After evaluating numerous patient glucose records, clinicians have remarked that if they could simply take food out of the equation, diabetes management would be so much easier. Achieving optimal postprandial glycemic control has proven to be a major challenge for clinicians and patients.

Wide glucose excursions are potent activators of oxidative stress, one of the main contributors to vascular complications. Current nutrition recommendations for individuals with diabetes stress the importance of implementing mealtime interventions that reduce postprandial glucose (PPG) excursions. Yet doing so is challenging with available tools. Patients are frequently encouraged to check blood glucose levels preprandially and again 2 hours after the start of the meal to determine their glycemic response to the meal. This method often underestimates the peak glucose value and fails to identify the duration of the PPG excursion.

Continuous glucose monitoring (CGM) has opened up a new world of opportunity to evaluate the glycemic response of food choices. Glucose values, trend arrows, line graphs, and alarms viewed on the device screen provide real-time perspective. Patients and clinicians can also evaluate glycemic responses to foods and meals retrospectively by analyzing glucose trends and patterns from data management reports. Initially, clinicians were concerned that the extra data provided by CGM might be intimidating to patients, but studies have found that the use of CGM data actually makes treatment and insulin dose decisions easier for patients.

**Factors Affecting Postprandial Glycemia**

Evaluating the glycemic response to a meal is difficult not only because of the composition of the meal, but also because of a number of other variables. Postprandial glycemia is based on how quickly carbohydrate is digested and absorbed and how quickly glucose is removed from the circulation. Carbohydrate is the major determinant of PPG levels, with the amount of carbohydrate being the primary contributor. The type of carbohydrate and other characteristics of the food, such as its physical form, ripeness, type of starch, style of preparation (cooking method, temperature, time, and amount of moisture used), and the degree of processing all influence the PPG response.

For patients treated with insulin, the timing and dosage of prandial insulin have major effects on PPG response. CGM allows patients to observe the pharmodynamics of insulin and better match meal timing with insulin action. In addition, premeal glucose level, available insulin, insulin resistance, other diabetes medications, physical activity, and stress must be taken into consideration in evaluating the PPG response.

**Evaluating Personal Glycemic Responses to Foods**

Many carbohydrate foods have been classified based on their glycemic response; however, outside of research settings, patients have unique and varied responses to carbohydrates. To determine individual responses to commonly eaten carbohydrate foods, patients can experiment with measured amounts of a variety of carbohydrates. For example, a patient can compare the response to a breakfast of steel-cut oats to a breakfast of dry cereal eaten at the same time of day with the same amount of carbohydrate. The patient can track the real-time...
glucose responses on the device screen by viewing the glucose value, trend arrow, or line graph (Figure 1). In addition, reports that overlay data from multiple days on one line graph (Modal Day/Sensor Daily Overlay) can be accessed from data management programs offered by the CGM manufacturers (Figure 2).

To evaluate the effect of a specific food or meal on PPG, other variables that influence PPG should be kept as constant as possible. The time of day, premeal glucose, timing and amount of bolus insulin, and physical activity can be electronically logged in some CGM devices or recorded on a paper log and considered when analyzing the data. A patient’s ability to estimate carbohydrate servings should also be frequently assessed because underestimating carbohydrate is a frequent occurrence that can significantly affect the insulin-to-carbohydrate ratio (ICR). A major benefit of CGM, however, is that when patients make an error in calculation or a poor decision, they can be alerted to change the course before a significant event occurs.

Evaluating PPG Response to Mixed Meals
In addition to the many factors that affect the glycemic impact of carbohydrate foods, the presence of other nutrients adds even more complexity to the task of predicting the glycemic effect of a mixed meal. Research has demonstrated that the presence of fat in a food or meal delays the peak glycemic response, and protein usually has little or no effect on blood glucose levels. CGM allows clinicians and patients to evaluate more easily the effect of various combinations of nutrients. In a pediatric clinical trial with CGM, Gandrud et al. suggested including protein and fat in the children’s typical breakfast of highly refined carbohydrate foods as one alternative to reduce the severity of glucose excursions.

To evaluate their own glycemic responses, patients can begin by using CGM as a learning tool to discover how different meals affect their glucose levels, without altering the type or amount of a favorite meal. Which meals have the highest glucose peak and why? How long does it take for the glucose to peak? Which meals have the longest PPG duration and why? Restaurant foods are particularly challenging because of the difficulty in assessing nutrient composition and portion sizes.

It is important for patients to understand how to interpret CGM results without drawing inaccurate conclusions. Patients need to keep in mind the following points:

- Specific mixed meals must be evaluated on more than one occasion.
- The effects of a specific type of meal can vary at different times of the day.
- Portion sizes must be consistent and estimated accurately (i.e., use of household measuring utensils or use of prepackaged meals that have Nutrition Facts labels).

PPG information provided by CGM reveals the extent and duration of hyperglycemia associated with the particular type of meal; this feedback helps patients plan a more effective strategy on the next occasion. For example, a high-fat meal that results in prolonged postprandial hyperglycemia might induce patients on insulin pump therapy to try a combination or dual-wave bolus or patients on multiple daily injections of insulin to split their prandial bolus the next time they choose a similar meal (Figure 3).

Prandial Insulin Dosing
Timing of meal bolus
CGM results have demonstrated the difficulty in controlling PPG excursions because of the pharmacodynamics and pharmacokinetics of currently available prandial insulins. The practice of dosing rapid-acting insulin at mealtime has come into question based on experience with CGM. Many clinicians are now recommending that patients dose premeal insulin earlier to prevent large PPG excursions.

Observing the downward trend arrows or change of slope in the line graph can help determine when premeal insulin begins to take effect and can be validated with SMBG. When glucose is in a rapid downward trend, the change in blood glucose will generally precede the change observed by the CGM device. Coordination of
bolus insulin timing with ingestion of food corrects one variable in PPG management.

Types of boluses
CGM provides information to help patients on insulin pump therapy determine the type and amount of insulin boluses that adequately cover a particular type of meal. Evaluating the glycemic response to high-fat meals can help determine the appropriate type and duration of a bolus to minimize the glycemic excursions. A study using three different bolus regimens with a consistent pizza meal determined that a dual-wave (combination) bolus over 8 hours was most effective in controlling PPG and preventing hypoglycemia during the 12 hours.10 Because glucose information is constantly available with CGM, patients can readily determine the duration of hyperglycemia from the meal and fine-tune the bolus for that particular type of meal on future occasions.

Correction boluses
A frequent concern with real-time CGM is the risk for excessive postprandial bolusing.9 It is imperative that patients be educated and trained in how to respond appropriately to postprandial hyperglycemia to avoid the risk of subsequent hypoglycemia. Some clinicians suggest that patients wait a designated time period (i.e., 2 hours) after administering premeal insulin before taking a correction dose to avoid “insulin stacking,” the practice of taking correction dose insulin before a previous dose of prandial insulin has had its full effect.11 Patients must consider the insulin remaining from the premeal bolus, referred to as “insulin on board,” the direction of the trend arrow, the type of carbohydrate, the meal composition, and the level of physical activity before taking extra insulin to treat postprandial hyperglycemia.9

Algorithms for responding to trend arrows that have been used in clinical studies with real-time CGM include the following recommendations:9,11

- If glucose is rising at > 2 mg/dl per minute, the bolus should be increased by 20%.
- If glucose is rising at 1–2 mg/dl per minute, the bolus should be increased by 10%.
- If glucose is decreasing by > 2 mg/dl per minute, the bolus should be decreased by 20%.
- If glucose is decreasing by 1–2 mg/dl per minute, the bolus should be decreased by 10%.

Determining the ICR and Insulin Sensitivity Using CGM
Experience with CGM has reinforced the fact that greater glycemic excursions occur after breakfast than after other meals of the day, an observation that patients usually make when determining their ICRs.6,11 Several data management reports provide the opportunity to evaluate ICR over a period of time. In addition to identifying PPG patterns on line graphs, patients and clinicians can identify meals with inadequate insulin coverage from pie charts, bar graphs, and statistics reports that show the percentage of pre- and postmeal glucose readings below, within, and above target range. Once it is determined that basal insulin is appropriate and a patient is correctly estimating carbohydrates, the ICRs for specific meals can be adjusted. Reports that provide information on the percentage of meals that require correction doses can also help to evaluate ICRs.

Conclusions
CGM has opened up a new world in the area of nutrition and diabetes. Clinicians and patients now have the opportunity to more effectively and easily evaluate their glycemic response to various types of foods and meals. This information provides patients the ability to more effectively adjust prandial insulin and lifestyle therapy based on their food choices. With the additional information available, clinicians have the responsibility to train patients in how to interpret the data and make appropriate decisions. The information will also facilitate researchers’ analysis of the PPG response to foods that may influence nutrition guidelines for individuals with diabetes.

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References:


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