THE OTHER 50% OF TDD: PRANDIAL INSULIN

Alison Evrett, M.S., RD, CDE

OBJECTIVES

Participant will be able to:
- List two formulas or "Rules" used to determine the prandial insulin dose.
- Describe two eating patterns or food habits that may evolve over time after following long-term adherence to the carbohydrate counting meal-planning approach.

NUTRITION THERAPY & INSULIN REQUIRING DIABETES

REFERENCES

- Refer to Handout
- June 2012 – American Diabetes Association’s – Guide to Nutrition Therapy for Diabetes

NUTRITION IS A SCIENCE, NOT AN OPINION

JENNIFER OKEMAH, M.S., RD, BC-ADM, CDE

- It is true – nutrition therapy recommendations change over time based on new research and evidence-based recommendations.
- As time goes by – new recommendations may contradict previous recommendations.
- Many of our colleagues may not understand the principles of diabetes nutrition therapy or emphasize its importance.

UNDERSTANDING & ADHERING TO NUTRITION THERAPY RECOMMENDATIONS

- In our society – food has many purposes in addition to meeting biological needs.
- When we ask our patients initiate basal-bolus insulin therapy, we are asking them to literally learn how to "think like a pancreas."
- Long-term application of basal-bolus insulin therapy is a lot of work.
- Adherence over time is difficult.

HEALTHY EATING PATTERNS KEY ELEMENT IN DIABETES MANAGEMENT - GOALS

- To establish optimal glucose and lipid control
- To help prevent complications such as CVD
- To address individual needs, taking into account, taking into account personal and cultural preferences and willingness to change.
- To maintain the pleasure of eating by only limiting food choices when indicated by scientific evidence.


DIABETES NUTRITION THERAPY: UNDER-UTILIZED THERAPY!

- Diabetes medications can lower A1C.
- Diabetes nutrition therapy can lower A1C, too.
- Nutrition therapy trials and outcome studies:
  - Type 1 diabetes: 1% reduction in A1C
  - Type 2 diabetes: 1.2% reduction in A1C

Pietras, JR; Warshaw, K; Duy A; Franz, MJ; National D. Diabetes Care. 3002;25:605-610.
Pietras JG; Franz MJ; Warchaw H; Duy A; Arnold MS. J Am Diet Assoc. 2003;103:827-831.
Without a strong nutrition component, most treatment plans will fall short.

John Bantle, MD

**Academy of Nutrition & Dietetics: Nutrition Recommendations and Interventions**

- Carbohydrate intake and available insulin are the primary determinants of postprandial glucose levels.
- Management of carbohydrate intake is the primary strategy for achieving glycemic control.


**American Diabetes Association: Nutrition Recommendations**

- Adjusting prandial insulin doses to match desired carbohydrate intake (using a meal-planning approach such as carbohydrate counting) in people with type 1 diabetes results in improved glycemic control.
- For individuals using fixed daily insulin doses, carbohydrate intake on a day-to-day basis should be kept consistent with respect to time and amount.


**Carbohydrate Counting**

- One of the more popular diabetes meal planning approaches.
- Used in the landmark Diabetes Control and Complications Trial in type 1 diabetes.
- Used outside the United States, the Dose Adjustment for Normal Eating (DAFNE) randomized, controlled trial using Flexible Intensive Insulin Therapy or "FIIT".

DAFNE Study Group. DMJ. 2002;305:748-750.

**Diabetes Nutrition—Basics**

- Protein — doesn’t impact blood glucose too much — although protein is a potent stimulant of insulin secretion.
- Fats — delay the emptying of the stomach for several hours.

**Goal—Teach Some Type of Method for Meal Planning**

- AKA — "Carbohydrate Awareness" (CA)
- Carbohydrate Counting
- Exchange System
- Glycemic Index
- WAG Method
- Small, Medium, Large Approach
UNDERSTAND HOW INSULIN WORKS
- INSULIN ACTION

- Patients must also understand how their insulin works.
- Need to understand integration of food and prandial insulin.
  - Onset: 10-15 minutes
  - Peak: 1-2 hours
  - Duration: 4.5 hours

THINK - LIKE A PANCREAS

PUTTING IT TOGETHER - match amount of carb to action of insulin

- Peak postprandial glycemic excursion – 1 to 2 hours
- Rapid acting insulin in peaking in – 1 to 2 hours

MATCH YOUR INSULIN TO YOUR CARBS

AMERICAN DIABETES ASSOCIATION: NUTRITION RECOMMENDATIONS

- For people with type 1 diabetes or insulin-requiring type 2 diabetes: when using flexible intensive insulin therapy: recommend dosing algorithms
- Prandial dosing: Insulin-to-carbohydrate ratio (ICR)
- Blood glucose correction: insulin sensitivity factor (ISF)

PRANDIAL DOSING ALGORITHMS

- Prandial and blood glucose correction algorithms: rules and formulas
- Dusseldorf model in the 1970s: basis of the DAFNE program in the 1980s, flexible intensive insulin dosing
- WHERE DO THE COMMONLY USED DOSING ALGORITHMS COME FROM IN THE US???

AIM FORMULAS

- Davidson and Bode in the 1980s: large endocrine practice, type 1 diabetes, using pumps
- Accurate Insulin Management formulas based on total daily dose (TDD) of insulin
- Mathematical models statistically correlated based on data from large endocrine practice (2 groups analyzed: well-controlled test group [n=167], A1C ≤ 7%, on pump >180 days and control group [n=209], A1C > 7%, on pump <180 days)

AIM FORMULAS
- PRANDIAL INSULIN

\[ CIR = 2.8 \times BWib/TDD \]
(\(BWib = \) body weight in pounds)

For example: if TDD = 50 units
- \(2.8 \times 180 \text{ lbs}/50 = 10\)
- \(CIR = 1:10\)

1 unit of rapid-acting insulin will "match" 10 grams carbohydrate

- BG CORRECTION INSULIN

\[ CF = 1700/TDD \]

For example: if the TDD = 34 units
- \(1700/34 = 50 \text{ mg/dL}\)
- \(CF = 1.50\)

1 unit of rapid-acting insulin will "lower" blood glucose 50 mg/dL.
AIM FORMULAS

**BASAL INSULIN**

\[ TDD = 0.24 \times BWib \]

Basal Units/day = 0.47 \times TDD

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**“USING INSULIN” OR “PUMPING INSULIN”**

PRANDIAL INSULIN RULES

If using the 500 Rule: 500/TDD

For example: if the TDD = 50 units

50/50 = 10

CarbF = 1.10

1 unit of rapid-acting insulin will “match” 10 grams carbohydrate

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**“USING INSULIN” OR “PUMPING INSULIN”**

MORE RULES/FORMULAS

**HOWORKA ALGORITHMS**

Insulin sensitivity coefficient \( K = \) current total insulin requirement / Basal insulin requirement

Theoretical basal insulin requirement = 0.20 (body weight)

Theoretical prandial insulin requirement = (average daily carbohydrate intake) / 2.2

Prandial insulin and correction of abnormal blood glucose \( (BG) \) values:

Insulin requirement for one 20 g carbohydrate portion = 2.2 \times K

One unit short-acting insulin: BG-lowering effect \( (BG) \) \( \text{mmol/L} \) = 1.94 \times K \times 0.03 kg

BG increase induced by one 20 g carbohydrate portion: \( \text{BG} \) (mmol/L) = 0.44 \times X

Basal insulin requirement: 0.20 \times \text{Kg} \times K

An additional formula for meal size \( k \) proposed by Howorka (1990) for meal size in carbohydrate: 1 \( \text{kg} \) (0.5) per meal or kg \times X

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**MORE RULES/FORMULAS**

Howorka Algorithms for Flexible Insulin Therapy

(adapted for 20 gram carbohydrate portions at mealtime)

**NOTE:** blood glucose units are in mmol/L to convert to mg/dL multiply mmol/L x 18

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**HOW DO WE CONFIRM PRANDIAL AND CORRECTION INSULIN ALGORITHMS AT THE UWMC DIABETES CARE CENTER?**

- **START WITH ALGORITHMS**
- **Record** (keeping to confirm)
- **Food intake** (Carb = grams)
- **Self-monitoring** of blood glucose (SMBG) records
- **Insulin doses**
- **3-4 days at a time**
**Prandial Insulin: Dose Depends on the Individual**

- **IC Ratios**
  - 1 unit of rapid-acting insulin will "match" a certain number of grams of carbohydrate.
  - Clinical Experience:
    - Toddlers—1:30 to 1:40
    - Children—1:15 to 1:20
    - Teenagers—1:30 to 1:10
    - Adults—1:10
    - Obese—1:11 to 1:5

- **ISF Ratios**
  - How much does 1 unit rapid-acting insulin drop BG mg/dL?
  - Clinical Experience:
    - Toddlers—1.75 to 1:100 mg/dL
    - Children—1:50 to 1:75
    - Teenagers—1:25 to 1:30
    - Adults—1:30 to 1:50
    - Overweight/Obese—1:10 to 1:30

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**Reducing Postprandial Hyperglycemia**

- The American Diabetes Association's 2011 Standards of Care noted that "some surrogate measures of vascular pathologic, such as endothelial dysfunction, are negatively affected by postprandial hyperglycemia."  
- Postprandial hyperglycemia may be related to the production of free radicals, which in turn can induce endothelial dysfunction and inflammation.

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**Dysglycemia**

- Dysglycemia of patients with diabetes is the sum of the two following disorders:
  - Sustained chronic elevations of glucose
  - Glycemic variability with postprandial excursions and downward changes
- Glucose variability is also associated with activation of oxidative stress, one of the main mechanisms leading to complications

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**Reducing Postprandial Hyperglycemia & Dysglycemia**

- Postprandial hyperglycemia can be caused by a mismatch between prandial insulin and carbohydrate intake.
- Our patients using continuous glucose monitoring see this happening in real time.
- Treatment strategies:
  - Nutrition therapy, patients need to know how many carbohydrates, we are consuming to correctly "match" their prandial insulin dose
  - Adjusting the timing of prandial insulin doses

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**Timing of Insulin Doses**

- DeWitt and Hirsch described the term "lag time" in their scientific review of outpatient insulin therapy for type 1 and type 2 diabetes.
- It's on the package insert.
- Three recent small studies recommend injecting prandial insulin 15-20 minutes before the start of the meal.

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**Lag Times Based on Degree of Preprandial Hyperglycemia**

<table>
<thead>
<tr>
<th>Pre-Meal Blood Glucose (mg/dL)</th>
<th>Lag Time (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>80-109</td>
<td>0</td>
</tr>
<tr>
<td>100-199</td>
<td>10-20</td>
</tr>
<tr>
<td>200-299</td>
<td>20-30</td>
</tr>
<tr>
<td>≥300</td>
<td>≥30</td>
</tr>
</tbody>
</table>

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**Tips for Keeping Our Long-Lived Patients Engaged**

- 3 studies exploring food and eating practices of PWD – type 1 over time
- UK/Australia – Flexible Intensive Insulin Therapy (FILT) – as a part of the DAFNE course
- Lawton, Rankin, Casey – 2011
TIPS FOR KEEPING OUR LONG-LIVED PATIENTS ENGAGED

- Lawton collected information after 12 months
- Greater rigidity in food choices over time
- Simplify/limit food choices to make carb estimation easier
- Reliance on packaged foods vs fresh food
- Leading to increased intake of saturated fat and sodium
- Increased consumption of low carb/no carb foods to reduce/eliminate prandial dose
- Despite education — fear of hypo and anxiety about miscalculation of prandial dose


TIPS FOR KEEPING OUR LONG-LIVED PATIENTS ENGAGED

- Rankin collected information after 12 months
- Participants generally preferred FIIT over “fixed” insulin dosing
- Many made adjustments in their lives in order to sustain this method
  - Adjusted food intake by creating food habit routines or maintained meal schedule
- Researchers suggest need to include interventions and strategies that can help PWD over time to follow FIIT long-term


TIPS FOR KEEPING OUR LONG-LIVED PATIENTS ENGAGED

- Casey — collected information at 6 weeks, 6 and 12 months
- Participants at 6 weeks felt support from other participants such as sharing experiences was important helpful
- After 6 months — began to value support from HCP that focused on collaborative decision making
- 6 months — important timeframe, motivation at this point was lowest for many

Casey D et al. BMC Public Health 11:672, 2011

TIPS FOR KEEPING OUR LONG-LIVED PATIENTS ENGAGED

- Gross — bolus calculator study with Medtronic Pump. Study findings
  - Most diligently perform calculations when beginning FIIT
  - Adherence may become relaxed over time
  - Tendency to approximate carb content by using “standard” or “usual” pre-meal doses
  - Many were actually hesitant to take responsibility for increasing/decreasing prandial doses


DIABETES NUTRITION THERAPY & PUMPS

TRANSITIONING TO INSULIN PUMP THERAPY

- PWD that wants to transition to pump
- Learn to count or quantify carbs
- Check BGs over 4-6x/day
- Encourage use of bolus calculator
- After the basal rates are confirmed — evaluate ICR and ISF
- May need different ICR for different time periods

OPTIMIZING USE OF INSULIN PUMP

- Is your patient using bolus calculator?
- Are they using it correctly?
- How can you tell?
- Download reports give us information that MDI can’t
- Look at BG records.

**CGM TECHNOLOGY**

- Glucose Level:
  - High
  - Mid
  - Low

**ESTIMATION OF CARB INTAKE**

- If your patient can’t count carbs, the bolus calculation won’t be correct.
- We do know that estimations can work, but they need to be fairly accurate.
- Smart (2009) – ranges
- Sharpn (2010) – mean % error greater with larger bolus carb

**“INSULIN ON BOARD” TIPS TO OPTIMIZE CONTROL.**

- Insulin On Board – key concept for our patients to understand.
- Give specific guidelines about how often your patient can administer a correction bolus.
- Remind your patient that 40-50% bolus still active after 2 hours.
- Discuss bolus coverage for extra food eaten between meals.
- If continually over-riding bolus estimate – may need to adjust settings.

**ART & SCIENCE OF PRANDIAL DOSING**

- Bolus insulin adjustments based on experience, more of an “art” than science-based.
- Not a lot of evidence available to guide practice.
- Based on information from SMBG and CGM, data meals with larger and varying amounts of protein and fat are found to prolong PP BG up to several hours.
- Suggesting – delayed absorption of glucose and additional prandial insulin may be needed.

**VARIABLE BOLUS FEATURES**

- Pump manufacturers developed ability to deliver prandial bolus in an attempt to “match” the circulating insulin levels to the rate of glucose absorption from the gut in order to minimize PP BGs.
- Variable Bolus Features:
  - Normal
  - Extended or Square-Wave
  - Combination or Dual-Wave
VARIABLE BOLUS FEATURES

RESEARCH

- Literature Review: PubMed/MEDLINE
- Search criteria: studies after 1999, human, English language
- 7 articles, 1 abstract, 4 youth/4 adult
- Excellent Review Article: Heinemann
- Limitations: small sample size, pre-meal BGs varied, only 2 confirmed BS rates prior to study, only 1 evaluated C-peptide levels, 2 did not specify type of insulin, 1 used regular


RESEARCH - PIZZA

- Chase/Lee J: evaluated different bolus delivery methods [NL bolus vs. DW bolus] with pizzameals (>35% fat) to reduce PP BG
- Chase: n=9 youth with type 1 used CSII
- Lee: n=10 adults with type 1, used CSII + CPM
- Jones: n=24 adults with type 1, used CSII + CPM

Lee SW et al. Diabetes Care 2010;33:247-252, 2010

RESEARCH - GLYCEMIC INDEX

- O’Connell - randomized crossover trial
- Findings:
  - DW bolus before low GI meal reduced PP AUC by up to 47% when compared to NL bolus

O’Connell NM J Diab Complications 2010;34:139-145, 2010

NOVEL ALGORITHM FOR PRANDIAL BOLUS

- Pankowska 2000-2011 - cross-sectional clinical trial & randomized control trial
- Evaluated use of DW or SW bolus on metabolic control
- 2000, n=490, youth with type 1, used CSII, insulin type ?
- Uncontrolled evaluation of data collected in OP clinic during routine outpatient visit
- 2011, n=24, youth with type 1 on CSII.

Pankowska E et al. Diabetes Technol Ther 2011

- FPU is administered using SW bolus which is extended based on number of FPUs
  - 1 FPU = SW bolus extend over 3 hr (100 kcal)
  - 2 FPU = SW bolus extend over 4 hr (200 kcal)
  - 3 FPU = SW bolus extend over 5 hr (300 kcal)
  - >3 FPU = SW bolus extend over 8 hr (>300 kcal)
- Due to lengthy calculations developed online software program - includes bolus calculator and nutrition database

Pankowska E et al. Diabetes Technol Ther 2011
THE OTHER 50% OF THE TDD – PRANDIAL INSULIN

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Evidenced-Based Nutrition Recommendations and Guidelines:


BASAL-BOLUS INSULIN THERAPY – CARBOHYDRATE COUNTING

Type 1:
DAFNE Study Group: Training in flexible, intensive insulin management to enable dietary freedom in people with type 1 diabetes: dose adjustment for normal eating (DAFNE) randomized controlled trial. BMJ 325:746–751, 2002


Casey D, Murphy K, Lawton J, White FF, Dineen S: A longitudinal qualitative study examining factors impacting on the ability of persons with T1DM to assimilate the Dose Adjustment of Normal Eating (DAFNE) principles into daily living and how these factors change over time. BMC Public Health 11:672, 2011


Type 2:
BOLUS CALCULATORS

DOsing algorithms


CARBOHYDRATE COUNTING – ESTIMATION AND RANGES

Smart CE, Ross K, Edge JA, Collins CE, Colyvas K, King BR: Children and adolescents on intensive insulin therapy maintain postprandial glycaemic

GLYCEMIC VARIABILITY & DYSGLYCEMIA


Monnier L, Lapinski H, Colette C: Contributions of fasting and postprandial plasma glucose increments to the overall diurnal hyperglycemia of type 2 diabetic patients: variations with increasing levels of HbA1C. *Diabetes Care* 26:881–885, 2003

INSULIN ANALOGS – TIMING AND ACTION


Meal studies:


INSULIN PUMP THERAPY – EDUCATION & INTERVENTIONS

**VARIABLE BOLUS RESEARCH STUDIES**

**OVERVIEW:**

**NOVEL INSULIN DOSING ALGORITHMS**


Pańkowska E, Blazik M, Groele L: Does the fat-protein meal increase postprandial glucose levels in type 1 diabetes patients on insulin pump: the conclusion of a randomized study. *Diabetes Technol Ther* Online abstract ahead of print, October 20, 2011