Prandial Insulin Dosing: How Long Does It Take to Go 80 Miles?

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There is a famous YouTube video in which a driver asks a passenger to determine the time it takes to travel 80 miles if one is traveling at 80 miles per hour (1). The passenger struggles with this concept despite the driver's best efforts to review basic math principles and, in fact, never quite gets the idea. It is humorous because the passenger keeps introducing elements that really have nothing to do with solving the equation, and viewers (and the driver) find it impossible to believe that the passenger cannot do such simple math. We recently came upon a pediatric prandial insulin order set that had us wondering if health care providers (HCPs) handle this kind of math any better.

This outpatient order set is an 11-page document written by providers with expertise in diabetes management and is intended for use by school nurses who manage diabetes and adjust insulin doses while children with diabetes are at school. It is administered via a widely used electronic health record that features a template to allow for consistency in order terminology. It also allows some flexibility in adjusting the specific details for a given order (e.g., to personalize a patient's insulin-to-carbohydrate ratio). The basal dose of insulin is typically given at home, and there is a separate set of orders for programming prandial insulin dosing for those who use an insulin pump. This commentary only focuses on the prandial component. The

pump and basal insulin orders will not be addressed. Depending on how a school manages diabetes for their students, the orders are engaged by either a nurse or a parent designated authority (PDA).

For those not familiar with the PDA concept, a PDA is someone from the general public who volunteers during the academic year to help manage diabetes for a child during the school day. A PDA usually is not an HCP but could be, for example, a secretary, teacher, or parent. PDAs are required to take some basic diabetes training to fulfill this role, typically a 3-hour course at least once, with additional training often also completed. In the state of Washington, most schools do not have a full-time onsite nurse, and available PDAs are helpful in these cases to allow children with diabetes to attend their local school. If a PDA model is not used, a common alternative is to send a child with diabetes by bus to a different school where a full-time nurse is available to provide care, even if that school is relatively far away and the child's siblings attend the local school.

Below, we present the elements of the order set that are pertinent to calculating the dose of rapid-acting insulin required during the day. These are verbatim orders for an arbitrary patient:

Insulin-to-carbohydrate ratio:

Breakfast: 1 unit per 2 grams of carbs

Lunch: 1 unit per 3 grams of carbs

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AM snack: 1 unit per 5 grams of carbs

Blood glucose correction factor:

1 unit per 200 mg/dL (correction factor) >250 md/dL (target blood sugar)

Calculating the insulin dose:

1. For carbohydrate coverage:
Total grams of carbs ÷ the insulin-to-carb ratio, which is $\frac{1}{3}$ = dose of insulin for food intake
2. For blood glucose correction:
Current blood glucose – target blood sugar ÷ correction factor = dose of insulin for blood glucose correction
3. Add two above answers together rounding DOWN to the nearest half unit to get the total insulin dose

Let's focus exclusively on the math required to calculate the dose of insulin for a lunch containing 15 g of carbohydrate and assume that the rest of the order set makes appropriate recommendations for modifying the dose, injection timing, and site. We will not address the correction dose or specifically address how the sentence structure of the order might contribute to inaccurate dosing calculations.

The insulin-to-carbohydrate ratio for lunch is 1 unit of insulin per 3 g of carbohydrate. To calculate an insulin dose, one must convert this to a number with units of measure: 1 divided by 3 with units of insulin per gram of carbohydrate or 0.33 units of insulin per gram of carbohydrate. We have normalized the insulin dosing relative to the carbohydrate dosing. To calculate the insulin dose to "cover" 15 g of carbohydrate, one would multiply 15 g of carbohydrate by 0.33 units of insulin per gram of carbohydrate, as illustrated in Eq. 1.

The numerator and denominator both contain carbohydrate grams as a unit of measure. These cancel each other out, and we are left with units of insulin as the final sole unit of measure.

However, when one uses the order set calculations ("Total grams of carbs ÷ the insulin-to-carb ratio, which is $\frac{1}{3}$ = dose of insulin for food intake"), note that there is a division sign present when, in fact, this should be a multiplication sign, as seen in Eq. 1. In addition, in the real world, the numbers are often viewed as unitless, so math rules are not always respected. Using the order set calculation as written would result in the following:

$$15 \div 0.33 = 45 \text{ units of insulin!}$$

These two results are vastly different from each other, and if a provider had followed the equation as written, a serious hypoglycemic response could have resulted from this ninefold difference in insulin dosing.

Intrigued by this discrepancy, we polled 12 providers, including endocrinologists, certified diabetes educators, and pharmacists, all of whom are experienced in diabetes management and insulin dosing. They were asked, "Pretend you are a provider with relatively little experience with insulin dosing. How much insulin would you give at lunch for 15 g of carbohydrate according to these instructions?" We received 11 responses, which are documented verbatim below.

1. 5 units. Do I pass?
2. 5
3. 5 units . . . is this a trick question???????
4. I would give 5 units based just on the first line (*Insulin-to-carb*

ratio: 1 unit per 3 grams of carbs) and your info about 15 grams of carbs. After reading the second part, someone might give 45 units. Based on 15 grams divided by $\frac{1}{3}$, so you multiply $15 \times 3 = 45$ units.

5. I think the intention is to give 5 U for the 15 g of CHO [carbohydrate], but the order makes no sense to me. Should say, total number of CHO divided by 3, not divided by the CHO ratio. And, I have no idea what they meant by, "which is $\frac{1}{3}$ = insulin dose."
6. 5. Unless the $\frac{1}{3}$ is read as a fraction, then give 45.
7. According to this, dividing by $\frac{1}{3}$ is multiplying by 3 right? So, according to these instructions, 45 (but the units are messed up). But if you balance out the units, you know that you have to divide by 3 to get units of insulin as the answer units. We had the same issue when we were putting together our protocol. We had to have it spelled out with the units and show the units cancelling, and it took a lot of education. And they still didn't always get it right.
8. The $\frac{1}{3}$ instead of 1:3 could be interpreted at $\frac{1}{3}$ or .33, which would cause the unskilled person to give 45 U instead of 5 U.
9. 5 units. ($15/3 = 5$). However, mentally, those with higher insulin needs often didn't really want to do the math. So I would start at "5 units for every serving of carbohydrate" (15 g) . . . 3 servings = 15 units . . . (still 45 g CHO and 15 units, but they accepted it more this way). For MDI [multiple daily injection] patients, I would use only 1:15, 1:10, and rarely 1:5; pumps excluded. Sorry for the rant . . . 13 years and all the diabetes and nutrition education for patients of 6 endos . . . I did whatever needed to get

$$15 \text{ g of carbohydrate} \times \left(\frac{0.33 \text{ units of insulin}}{1 \text{ g of carbohydrate}} \right) = 15 \text{ g of carbohydrate} \times \left(\frac{0.33 \text{ units of insulin}}{1 \text{ g of carbohydrate}} \right) = 15 \times 0.33 \text{ units of insulin} = 5 \text{ units of insulin}$$

EQ. 1

them to take their insulin and other meds.

10. I hope I pass the test. ☺ I would interpret this as a dose of 5 units for 15 grams CHO. I would be concerned, however, in misinterpretation of the directions by including the fraction ($\frac{1}{3}$) such that someone could calculate as: $15 \div \frac{1}{3} = 45$ units. I've worked on a few insulin overdose cases where this was done.
11. Okay, that is TOTALLY confusing! I am not sure what I would come up with because I hate fractions.

Those surveyed provided a broad range of responses to what is intended to be a simple order set. The likely intent of the order is to administer 5 units. However, if the order set is followed exactly as written, the dose administered would be 45 units. We specifically asked the polled providers to calculate a dose following the instructions as written, but we believe many of them were so experienced (and probably too busy seeing patients to think too hard about what was being asked) that they just converted to the dose of insulin that they felt was correct rather than following the order set mandate. This lack of clarity in the order set could have had drastic consequences in the hands of an inexperienced provider. In fact, we are aware of litigation that resulted from incorrect dosing of insulin administered in response to a similar order set.

Several guidelines and standardized order sets exist for the management of inpatient hyperglycemia, and these have documented benefits for care (2). Outpatient guidelines exist for the initiation of basal insulin dosing, but we are unaware of any specific national

guidelines for managing outpatient prandial dosing specifically using carbohydrate counting.

In general, the information that is available is developed at the local level and does not use consistent terminology. The terms "insulin-to-carbohydrate ratio" and "carbohydrate-to-insulin ratio" are used interchangeably and inconsistently. Specific examples of calculations are not reviewed. Most instruction sheets are written using terminology intended for HCPs and ignore the principle that patient-level instructions should be written at an eighth-grade (or lower) reading level. Most do not include units in their calculations, and often the wrong number is inserted into the calculation. For example, a common mistake is to make a statement such as, "The insulin-to-carb ratio is 10." This is not the insulin-to-carbohydrate ratio, but rather the carbohydrate-to-insulin ratio. The insulin-to-carbohydrate ratio is 0.1 units of insulin per gram of carbohydrate consumed. Using our YouTube video example above, one would laugh at the notion of confusing 80 miles per hour with 80 hours per mile, yet we routinely do something similar with our insulin-to-carbohydrate ratio instructions.

Order sets should not be subject to interpretation. They should be clear and concise and should lead to a single result. This is true with any order set, but especially with insulin dosing because of the acute and dangerous risk of hypoglycemia. Many of the people who administer insulin are not experienced with insulin dosing, and the difference between 45 units and 5 units may not seem unusual to them. However, this kind of dosing error can have catastrophic consequences.

When writing instructions for patients or considering order sets for

prandial insulin dosing, we propose the following:

1. Be mindful of units and phrasing. The insulin-to-carbohydrate ratio is different from the carbohydrate-to-insulin ratio.
2. Write the equations down and cancel the units. It is easy to make a mistake by multiplying when one should divide, and vice versa.
3. Use specific written examples whenever possible.
4. Ask a non-expert to review the instructions for clarity. Remember that the people reading your order set may not have your level of diabetes expertise.
5. If the orders are intended for patients or lay caregivers, write them in a way that is easy to understand (3).

We urge you to review your prandial insulin instructions and order sets. How long does it take *you* to go 80 miles?

Duality of Interest

Dr. Mystkowski is employed as a senior medical liaison by Novo Nordisk, Inc. He wrote on his own behalf, and the information provided and views expressed are those of the authors and should not be attributed to Novo Nordisk, Inc. No other potential conflicts of interest relevant to this article were reported.

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