

# Does Anyone Here Know How to Make Insulin Work Backwards?

## Why Sliding-Scale Insulin Coverage Doesn't Work

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You are treating a patient admitted to the hospital for *Streptococcus pneumoniae* pneumonia. You write the following orders:

1. Check the patient's temperature every four hours.
2. If the temperature is below 101° F, give no antibiotic.
3. If it is between 101 and 102 give penicillin 600,000 units IV.
4. If it is between 102.1 and 103 give penicillin 1,200,000 units.
5. If it is between 103.1 and 104 give penicillin 2,400,000 units.
6. If it is above 104, call the doctor.

I am quite sure that any physician reading this article will recognize that the orders above are ridiculous. They do not address the basic problem afflicting the patient, pneumococcal pneumonia, but merely one manifestation of that problem, the fever. They allow the patient's infection to escape from control repeatedly. They do not reflect our knowledge about the disease, the patient, or our ability to reverse the pathophysiology with proper treatment. Yet there are many physicians who see the inadequacy of these orders but who, when treating diabetic patients, will write insulin orders which similarly bear no relationship to the disease, the patient, normal physiology, and the pathophysiology of the disease. The system of orders to which I refer is called sliding-scale insulin coverage, fractional coverage, or a similar name. It was developed when the normal physiology of insulin secretion and metabolic control was not understood and when the determination of blood sugar was laborious and time consuming. It was designed when urine sugar determinations were used to judge how much insulin the patient needed, and that was the only way to do it at that time. It was not physiological at the time and, although adapted for use with blood sugar determinations, which can now be performed in a more timely fashion, it remains non-physiological today.

In treating a diabetic patient, it should be our goal to restore and maintain metabolic normalcy. We should attempt to keep the patient's blood sugar as stable and euglycemic as possible without causing problems in that attempt (avoiding hypoglycemia particularly). The objective is not to let the patient become repeatedly sick (hyperglycemic, hyperlipemic, hyperosmolar, polyuric) and then to try to treat the problem that we have allowed to occur. Yet, this is precisely what sliding-scale insulin coverage does, in whatever form it is used.

Many reasons are given for using sliding scale insulin coverage. Among them are that this is a way of evaluating the patient's sensitivity and responsiveness to insulin when that patient's insulin requirements are unknown. It is said to be a way of preventing the diabetes from going too far out of control. It has been considered a method of establishing the patient's insulin needs so that the patient can be switched to intermediate or long-acting insulin at the appropriate time in an appropriate dose. These arguments are all specious. Even under the best of circumstances, treating a patient by reacting to what his blood or urine sugar was is equivalent to trying to make insulin work backwards. It does not work. It allows the patient's blood sugar to reach a level that is dearly pathological and then attempts to bring it back to a more normal level. No effort is made to maintain the patient in a stable eumetabolic state. This method of treatment is potentially harmful to the patient and clearly inimical to good control.

It is well established that in Type II diabetes glucose acts as a beta-cell toxin. Several studies have shown that as blood sugar levels rise to around 200 mg/dl the beta cells produce less and less insulin in response to a glycemic stimulus (the so-called reverse horseshoe effect demonstrated in studies on the Pima Indians). This is exactly what is being done when sliding scale coverage is used. By allowing the patient's blood sugar to rise and then giving insulin in response to that rise, the physician is allowing the ability of the patient's own pancreas to secrete insulin to be paralyzed. This does not help to establish normalcy. Clearly, when the patient's blood sugar is brought closer to normal and he again begins to make insulin in response to a glycemic stimulus, the insulin he produces will change the need for administered insulin.

Other studies have shown that the effectiveness of injected insulin as measured by glucose disposal rate is inversely proportional to the fasting blood sugar. Thus, the higher the glucose, the more insulin is needed to get the same effect. Again, employing sliding-scale insulin coverage that depends upon the patients having achieved a high blood sugar level prior to the administration of insulin forces that insulin to be given when it will be less effective. If it were given when the patients blood sugar were closer to normal, less insulin would be needed for the same effect.

One of the reasons given for using sliding-scale coverage is that it keeps patients from getting into trouble by keeping the blood sugar within reasonable limits. What is meant by this is that the blood sugar will be kept below a level at which acute metabolic problems due to insulin lack will occur and above the level of hypoglycemia. These are very wide limits. At levels of blood sugar permitted by coverage schedules, polymorphonuclear leukocytes first lose their chemotactic ability, then their ability to ingest bacteria, and finally, as the blood sugar rises even higher, their ability to digest these organisms. By employing insulin coverage, the physician allows the patient's blood sugar to rise to a level which inhibits leukocyte function.

Picture the osmotic state of the nervous system, particularly the brain, as the patient's blood sugar is allowed to rise and then is rapidly lowered by administered insulin. There is no dear proof that such rapid, unphysiological osmotic changes are harmful to the central nervous system, but they are certainly not good for it or for any other organ system. The physiologic mechanisms designed to protect the body from osmotic variability are of major importance in maintaining internal homeostasis and life itself in an unfriendly osmotic environment. By using insulin coverage schedules, we challenge the ability of these mechanisms to cope, frequently overwhelming them. We cause alternating plasma and cellular hypertonicity and dilution as the patient drinks and water is moved from the intracellular to extracellular space to dilute the glucose, and then the glucose is lowered by insulin and water enters the cell again. The degree of cerebral swelling and shrinking that occurs under these circumstances is of major concern.

Clearly, then, giving insulin in response to a high blood sugar as a routine form of treatment is not physiologic, does not protect the patient, is not really a way of assessing the patient's insulin sensitivity, and bears little if any relationship to the insulin needs of the patient under normal circumstances. Indeed, in terms of insulin secretion, infection, and osmotic regulation, this mode of therapy may be dangerous to the patient. It is always playing catch-up. If our goal is to maintain the patient in the best possible metabolic state, we cannot allow the patient's glucose utilization and attendant blood sugar and lipid levels to seesaw throughout the day.

This is not to say that insulin should never be given if the blood sugar is high. Indeed it should, particularly if the glucose reflects a state of dysmetabolism that is dangerous to the patient, such as diabetic ketoacidosis or hyperosmolar nonketotic states. In patients with these problems, insulin must be given, it must be given in relation to measured parameters of the dysmetabolism, one of which may be the blood glucose level, and it usually is given without providing nutrition to the patient either enterally or parenterally. Under physiologic circumstances, however, although insulin production increases when blood glucose is high, the system is not primarily designed to react to a high blood sugar; but to keep glucose utilization and storage at such a level that the blood sugar does not change substantially whether the patient has just eaten or is just about to eat. Normal metabolic regulation provides for the relatively continuous secretion of insulin at a baseline level that limits glycolysis and gluconeogenesis. At this level, the patient's blood sugar can be elevated by counterregulatory hormones, but the insulin secreted regulates the rate at which these processes can proceed and prevents extreme rises in the glucose level and wasting of protein and fat reserves. When food is consumed, insulin is secreted in bolus fashion, allowing the food to be used immediately and/or to be stored as reserve energy. As a result, blood glucose does not rise to extreme levels and the levels of plasma lipids and amino acids are also regulated. This system, together with the counterregulatory hormones, maintains the blood glucose at levels that are quite stable despite large binges of food intake or prolonged fasting in the normal individual. If our goal is to approximate normal control as closely as possible, then we should do what we can to mimic normal insulin secretion. This entails giving insulin so that it can function prospectively and not attempting to make it work retrospectively.

Except when the patient is so dysmetabolic as to require insulin without food, insulin should always be prescribed with caloric intake and in relation to that intake. If the patients intake of calories is continuous, as when the patient is receiving continuous infusions of glucose-containing fluids or continuous enteral feeding by tube, then insulin administration should be as continuous as possible, preferably by continuous intravenous infusion or, if that is not possible, by the less desirable route of repeated intramuscular or subcutaneous injections. Whichever method is chosen, this should be given on a continuous, around-the-dock basis as long as the calories are given on that basis.

**NOTE: This article was written prior to the development of the current types of rapid acting and long acting insulins. Today we most commonly use a 4 shot a day basal/bolus plan using either Novolog or Humalog rapid-acting insulin at meals (bolus) and a long acting insulin such as Lantus or Levemir at bedtime to mimic the basal activity of the pancreas. The following paragraph still holds good information but remember the types of insulin have changed greatly. (comments by Dr. Phil Challans, Mid-America Diabetes Associates)**

*The patient who is getting intermittent feedings (i.e., breakfast, lunch, and supper with or without a bedtime snack) should receive insulin before each feeding. The insulin dose is empirical and the premeal insulin should be Regular insulin given subcutaneously. Human Regular insulin is preferred. A reasonable starting dose is between 0.075 units and 0.10 units of insulin per kilogram of body weight. The blood glucose is measured prior to and between one and two hours after the meal to determine the sensitivity and responsiveness of the patient and the success of that particular dose of insulin. The level of the dose of insulin is then modified for the next meal the patient eats. The degree and direction of the modification depends on the success of the previous dose and the content of the next meal, both in terms of calories and carbohydrate content. If the patient is going to be active or stressed (e.g., going for a procedure or experiencing fever), that should be considered also, as should whether the patient is going to be relieved of stress (infection treated or procedure completed). Of primary importance is whether the patient is going to eat and how much of the food he seems ready to consume. Using these guidelines, you can keep the patient on a very flexible schedule that accomplishes what sliding-scale insulin was meant to do in a much more physiological manner and without the gross swings in blood sugar that occur with sliding-scale coverage. This is usually all that is needed for the Type II diabetic-who is brought to the hospital with a stressful illness. For the Type I patient or the Type II patient with deficient insulin secretion who is not fully controlled on the above regimen, it is necessary to add baseline insulin. This can be accomplished by one of several methods. One or more doses of an intermediate acting insulin (NPH or Lente) may be given. It is particularly valuable in many patients to give a single dose of intermediate acting insulin at bedtime. This has its peak effect around the time the patient rises and needs the insulin most. An additional dose of intermediate-acting insulin may be added in the morning if needed. If that is done, the dose of Regular insulin given before lunch can frequently be eliminated. Alternatively, one or preferably two daily doses of long-acting insulin-zinc suspension (Ultralente) of other than human structure may be used. Human insulin-zinc is shorter acting and tends to peak more than the pure beef or mixed beef-pork long-acting insulin. Another approach, which combines both pre-prandial and baseline insulin administration, is to start the patient on continuous subcutaneous insulin infusion. Any of these methods might be used in the hospital only or as part of a plan for controlling the patient's diabetes at home as well.*

Finally, let me point out that there is absolutely nothing wrong, in the well controlled patient, with using the same regimen the patient was using at home or a regimen very close to it if the patient can eat normally and at normal times and be reasonably normally active. On the other hand, if the patient is acutely ill with a problem other than diabetes, modification of the regimen with less intermediate or long-acting insulin and more frequent Regular insulin may be needed.

Most diabetes treatment centers try to mimic the patient's home routine with regard to food and activity. This is something that distinguishes care in such centers from care on the general hospital floor. When the patient's condition permits, using the patient's normal daily routine is the ideal way to approach the hospitalized diabetic patient. Whatever the regimen chosen, any method of administering insulin that depends upon the patient's metabolism worsening before the insulin is given is unphysiological, inappropriate, and may be dangerous to the patient. Insulin should be given in a manner that will stabilize and not destabilize a patient's metabolism. We need to move out of the era when insulin coverage was all we had and understood. Today, we can understand the metabolic needs of the diabetic patient and can meet them more appropriately.