Disclosure

- Book sales – all pump companies
- Advisory Boards – Tandem Diabetes, Convatec, Halozyne, AgaMatrix, PicoLife Technologies
- Consultant – Bayer, Roche, BD, Abbott, Tandem Diabetes, Acon Laboratories
- Speakers Bureau – Tandem Diabetes, Animus
- Sub-Investigator – Glaxo Smith Kline, Animus, Sanofi-Aventis, Bayer, Biodel, Dexcom, Novo Nordisk, Halozyne
- Pump Trainer – Accu-Chek, Animas, Medtronic, Omnipod, Tandem
- Web Advertising – Sanofi-Aventis, Sooil, Medtronic, Animas, Accu-Chek, Abbott, etc.
What We’ll Cover

- Glucose Management – Slide 12
- Actual Pump Practices Study Results – Slide 18
- Tuning the Bolus Calculator – Slide 30
- Special Issues
  - DIA, BOB, and Insulin Stacking – Slide 79
  - Infusion Sets – Slide 103
- Continuous Glucose Monitors – Slide 116
Terms

- **TDD** – total daily dose (all basals and boluses) of insulin
- **Basal** – background insulin released slowly through the day
- **Bolus** – a quick release of insulin – Carb boluses cover carbs and Correction boluses lower high readings
- **Bolus Calculator (BC)** – what calculates bolus recommendations
- **Correction Target** – the BG aimed for with correction bolus
- **Bolus On Board (BOB)** – bolus insulin still active from recent boluses, active insulin, insulin on board
- **Duration of Insulin Action (DIA)** – how long a bolus will lower the BG – used to measure BOB
Pump Advantages

- More reliable insulin action, better control, lower TDD
- Precise basal delivery – 0.05 u compared to 0.5 u
- Automatic dose calculations with accurate boluses
- Avoids common problem of insulin stacking
- Fewer missed/skipped doses
Why People Choose Them

- Convenience
- Better lifestyle
- Less hypoglycemia
- Improved sense of well being
- Flexible insulin delivery – exercise, skipping meals
- Less hassle and anxiety with erratic schedule, shiftwork, travel, time zones
Why Physicians Recommend Them

- Poor control, high A1c, wide BG excursions
- Nocturnal or frequent lows, hypo unawareness
- Frequent hospitalization/DKA
- Increased insulin sensitivity
- Varied or intense exercise/activity
- Dawn phenomenon, gastroparesis, pregnancy
- Varied work or school schedule, travel
- Insulin resistance, Type 2 diabetes, teens
Infusion Line Pumps

Accu-Chek Combo  Animas Ping  Medtronic Revel
Patch Pumps

Omnipod Eros
Valeritas V-Go
Calibra Finesse

Also: Medtronic

Accu-Chek Solo
Debiotech Jewel
Remote Controls

- Integrated glucose meter allows convenient testing
- Carb and correction boluses can be discreetly given
- Basal adjustments from some remotes
- Omnipod remote must be present to give boluses
# Pump plus CGM Options

<table>
<thead>
<tr>
<th>CGM:</th>
<th>Pump:</th>
<th>Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dexcom 4G</td>
<td>Animas</td>
<td>2013?</td>
</tr>
<tr>
<td></td>
<td>Tandem</td>
<td>2013?</td>
</tr>
<tr>
<td>Paradigm Enlight</td>
<td>Medtronic</td>
<td>Now</td>
</tr>
</tbody>
</table>
Glucose Management
ADA Glucose Guidelines

Therapeutic goals for glycemic control

- **Adults:**
  - Goal of therapy: <7.0% HbA1c
  - Action suggested: >8.0% HbA1c

- **Pediatric patients:**
  - Toddlers and preschoolers: <8.5% (but >7.5%)
  - School age (6–12 years): <8%
  - Adolescents and young adults (13–19 years): <7.5%
Canadian/European Pediatric Guidelines

**Pediatric patients:**
- Toddlers and preschoolers: <8.5 % (but >7.5%)
- School age (6–12 years): <8.0%
- Adolescents and young adults (13–19 years): <7.0%

**Internat. Society for Pediatric & Adolescent Diabetes:**
- Everyone: <7.5%, close to 7% without problematic hypos
Tips –
Dose For Success

1. Stop lows first
2. Find an iTDD – for normal, stable BGs
3. Set & test basals – keeps overnight readings level
4. Set & test CarbF – fine-tune premeal BGs
5. Lower post meal BGs – bolus early, low GI foods, Symlin, etc.
6. Set & test CorrF – to bring highs down safely

Enjoy good control or return to #1

Brittle diabetes or frequent highs? Usually = the wrong settings!
Don’t Compound Errors

Each error **MAGNIFIES** the total dosing error!

Eliminate errors:

**In the Pump:**
- Basal rates
- CarbF
- CorrF
- DIA/insulin stacking
- Correction target
- Meter accuracy

**By the Wearer:**
- Carb counts
- Glucose monitoring
- Accounting for BOB
- Adjustments for activity, menses, stress, pain, etc.
The “Other Things” Needed

- Check glucose 6 x a day or wear a CGM
- Use the bolus calculator for all boluses
- Cover all carbs with a bolus before eating, unless there’s a good reason not to
- When low, don’t over-treat with carbs
- When high, don’t over-treat with insulin
- Don’t give blind boluses
The Actual Pump Practices Study

In the APP Study, we looked retrospectively at over a thousand pump wearers across the U.S. to find:

- How pumps are actually used and
- What influences success
APP Study Background

- Data from Deltec Cozmo insulin pumps were downloaded during a routine software upgrade in 2007.
- 396 pumps had BG values directly entered from an attached CozMonitor Freestyle meter were chosen.
- These pumps averaged over 73 days of data and over 300 glucose tests per pump.
- Pumps were divided into thirds by average glucose.

APP Study

- Two types of results
  - Typical behaviors of all pumpers
  - Behaviors and data from third with lowest avg. BG

- Basal %, CarbF and CorrF formulas were derived from the third with the lowest avg. BG

- 92.7% of pump wearers used the BC to cover carbs (> 2 meals a day)

- 96.5% used the BC to correct high readings

The CarbF and CorrF are inversely related to glucose. That is, when the avg. glucose is high, these factors are lowered, and vice versa.
# APP Study – BGs and Basal Rates

<table>
<thead>
<tr>
<th>Glucose, Insulin and Carb Data</th>
<th>Group: All 396 Pumps</th>
<th>Low Third</th>
<th>Mid Third</th>
<th>High Third</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. Meter BG</td>
<td>184 mg/dL 10.2 mmol/L</td>
<td>144 mg/dL 8.0 mmol/L</td>
<td>181 mg/dL 10.0 mmol/L</td>
<td>227 mg/dL 12.6 mmol/L</td>
</tr>
<tr>
<td>BG Tests/Day</td>
<td>4.38</td>
<td>4.73</td>
<td>4.41</td>
<td>4.01</td>
</tr>
<tr>
<td>TDD</td>
<td>49.4</td>
<td>47.9</td>
<td>49.1</td>
<td>51.1</td>
</tr>
<tr>
<td>Basal %</td>
<td>47.6%</td>
<td>47.6%</td>
<td>47.2%</td>
<td>47.8%</td>
</tr>
</tbody>
</table>

APP Study – Carb Boluses and CarbFs

<table>
<thead>
<tr>
<th>Glucose, Insulin and Carb Data</th>
<th>All 396 Pumps</th>
<th>Low Third</th>
<th>Mid Third</th>
<th>High Third</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. Meter BG</td>
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<td>144 mg/dL 8.0 mmol/L</td>
<td>181 mg/dL 10.0 mmol/L</td>
<td>227 mg/dL 12.6 mmol/L</td>
</tr>
<tr>
<td>CarbBolus U/d</td>
<td>20.4 u</td>
<td>20.9 u</td>
<td>20.4 u</td>
<td>19.8 u</td>
</tr>
<tr>
<td>CarbBolus/Day</td>
<td>4.14</td>
<td>4.07</td>
<td>4.20</td>
<td>4.14</td>
</tr>
<tr>
<td>CarbGram/Day</td>
<td>189.9</td>
<td>185.2</td>
<td>196.3</td>
<td>187.9</td>
</tr>
<tr>
<td>CarbF</td>
<td>11.4</td>
<td>10.8</td>
<td>12.2</td>
<td>11.2</td>
</tr>
</tbody>
</table>

APP Study – How Much More Insulin Is Needed?

<table>
<thead>
<tr>
<th>Insulin Use In The APP Study</th>
<th>All 396 Pumps</th>
<th>Low Third</th>
<th>Mid Third</th>
<th>High Third</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. Meter BG</td>
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<td>144 mg/dL 8.0 mmol/L</td>
<td>181 mg/dL 10.0 mmol/L</td>
<td>227 mg/dL 12.6 mmol/L</td>
</tr>
<tr>
<td>TDD (u/day)</td>
<td>49.4 u</td>
<td>47.9 u</td>
<td>49.1 u</td>
<td>51.1 u</td>
</tr>
<tr>
<td>Improved iTDD</td>
<td>52.7 u</td>
<td>–</td>
<td>52.1 u</td>
<td>58.2 u</td>
</tr>
<tr>
<td>Extra units</td>
<td>+ 3.3 u</td>
<td>–</td>
<td>+ 3.0 u</td>
<td>+ 7.1 u</td>
</tr>
</tbody>
</table>

Add 1% to the TDD for each 0.3 mmol/L * drop in average glucose.

Use 7.8 mmol/L (140 mg/dl) as target glucose, unless there are other factors, like pregnancy, living alone, or hypoglycemia unawareness

* Or 1% for each 6 mg/dl
APP Study –
Correction Bolus, CorrF

<table>
<thead>
<tr>
<th>Correction Doses</th>
<th>All 396 Pumps</th>
<th>Low Third</th>
<th>Mid Third</th>
<th>High Third</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. Meter BG</td>
<td>184 mg/dL</td>
<td>144 mg/dL</td>
<td>181 mg/dL</td>
<td>227 mg/dL</td>
</tr>
<tr>
<td></td>
<td>10.2 mmol/L</td>
<td>8.0 mmol/L</td>
<td>10.0 mmol/L</td>
<td>12.6 mmol/L</td>
</tr>
<tr>
<td>CorrBoluses/d</td>
<td>2.12</td>
<td>1.92</td>
<td>2.10</td>
<td>2.35</td>
</tr>
<tr>
<td>CorrBolus U/d</td>
<td>5.59 u</td>
<td>4.18 u</td>
<td>5.57 u</td>
<td>7.03 u</td>
</tr>
<tr>
<td>CorrBolus %</td>
<td>11.6%</td>
<td>9.0%</td>
<td>11.6%</td>
<td>14.2%</td>
</tr>
<tr>
<td>CorrF</td>
<td>55.7</td>
<td>53.6</td>
<td>61.1</td>
<td>52.5</td>
</tr>
<tr>
<td>CorrF x TDD</td>
<td>2160</td>
<td>1960</td>
<td>2360</td>
<td>2330</td>
</tr>
</tbody>
</table>

APP Study – Unexpected Results

- Basals averaged 48% in low, medium, and high glucose groups – no impact on glucose outcomes
- No difference in grams of carb eaten or number of carb boluses and correction boluses given per day
- Glucose tests per day showed “significance” but had no meaningful impact on glucose outcomes – the high BG group tested BGs almost as often as low
- Occlusions significantly raised avg BG
- Those with highest BGs used MORE insulin → they either need more insulin OR need to stop losing it

APP Study – Major Finding

- Find an accurate TDD
- Then get pump settings from it

Pattern management starts after TDD is accurate.
APP Study – 
Pump Setting Formulas¹

**Basal** = ∼ 48% of TDD

\[
\text{CarbF} = 5.7 \times \frac{Wt(kg)}{TDD} \quad \text{or} \quad 2.6 \times \frac{Wt(lbs)}{TDD}
\]

**Corr. Factor** = 110/TDD (mmol/L) or 2000/TDD (mg/dl)

The correction factor is inversely related to TDD and to avg. BG

Or use the Pump Settings Tool at
www.diabetesnet.com/diabetes_tools/pumpsettings/

*Lower this CorrF number for higher avg BGs

APP Study –
The Doses that Successful Pumpers Use

Insulin use in the third (132 pumps) with the lowest average glucose in APP Study

### 2. Optimal Insulin Use

<table>
<thead>
<tr>
<th>Insulin Source</th>
<th>% of TDD</th>
<th>Interquartile Range (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basal</td>
<td>47.8%</td>
<td>39.6% to 54.9%</td>
</tr>
<tr>
<td>Carb Boluses</td>
<td>43.1%</td>
<td>35.6% to 51.2%</td>
</tr>
<tr>
<td>Corr Boluses</td>
<td>9.0%</td>
<td>6.2% to 11.3%</td>
</tr>
</tbody>
</table>

CorrF Rule Number* = 1960 mg/dl per unit (IQR = 1413 to 2151)

* CorrF Rule Number = Avg CorrF x Avg TDD

Tuning the Bolus Calculator

The BC helps user find bolus recommendations that better match carb intake and the current glucose while minimizing insulin stacking.
## Bolus Calculator Settings

<table>
<thead>
<tr>
<th>This Setting</th>
<th>Assists</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basal rates</td>
<td>Safe sleep (~50% of TDD)</td>
</tr>
<tr>
<td>CarbF or I:C ratio</td>
<td>Cover carbs well</td>
</tr>
<tr>
<td>CorrF or ISF</td>
<td>Lower highs safely</td>
</tr>
<tr>
<td>Target glucose</td>
<td>Correct to specific goal</td>
</tr>
<tr>
<td>DIA</td>
<td>Accurately measure IOB to minimize insulin stacking</td>
</tr>
</tbody>
</table>

**Average TDD** – controls the frequency of low and high gluoses  
**BOB (IOB, active insulin)** – units of glucose lowering activity left from recent boluses
Bolus Calculator

Input: Current glucose  Grams of carb

Output: A recommended bolus with display of units for carbs, correction (if any), and remaining IOB (if any)
Set Correction Target with Care

Where In Correction Target Range Does The Pump Aim?

<table>
<thead>
<tr>
<th></th>
<th>BGs inside target range are <em>not corrected</em>.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animals, Omnipod</td>
<td>Middle</td>
</tr>
<tr>
<td>Medtronic</td>
<td>Top or Bottom</td>
</tr>
<tr>
<td>Tandem</td>
<td>3.9 mmol/L (70 mg/dl)</td>
</tr>
</tbody>
</table>

Bottom Line: Use a single correction target (ie, 110 mg/dl or 6.1 mmol/L), OR a narrow correction range (ie, 100-120 mg/dl or 5.6-6.7 mmol/L).

*
Size Up the Glucose Problem

- If it ain’t broke, don’t fix it!

- **Severe** – Reset the TDD to an improved TDD (iTDD) to correct problem and select new settings from this iTDD.

- **Moderate** – Reset to an iTDD if needed, and use pattern management to fine tune doses and pump settings

- **Mild** – tweak pump settings
Adjust the TDD to an Improved TDD (iTDD)

iTDD = TDD (avg. of basal + all boluses, 10-30 d)

1. Lowered by 5% to 10% for:
   - Frequent lows, OR for highs and lows IF lows come first

   o Raised with the iTDD Table for high A1c or high meter average with few lows, OR increase TDD by 1% for each 0.33 mmol/L (6 mg/dl) drop desired in avg BG

Avg BG on pumps is 184 mg/dl (10.2 mmol) – most need larger TDD.
Critical Pump Data – Avg. TDD and Basal/Bolus Balance

TDD = 35.19 u

Basal % is low at 36%

2 grams of carb/day means bolus calculator is not used
Find the Current TDD

<table>
<thead>
<tr>
<th>Statistics</th>
<th>5/3 - 5/16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg BG (mmol/L)</td>
<td>12.3 ± 5.0</td>
</tr>
<tr>
<td>BG Readings</td>
<td>86</td>
</tr>
<tr>
<td>Readings Above Target</td>
<td>66</td>
</tr>
<tr>
<td>Readings Below Target</td>
<td>2</td>
</tr>
<tr>
<td>Sensor Avg (mmol/L)</td>
<td>10.3 ± 3.7</td>
</tr>
<tr>
<td>Avg AUC &gt; 7.8 (mmol/L)</td>
<td>2.94</td>
</tr>
<tr>
<td>Avg AUC &lt; 3.9 (mmol/L)</td>
<td>0.01</td>
</tr>
<tr>
<td>Avg Daily Carbs (g)</td>
<td>101 ± 39</td>
</tr>
<tr>
<td>Carbs/Bolus Insulin (g/U)</td>
<td>6.8</td>
</tr>
<tr>
<td>Avg Total Daily Insulin (U)</td>
<td>35.5 ± 5.5</td>
</tr>
<tr>
<td>Avg Daily Basal (U)</td>
<td>20.8</td>
</tr>
<tr>
<td>Avg Daily Bolus (U)</td>
<td>14.8</td>
</tr>
</tbody>
</table>

With an avg BG of 12.3 mmol/L (221 mg/dl), the **TDD** of 35.5 u is too low. **Basal %** is OK (or slightly high) at 58%.
Stop Frequent Lows –

- *You cannot tell how much excess insulin there is!*

- Start with a 5% or 10% reduction in the TDD

- Compare the current TDD to an “ideal” TDD for weight.
  - Divide weight (kgs) by 1.8 to see what TDD would use if they have an average sensitivity to insulin

**Example:** Someone who weighs 72 kg would be expected to have a TDD of 40 units (72/1.8 = 4.0).
Example – Hypoglycemia

41 yo female with A1c = 6.9%

156lb/4 = 38.0 u/d

Actual TDD = 50.5 u/d
Not All Lows Show Up On a BG Meter

This person felt low, ate, but never tested with a meter. There is no record of these lows without the CGM!
What To Do?

70 mg/dl (3.9 mmol)

~ 2 Lows-to-Highs per day

Frequent lows → lower the average TDD
Clever Pump Trick – How Many Carbs for a Low?

1. 10 grams for each 35 kg or 80 lb of weight
2. **PLUS** grams = current BOB* \( \times \) CarbF

Example:

- Amy weighs 70 kg (20 grams of carb)
- And she has 2 units of BOB with a CarbF of 8 grams/unit
  \[ 2 \text{u} \times 8 \text{g/u} = 16 \text{ grams} \]
- So, for the low she needs:
  \[ 20 \text{g} + 16 \text{g} = 36 \text{ grams} \]

Add extra carbs as needed for recent or planned exercise.

* *To get an accurate BOB, the pump’s DIA time setting must be accurate.*
Stop Frequent Highs –

When average BG is high with few lows:

**Raise TDD by 1% to lower the average glucose by 0.33 mmol/L (6 mg/dl) or the A1c by 0.2%**

**Example:** Amy’s avg TDD is 40 u/day, avg BG is 12 mmol/L (217 mg/dl) with few lows, and her BG goal is 8 mmol/L (145 mg/dl):

\[
12 \text{ mmol/L} - 8 \text{ mmol/L} = 4 \text{ mmol/L}
\]

\[
4 \text{ mmol/L} \div 0.33 = 12\% \text{ rise needed in TDD}
\]

\[
40 \text{ units} \times 1.12 = 44.8 \text{ units}
\]
What To Do?
What To Do?

Hourly Statistics from 12/11/2009 12:00 AM to 12/19/2009
Highs And Lows – With A Pattern

5 day average:
Avg BG: 11.3 (203)
Range: 2.2 to 22.3 (39 to 401)
SD: 89.9

Frequent lows and highs → needs slightly higher average TDD with either a lower night basal or smaller correction boluses at night

Low BGs between 5 am and 7 am

Highly variable
The iTDD Table For High Avg. BGs

For frequent highs and few lows, this table suggests how much to increase the current TDD from meter 14 day average BG or a recent A1c.

<table>
<thead>
<tr>
<th>Your New Improved TDD (ITDD)</th>
<th>155 (8.6)</th>
<th>169 (9.4)</th>
<th>183 (10.2)</th>
<th>197 (10.9)</th>
<th>212 (11.8)</th>
<th>226 (12.6)</th>
<th>240 (13.3)</th>
<th>255 (14.2)</th>
<th>269 (14.9)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A1c</strong></td>
<td>7.0</td>
<td>7.5</td>
<td>8.0</td>
<td>8.5</td>
<td>9.0</td>
<td>9.5</td>
<td>10.0</td>
<td>10.5</td>
<td>11.0</td>
</tr>
<tr>
<td>15 u</td>
<td>15.3</td>
<td>15.6</td>
<td>16.0</td>
<td>16.3</td>
<td>16.7</td>
<td>17.0</td>
<td>17.4</td>
<td>17.8</td>
<td>18.1</td>
</tr>
<tr>
<td>20 u</td>
<td>20.3</td>
<td>20.8</td>
<td>21.3</td>
<td>21.7</td>
<td>22.2</td>
<td>22.7</td>
<td>23.2</td>
<td>23.7</td>
<td>24.1</td>
</tr>
<tr>
<td>25 u</td>
<td>25.4</td>
<td>26.0</td>
<td>26.6</td>
<td>27.2</td>
<td>27.8</td>
<td>28.4</td>
<td>29.0</td>
<td>29.6</td>
<td>30.2</td>
</tr>
<tr>
<td>30 u</td>
<td>30.5</td>
<td>31.2</td>
<td>31.9</td>
<td>32.6</td>
<td>33.4</td>
<td>34.1</td>
<td>34.8</td>
<td>35.5</td>
<td>36.2</td>
</tr>
<tr>
<td>35 u</td>
<td>35.6</td>
<td>36.4</td>
<td>37.2</td>
<td>38.0</td>
<td>38.9</td>
<td>39.7</td>
<td>40.5</td>
<td>41.4</td>
<td>42.2</td>
</tr>
<tr>
<td>40 u</td>
<td>40.7</td>
<td>41.6</td>
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<td>43.5</td>
<td>44.5</td>
<td>45.4</td>
<td>46.3</td>
<td>47.3</td>
<td>48.3</td>
</tr>
<tr>
<td>45 u</td>
<td>45.8</td>
<td>46.8</td>
<td>47.9</td>
<td>48.9</td>
<td>50.0</td>
<td>51.1</td>
<td>52.1</td>
<td>53.3</td>
<td>54.3</td>
</tr>
<tr>
<td>50 u</td>
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<td>52.0</td>
<td>53.2</td>
<td>54.3</td>
<td>55.6</td>
<td>56.8</td>
<td>57.9</td>
<td>59.2</td>
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</tr>
<tr>
<td>55 u</td>
<td>55.9</td>
<td>57.2</td>
<td>58.5</td>
<td>59.8</td>
<td>61.1</td>
<td>62.4</td>
<td>63.7</td>
<td>65.1</td>
<td>66.4</td>
</tr>
<tr>
<td>60 u</td>
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<td>62.4</td>
<td>63.8</td>
<td>65.2</td>
<td>66.7</td>
<td>68.1</td>
<td>69.5</td>
<td>71.0</td>
<td>72.4</td>
</tr>
<tr>
<td>65 u</td>
<td>66.1</td>
<td>67.6</td>
<td>69.1</td>
<td>70.6</td>
<td>72.3</td>
<td>73.8</td>
<td>75.3</td>
<td>76.9</td>
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<tr>
<td>70 u</td>
<td>71.2</td>
<td>72.8</td>
<td>74.4</td>
<td>76.1</td>
<td>77.8</td>
<td>79.5</td>
<td>81.1</td>
<td>82.8</td>
<td>84.5</td>
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<tr>
<td>75 u</td>
<td>76.3</td>
<td>78.0</td>
<td>79.8</td>
<td>81.5</td>
<td>83.4</td>
<td>85.1</td>
<td>86.9</td>
<td>88.8</td>
<td>90.5</td>
</tr>
<tr>
<td>80 u</td>
<td>81.3</td>
<td>83.2</td>
<td>85.1</td>
<td>86.9</td>
<td>88.9</td>
<td>90.8</td>
<td>92.7</td>
<td>94.7</td>
<td>96.5</td>
</tr>
<tr>
<td>85 u</td>
<td>86.4</td>
<td>88.4</td>
<td>90.4</td>
<td>92.4</td>
<td>94.5</td>
<td>96.5</td>
<td>98.5</td>
<td>100.6</td>
<td>102.6</td>
</tr>
<tr>
<td>90 u</td>
<td>91.5</td>
<td>93.6</td>
<td>95.7</td>
<td>97.8</td>
<td>100.1</td>
<td>102.2</td>
<td>104.3</td>
<td>106.5</td>
<td>108.6</td>
</tr>
<tr>
<td>95 u</td>
<td>96.6</td>
<td>98.8</td>
<td>101.0</td>
<td>103.2</td>
<td>105.6</td>
<td>107.8</td>
<td>110.0</td>
<td>112.4</td>
<td>114.6</td>
</tr>
<tr>
<td>100 u</td>
<td>101.7</td>
<td>104.0</td>
<td>106.3</td>
<td>108.7</td>
<td>111.2</td>
<td>113.5</td>
<td>115.8</td>
<td>118.3</td>
<td>120.7</td>
</tr>
</tbody>
</table>

Derived from the APP Study
© 2012 Diabetes Services, Inc.

J Walsh and R Roberts: 
Pumping Insulin (5th ed), 2012
BGs & TDD before & after Adjustment

Starting TDD = 36 u

- Raised basal by 0.05 u/hr all day (+1.2 u/day)
- Lowered carb factor from 1u/13g to 1u/12g (+1.8 u/day)

Ending TDD = 39 u
The TDD Must Change For:

- Frequent lows or frequent highs
- Going on or off a diet
- Loss or gain of weight
- Seasonal changes
- Change in activity or sports
- Vacation
- Growth spurts
- Puberty and menses

Don't wait until the next clinic visit!
## APP Study – Importance of the TDD

<table>
<thead>
<tr>
<th>Insulin Source</th>
<th>% of TDD</th>
<th>Interquartile Range (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basal</td>
<td>47.8%</td>
<td>39.6% to 54.9%</td>
</tr>
<tr>
<td>Carb Boluses</td>
<td>43.1%</td>
<td>35.6% to 51.2%</td>
</tr>
<tr>
<td>Corr Boluses</td>
<td>9.0%</td>
<td>6.2% to 11.3%</td>
</tr>
</tbody>
</table>

Insulin use in the third (132 pumps) with the lowest average glucose in APP Study


**2. Optimal Insulin Use**

Mean Values For Optimal Doses In Best Control Tertile

*CorrF Rule Number* = 1960 mg/dl per unit (IQR = 1413 to 2151)

* CorrF Rule Number = Avg CorrF x Avg TDD
Use the TDD to Find Pump Settings

<table>
<thead>
<tr>
<th>TDD or iTDD u/day</th>
<th>Basal 1 u/day</th>
<th>Basal u/hr</th>
<th>Carb Factor 2 in grams/u</th>
<th>CorrF 3 (mg/dl) / u</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>7.7</td>
<td>0.32</td>
<td>16.3 17.9 19.5 21.1 22.8</td>
<td>122</td>
</tr>
<tr>
<td>20</td>
<td>9.6</td>
<td>0.40</td>
<td>13.0 14.3 15.6 16.9 18.2</td>
<td>98.0</td>
</tr>
<tr>
<td>24</td>
<td>11.5</td>
<td>0.48</td>
<td>10.8 11.9 13.0 14.1 15.2</td>
<td>173</td>
</tr>
<tr>
<td>28</td>
<td>13.4</td>
<td>0.56</td>
<td>9.3 10.2 11.1 12.1 13.0</td>
<td>173</td>
</tr>
<tr>
<td>32</td>
<td>15.4</td>
<td>0.64</td>
<td>8.1 8.9 9.8 10.6 11.4</td>
<td>146</td>
</tr>
<tr>
<td>36</td>
<td>17.3</td>
<td>0.72</td>
<td>7.2 7.9 8.7 9.4 10.1</td>
<td>113</td>
</tr>
<tr>
<td>40</td>
<td>19.2</td>
<td>0.80</td>
<td>6.5 7.2 7.8 8.5 9.1</td>
<td>98.0</td>
</tr>
<tr>
<td>45</td>
<td>21.6</td>
<td>0.90</td>
<td>5.8 6.4 6.9 7.5 8.1</td>
<td>92.0</td>
</tr>
<tr>
<td>50</td>
<td>24.0</td>
<td>1.00</td>
<td>5.2 5.7 6.2 6.8 7.3</td>
<td>104</td>
</tr>
<tr>
<td>55</td>
<td>26.4</td>
<td>1.10</td>
<td>4.7 5.2 5.7 6.1 6.6</td>
<td>117</td>
</tr>
<tr>
<td>60</td>
<td>28.8</td>
<td>1.20</td>
<td>4.3 4.8 5.2 5.6 6.1</td>
<td>130</td>
</tr>
<tr>
<td>65</td>
<td>31.2</td>
<td>1.30</td>
<td>4.0 4.4 4.8 5.2 5.6</td>
<td>146</td>
</tr>
<tr>
<td>70</td>
<td>33.6</td>
<td>1.40</td>
<td>3.7 4.1 4.5 4.8 5.2</td>
<td>163</td>
</tr>
<tr>
<td>80</td>
<td>36.4</td>
<td>1.60</td>
<td>3.3 3.6 3.9 4.2 4.6</td>
<td>180</td>
</tr>
<tr>
<td>90</td>
<td>39.2</td>
<td>1.80</td>
<td>2.9 3.2 3.5 3.8 4.0</td>
<td>218</td>
</tr>
<tr>
<td>100</td>
<td>42.0</td>
<td>2.00</td>
<td>2.6 2.9 3.1 3.4 3.6</td>
<td>254</td>
</tr>
</tbody>
</table>

1 Basal = TDD x 0.48  
2 Carb Factor = 10.8 x insulin sensitivity = (2.6 x Wt (lb))/TDD  
3 Correction Factor = 1960/TDD

For exact calculations, use the Pump Setting Tool at opensourcendiabetes.org

J Walsh and R Roberts: Pumping Insulin (5th ed), 2012
APP Study –
Pump Setting Formulas

**Basal** = ~ 48% of TDD

**CarbF** = $5.7 \times \frac{\text{Wt(kg)}}{\text{TDD}}$ or $2.6 \times \frac{\text{Wt(lbs)}}{\text{TDD}}$

**Corr. Factor** = $110/\text{TDD}$ (mmol/L) or $1960/\text{TDD}$ (mg/dl)

The correction factor is inversely related to TDD and to avg. BG

Or use the Pump Settings Tool at
www.diabetesnet.com/diabetes_tools/pumpsettings/

---

200 Unit or 300 Unit Reservoir?

- Most people change infusion sets every 2 to 3 days

- In the APP Study, 72% of pumpers (286 of 396) used less than 60 units of insulin a day (180 units over 3 days)

- Most people can use a 200 unit syringe
Basal Rates

Optimal basal rates keep the glucose flat in a desired range when fasting.

Must be accurate before CarbF and CorrF can be tested.

Raise (or lower) basal rates a couple of hours before the glucose begins to rise (or fall) and 4-8 hours before the high or low glucose you want to avoid.

More than 4 or 5 basal rates a day usually makes no sense.
How Many Basals?

Percentage of pumpers who use 1 to 10 basals per day from self reports of several hundred pumpers at insulin-pumpers.org

Basal changes take at least 3-5 hours to have their full effect* when basal rates are doubled, so >5 basals has dubious benefit

Pump Adjustments

Current Basal rate: 0.85 u/hr  ICR: 12  CorrF: 2.5

<table>
<thead>
<tr>
<th>Day</th>
<th>Breakfast</th>
<th>Lunch</th>
<th>Dinner</th>
<th>HS</th>
<th>2 am</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>9.2</td>
<td>7.2</td>
<td>6.5</td>
<td>7.0</td>
<td>7.1</td>
</tr>
<tr>
<td>Tuesday</td>
<td>10.1</td>
<td>6.9</td>
<td>5.2</td>
<td>6.2</td>
<td>6.0</td>
</tr>
<tr>
<td>Wednesday</td>
<td>9.6</td>
<td>7.9</td>
<td>6.5</td>
<td>7.4</td>
<td>6.8</td>
</tr>
</tbody>
</table>

Does this patient need a basal or bolus adjustment?

What time would you change the basal rate?

How much would you change the rate?
Overnight Basal Check

Lower basal 2 to 3 hrs before BG drop begins
BG drop starts here

4 mmol/L (70 mg/dl) drop in 4 hrs
Don’t Always Change One Setting!

- A pump user may change only basal rates or only CarbFs (or CorrF or DIA) to fix all control problems.
- This often throws off basal/carb bolus balance.
- Periodically review basal/carb bolus balance!
Clever Pump Trick – Never Stop A Pump!

- It’s too easy to not turn it back on
- It’s rarely needed
- It doesn’t help a low glucose until 60-90 min. later

Instead, use a temp basal reduction for 30 to 60 min so pump restarts on time with no followup highs.

For more than an hour off pump, give bolus to cover some missing basal, then disconnect (~4 hrs max).
Temp Basal Rates

- Temp basal reductions are great for physical activity
- Temp basal increases are great for illness, fever, menses
Carb Factor and Carb Boluses

CarbF = How many mmol/L (or mg/dl) one unit of insulin lowers the glucose.

CarbF = \( \frac{Wt(kg)}{5.7}\) or \( \frac{Wt(lb)}{2.6}\) TDD
Types of Carb Boluses

- **Regular**
  - Taken immediately – for most meals

- **Combo / dual wave**
  - Some now, some later – bean burrito, some pastas and pizzas, Symlin

- **Extended / square wave**
  - Extended over time – gastroparesis

Don’t take combo/extended boluses without a clear reason.
In APP Study, the carb factors were not evenly distributed. “Magic” numbers – like 5, 10, 15, and 20 g/unit – are preferred. Use formulas for settings -> much better than WAG!

Don’t use “magic” numbers!

Pump Adjustments

Current Basal rate: 0.85 u/hr  CarbF: 12  CorrF: 2.5

<table>
<thead>
<tr>
<th>Day</th>
<th>Breakfast</th>
<th>2 hr post</th>
<th>Lunch</th>
<th>2 hrs post</th>
<th>Dinner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>6.7</td>
<td>8.9</td>
<td>6.6</td>
<td>12.2</td>
<td>9.4</td>
</tr>
<tr>
<td>Tuesday</td>
<td>6.4</td>
<td>8.0</td>
<td>5.3</td>
<td>10.6</td>
<td>8.8</td>
</tr>
<tr>
<td>Wednesday</td>
<td>5.5</td>
<td>7.6</td>
<td>6.5</td>
<td>10.9</td>
<td>9.9</td>
</tr>
</tbody>
</table>

Does this patient need a basal or bolus adjustment?

At what meal would you change the CarbF?

How much would you change the CarbF?
CarbF Change = Large BG Change

When CarbF is lowered from 1/10 to 1/9 for TDD = 40 u and Corr F = 2.7 mmol/L per u

<table>
<thead>
<tr>
<th>Meal Size</th>
<th>Extra bolus u from CarbF</th>
<th>Fall in BG/meal *</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 grams</td>
<td>0.67u</td>
<td>x 2.7 = – 1.8 mmol/L</td>
</tr>
<tr>
<td>100 grams</td>
<td>1.1u</td>
<td>x 2.7 = – 3.0 mmol/L</td>
</tr>
</tbody>
</table>

* Calculated as \[
\left(\frac{\text{carbs in meal}}{\text{new carb factor}} - \frac{\text{carbs in meal}}{\text{old carb factor}}\right) \times \frac{110}{\text{TDD}}
\]
CarbF and CorrF Accuracy Is Important

- Do not use “magic” numbers for CarbFs and CorrFs
- Always use formulas to select the CarbF and CorrF
Pregnancy

BGs are relatively flat, but slightly high for pregnancy (red lines). A slightly higher day basal and lower carb factor may help.
Clever Pump Trick – Stop Post Meal Spikes

- Count carbs carefully
- Bolus 15 to 30 min before meals when possible
- Use combo bolus (part now/part later) with picky eaters
- When high, wait till below 8 mmol/L (144) before eating
- Eat low GI foods, fewer carbs
- Add fiber/psyllium/acarbose/Symlin/GLP-1 agonist
- Exercise after meals
- Use a Super Bolus
Carb Overload

Large carb meals (95 grams) cause postmeal spiking.
A lower CarbF cannot stop this!
Clever Pump Trick –
Super Bolus – Shift Basal To Bolus

Future: Super Bolus shifts part of the next 2 to 3.5 hrs of basal insulin into the bolus with less risk of a low later.¹,²

Helps when eating over 30 to 40 grams of carb

Max carbs/meal = Wt(lb) X 0.36 to stay in control ²

Clever Pump Trick –
Measure Insulin Sensitivity*

Insulin Sensitivity = $\frac{Wt(kg) \times 0.53}{TDD}$ or $\frac{Wt(lb) \times 0.24}{TDD}$

Or use www.diabetesnet.com/diabetes_tools/pumpsettings/

*NOT the correction factor (CorrF)
Correction Boluses

- These doses make up for deficits in basal rates or carb boluses
- Ideally, correction doses are $\leq 9\%$ of TDD
CorrF Formula

Corr. Factor = 110/TDD (mmol/L)
or 1960/TDD (mg/dl)

The CorrF is inversely related to TDD and to the A1c or the average BG

Or use the Pump Settings Tool at
www.diabetesnet.com/diabetes_tools/pumpsettings/

Secrets of the Correction Factor
Rule Number

- A 110 Rule (ie, 110 / TDD = CorrF for mmol/L, or 2000 / TDD = CorrF for mg/dl) works well for people in reasonable control
- Lower CarbF rule numbers (80 or 90 for mmol/L or 1500 or 1700 for mg/dl) are better when avg. BG is high due to larger deficits in basal or carb boluses
- Higher rule numbers (120 or 130 for mmol/L or 2200 or 2400 for mg/dl) are better when BGs are well controlled and there are smaller deficits in basal rates and carb boluses
Pump Adjustments

Basal: 0.85 u/hr  CarbF: 12  CorrF: 2.5  Target: 6.0  DIA: 5 hrs

<table>
<thead>
<tr>
<th>Day</th>
<th>10 pm</th>
<th>12 am</th>
<th>3 am</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>14.0 (4.0 units)</td>
<td>7.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Tuesday</td>
<td>16.0 (5.0 units)</td>
<td>8.0</td>
<td>2.8</td>
</tr>
</tbody>
</table>

1) What does this tell you about this patient’s CorrF?
2) How much does BG drop per unit of insulin?
3) How would you adjust the CorrF?
4) What if their DIA were set to 3 hrs?
Test the Correction Factor (and the DIA)

1. Clearout
   - No bolus for 5 hrs
   - No carbs for 3 hrs

2. Give correction bolus for a BG above 250 mg/dl (13.9 mmol)

3. Glucose near target BG by end of DIA time

4. NO LOWS for at least 5 hrs after bolus

CGM helps check both correction factor and DIA time
### Not All High Readings Are Identical

<table>
<thead>
<tr>
<th>Cause</th>
<th>Corr. Dose Needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Jelly on the finger</td>
<td>▪ None (wash, repeat test)</td>
</tr>
<tr>
<td>▪ Forgot to bolus</td>
<td>▪ Corr dose only</td>
</tr>
<tr>
<td>▪ Infusion set failure</td>
<td>▪ Corr + basal replacement</td>
</tr>
<tr>
<td>▪ Hypo rebound from release of stress hormones</td>
<td>▪ Corr + stress coverage</td>
</tr>
<tr>
<td>▪ Ketoacidosis or infection</td>
<td>▪ Raise TDD (basal and bolus) by 1.5 to 3 fold + corrections until resolution</td>
</tr>
</tbody>
</table>
The Correction Target

Where in the Correction Target Range Does the Pump Aim?

<table>
<thead>
<tr>
<th></th>
<th>Animas</th>
<th>Medtronic</th>
<th>Omnipod</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle</td>
<td>Top and</td>
<td>Middle</td>
<td></td>
</tr>
</tbody>
</table>

A glucose inside the correction target range will not be corrected.

For a range of 4-10 mmol/L (72 to 180 mg/dl), a BG of 4.1 or 9.9 (73 or 179 mg/dl) is not adjusted for.

Use a single correction target, like 6.1 mmol/L (110 mg/dl), or narrow correction range, like 5.6-6.7 mmol/L (100-120 mg/dl).
DIA, BOB, and Insulin Stacking

Duration Of Insulin Action (DIA)
How long a bolus lower the glucose

Bolus On Board (BOB)
Bolus insulin still active from recent boluses

Insulin Stacking
Buildup of active bolus insulin
Concerns about the Bolus Calculator

- Most boluses are given within 4.5 to 5 hours of each other and involve insulin stacking.

- The DIA has to be accurate to account for stacking – 4.25 to 6.25 hours.

- Most BCs calculate BOB well, but differ in how they subtract BOB to get a bolus recommendation.

All current BCs can recommend excessive bolus doses.
BOB Is Present In 65% Of Boluses

APP Study Results

Of 201,538 boluses, 65% were given within 4.5 hrs of a prior bolus

Insulin stacking is common in most boluses taken after breakfast

J. Walsh, D. Wroblewski, and TS Bailey: Disparate Bolus Recommendations In Insulin Pump Therapy. AACE Meeting 2007
Rapid insulin lowers the glucose for 4.5 to 6.5 hrs. This is physiologic – it DOES NOT CHANGE in the body when the DIA is changed in the pump!
## Typical Carb Digestion Times

<table>
<thead>
<tr>
<th>Food Digestion Time</th>
<th>Food Digestion Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>water</td>
<td>fish</td>
</tr>
<tr>
<td>0 m</td>
<td>30-60 m</td>
</tr>
<tr>
<td>fruit/veg juice</td>
<td>milk/cot cheese</td>
</tr>
<tr>
<td>5-20 m</td>
<td>90 m</td>
</tr>
<tr>
<td>fruit/veg salad</td>
<td>legumes/beans</td>
</tr>
<tr>
<td>20-40 m</td>
<td>2 hr</td>
</tr>
<tr>
<td>melons/oranges</td>
<td>egg</td>
</tr>
<tr>
<td>30 m</td>
<td>45 m</td>
</tr>
<tr>
<td>apples/pears</td>
<td>chicken</td>
</tr>
<tr>
<td>40 m</td>
<td>1.5-2 hr</td>
</tr>
<tr>
<td>broccoli/caulif</td>
<td>seeds/nuts</td>
</tr>
<tr>
<td>45 m</td>
<td>2.5-3 hr</td>
</tr>
<tr>
<td>raw carots/beets</td>
<td>beef/lamb</td>
</tr>
<tr>
<td>50 m</td>
<td>3-4 hr</td>
</tr>
<tr>
<td>potatoes/yams</td>
<td>cheese</td>
</tr>
<tr>
<td>60 m</td>
<td>4-5 hr</td>
</tr>
<tr>
<td>cornmeal/oats</td>
<td></td>
</tr>
<tr>
<td>90 m</td>
<td></td>
</tr>
</tbody>
</table>

**Take Home:** Choose combo foods to lengthen carb digestion time
Problem
Most Carbs Are Faster Than “Rapid” Insulin

An hour later, half of most meal’s glucose rise has occurred, but 80% of rapid insulin activity remains.

Time over which most meals affect the BG

% bolus activity remaining

Take Home:  Bolus 15 to 30 minutes before meals
Use extended and combo boluses sparingly

From Pumping Insulin
Clever Pump Trick – Bolus Early To Stop Meal Spiking

Figure shows Regular insulin injected 0, 30, or 60 min before a meal

Normal glucose and insulin profiles in the shaded areas

Even though, best glucose occurred with 60 minute bolus – too risky to recommend!!

Early boluses – the best-kept secret for better control

Pharmacodynamics starts when insulin is given (A) and ends when IV glucose infusion stops (C), but does not include time it takes for insulin to suppress or recover basal insulin output from a healthy pancreas.

Often quoted as “3 to 5 hours” in insulin handouts.

* Glucose infusion rate study

Adapted from Pumping Insulin, 5th ed
Duration of Insulin Action for Pumps
DIA – Needed to Give Accurate Boluses

**Fig. 3 Duration of Insulin Action (DIA)**

*DIA* is measured from the time a pump bolus is given (A) to when the bolus insulin action ends (D) while basal insulin is also given.

Adapted from Pumping Insulin, 5th ed
Does Dose Size Really Change DIA?

Traditional GIR studies make small insulin doses appear faster than they really are.

Don’t believe “insulin action time = 3 to 5 hrs”

Set DIA to 4.5 to 6.5 hrs to accurately calculate BOB and bolus doses

Bolus On Board (BOB)\(^1\)
Glucose-lowering activity remaining from recent boluses

An accurate BOB

- Reduces insulin stacking
- Improves bolus accuracy
- Reveals current carb or insulin deficit when BG test is done (HypoManager)

- **Depends on an accurate DIA**

*Basal insulin is NOT included in BOB!*

aka: insulin on board, active insulin, unused insulin*\(^1\)

\(^1\) Introduced as The Unused Insulin Rule in Pumping Insulin, 1st ed, 1989, Chap 12, pgs 70-73
BOB Is Present In 65% Of Boluses

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J. Walsh, D. Wroblewski, and TS Bailey: Disparate Bolus Recommendations In Insulin Pump Therapy. AACE Meeting 2007
# How Pumps Handle BOB

<table>
<thead>
<tr>
<th>What’s In BOB &amp; What’s It Applied Against?</th>
<th>BOB Includes this Bolus</th>
<th>BOB Is Subtracted from this Bolus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Carb</td>
<td>Correction</td>
</tr>
<tr>
<td>Injections</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Ideal</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Animas, Omnipod, Medtronic, Tandem</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

* Except when BG is below target BG

YES = Safer
Ping BOB Can Be Seen During Bolus

In this example, BOB of 4.35 u is larger than both corr bolus of 1.23 u AND carb bolus of 2.88 u.

More carbs may be needed!
Insulin Stacking

- Happens anytime two or more boluses overlap
- Measured in pump as bolus on board (BOB, IOB, active insulin)
- Used in new bolus calculation *once a glucose is entered*
- Impact of a bolus can’t be measured accurately against BG value until 90 to 120 minutes after it was given
- The safest way to minimize insulin stacking is to subtract BOB from correction bolus first, then from a carb bolus if there is BOB remaining
Insulin Stacking

Bedtime BG = 10 mmol/L (180 mg/dl) – is there an insulin or a carb deficit?
A Short DIA Hides Insulin Stacking

3 hours after a 10 unit bolus, this shows how much BOB a pump will think is left using different DIA times:

<table>
<thead>
<tr>
<th>For a DIA setting =</th>
<th>3 hr</th>
<th>4.5 hr</th>
<th>5.0 hr</th>
<th>5.5 hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated IOB =</td>
<td>0 u</td>
<td>2.5 u</td>
<td>3.4 u</td>
<td>4.0 u</td>
</tr>
</tbody>
</table>

Always set the DIA from an insulin’s real action time

*Do not change DIA to fix control problems*
Pump BCs May at Times Give Excess Bolus Recommendations

Two hours after dinner with 5 u of BOB left, a pump user eats a 50 gram dessert on 4 consecutive nights. Glucose and bolus recommendations are shown.

<table>
<thead>
<tr>
<th>Glucose</th>
<th>Actual Need</th>
<th>Animas</th>
<th>Other Pumps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Night 1: BG = 6.6 mmol/L</td>
<td>0 u</td>
<td>0 u</td>
<td>5 u</td>
</tr>
<tr>
<td>Night 2: BG = 6.8 mmol/L</td>
<td>0 u</td>
<td>5 u</td>
<td>5 u</td>
</tr>
<tr>
<td>Night 3: BG = 11.1 mmol/L</td>
<td>2 u</td>
<td>5 u</td>
<td>5 u</td>
</tr>
<tr>
<td>Night 4: BG = 16.7 mmol/L</td>
<td>4 u</td>
<td>5 u</td>
<td>5 u</td>
</tr>
</tbody>
</table>

CarbF = 10 gr/u; CorrF = 2.8 mmol/L; Target = 6.7; DIA = 5 hrs
What Would You Do?

Your daughter’s glucose is 6.7 mmol/L (121 mg/dl) at bedtime and she wants a 40 gram snack with 4 units of BOB.

CarbF = 10 g/u, CorrF = 3 mmol/L (54 mg/dl)
Target = 6.7 mmol/L (120 mg/dl)

Would you:

A. Cover her bedtime carbs with a 4.0 u bolus?
B. Give a smaller bolus for these carbs?
C. Give no carb bolus?
Example: Bolus Recommendations from 2 Different Pumps on One Morning

### Bolus Recommendation Differences between 2 Pumps

<table>
<thead>
<tr>
<th>Time</th>
<th>BG</th>
<th>Carbs Eaten</th>
<th>Carb Bolus</th>
<th>Pump X</th>
<th>Pump Y</th>
<th>Bolus Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>6:54 am</td>
<td>111 (6.2)</td>
<td>16</td>
<td>0</td>
<td>0 u</td>
<td>0 u</td>
<td>0 u</td>
</tr>
<tr>
<td>9:52 am</td>
<td>174 (9.7)</td>
<td>0</td>
<td>3.0 u *</td>
<td>4.3 u</td>
<td>4.3 u</td>
<td>0 u</td>
</tr>
<tr>
<td>10:35 am</td>
<td>140 (7.8)</td>
<td>50</td>
<td>5.0 u</td>
<td>5.0 u</td>
<td>2.15 u</td>
<td>+ 2.85 u</td>
</tr>
<tr>
<td>11:58 am</td>
<td>117 (6.5)</td>
<td>40</td>
<td>4.0 u</td>
<td>4.0 u</td>
<td>0.5 u</td>
<td>+ 3.5 u</td>
</tr>
<tr>
<td>1:12 pm</td>
<td>137 (7.6)</td>
<td>0</td>
<td>0</td>
<td>0 u</td>
<td>Eat 19 g</td>
<td></td>
</tr>
</tbody>
</table>

**6.35 more units recommended by Pump X in just 6 hours!**

TDD = 38 u, carb factor = 10 g/u, corr factor = 3.6 mmol/L (65 mg/dl)

3.6 mmol/L x 6.35 u = 22.9 mmol (413 mg/dl) fall in BG from Pump X’s advice
When to Override a Recommended Bolus

- A pump doesn’t know everything – override a bolus recommendation when the situation demands.

- Dr. Irl Hirsch suggests that about 25% of all bolus recommendations will be changed when the user knows what they’re doing.

- Look at the CGM’s trend arrow and check the BOB for guidance on overrides.
Clever Pump Trick –
Get Accurate Boluses

1. If BOB is SMALLER than the correction bolus, pump’s recommendation is CORRECT

2. If BOB is LARGER than the correction bolus, subtract BOB from the combined carb plus correction bolus

Example: Carb bolus = 4.0 u
Corr bolus = 1.0 u
BOB = 2.0 u  BOB larger than Corr bolus
Accurate bolus = 4 + 1 – 2 = 3 units
DIA Tips

- Research studies show that DIA times are NOT different between children and adults.

- If the pump does not “give enough bolus insulin”, do NOT shorten DIA to get larger boluses. Look for the real reason:
  - a basal rate that is too low
  - or carb factor that is too high

- Some things do shorten insulin’s action time:
  - Increased activity and exercise
  - Hot weather

But don’t shorten DIA for occasional events
Infusion Sets

The Achilles Heel of Pumps
Average BG levels during 6 hr intervals before and after infusion set change in 396 pumps with ~20 infusion set changes/pump.

Unpublished data from Actual Pump Practices Study by J Walsh, R Roberts, and T Bailey
Why Infusion Sets & Patch Pumps Fail

Infusion sets fail from:

- Partial or complete pullout
- Tugging (unanchored sets)
- Leaks along Teflon to skin (common)
- Loose hub
- Use of auto-inserter
- Pets & punctures
- Occlusions
Is There an Infusion Set Problem? Ask:

- Do sites often “go bad”?
- Told you have “scarring” or “poor absorption”?
- Two or more “unexplained” highs in a row?
- Do highs correct when the infusion set is changed?
- Does this happen more than once a year?

*If the answer is yes:*

- Anchor the infusion line with tape
- Review site prep technique
- Switch to a different brand of infusion set
Infusion Set Failure Shown On CGM

DIA = 5 hrs or more

Alert for rising BG. Took 1st "bolus"

2nd rising BG, BG test. Found set detached
Took "2nd" corr. bolus after set replaced
Use Reliable Infusion Sets

ALWAYS anchor the Comfort infusion line with 1” tape to minimize site irritation and reduce tugging that can cause leaks.
Anchors – Not Just For Boats!!!

1” tape on infusion line:

• Stops movement of Teflon under the skin
• Stops “unexplained highs” from insulin leaks to skin surface
• Less irritation
• Prevents pull outs
• Tugs on Teflon

Lose tape not insulin!

No anchor!
Set Failure

Infusion set problem started on the afternoon of May 1\textsuperscript{st} and lasted until late in the day on the 2\textsuperscript{nd} when the infusion set was finally changed.
Is There an Infusion Set Problem? Ask:

- Do sites often “go bad”?
- Have “scarring” or “poor absorption”?
- Two or more “unexplained” highs in a row?
- Do highs correct when the infusion set is changed?
- Does this happen more than once a year?

*If the answer is yes:*

- Anchor the infusion line with tape
- Review site prep technique
- Switch to a different brand of infusion set
# Infusion Set Failure – Patrice

## Breakfast
- 5 AM: 12.8
- 6 AM: 11
- 7 AM: 7.7
- 8 AM: 8.5
- 9 AM: 0.5
- 10 AM: 7.1
- 11 AM: 14.4
- 12 PM: 16

## Lunch
- 1 PM: 9.9
- 2 PM: 9.3
- 3 PM: 12.8
- 4 PM: 16.3
- 5 PM: 20
- 6 PM: 2.5
- 7 PM: 1.9
- 8 PM: 2.6
- 9 PM: 4.8
- 10 PM: 8.4

## Dinner
- 11 PM: 11.8

## Daily Totals
- Average (6): 12.2mmol/L
- Carbs: 76g
- Insulin: 34.3U Bolus: 38%
- Average (6): 8.5mmol/L
- Carbs: 35g
- Insulin: 26.3U Bolus: 19%
- Average (10): 18.4mmol/L
- Carbs: 106g
- Insulin: 43.7U Bolus: 52%
- Average (4): 8.9mmol/L
- Carbs: 80g
- Insulin: 30.9U Bolus: 31%

## Graphs
- Lunch: 11.3
- Dinner: 11.8
- Graphs showing glucose levels over time with high peaks between 19.1 and 22.2.
## APP – Occlusions
Worsen Control

<table>
<thead>
<tr>
<th>BG Tertile</th>
<th>Low</th>
<th>Middle</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Avg BG</strong></td>
<td>144 mg/dL</td>
<td>181 mg/dL</td>
<td>227 mg/dL</td>
</tr>
<tr>
<td></td>
<td>8.0 mmol/L</td>
<td>10.0 mmol/L</td>
<td>12.6 mmol/L</td>
</tr>
<tr>
<td>Blocks/Month</td>
<td>1.36</td>
<td>3.04</td>
<td>3.57</td>
</tr>
</tbody>
</table>
Occlusions / Blockages

Should not happen!
More than once a month?

- Change infusion set type
- Or brand of insulin (rare)
Cost Savings on Tight Budgets

- Savings are derived from longer use of infusion sets
- Evaluate risks versus rewards first
- Staph carriers have a higher risk for infection – identify these individuals by history of ANY skin infection
- Emphasize sterile technique with extended use
- Anchor the infusion line to reduce irritation and loss
- Use lower cost metal infusion sets
- Avoid auto-inserters (close to 10% failure)
Continuous Glucose Monitors

The Next Step toward Total Control
CGM by Jackson Pollack

One Pollack painting sold for $140 million in 1996!
Make Your Own Jackson Pollack

Create your own Pollack – Only $1,000!
Not All BGs Are Equal!

Level of a BG’s risk depends on its trend

Greater Risk Going Down

Less Risk Going Up

3.6 mmol/L

Glucose (mg/dl)

Minutes

Less Risk

Going Up

Greater Risk

Going Down
CGM Screen Information

- **Glucose value** – updated every 5 min
- **Trend line** – direction of glucose change
- **Trend arrow** – rate of change: one arrow = 3.3 to 6.7 mmol/L, two arrows = 6.7 to 10 mmol/L
- **Alerts**
  - High and low thresholds
  - Prediction
Where To Set Starting CGM Alerts

**LOW:** 4.4 mmol/L (80 mg/dl)
Less than 4.4 in pregnancy
Higher for young children, high risk jobs

**HIGH:** 11.1 mmol/L (200 mg/dl) to start
Gradually lower to 10, 8.9, 7.8
The lower the high alert is, the earlier the wearer gets alerted to a rising BG

Trends And Predictions

- Help minimize highs and lows
- Great for:
  - Driving
  - Sports
  - Basal tests
  - Reducing uncertainty
  - Overriding bolus recommendations
Analyze Last Bolus On CGM

<table>
<thead>
<tr>
<th>Carbs + BG</th>
<th>Insulin/Carbs in last 5 hrs:</th>
</tr>
</thead>
<tbody>
<tr>
<td>High, low, or normal</td>
<td>Too Low: Bolus too large</td>
</tr>
<tr>
<td></td>
<td>In Target: Bolus in balance</td>
</tr>
<tr>
<td></td>
<td>Too High: Bolus too small</td>
</tr>
</tbody>
</table>

If BG 4-5 hrs later is:

- Too High: Bolus too small
- In Target: Bolus in balance
- Too Low: Bolus too large

This assumes that the basal rates are appropriate!
CGM Calibration Tips

- Use a **VERY** accurate meter
- Use good technique – clean fingers, no expired strips, enter reading right away
- Follow manufacturer’s instructions
- Calibrate up to 4 times a day when the glucose is flat (no arrows)
Verify CGM with Fingerstick

- For the first 12 to 24 hours
- When readings differ by 1.7 mmol/L (30 mg/dl) or more
- If CGM readings are erratic or don’t seem right
- Before driving
- If CGM remains low 20 or more min. after treating low
- When MAD (mean absolute difference) is above 20%
- Before treating unexplained highs
Adjust Boluses For the BG, the Trend, and the BOB

- **BG Stable:**
  Usual Bolus Dose

- **BG Rising Gradually:**
  ↑ bolus 10%

- **BG Rising Sharply:**
  ↑ bolus 20%

- **BG Dropping Gradually:**
  ↓ bolus 10%

- **BG Dropping Sharply:**
  ↓ bolus 20%
CGM As Behavior Mod Tool: A Chef’s First Two Days On CGM

Chef with Type 1 diabetes for 13 years on insulin pump
Chef’s CGM Next Two Days

Chefs can eat anytime they want – Result: micro-carbing with excellent readings!
An Ideal Pump
Long-Lasting Implanted CGMs

- Few disposables
- Minor surgery
- Funded as rental?

Dexcom G1 2004

Sensors For Medicine

MicroCHIPS Illume

GlySens
CGM – Implanted Fluorescent Molecules

- Molecules fluoresce & change color as glucose rises or falls
  - Small size, low power, low cost, long life, great accuracy
  - Dual fluorescent chambers for low and high BGs

*From Y. J. Heo et al: Institute of Industrial Science at the University of Tokyo*
CGM Tips

- Wear the CGM at least 90% of the time
- Look at the monitor 10-20 times per day
- Look at trends not just individual values!
- Don’t over-react to data – Avoid frequent between meal corrections until pattern is clear
- A rapid rise usually means more insulin needed, BUT check BOB first!
- Lag times are longest when the glucose is changing direction from down to up or up to down
- Calibrate!
CareLink® 3.0 Online Reports

Sensor daily overlay

Sensor results by meal
Future Pump Features

- Show How A Setting Change Will Impact TDD & BG
- Temp Basal + Bolus Doses
- Super Bolus
- Meal Size Boluses
- Excess BOB Alert (bolusing without BG but ++BOB)
- Low BG Predictor Using Meter (HypoManager)
- Exercise Compensator
- Infusion Set Monitor – Leak Detector
- Automated Bolus and Basal Testing
References


References


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