Chapter 14

Monitoring Blood Sugar Control

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INTRODUCTION

The term "sugar control" is used in diabetes to describe how close the blood sugar is kept to normal limits. "Good sugar control" refers to blood sugar levels that more closely approach the normal sugar levels of someone without diabetes. A person with constant high blood sugar levels is considered "in poor sugar control" and may have side effects such as:

- ✔ frequent thirst
- ✔ frequent urination
- ✔ weight loss (generally a good sign if type 2 diabetes)
- ✔ episodes of acidosis

It is important to have a reliable method to measure "overall" blood sugar control. It is obviously not possible to measure the blood sugar level every second of the day. Advances were made in the late 1970s to make the measurement of "overall" sugar control possible. This is done using the hemoglobin A_{1c} (HbA_{1c}) test. (The glycohemoglobin, glycated hemoglobin or hemoglobin A_1 [HbA_1] tests are names for similar tests.) These tests all reflect how often the blood sugars have been high every second of the day in the past 90 days. This test will be discussed later in this chapter.

TOPIC:
Monitoring (Blood Sugar, HbA_{1c})

TEACHING OBJECTIVES:

1. **Discuss the four factors associated with good sugar control.**
2. **Describe the HbA_{1c} test and its relationship to blood sugar control.**

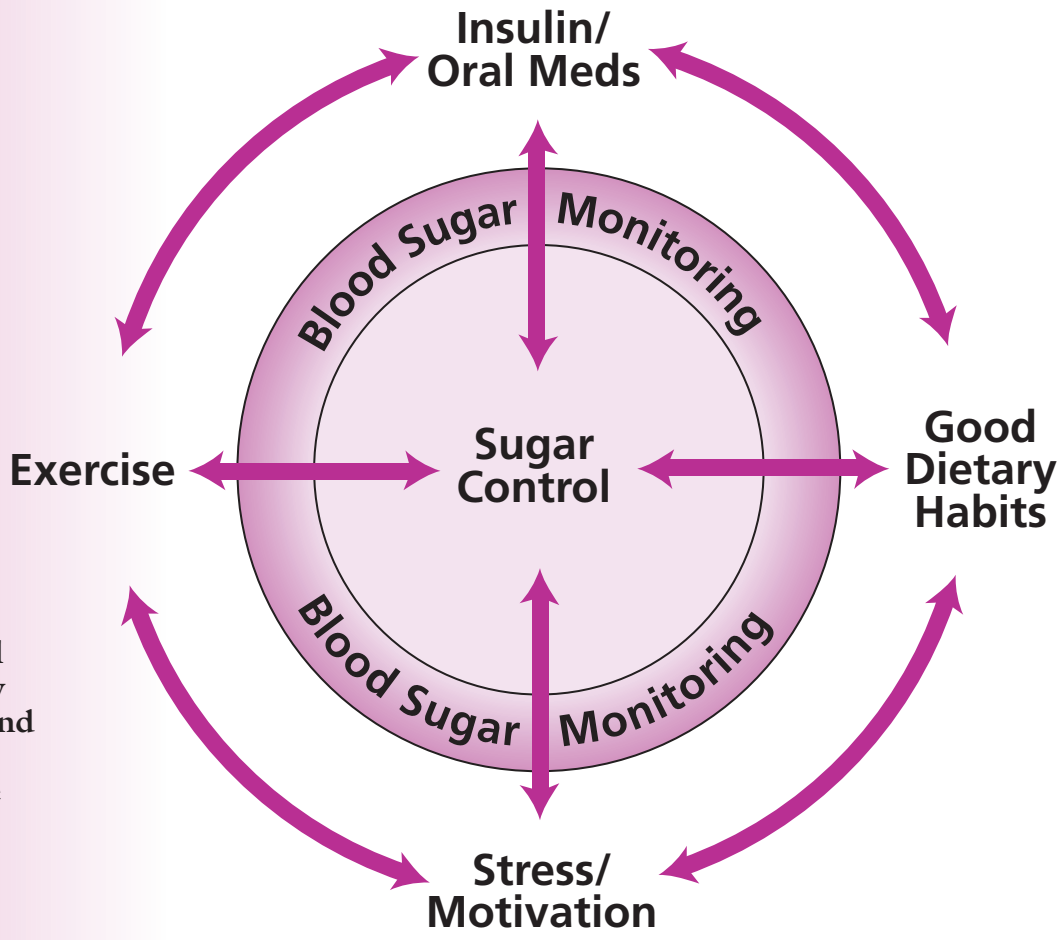
LEARNING OBJECTIVES:

Learner (parents, child, relative or self) will be able to:

1. **List two factors that can affect blood sugar control.**
2. **Explain the HbA_{1c} test, current value and recommended range.**

Four of the major influences on blood sugar control.

All four must be in balance for the best sugar control. Blood sugar control is measured by daily blood sugar levels and by Hemoglobin A_{1c} (HbA_{1c}) levels done every three months.



THE DIABETES CONTROL AND COMPLICATIONS TRIAL (DCCT)

In 1993, the DCCT proved for people with type 1 diabetes that good sugar control helped to prevent eye, kidney and nerve complications of diabetes. People receiving **"intensive management"** (insulin pumps or 3-4 shots of insulin per day along with at least four blood sugar levels per day) had better sugar control (lower HbA_{1c} values) than people receiving **"conventional management"** (1-2 shots of insulin per day with 0-2 blood sugars per day). The intensive management group was shown to have a lower chance for eye, kidney and nerve complications than did the conventional management group. A recent report has also shown a reduced likelihood of later heart attacks for people with better sugar control.

Similar studies done in the U.K. and Japan showed good sugar control in people with type 2 diabetes also resulted in a reduction in eye, kidney and nerve complications of diabetes. Some of the studies have also shown a decrease in the risk for heart attacks and strokes with good sugar control.

SUGAR CONTROL

Good blood sugar control for people with type 1 or type 2 diabetes is the result of balancing the following four factors:

1. the correct insulin/oral medicine dosage
2. getting regular exercise
3. having good dietary habits
4. positive ways to cope with stress/developing motivation based on realistic goals

Monitoring blood sugar levels assists in maintaining the proper balance between all four factors. (See diagram in this chapter.) Each of these factors is discussed elsewhere in this book in more detail. For people with type 1 diabetes, perhaps the most important of the four is the correct insulin dosage given at the right times. Blood sugar control will remain poor if insulin is lacking, even if the other three factors are in balance. It will not help to do extra exercise if the person is not receiving the correct insulin dosage. However, any one of the four factors can result in poor sugar control. For example, if the other three factors are normally in balance, but the person decides to constantly drink sugar pop (10 tsp of sugar per can), good blood sugar control will likely be lost. Similarly, with a lot of stress, the adrenaline (excitatory hormone) levels will be high and will raise the blood sugar levels. Finally, exercise (Chapter 13) is important both for "burning" extra sugar and for making people more sensitive to insulin. Thus, all four of these factors must be in balance to result in the best sugar control possible for any person.

For type 2 patients, good sugar control results from a combination of exercise, diet, oral medications (or insulin) and motivation. (See the diagram in this chapter.) Little weight will be lost if total food and fat intake are not reduced as an exercise program is initiated. Similarly, following a diet without also exercising is often fruitless. If oral medicines (or insulin) are missed, blood sugars will remain high. If the person does not have realistic goals that result in motivation, they will not succeed. All must be in balance for optimal diabetes control. The regular monitoring of blood sugar levels (Chapter 7) is essential to understand the effects of these four influences.

SIGNS AND SYMPTOMS OF HIGH SUGAR LEVELS

It is not always easy to decide whether a person has good or poor blood sugar control. *Some helpful things that reflect sugar control are the following:*

Control of Symptoms of Diabetes

A person who goes to the bathroom very frequently (particularly if a person is getting up two or more times per night), or who is often thirsty has obvious symptoms of high blood and urine sugar. This person usually needs more insulin (or oral medicines), less sugar in the diet or more daily exercise.

Occasionally, blurred vision may occur as a symptom of poor sugar control. High sugar levels in the lens of the eye pull water into the lens. This extra fluid makes it difficult for the shape of the lens to change in order to focus for clear vision. The blurred vision usually stops when blood sugar control improves. People should not be fitted for glasses unless blood sugar levels are stable. If the blurred vision does not improve when blood sugar control improves, the eye doctor should be contacted.

People with diabetes may have numbness, tingling or pain in the feet. This is due to neuropathy (see Chapter 22), which is related to high sugar levels. The sugar and its by-products can collect in the nerves over a period of years.

Vaginal yeast infections are more common in females with diabetes, particularly if the blood sugar levels have been high. This may be because yeast grows well in a high-sugar environment. When antibiotics are taken for bacterial infections, yeast also tends to grow as the bacteria disappear. If vaginal itching or burning is noticed, the primary care provider should be contacted.

Normal Physical and Emotional Growth

Children and adolescents who have poor blood sugar control sometimes have slow gains

in height or weight. Even the difference between "fair" and "excellent" control can change the rate of growth in height. One study showed an average growth rate of two inches per year during the adolescent growth spurt when the HbA_{1c} averaged 12.4 percent, but a gain of 3.3 inches per year when the HbA_{1c} averaged 8.4 percent. Research reported in 1995 from our Clinic showed final adult height was more likely to be taller if blood sugar control was good during adolescence. Following the height and weight every three months is an important part of the diabetes clinic visit.

Some people just don't feel well when they have high blood sugar levels. They may be constantly tired, have a bad temper or have any of a variety of symptoms. When better sugar control is achieved, they often are surprised to realize how much better they feel. Feeling tired and poorly over a long time does not allow for normal emotional growth.

Sugar levels that do not produce such severe symptoms may still be too high and result in long-term problems (Chapter 22).

HOW IS SUGAR CONTROL MEASURED?

1. Blood Glucose (Sugar) Measurements

BLOOD GLUCOSE TESTS ARE THE BEST WAY TO MEASURE SUGAR CONTROL ON A DAY-TO-DAY BASIS and are discussed in detail in Chapter 7. As noted in a previous section, the intensive treatment group in the DCCT tested at least four blood sugar levels each day. All families with someone with diabetes must have a method in the home for measuring blood sugars and must know how to do the tests accurately. Studies have shown that checking blood sugars and using the test results are as important for good sugar control as is the method of giving insulin (two shots per day, an insulin pump or more than two shots per day).

The blood sugar levels (fasting, two hours after meals, or anytime food has not been eaten for two or more hours) we consider representative of good sugar control vary with the person's age. *Suggested ranges are:*

Age	Desired Range
under 5 years	80-200 mg/dl or (4.5-11.1 mmol/L)
5-11 years	70-180 mg/dl or (3.9-10.0 mmol/L)
12 years and older	70-150 mg/dl or (3.9-8.3 mmol/L)

If sugar levels are in the desired range for age at least 50 percent of the time, the overall glucose control (HbA_{1c}) is usually good. If more than 50 percent of values are consistently above the desired range or if more than 14 percent of values are below these levels, the sugar control is not good. Blood sugar levels may also give insight when done two hours after a meal. Some families use the above ranges for two hours after a meal. Others aim for all two hour values to be below 140 mg/dl (7.8 mmol/L). It is useful to think of half of the HbA_{1c} value related to the fasting blood sugar values and the other half related to blood sugar levels after meals. The values recommended by the ADA in 2005 (Table 1) are slightly different than the recommended values in this book.

It is important not to be unhappy with a blood test result, but instead to always be pleased that the test was done. Hopefully, the results will be used as information to help attain better sugar control. Blood sugar monitoring was discussed in detail in Chapter 7.

In contrast to blood sugar testing at home, blood sugar measurements in a doctor's office may be of little value. There may be stress associated with the office visit, or the drawing of blood through an arm vein may lead to stress. The adrenaline output with stress may cause the blood sugar level to be high in the office.

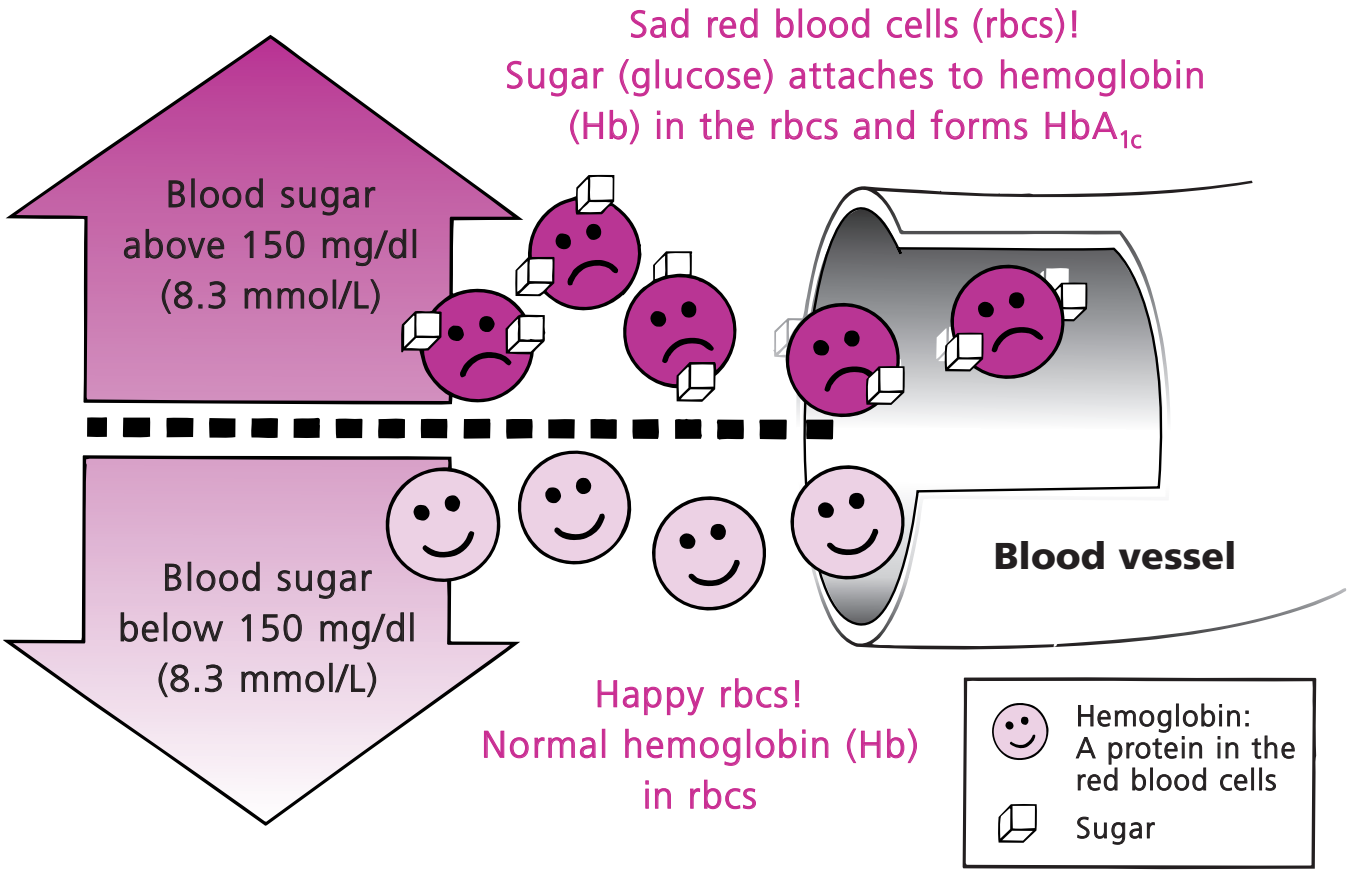
Table 1

Normal and Acceptable HbA_{1c} and Blood Glucose Values

(ADA: 2005*)

	(Hemoglobin A_{1c}) HbA_{1c} Values	Blood Glucose : mg/dl (mmol/L) (ADA: 2005*)	
Normal (Non-diabetic):	≤ 6.3%		
Desired ranges for someone with diabetes:		**Before Meals**	**Bedtime/Overnight**
below six years	7.5-8.5%	100-180 (5.5-10.0)	110-200 (6.1-11.1)
6-12 years	< 8.0%	90-180 (5.0-10.0)	100-180 (5.5-10.0)
13-19 years	< 7.5%	90-130 (5.0-7.3)	90-150 (5.0-8.3)
> 19 years	< 7.0%	90-130 (5.0-7.3)	— —

*ADA *"Diabetes Care"* 28 (suppl 1, S4), 2005

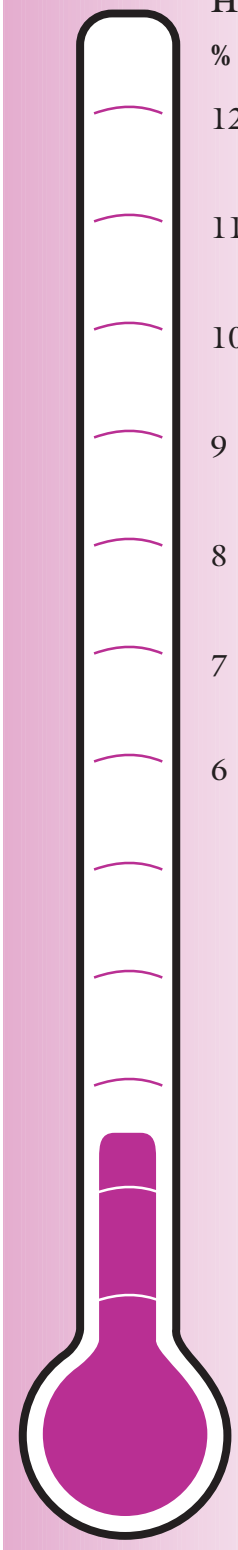


2. Hemoglobin A_{1c} (HbA_{1c}) (Glycohemoglobin [HbA_1] or Glycosylated [or Glycated] Hemoglobin)
These names are used for slightly different forms of the same test.

THE HbA_{1c} TEST IS THE MOST VALUABLE WAY TO MONITOR BLOOD SUGAR LEVELS OVER TIME.
Hemoglobin is the protein in the red blood cells that carries oxygen to the various parts of the body. It was found, by chance, that the hemoglobin molecule has a secondary property that could be used to monitor sugar control. If the blood sugar is high, sugar attaches to the hemoglobin and remains there for the life of the red blood cell (an average of 2-3 months). The sugar doesn't come off if a low blood sugar occurs. For the purposes of this book, we will call hemoglobin with sugar attached hemoglobin A_{1c} or HbA_{1c}. The HbA_{1c} reflects how often the blood sugars have been high for every second of the past three months (for the past 7,776,000 seconds). No one could do that many blood sugars. **The HbA_{1c} represents the forest while the daily blood sugars reflect the trees.** The HbA_{1c} and glycated hemoglobin tests have been used routinely since the late 1970s and have been called the "answer to a prayer" for people with diabetes and their doctors. Previously there was no good test to monitor long-term blood sugar control. No one really knew if they were in good sugar control. The HbA_{1c} test solved that problem.

The HbA_{1c} test can be done at the time of the clinic visit and the person does not have to be fasting. Many clinics now do the test by finger-poke and may have the result done in 10 minutes. THE TEST IS NOT ALTERED BY ANYTHING THE PERSON DOES ON THE DAY THAT THE TEST IS DRAWN. Other tests, such as a blood sugar level, can be affected if eating, exercise habits or emotions are changed on the day of the test. The main disadvantage of this test is that an illness may make the level go up quickly by as much as one to two points. After the illness, the HbA_{1c} value comes down much more slowly. (It is a very "unforgiving" test.)

Table 2
Approximate HbA_{1c} and Blood Glucose Correlations*



HbA_{1c}	Blood Glucose (Sugar) Level	
%	mg/dl	mmol/L
12	345	19.2
11	310	17.2
10	275	15.3
9	240	13.3
8	205	11.3
7	170	9.5
6	135	7.5

This graph shows the approximate relation between average blood sugar levels and the HbA_{1c}. (The HbA_{1c} does not truly reflect "average" blood sugar as sugar goes onto the molecule when the blood sugar is high but does not come off when the blood sugar is low.)

**Taken in part from a production of Partnership to Advance Care and Education (PACE.)*

In January 2005, for the first time, the ADA (American Diabetes Association) made recommendations for the HbA_{1c} levels for children in the U.S., which are shown in the Table 1. Most children's diabetes clinics now use a micro-method for doing the HbA1c so it can be done on a finger-stick and not require a venous blood draw. It is also important to be able to get the result back in a few minutes so the health team can discuss the result and future goals with the family. The DirecNet research group showed that the DCA 2000 instrument, which fulfills all of these goals, was also very accurate.

Half of the HbA_{1c} value reflects the past 30 days. The other half reflects the previous two months. When the result is not in a good range (e.g., after an illness with high blood sugars), it may be helpful to repeat the value monthly until it is in the desired range.

We encourage different ranges for different ages. We want people 13 years old and above, when complications are more likely to develop, to be in better sugar control than younger children. The pre-teens do not have the same risk for complications, so their values do not have to be as low. Finally, low blood sugars are more dangerous for preschoolers, as the brain continues to grow for the first four years after birth. Low blood sugars are dangerous to a growing brain. The blood sugar values of preschoolers should NOT be kept as low as those of older children. The lower the HbA_{1c} value, the greater the chance for low blood sugars. After age 19 years, growth has decreased and life (hopefully) starts to become more consistent so that an even lower HbA_{1c} can be a goal (see Table 1 in this chapter). The ADA recommends that the HbA_{1c} goal for adults be below 7.0 percent. The ADA Standards of Care (see Chapter 20) recommend this test be done every three months for a person with diabetes. IT IS THE ONLY WAY TO KNOW HOW A PERSON WITH DIABETES IS DOING EVERY SECOND OF THE DAY. We consider it the single best test for measuring long-term diabetes control. **It is currently estimated that for every percentage point reduction in HbA_{1c} levels, there is a 35 percent reduction in the likelihood of eye, kidney and nerve damage (Chapter 22).** The test is thus very important in relation to diabetes complications. The desired ranges shown in Table 1 are achievable and families should continue to strive to reach these goals.

3. Fructosamine (or Glycosylated Albumin) Test

This test measures the amount of sugar attached to the main serum protein, albumin. It reflects the blood sugars every second of the day for the past 2-3 weeks (whereas the HbA_{1c} reflects the past two or three months). It is often helpful to know how someone is doing more recently (in contrast to the past three months). The test is also helpful for someone who is changing treatment (more shots, an insulin pump, etc.).

4. Blood Cholesterol and Triglyceride Levels

High blood fat (triglyceride or cholesterol) levels in some people with diabetes are related to poor sugar control. Others may have high blood fat levels from eating poorly or it may be because they inherited a tendency to have high blood fat levels. High blood fat levels are sometimes part of the disease process for people with type 2 diabetes. As high blood fat levels can lead to earlier blood vessel aging, this may be a link between high blood sugar levels and later changes in blood vessel walls. We generally recommend that a lipid panel including total cholesterol, triglyceride, LDL and HDL levels be measured at least every third year in children and annually in adults. The total cholesterol value should be under 200 mg/dl (5.2 mmol/L). The triglyceride levels vary by age, but fasting levels should be below 130 mg/dl (1.5 mmol/L) for children and young adults. Cholesterol, triglyceride, LDL and HDL levels are also discussed in Chapter 11 (with desired levels given in Table 2; Chapter 11).

DEFINITIONS

ADA: American Diabetes Association

Bacteria: Microscopic (only able to be seen with a microscope) agents that cause infections such as "strep throat."

DCCT: The Diabetes Control and Complications Trial. A very large research trial which showed that better sugar control reduced the likelihood of eye, kidney and nerve problems in people over age 13 years with type 1 diabetes.

Emotions: How one feels psychologically (e.g., happy, sad).

Fructosamine: A test that measures the sugar attached to the albumin in the blood. This test reflects how often the blood sugars have been high over the past two or three weeks.

HDL: **H**igh **D**ensity **L**ipoprotein. This is the "good" cholesterol protein which is believed to carry cholesterol from the blood vessel wall. A higher value is good. (See desired values in Table 2, Chapter 11.)

Hemoglobin A_{1c} (HbA_{1c}): Hemoglobin protein in the red blood cells with sugar attached to it. This is used as a measure of sugar control over the previous three months.

LDL: **L**ow **D**ensity **L**ipoprotein. This is the "bad" cholesterol protein, which is believed to carry cholesterol into the blood vessel wall. The aim is to have to have LDL levels below 130 mg/dl (3.35 mmol/L) for the general population or below 100 mg/dl (2.6 mmol/L) for people with diabetes (see Table 2 in Chapter 11).

Lens: The structure in the front of the eye that changes to allow the eye to focus on near or distant objects (see picture in Chapter 22).

Serum: The clear part of the blood when the blood cells are removed.

Symptoms: The complaints of a person; how they are feeling.

Yeast: A fungus that grows more readily when blood sugar levels are high and can cause an infection.

QUESTIONS AND ANSWERS FROM NEWSNOTES

Q **Does the hemoglobin A_{1c} really give the average blood sugar over the past three months?**

A No. It reflects how often the blood sugars have been high over the past three months. When the blood sugar is high, the sugar attaches to all body proteins (including the red blood cell hemoglobin) and then stays attached to the hemoglobin (as hemoglobin A_{1c} or HbA_{1c}) until the red blood cell is replaced 2-3 months later. To represent the "average blood sugar," the sugar molecule would also have to detach from the protein when the blood sugar is low. This does not happen. Thus, the test only reflects how often the blood sugar has been high. The test is still far superior to any test in the past which reflects blood sugar control. It should be done on all people with diabetes every three months. In our research, reported in the *"Journal of the American Medical Association"* in 1989, higher longitudinal HbA_{1c} values correlated with a greater likelihood of developing eye and kidney complications of diabetes. The DCCT confirmed this observation.

Q **Our daughter's HbA_{1c} has not reached the desired level. With all the concern from the DCCT on preventing complications, could you please make any suggestions on ways to achieve better control?**

A *I have six suggestions:*

1. This question was addressed in relation to the idea of doing an afternoon blood sugar after school and judging the afternoon snack and/or insulin supplement on the value at that time. This can be helpful in lowering the HbA_{1c}.
2. The use of rapid-acting insulin, given prior to food intake, may result in some improvement.

3. One of the biggest keys to better control, which was reported in the DCCT, was more frequent blood glucose monitoring, along with making good use of the results. All subjects did a **minimum** of four blood glucose levels each day. An unfortunate trend in recent years has been to not record results as they are all recorded in the meter. When this is not done, trends for high and low values are often missed and insulin adjustments may not be made. We prefer using the data sheets for either one or two weeks of values (see Chapter 7). Then fax the results to your diabetes care provider if more than half of the values at anytime of day are "above range" for the age. Include any notes which might help to explain any unusual blood sugar values. In addition, include your analysis of the values and what insulin adjustments you think need to be made. This will help you to learn dose adjustments. Be sure to include a fax and/or phone number where you can be reached.

4. Strangely enough, preventing low blood sugars is often important in achieving better control. Low blood sugars often result in excessive eating and sending the blood sugar up to 300 or 400 mg/dl (16.7 or 22.2 mmol/L). Although excessive eating is probably the major cause of the subsequent high blood sugars, output of balancing hormones (rebounding) likely plays a secondary role in some people.

5. I do think that "turning off" the liver's production of glucose (sugar) in the early morning is important in relation to keeping liver glucose production "turned off" all day long. If the morning blood sugars are above the recommended range, the dose of Lantus insulin likely needs to be increased.

6. Last but not least, a word must be said about missed insulin shots. One shot missed per week results in upsetting balancing hormone equilibrium and secondarily having very high HbA_{1c} values. It is essential not to miss insulin injections.

Q **How do the following affect blood sugar?**

✔ **Exercise?**

A This varies according to the duration and difficulty of the exercise, as well as the person. Some people release epinephrine (adrenaline) during exercise which initially makes the blood sugar rise. If the insulin was injected in an exercising extremity, the insulin levels may also increase as more blood

flows through the extremity and more insulin is absorbed from the injection site. The more rapid absorption of insulin can lower the blood sugar.

Another important variable is the blood sugar level prior to starting the exercise. If the level is below 120 mg/dl (6.7 mmol/L) prior to starting, the person will be more likely to have a reaction during the exercise.

Keep good records the first time the exercise is done so that this information can be used in the future. It should be remembered that the sugar goes back into the muscle in the two to 12 hours following the exercise, and low blood sugars (**delayed hypoglycemia**) can occur at any time in this "after-exercise" period.

✔ **Illness?**

Blood sugars most frequently increase with illnesses. Remember that ketones must also be checked. Some people who are in excellent sugar control or who still make some of their own insulin may have a lower blood sugar with illness. Also, if vomiting or diarrhea is a problem, there will be less food in the stomach to maintain the blood sugar and low sugars may be a problem. If there is a question regarding the insulin dose, the diabetes care provider should be phoned before the next insulin dose.

✔ **Alcohol?**

Alcohol, or liquids consumed with alcohol, may initially increase the blood sugar. However, this is temporary and the main effect of alcohol will be to block the release of sugar from the liver and to lower the blood sugar level (up to 12 hours later). It is important, when alcohol is consumed, to have the carbohydrate/protein bedtime snack even if the blood sugar is high. It is also important to get up at a reasonable time the next morning to check a blood sugar level and to get food and insulin into the body.

✔ **Stress?**

Stress usually results in epinephrine (adrenaline) release and an increase in blood sugar.

✔ **Excitement?**

Young children react by burning more sugar and lowering the blood sugar. Older children may increase their blood sugar.

✔ **Good Weather?**

Children tend to play outside for longer hours in good weather and the blood sugars are generally lower. The insulin dose may have to be reduced. This is especially true of the evening rapid-acting insulin when children are active after supper in the summer months.

✔ **Tobacco?**

There has been some evidence that nicotine (smoking or chewing) can increase the blood sugar. People report a "buzz" after either, and this may resemble the feelings of low blood sugar. People with (or without) diabetes should not smoke or chew tobacco.

Q **Changes in our daughter's insulin dose have confused my wife and me. Initially she was on a low insulin dose which you increased after reviewing her blood sugars and seeing that her HbA_{1c} was high. She got into good sugar control, but now her dose is coming back down again. This doesn't make sense to us.**

A This is quite common, and follows an old adage that: **"Good control breeds good control; poor control breeds poor control."** Thus, for someone in poor sugar control, when the liver is making sugar at a very high rate, it takes very little (stress, infection, etc.) to make even more sugar and it may take a lot of insulin to get the liver's sugar production machinery turned off. This may also be the case for a newly-diagnosed person.

However, once the liver's pathways for making sugar are turned off, it may not take as much insulin to keep them turned off. Also, stress and infections will not have as great an effect in a person in good sugar control. This may be part of the reason for the "honeymoon" period in the newly diagnosed person.