Managing Insulin Requirements at School

by Rodney Lorenz, MD and Janet Silverstein, MD

Introduction

Multiple advances over the past decade have revolutionized treatment of diabetes in youth. Two fundamental principles underlie most of the change. First, the predominant goal of therapy is to achieve and maintain blood glucose levels as close to normal as is safely possible. Second, to a much greater extent than before, insulin therapy may be customized to fit the patient's preferred lifestyle. Diabetes care providers can now instruct patients to follow an eating pattern and lifestyle that is normal for them, and to adjust their insulin doses accordingly, rather than asking patients to adhere to a rigid meal plan and insulin dose. Thus, modern therapy has both health and lifestyle benefits.

Successful diabetes management requires meticulous attention to the coordination of insulin, carbohydrate intake, and physical activity, as well as frequent blood glucose monitoring to guide treatment decisions. These tasks are relevant throughout the day, and, therefore, necessarily include schools and school personnel. This article provides information needed by school staff to implement the child's diabetes treatment plan when insulin is involved. For a complete guide on the topic, please see *Helping the Student with Diabetes Succeed: A Guide for School Personnel*, available from the National Diabetes Education Program at http://ndep.nih.gov/diabetes/youth/youth.htm.

Physiology of insulin secretion

Normal insulin secretion has two major components: basal secretion and meal-related secretion. Basal secretion is the component that continues after the absorption and disposition of the last meal. Basal insulin secretion functions as part of a homeostatic system designed to maintain glucose availability for the brain during fasting. In concert with other hormones, basal insulin secretion regulates glucose production to exactly match glucose use in the fasting state, and also regulates the breakdown of fat as an energy source. Therefore, insulin is required even during fasting. Another characteristic of basal insulin secretion that is relevant to insulin therapy is the response to exercise. Basal insulin secretion falls during exercise in normal subjects to allow increased glucose production. In short, basal insulin requirements may change with physical activity and other circumstances.

The second component of insulin secretion occurs after meals. Meal-related insulin secretion increases glucose uptake by insulin-sensitive tissues, and is responsible for the disposition of ingested carbohydrate. Unless injected insulin is precisely matched in timing and quantity to the absorption of carbohydrate, blood glucose will be too high or too low after meals.

Modern insulin therapy attempts to normalize glucose metabolism by combining basal and meal-related insulin doses to simulate normal insulin physiology. In ideal insulin replacement therapy, insulin would be delivered at a low constant rate that could be changed easily for exercise or other circumstances, to

TABLE 1: PHARMACOKINETIC CHARACTERISTICS OF INSULIN FORMULATIONS (TIME IN HOURS)

Type of Insulin	Onset	Peak	Duration
Slow-acting			
Ultralente	3-5	10-16	18-24
Glargine	1-2	NA	24
Intermediate-acting			
NPH	1-2	6-10	12-20
Lente	2-4	6-12	12-20
Short-acting			
Regular	0.5-1	2-4	4-8
Lispro/aspart	immediate	0.5-2	3-4

simulate basal insulin secretion. Additionally, meal insulin would be given in a form that rapidly increases serum insulin levels by severalfold each time carbohydrate is eaten. As will be seen below, these requirements can be approximated by a variety of methods.

Insulin formulations and pharmacokinetics

Best results are obtained when the patient and healthcare team are able to take advantage of the characteristics of several different insulins. These are summarized in Table 1.

Slow-acting insulin

Two currently available slow-acting insulins are glargine insulin and ultralente. Both of these insulins are used to approximate basal insulin secretion. Glargine insulin delivers reasonably constant serum insulin levels for about 24 hours; it is given once daily, usually at bedtime. In some children, the dose of glargine may be divided into two doses, or may be given in the morning. Ultralente insulin is typically given in two roughly equal doses at breakfast and supper. Glargine insulin cannot be mixed with any other insulin preparation, while ultralente insulin is typically drawn into a syringe with the breakfast or supper meal insulin. In simple terms, the dose of slow-acting insulin is adjusted to maintain a stable glucose level when the child is not eating (e.g., overnight).

Intermediate-acting insulin

NPH and lente are called intermediate-acting because the time course of their effects is intermediate between the slow- and fast-acting insulins. Both NPH and lente have been used extensively in regimens of one or two daily doses, usually in mixture with Regular insulin. When given before breakfast, both NPH and lente exhibit a peak effect that occurs approximately in mid-afternoon, which provides the insulin effect needed for disposal of carbohydrate eaten at lunch. A major disadvantage of these insulins is that the user is required to eat meals on a rigid time schedule, so that carbohydrate intake will match the effect of the insulin dose administered several hours earlier. Between-meal snacks may also be required by the prolonged effect of these insulins. NPH and lente are often useful when given at bedtime because their effects may match the rising insulin requirement observed in the early morning hours in many patients.

Fast-acting insulin

For decades the only fast-acting insulin was Regular, or crystalline insulin in solution. Its rapid action allowed use as a meal-related dose. Regular insulin should be taken 30 to 45 minutes before eating in order for the rise in circulating insulin to match the rise in blood glucose following meals. Lispro insulin and aspart insulin are analogues of human insulin modified to produce faster onset and shorter duration of action than Regular insulin and, thus, more closely match the rise and fall in blood glucose levels associated with food absorption; these insulins should be taken immediately before eating. The carbohydrate content of the meal is responsible for the immediate rise in blood glucose concentrations, and, thus, the pre-meal insulin dose is based on the amount of carbohydrate ingested during a meal. In very young children and those with variable appetites, lispro and aspart may be given immediately after the meal is eaten, when the amount of ingested carbohydrate is known, thereby allowing for more accurate dosing.

Modern insulin regimens for type 1 diabetes

The basic elements of modern therapy for Type 1 diabetes are 1) explicit blood glucose targets that are near normal, 2) an insulin delivery regimen that simulates normal physiology by combining basal and meal-related doses, 3) use of frequent blood glucose monitoring to adjust therapy, and 4) meticulous attention to matching carbohydrate intake, physical activity, and insulin doses. In general, modern therapy is indicated when the patient's age and health are such that he/she is able to enjoy the long-term health benefits of improved blood glucose control. The paragraphs below describe regimens most commonly used today. The principles underlying all the regimens are similar.

Insulin pump therapy

Continuous subcutaneous insulin infusion (CSII), or insulin pump therapy, is the regimen that most closely approximates physiologic insulin delivery. External insulin pumps are battery-powered devices that contain a syringe reservoir filled with fast-acting insulin, connected by small caliber tubing to an indwelling subcutaneous needle or catheter. The user programs the pump separately for one or more basal rates and for a bolus dose with each meal. Some patients require different basal rates at different times of the day. The infusion site is changed every second or third day.

Many experienced clinicians believe that insulin pumps offer slightly better blood glucose control than multiple injection regimens. The major advantage may be in the use of only fast-acting insulin, which may have more consistent and predictable biologic effects. Another advantage of insulin pump therapy is that the basal rate can be quickly adjusted to accommodate different levels of physical activity or basal insulin requirements that vary with time of day. Many patients like the freedom from injections and increased flexibility of insulin pump therapy. Disadvantages of pump therapy include greater cost, risk of infection at infusion sites, difficulty integrating insulin pump therapy with certain activities such as contact and water sports, and the risk of rapid development of ketoacidosis if the insulin infusion is interrupted.

Multiple daily injection (MDI) regimens

MDI therapy employs a single dose of glargine or two daily injections of ultralente to provide basal insulin requirements, combined with lispro or aspart insulin before each meal (or large snack). Timing of meals can be very flexible when using these regimens, because the insulin level provided by an appropriate basal regimen will maintain blood glucose in the desired range until the next meal. Patients using this regimen may omit meals, delay meals by several hours, or eat extra meals accompanied by an extra meal-related insulin dose. The amount of basal insulin required is typically 40-60% of the total daily dose.

Most patients using MDI or an insulin pump learn to adjust meal doses for variable food intake. The child or parent calculates each meal dose from the planned or actual carbohydrate intake

using an insulin:carbohydrate ratio. In children and adolescents, insulin:carbohydrate ratios may vary from 1 unit per 25 grams to 1 unit per 5 grams. The insulin:carbohydrate ratio is validated empirically by multiple trials. For example, if preprandial glucose is in the target range but postprandial glucose is repeatedly high, the insulin:carbohydrate ratio should be adjusted to provide more meal insulin.

The meal insulin dose is also adjusted for current blood glucose level. This is done by means of an insulin algorithm, or "sliding scale" to guide dose adjustments several times a day. The algorithm should be clearly indicated in the IHP. These adjustments are made with fast-acting insulin each time insulin is given. If the algorithm does not restore normoglycemia consistently, it may be adjusted by raising or lowering the glucose levels that trigger a dose adjustment, by raising or lowering the dose adjustments, or by changing the blood glucose intervals.

MDI therapy is facilitated by use of an insulin injection pen. The insulin pen is a device small enough to carry in a shirt pocket that contains a cartridge of fast-acting insulin. Patients especially appreciate the convenience of the device when giving injections away from home because it eliminates the need to carry separate syringes and insulin vials.

Simplified insulin regimens

Simplified insulin regimens may be indicated when less stringent blood glucose goals are appropriate, or when the patient's circumstances are such that modern therapy is not feasible. Simplified insulin regimens generally include two injections per day. The old twice-daily mixture of intermediate- and fast-acting insulin given before breakfast and supper is an example.

One hybrid regimen has characteristics of MDI and simplified regimens; this regimen includes a breakfast injection of mixed NPH or lente and fast-acting insulin, an injection of only fast-acting insulin at supper, and a bedtime injection of NPH or lente. The bedtime dose of intermediate insulin may be especially useful in patients with a prominent early-morning rise in blood sugar, called the dawn phenomenon. Use of intermediate-acting insulin in the morning usually means that lunch must be eaten on time, in an amount appropriate for the dose given several hours earlier.

Insulin therapy in type 2 diabetes

Many youth with type 2 diabetes will require insulin therapy. The specific regimen used may vary between patients or from time to time in the same patient. Some adolescents early in the course of type 2 diabetes may be well controlled with a single daily injection of glargine insulin; others may require an MDI regimen that is virtually identical to that used for type 1 diabetes.

Insulin Administration

All students with type 1 diabetes and some with type 2 diabetes require insulin to be administered at various times during the day. Generally, insulin is administered in the school setting according to the child's Individual Health Plan (IHP) for meal coverage, for treatment of hyperglycemia, or for treatment of urinary ketones. The IHP will specify the individualized dosage and schedule for insulin administration for each student. The nurse should contact the child's parents or diabetes care team if insulin must be given for ketonuria. The insulin dose may vary based on blood glucose readings, food availability/preference, and physical activity level. The meal dosage is based upon the insulin-to-carbohydrate ratios for meals and snacks and a correction dosage to treat hyperglycemia. These formulas should be explicitly stated in the IHP.

Opened vials of insulin will retain potency for 30 days when left at room temperature but will keep for 3 months if refrigerated. Unopened vials of insulin should be stored in the refrigerator and will remain good until the expiration date noted on the insulin box. All diabetes supplies, including insulin, should be supplied to the school by the child's parents and accommodations for storage of the medication should be explicitly discussed.

Insulin may be administered using a syringe, pen device or pump. These are described separately in the paragraphs below. More in-depth training is provided on the American Diabetes Association website www.diabetes.org/advocacy.

Insulin Syringe

Syringes are available as 25, 30, 50 and 100 unit sizes and are equipped with short (8 mm) or regular (12.7 mm) length needles. Most syringes have needles of small caliber (30 or 31 gauge) and are relatively painless. Very small doses of insulin are best delivered using the smaller syringes, whereas all children taking more than 50 units of insulin as a single injection need to use the 100 unit syringe. Several different types of insulin may be mixed in a single insulin syringe, with the most rapid insulin being drawn up first, followed by the next most rapid and so on. Before withdrawing insulin from a syringe, it is important to inject air in an amount equivalent to the amount of insulin to be withdrawn in order to avoid formation of a vacuum. Thus, for every unit of insulin being taken out, a unit of air must first be inserted into the vial.

Technique for insulin administration using an insulin syringe is described below:

1. Gather all supplies needed to perform the injection.
   - insulin (verify)
   - syringe
   - alcohol wipe
   - disposable gloves
   - sharps container
2. Put on disposable gloves and wipe top of insulin vial with alcohol.
3. Have student select injection site.
4. Clean the injection site.
5. Check the insulin dose.
6. Remove the cap from syringe.
7. Pull the plunger down to number of units to be administered.
8. Place the needle of the syringe into the insulin vial and inject air into bottle.
9. Draw out prescribed number of units of insulin as per IHP.
10. Pinch up the skin.
11. Push needle into skin at 90° angle.
12. Release pinch.
13. Push the plunger in.
14. Count to "5."
15. Remove needle and dispose of syringe in sharps container.

Insulin Pen Devices

Insulin pens derive their names from their similarities in appearance to fountain pens. The pen holds a cartridge of insulin and a small needle is screwed

onto its tip before use. This needle must be unscrewed and discarded immediately after the injection in order to maintain a closed system and to minimize the chance of outside contamination. Insulin pens are available with cartridges containing several types of insulin, including the rapid acting analogues (Humalog and Novolog), Regular, NPH, and pre-mixed combinations (70/30, 75/25, 50/50).

Techniques for insulin administration using an insulin pen are as follows:

1. Gather supplies. Verify insulin type.
   - pen device (with cartridge)
   - pen needle
   - alcohol wipe
   - sharps container
2. Wash hands.
3. Choose injection site as above.
4. Clean injection site.
5. Screw on pen needle.
6. Prime: Dial "2" units to get rid of dead space.
7. Remove air by pressing the plunger. A drop of insulin will appear at the end of the needle. Repeat "Prime" if no insulin shows.
8. Dial number of units to be administered as per IHP.
9. Pinch up the skin.
10. Push the needle into the skin at 90° angle.
11. Release pinched skin.
12. Push down on the plunger.
13. Count to "5."
14. Remove and dispose of pen needle in sharps container.

Insulin Pumps

Pumps are worn 24 hours a day, usually on the child's belt or waistband. The infusion cannula is inserted in the abdomen or buttocks using a guide needle. Following insertion of the needle, the cannula is taped in place and the guide needle is removed. The cannula is usually changed every 2 to 3 days to minimize the risk of infection at the insertion site. Insulin coverage for meals and for high blood glucose levels is provided by the nurse or child, with the insulin dose based on the insulin:carb ratio and the correction factor (sliding scale) for hyperglycemia. The newer pumps have the child's specific algorithms for insulin coverage of meals and hyperglycemia already pre-programmed, making it easy to calculate the bolus insulin dose to be given before meals or to cover high blood glucose levels. The number of units of insulin thus derived is displayed and will be infused once the appropriate button is pressed. In addition, many of the newer pumps now have the ability to have blood glucose values transmitted directly to the pump using infrared technology.

- Once the insulin is administered, you should check the insertion site for leakage of insulin.
- Insulin must be administered immediately before a meal or, in the event the child does not know what or how much he or she will eat, immediately after the meal.
- If a correction dose of insulin is given to treat hyperglycemia, the blood glucose level should be checked again in 1 to 2 hours, as dictated by the IHP to make certain that the blood glucose level is decreasing as expected.
- If there is no decrease in glucose level, urine should be checked for ketones and, if positive, the correction dose of insulin should be given via syringe and the insertion site of the pump should be changed.
- If there are no urinary ketones, insulin can be administered through the pump and blood glucose, again checked in 1 hour.
- If the blood glucose level remains high, the insertion site is probably not working and the above procedure should be followed with subcutaneous administration of insulin using an insulin syringe.

The student's parent should provide the pump supplies to the school and should include

- Infusion set
- Reservoir
- Insulin
- Skin prep items
- Alcohol wipes
- Syringe (in case of malfunction)
- Pump batteries
- Inserter (if used)
- Manufacturer's manual, alarm card

Technical difficulties with pump use are addressed by the manufacturers, who are available to help troubleshoot. The contact information for the four most widely used pumps is

- Animas Corporation
  1-877-YES-PUMP (937-7867)
  www.animascorp.com
- Medtronic MiniMed, Inc.
  1-800-MINIMED (646-4633)
  www.minimed.com
- Disetronic Medical Systems, Inc.
  1-800-280-7801
  www.disetronic-usa.com
- Deltec Cosmo
  1-800-826-9703
  www.deltec.com

Responsibilities of the child, parent and school personnel

The Child

Responsibilities for the student depend on the age of the child. The child in elementary school may not be able to check blood glucose levels independently and will always need to be supervised. Many students in middle school and high school, on the other hand, may be very responsible and knowledgeable about their diabetes care and may be able to do blood glucose checks independently.

In general, the student should know when to check blood glucose levels and to make certain meals and insulin administration occur in a timely manner. Older students may be responsible for participating in determining insulin dose and in administering insulin, based on the child's age and level of maturity. All students should be responsible for appropriately discarding lancets, needles, and other supplies used for insulin administration.

The Parent

The parent of the child with diabetes must be responsible for providing the signed Individual Health Plan (IHP) (or *Diabetes Medical Management Plan*) to the school nurse and for meeting with the school health team to discuss the specifics and implementation of the IHP. An annual meeting to put a 504 plan into effect will clarify both parental and school expectations with regard to the student's diabetes management. This includes discussing timing of scheduled insulin administration and indications for giving additional insulin. The parent should explain the insulin:carb ratio and

correction factor and provide the nurse with a chart detailing the dosing. The location of storage of insulin supplies and location of insulin administration should be clarified.

The parent should also give signed permission for the school personnel and the child's health care team to share information regarding the student's diabetes. It is, furthermore, the parent's responsibility to inform the school of any changes in the child's diabetes regimen.

If children bring their lunch to school, the parents should provide the carbohydrate content for these foods to the school nurse to allow for accurate determination of the carbohydrate:insulin ratio. The school food service should assist the parent/school nurse by securing information about the specific foods served at school, so that insulin can be dosed accurately when the child eats food served at school.

As previously mentioned, the parent is responsible for providing and maintaining all diabetes supplies, including those necessary for insulin administration. These supplies should be stored in a safe place in the school itself and be available when the child is participating in extracurricular activities.

School Personnel

The school nurse is the school professional who has the responsibility for assuring that children with diabetes are adequately cared for, according to their IHPs. As such, the nurse must understand the student's IHP and is expected to arrange and participate in the child's 504 plan. The nurse is expected to perform the diabetes care tasks outlined in the student's medical plan, including insulin administration, and to document the timing and dose of all insulin given to the student. The nurse is also responsible for clarifying insulin regimens with the parents or the child's diabetes care team if there is any uncertainty about insulin dosing. The storage of insulin and other diabetes supplies will be under the supervision of the school nurse. The setting in which the insulin is given will be determined by the school nurse, in conjunction with the parent. As many children now receive pre-lunch insulin dosing, it is imperative that they miss as little class time as possible in the performance of their diabetes tasks, which can sometimes become a significant issue.

As the student's advocate, the nurse is expected to encourage independence in insulin administration, consistent with the student's level of maturity and skill. If a school nurse is not available at the school, the nurse assigned to the school on a part- time basis is responsible for training, assessing the competence, and then monitoring the performance of appropriate school personnel in carrying out the prescribed health care procedures in those instances in which a nurse is not available.

ABOUT THE AUTHORS

Rodney Lorenz, MD, Professor and Chair, Department of Pediatrics, University of Illinois at Peoria, Peoria, Illinois. Vice Chair, Diabetes in Children and Adolescent Workgroup of the National Diabetes Education Program.

Janet Silverstein, MD, Professor and Chief, Division of Pediatric Endocrinology, University of Florida College of Medicine, Gainesville, Florida. Chair, Diabetes in Children and Adolescent Workgroup of the National Diabetes Education Program.