Overview

- Definitions
- Risks
- Detection
- Management

After-Meal Peaks Defined
The net rise that occurs from before eating to the highest point after eating.

- ADA Goal: <180 mg/dl 1-2 hrs after start of meal
- AACE Target: <140 mg/dl at “peak”
- European Diabetes Policy Group: <165 (to prevent complications)
- International Diabetes Federation: <140 mg/dl 2 hrs after meal

After-Meal Goals

- Children:
  - < 200-240 @ peak
  - (< 100 pt. Rise)
- Adults:
  - < 180-200 @ peak
  - (< 80 pt. Rise)
- Pregnancy
  - < 140-160 @ peak
  - (< 60 pt. Rise)

After-Meal Peaks: Reality in Type-1 Diabetes

Source: Boland et al, Diabetes Care 24: 1858, 2001
**After-Meal Highs: Immediate Problems**

- Tiredness
- Difficulty Concentrating
- Impaired Athletic Performance
- Decreased desire to move
- Mood Shifts
- Enhanced Hunger

**Australian Study of Children w/Type 1. Parents & children reported BG > 270 had negative impact on:**

- Thinking (68%)
- Mood/Emotions (75%)
- Coordination (53%)

**Long-Term Problems**

**Relative Influence on HbA1c**

Source: Mounier et al., Diabetes Care, 26, 3/03, 881-885

**Long-Term Problems (contd)**

52 Type 1’s, similar BP between groups

<table>
<thead>
<tr>
<th>Post-prandial glucose</th>
<th>Range</th>
<th>Time to onset of proteinuria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Persistent &lt;200</td>
<td>110-198</td>
<td>23 yrs</td>
</tr>
<tr>
<td>Intermittent &gt;200</td>
<td>118-228</td>
<td>19 yrs</td>
</tr>
<tr>
<td>Persistent &gt; 200</td>
<td>204+</td>
<td>14 yrs</td>
</tr>
</tbody>
</table>

Source: Kidney Intl. 1987; 32 (supp 22): S53-S56

**Long-Term Problems (contd)**

<table>
<thead>
<tr>
<th>Type-2s Starting on Oral Meds</th>
<th>Meds to limit post-meal rise</th>
<th>Meds to control pre-meal BGs</th>
</tr>
</thead>
<tbody>
<tr>
<td>HbA1c reduction</td>
<td>Identical</td>
<td>Identical</td>
</tr>
<tr>
<td>Fasting BG</td>
<td>Identical</td>
<td>Identical</td>
</tr>
<tr>
<td>Cognitive Function</td>
<td>Unchanged</td>
<td>Declined</td>
</tr>
</tbody>
</table>

Source: Neurology 2006; 67: 235-240

**Long-Term Problems (contd)**

Rates of eye and kidney disease based on glucose variability (using CGM) in Type-2 Diabetes

**Long-Term Problems (contd)**

22-yr CVD Mortality Risk by Baseline post-challenge glucose


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**Long-Term Problems (contd)**

Glycemic Variability A Better Predictor of Major Cardiac Events than Admission BG or A1c for Acute MI

(Su et al, Diabetes Care online, 1/24/2013)

1 & 2-Hr. BG levels predicted CHD better than fasting BG (Pyorala et al, J Chronic Dis. 1979; 32: 729-755)


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**Long-Term Problems (contd)**

Post-Lunch BG Linked Strongly to Hazard Ratio for First CV Event


Post-Breakfast BG predicted mortality better than fasting BG (Hanefeld et al, Diabetologia 1996; 39: 1577-1583)

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**Long-Term Problems (contd)**

Acute Hyperglycemia: Proposed Mechanism of Damage

Source: Antonio Ceriello, Univ. of Udine, Italy. Diabetes 54: 1-7, 2005

- Coagulation Abnormality
- Oxidative Stress
- Endothelial Dysfunction

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**Contribution of endothelial progenitor cells (EPCs)**

- Damage to inner lining of blood vessels (endothelium) leads to vascular complications
- EPCs “patch” endothelial injuries
- EPC count increases with reduction in glycemic excursions


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**Measurement of After-Meal Peaks**

- **Fingerstick BG Checks**
  - Capillary (finger) sample
  - Check BG 1 Hr after completion of meal
  - (or) every 15, 20 or 30 min until 2 consecutive BG reductions occur (No addl. Food/insulin until test is completed)
**Meter Test Example**

<table>
<thead>
<tr>
<th>Breakfast</th>
<th>Lunch</th>
<th>Dinner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>1h Post</td>
<td>Pre</td>
</tr>
<tr>
<td>117</td>
<td>281</td>
<td>157</td>
</tr>
<tr>
<td>90</td>
<td>302</td>
<td>58</td>
</tr>
<tr>
<td>151</td>
<td>264</td>
<td>77</td>
</tr>
</tbody>
</table>

Interpretation:
Excessive after-meal peak following breakfast; not after lunch or dinner

**Time** pp | **BG Value**
--- | ---
Premeal | 135
:20 | 155
:40 | 168
1:00 | 214
1:20 | 222
1:40 | 175
2:00 | 141

Interpretation:
Peak occurred at 1hr, 20min pp; rise from premeal to peak was approx. 90 mg/dl

**Measurement of After-Meal Peaks**

- **Blinded CGM**
  - Medtronic iPro (72 hrs) or Blinded Dexcom 7+ (7 days)
  - BG data every 5 minutes
  - Analysis software shows post-meal patterns

- **Real-Time Continuous Glucose Monitors**
  - Allow tracking of post-meal trends
  - Produce BG estimates every 5 minutes

**CGMS Case Study**

- 37 year old man (insulin pump)
- 8 year old girl (glargine/MDI)
**CGMS Case Studies**

60-year old woman (oral meds)

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-20</td>
<td>1000</td>
<td>150</td>
</tr>
<tr>
<td>1-20</td>
<td>1200</td>
<td>180</td>
</tr>
<tr>
<td>1-20</td>
<td>1400</td>
<td>200</td>
</tr>
<tr>
<td>1-20</td>
<td>1600</td>
<td>220</td>
</tr>
<tr>
<td>1-20</td>
<td>1800</td>
<td>240</td>
</tr>
</tbody>
</table>

- **Spike Measurement**
  - **1,5 - anhydroglucitol (AG) “GlycoMark”**
  - Laboratory Blood Test
  - Measures Duration & Magnitude of High BG Excursions for past 10-14 days
  - “Normal” is >14 µg/ml
  - >10 is “good”

- **Why Do We Spike?**
  - Insulin/Meds Work Too Slowly
    - Lag far behind pancreatic insulin
    - Glucagon is not properly suppressed
  - Food Works Too Quickly
    - Lack of amylin hormone

- **Spike Control**
  - Make Insulin Work Faster
  - Make Food Work Slower

- **Slowing Food 1:**
  - Use of Glycemic Index
    - All carbs (except fiber) convert to blood glucose eventually
    - G.I. Reflects the magnitude of blood glucose rise for the first 2 hours following ingestion
    - G.I. Number is % or rise relative to pure glucose (100% of glucose is in bloodstream within 2 hours)

- **Glycemic Index (contd.)**
  - Example: Spaghetti
    - GI = 37
    - Only 37% of spaghetti’s carbs turn into blood glucose in the first 2 hours.
    - The rest will convert to blood glucose over the next several hours.
Glycemic Index (contd.)

- Lower GI foods digest & convert to glucose more slowly
- High-fiber slower than low
- Hi-fat slower than low
- Solids slower than liquids
- Cold foods slower than hot
- Type of sugar/starch affects GI

<table>
<thead>
<tr>
<th>Fastest</th>
<th>Slowest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose</td>
<td>Starch (straight-chain)</td>
</tr>
<tr>
<td>Dextrose</td>
<td>Starch (branch-chain)</td>
</tr>
<tr>
<td>Fructose</td>
<td>Lactose</td>
</tr>
<tr>
<td>Sucrose/Corn Syrup</td>
<td>Galactose</td>
</tr>
<tr>
<td>Sugars</td>
<td>Sugar Alcohol</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Slow Stuff</th>
<th>Average Stuff</th>
<th>Fast Stuff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasta</td>
<td>Fruit</td>
<td>Breads/Crackers</td>
</tr>
<tr>
<td>Legumes</td>
<td>Juice</td>
<td>Salty Snacks</td>
</tr>
<tr>
<td>Salad Veggies</td>
<td>Pizza</td>
<td>Potatoes</td>
</tr>
<tr>
<td>Dairy</td>
<td>Soup</td>
<td>Rice</td>
</tr>
<tr>
<td>Chocolate</td>
<td>Cake</td>
<td>Cereals</td>
</tr>
<tr>
<td>Slow Stuff</td>
<td></td>
<td>Sugary Candies</td>
</tr>
<tr>
<td>Fast Stuff</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Common Substitutions

<table>
<thead>
<tr>
<th>Meal</th>
<th>High-GI Options</th>
<th>Low-GI Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakfast</td>
<td>Cereal, Bagel, Waffle, Pancakes, Muffins</td>
<td>Oatmeal, Milk, Whole Grain</td>
</tr>
<tr>
<td>Lunch</td>
<td>White Bread, Fries, Tortillas, Cupcake</td>
<td>Sourdough/Pumpernickel, Yogurt, Corn, Crackers</td>
</tr>
<tr>
<td>Snacks</td>
<td>Pretzels, Chips, Crackers, Doughnuts</td>
<td>Fruit, Popcorn, Nuts, Ice Cream, Chocolate</td>
</tr>
<tr>
<td>Dinner</td>
<td>Rice, Mashed or Baked Potatoes, Rolls</td>
<td>Pasta, Peas, Beans, Sweet Potato, Salad Veggies</td>
</tr>
</tbody>
</table>

Slowing Food 2: Splitting The Meal

- Part at the usual mealtime
- Part 60-90 minutes later
- Full insulin/meds given prior to meal

Slowing Food 3: Post-Meal Physical Activity

- Muscle Use Soon After Eating
- Accelerated Insulin Absorption
- Delayed Digestion
- Glucose Uptake Utilization
- Improved After-Meal Control

Slowing Food 4: Add Some Acidity

- 60-min glucose response 55% *
- Tomatoes
- Sourdough
- Vinegar (Salad Dressing/Condiments)

Slowing Food 5: Meal Sequencing

- Eat veggies before starch when having mixed meals
- Make lunch the “higher carb” meal (less at breakfast & dinner)


Slowing Food 6: Medicinal Approaches

α-Glucosidase Inhibitors
- (acarbose, miglitol)
  + Slows carb absorption in the small intestine
  + Gradual glycemic rise post-meal
  + Often causes GI upset/flatulence

Medicinal Approaches

DPP-IV Inhibitors:
- (sitagliptin, vildagliptin)
  + facilitate glucose-dependent insulin secretion
  + suppress glucose-dependent glucagon secretion
  + slow gastric emptying

GLP-1s
- (exenatide, liraglutide)
  + subcutaneous injectible hormone
  + enhances 1st & 2nd phase insulin secretion
  + slow gastric emptying
  + suppresses appetite
  + may cause nausea

Amylin Analog:
- (pramlintide)
  + subcutaneous injectible hormone
  + enhances satiety
  + slows gastric emptying
  + suppresses post-meal glucagon secretion
  + may cause nausea

Effect of Pramlintide on Gastric Emptying in Type 1 Diabetes

- Mean Half-Emptying Time (h)
  - Insulin + Placebo
  - Insulin + Pramlintide
  - 1-h delay

Data from Kong MF, et al. Diabetologia 1998; 41:577-583
Pramlintide Reduces Postprandial Glucagon

Type 2 Diabetes, Late Stage

Type 1 Diabetes

Pramlintide

Placebo

Insulin

Sustacal®

0 2 4 6

0 2 4 6

0 200 150 100 50

0 2 4 6

0 2 4 6

0 200 150 100 50

Does Timing Matter?

• Bolus w/meal

• Bolus pre-meal

Source: Clinical Therapeutics 2004; 26:1492-7.

Slowing Food 7: Avoiding Pre-Meal Hypoglycemia

Symptomatic hypoglycemia produces “Sieve Effect”

Accelerates gastric emptying of liquids and solids

Produces more rapid BG rise after meal

J Clin Endo Metab 2005; 90: 4489-95

Speeding Insulin 1: Choice of Bolus Insulin

Aspart, Glulisine, Lispro Vs. Regular Insulin

• 1-hr. peak

• 3-4 hr. effective duration

• 2-3 hr. peak

• 4-6 hr. effective duration

Speeding Insulin 2: Timing of Bolus Insulin

(rapid analog)

BG Above Target Range

High GI

Moderate GI

Low GI

BG Within Target Range

BG Below Target Range

Does Timing Matter?

Note: Carbs estimated w/pre-meal insulin. Carbs known with post-meal insulin.

Source: Clinical Therapeutics 2004; 26:1492-7.

Does Timing Matter?
- Insulin taken with meal
- Insulin taken 15-30 min Pre-Meal (if >150)

Speeding Insulin 3: Choice of Insulin Program
- Pump & MDI
  - Meal/snack boluses
- Daytime NPH
  - Prolonged peak covers midnight meals/snacks

Speeding Insulin 4: Warming The Injection/Infusion Site
- “Insupatch” (experimental)
  - Heating element in pump infusion site
  - Warms site to 38-40°C
  - 30-40 minute earlier insulin peak

Speeding Insulin 5: Afrezza

Speeding Insulin 6: IM Injection


**Speeding Insulin 6: IM Injection**

![Graph showing IM Injection given at 1 PM with peak glucose level 2 hours later]

**Speeding Insulin 7: Sulfonylurea Substitutes**

- **Meglitinides:**
  - (repaglinide, nateglinide)
  - Stimulates pancreatic insulin secretion
  - **Rapid-acting** (1-2 hour peak)
  - ↑ Risk of hypoglycemia
  - Must have beta-cell function

**Meglitinide Comparisons**

<table>
<thead>
<tr>
<th></th>
<th>Mean max BG at peak</th>
<th>% of time &gt;200 mg/dl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repaglinide</td>
<td>210</td>
<td>1%</td>
</tr>
<tr>
<td>Glimepiride</td>
<td>256</td>
<td>5%</td>
</tr>
</tbody>
</table>

Li et al., Diabetes, June 2008, V57 suppl. 1, 1970-P2.

**Speeding Insulin 8: Post-Meal Physical Activity**

- **Muscle Use Soon After Eating**
  - Improved After-Meal Control

- **Insulin Absorption**
  - Accelerated
  - Delayed Digestion
  - Glucose Uptake/Utilization

**Examples: After-Meal Activity**

- Walking Pets
- Household Chores
- Planned Exercise
- Shopping
- Gardening
- Casual Stroll
- Dancing
- Bowling
- Mini Golf
- Skating

**Effects of Post-Meal Walking**

- 30 Minutes of casual stop & go walking after meals
- Avg. 30 mg/dl (1.75 mmol/L) BG reduction
- Peak post-meal glucose 45% higher when not walking

Kadow, et al., Diabetes Care, published online Aug 8, 2012.
Summary

After-Meal Blood Sugar Levels Are:
- Important to Control
- Measurable
- Manageable

Post-Meal Mgt Summary

**To Slow Food:**
1. Choose Low-GI
2. Split Meal
3. Sequence Properly
4. Add Acidity
5. Use αGlucosidase Inhibitor
6. Use GLP1/Amylin
7. Post-Meal Activity

**To Speed Insulin:**
1. Use rapid analogs
2. Pre-Bolus
3. Warm Site
4. Inhaled Insulin
5. Intramuscular Injection
6. Use Meglitinide (oral)
7. Post-Meal Activity

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