thoroughly investigating the WHAT and WHY. It is important to answer those questions first before moving to this step.

It is essential to remember good diabetes practice when considering how to modify insulin regimens. Chapter 23 of Understanding Diabetes (3) is a good starting place for reviewing insulin actions before trying to change insulin doses and behaviors.

Below are some strategies to deal with the problems identified in Answer #2 — The Why:

• **If insulin doses are missed:** If this is the reason for glucose levels out of target range, insulin doses should not be adjusted but behavior should be adjusted. It is common for children to miss insulin doses around mealtimes, so a plan needs to be developed so that they will be reminded. Many insulin pumps have an alarm that can be programmed to sound if a dose of insulin is not given in a certain period of time. This can also be done by setting an alarm on a cell phone. Finally, a responsible adult may need to remind the person to take insulin at that period of time until it becomes a reliable habit.

• **The person has been sick, under stress, or exercising more than usual:** These behaviors are intermediate in duration, so permanent changes may not be needed. There are many ways to deal with these situations. Briefly, illness and acute stress may require increases in insulin which are best accomplished with a temporary basal rate (Chapter 5) or extra insulin injections. Heavy exercise can be dealt with by eating more snacks than usual, or by temporarily reducing the basal insulin (on a pump) or other insulins.

• **The insulin doses are not set correctly and need to be changed:** Here are a few ground rules for changing insulin doses:

1. **Make only one or two changes at a time.** If more changes are made, it is impossible to know what worked and what didn't work.

2. **Make very small changes each time.** Insulin is a very powerful hormone and it does not take very much to make a big difference in glucose control. We suggest the guidelines in Table 2 for making insulin dose changes.

3. **For any period of time when glucose levels are consistently out of range,** changes will need to be projected far enough in advance. Since rapid-acting insulin can take 100 minutes to peak, insulin changes must be made before the problem develops.

4. **Table 3 provides suggestions** for changing insulin dosages for different times of day.

Choose only one option at a time to see how it affects glucose levels. There may be other ways to change the diabetes management that are not listed here, but these are some common ways.

TABLE 2:
GUIDELINES FOR MAKING INSULIN DOSE CHANGES

TYPE OF INSULIN	ADMINISTERED AS	SUGGESTED CHANGE
Long-acting (Lantus or Levemir)	Long-acting insulin	0.5 to 2 units
Intemediate-acting (NPH)	NPH	0.5 to 1 unit
Rapid-acting (Humalog, Novolog or Apidra)	Sliding scale insulin Insulin to carbohydrate ratio (I/C ratio)	0.5 to 1 unit per dose 2 to 5 grams carbohydrate per ratio
	Correction factor (sensitivity)	10-20 mg/dl (0.6-1.1 mmol/L) per sensitivity
	Basal rate in insulin pump	0.025-0.2 units/hour

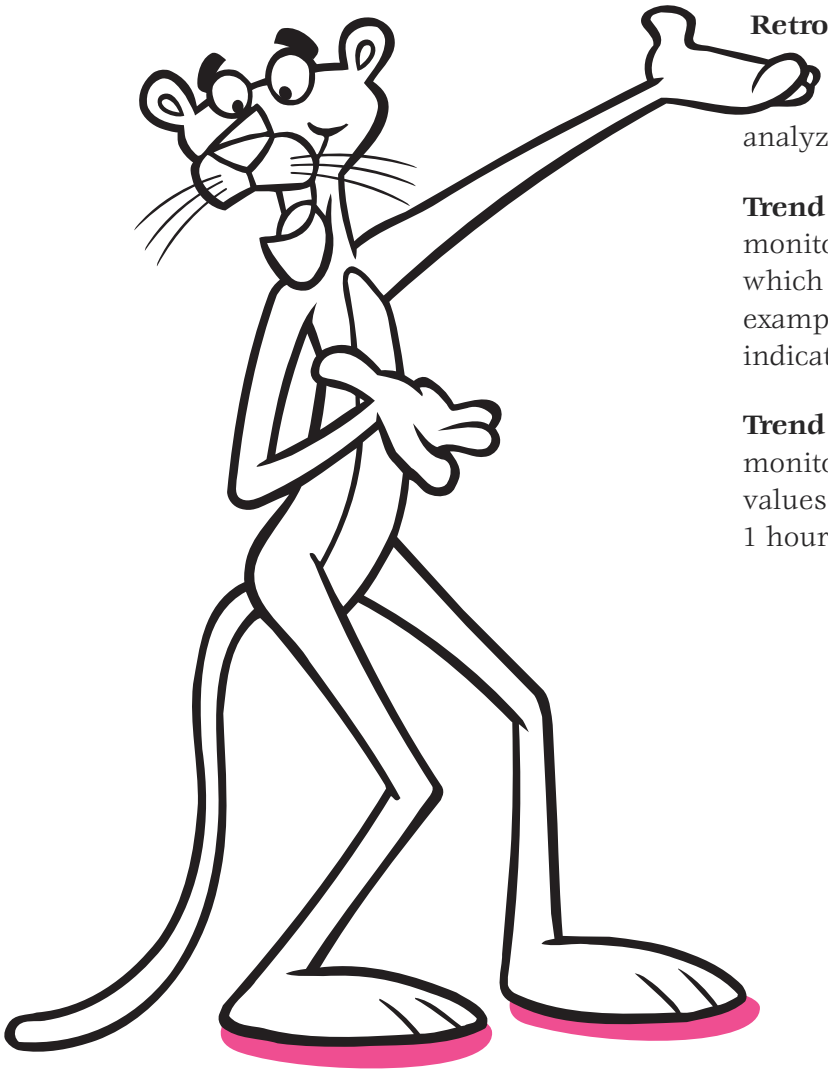
TABLE 3:

GUIDELINES FOR MAKING INSULIN DOSE CHANGES FOR DIFFERENT TIMES OF DAY

GLUCOSE PATTERN (2-3 DAYS)	SUGGESTED CHANGES
FASTING GLUCOSE LEVELS IN MORNING **Bedtime or overnight management needs to change**	**HIGH** • Change bedtime management first before changing overnight insulin (e.g., eating less for a bedtime snack or giving more insulin for a bedtime snack) • To change overnight insulin: Increase long-acting insulin or increase basal insulin on pump
	LOW • Change bedtime management first before changing overnight (eating a larger snack or giving less insulin for a bedtime snack) • To change overnight insulin: Decrease long-acting insulin or decrease basal insulin on pump
GLUCOSE LEVELS PRE-LUNCH **Breakfast or morning management needs to change**	**HIGH** • Increase breakfast sliding scale or I/C ratio • Cut out or reduce mid-morning snack • Increase morning basal rate
	LOW • Decrease breakfast sliding scale or I/C ratio • Add or increase mid-morning snack • Decrease morning basal rate
GLUCOSE LEVELS PRE-DINNER **Lunch or afternoon management needs to change**	**HIGH** • Increase lunch sliding scale or I/C ratio • Decrease afternoon snack or take more insulin with snack • Increase afternoon basal insulin rates
	LOW • Decrease lunch sliding scale or I/C ratio • Increase afternoon snack or take less insulin with snack • Decrease afternoon basal insulin rates
BEDTIME AND EVENING **Dinner or bedtime management needs to change**	**HIGH** • Increase dinner sliding scale or I/C ratio • Increase evening basal rates
	LOW • Decrease dinner sliding scale or I/C ratio • Decrease evening basal rates

SUMMARY

Learning to use the results from CGM will take time. The person/family should remember to make one management change at a time and learn what works and doesn't work. It is important not to become overwhelmed by the amount of information. Since long-term glucose control is the goal of diabetes care, it is not as important to fix every single high or low blood sugar. Remember that in the long term, the use of CGM will likely lead to improved health for the person with diabetes.



DEFINITIONS

Insulin stacking: The build up of insulin in the body from taking too many correction doses of rapid acting insulin within a short period of time. This can often lead to hypoglycemia. Insulin stacking should be avoided by not correcting high blood sugar levels more often than every two hours, or by using a smart insulin pump.

Modal day report: A graph that displays several days of data overlapped on top of each other so that trends can be analyzed.

Pie charts: A circular graph that displays the percentage of time spent with high, low, and in target glucose values. Pie charts can represent whole days and also be broken down by time of day.

Retrospective glucose data: CGM data previously collected and downloaded into software programs that can help the user analyze glucose trends.

Trend arrows: A feature on some CGM monitors that shows the direction and rate at which sensor glucose values are changing. For example, an upward arrow on a CGM would indicate that the glucose values are rising.

Trend graph: A graph feature on some CGM monitors that shows a trend line of glucose values in the past. Trend graphs can range from 1 hour to 24 hours of glucose values.