Glucose Management and the Actual Pump Practices Study

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Disclosure

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What We’ll Cover

- Glucose Management Overview – In Part 1
- Actual Pump Practices Study Results – In Part 1
- Bolus Calculator Settings – Part 2
- BOB, DIA, and Insulin Stacking – Part 3
- Infusion Set Issues – Part 4
- CGMs for Better Control – Part 5

Terms

- TDD – total daily dose (all basal and boluses) of insulin
- Basal – background insulin released slowly throughout 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

Glucose Management

...
Dose For Success

1. Stop lows first
2. Find an improved TDD – gives 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, GLP-1 agonists, Symlin, acarbose, etc.
6. Set & test CorrF – bring highs down safely

Enjoy good control or return to #1

Brittle diabetes or frequent highs usually = wrong settings

Don’t Compound Errors

Every error in settings or action MAGNIFIES the total dosing error!

Settings:
- Basal rates
- CarbF
- CorrF
- DIA/insulin stacking
- Correction target
- Meter accuracy

Actions:
- Carb counts
- Glucose monitoring
- Activity
- Menses, stress, pain, etc.
- Accounting for BOB

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

Size Up the Glucose Problem

- If it ain’t broke, don’t fix it!
- Severe – An improved TDD (iTDD) will correct most major glucose problems once new settings are selected from the iTDD
- Moderate – use pattern management to fine tune doses and pump settings
- Mild – tweak pump settings

Therapy Guides

- TDD – Raise for frequent highs or high A1c
  Lower for frequent lows or frequent lows and highs
- Basal/Bolus Balance – about 50% of TDD
- Corr Factor = 109/TDD (mmol/L) or 1960/TDD (mg/dl)
- Correction Bolus % – if over 9% of TDD, move excess into basals or carb boluses
- Average BG – < 160 when checking before & after meals,
  < 140 when checking mainly before meals
- Standard Deviation – Keep less than 1/3 of avg BG

The Actual Pump Practices Study

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

Which Way Do You Adjust Settings?

### Which Way Do You Change Your Pump Settings?

<table>
<thead>
<tr>
<th>If you are having:</th>
<th>Basal Rates</th>
<th>Carb Factor</th>
<th>Corr Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequent lows</td>
<td>↓</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Frequent highs</td>
<td>↑</td>
<td>↓</td>
<td>↓</td>
</tr>
</tbody>
</table>

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 – What We Found

<table>
<thead>
<tr>
<th>Glucose, Insulin and Carb Data</th>
<th>Group</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/10.2 mmol</td>
<td>144 mg/dl (8.0)</td>
<td>181 mg/dl (10.0)</td>
<td>227 mg/dl (12.6)</td>
<td></td>
</tr>
<tr>
<td>BG Tests/Day</td>
<td>4.38</td>
<td>4.73</td>
<td>4.41</td>
<td>4.01</td>
<td></td>
</tr>
<tr>
<td>TDD</td>
<td>49.4</td>
<td>47.9</td>
<td>49.1</td>
<td>51.1</td>
<td></td>
</tr>
<tr>
<td>Basal %</td>
<td>47.6%</td>
<td>47.6%</td>
<td>47.2%</td>
<td>47.8%</td>
<td></td>
</tr>
<tr>
<td>CarbBolus/Day</td>
<td>4.14</td>
<td>4.07</td>
<td>4.20</td>
<td>4.14</td>
<td></td>
</tr>
<tr>
<td>CarbGram/Day</td>
<td>189.9</td>
<td>185.2</td>
<td>196.3</td>
<td>187.9</td>
<td></td>
</tr>
<tr>
<td>CarbF</td>
<td>11.4</td>
<td>10.8</td>
<td>12.2</td>
<td>11.2</td>
<td></td>
</tr>
<tr>
<td>CorrBoluses/d</td>
<td>2.12</td>
<td>1.92</td>
<td>2.10</td>
<td>2.35</td>
<td></td>
</tr>
<tr>
<td>CorrBolus Std &amp;</td>
<td>5.59 u</td>
<td>4.18 u</td>
<td>5.57 u</td>
<td>7.03 u</td>
<td></td>
</tr>
<tr>
<td>CorrBolus %</td>
<td>11.6%</td>
<td>9.0%</td>
<td>11.6%</td>
<td>14.2%</td>
<td></td>
</tr>
<tr>
<td>CorF</td>
<td>55.7</td>
<td>53.6</td>
<td>61.1</td>
<td>52.5</td>
<td></td>
</tr>
<tr>
<td>CorrF x TDD</td>
<td>2160</td>
<td>1960</td>
<td>2360</td>
<td>2330</td>
<td></td>
</tr>
</tbody>
</table>


Unexpected APP Study Results

- Between low, medium, and high glucose groups:
  - Basal averaged 48% in each group and had no impact on glucose outcomes.
  - No difference in grams of carb eaten, or in the number of carb boluses and correction boluses given per day.
  - Glucose tests per day were “significant” but had no meaningful impact on glucose outcomes – the highest third tested their glucose almost as often.
  - Infusion set failures and occlusions significantly raised the average glucose.
  - The third with highest BG used MORE insulin – they either need more insulin OR they need to stop losing it.

APP Study – What Doses Did Successful Pumpers 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>30.6% to 54.9%</td>
</tr>
<tr>
<td>Carb Rebounds</td>
<td>43.1%</td>
<td>35.0% to 51.2%</td>
</tr>
<tr>
<td>Corr Rebounds</td>
<td>9.0%</td>
<td>6.2% to 11.3%</td>
</tr>
</tbody>
</table>

Corr Rule Number** = 1962 mg/dl per unit (IQR = 1413 to 2551)

*Corr Rule Number = Avg Corr x Avg TDD

APP Study – Pump Setting Formulas

 Basal = ~ 48% of TDD

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

 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/

The Bolus Calculator

Uses settings and logic to make carb and correction bolus recommendations that will match carbs eaten, safely lower high readings, and minimize insulin stacking.

To Set Up a Bolus Calculator, You Need

- The MAJOR factor that is an accurate TDD – adjusted for frequent lows or highs
- Accurate basals (~50% of TDD) – sound sleep
- An accurate CarbF – postmeal control
- An accurate CorrF – lower highs safely
- A glucose correction target or target range
- An accurate DIA – bolus accuracy, avoid stacking

Terms

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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 insulin stacking – 4.25 to 6.25 hours
- BCs calculate BOB well (except current U.S. Omnipod)
- BCs dramatically differ in how they subtract BOB to get a bolus recommendation

Adjust the TDD to an Improved TDD (iTDD)

$$iTDD = TDD \text{ adjusted for frequent lows or for avg. BG or A1c when lows are infrequent}$$

$$TDD = \text{total daily dose (basal + all boluses)}$$
Find the Current TDD in the Pump

\[ \text{TDD} = 35.19 \text{ u} \]

Basal % is low at 36%

2 grams of carb/day means Bolus Wizard is not being used

Utilities → Average TDD (10 to 30 days)
Or hit escape button from home screen.

Find the Current TDD in CareLink®

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%

When to Change To an iTDD and Why

1. For frequent lows, OR highs and lows WHEN the lows come first, lower the current TDD by 5% to 10%
   - With frequent lows, you cannot tell how much excess TDD there is!
2. For a high A1c or high avg. BG on a meter WITH FEW LOWS, raise the TDD, using the iTDD Table
3. This gives the improved TDD (iTDD)

The avg BG for pumps in the APP Study was 10.2 mmol (183.9 mg/dl) –
Most people on a pump need a larger TDD.

For Frequent Lows –

- You can't tell how much excess insulin there is!
- Start with a 5% or 10% reduction in the TDD
- Or:
  - Divide weight(kg) by 1.9, or weight(lb) by 4, to see what TDD they would use if they had a normal sensitivity to insulin
  - Compare the current TDD to this "ideal" TDD for weight.

Example: Someone who weighs 38 kg (84 lbs) would be expected to have a TDD of about 20 units.

What To Do – Reactive Renita

A1c is 6.9%
70 kg/1.9 = 36.8 u/d
Actual TDD = 50.5 u

Speed of drop in glucose suggests she is taking correction dose AND covering carbs in prior meal.

Not All Lows Show Up On a BG Meter

This person felt low and ate, but never tested with a meter. There’s no record of these lows without a CGM!
Check for Hidden Lows

People often treat lows from symptoms **BUT DON'T TEST** their glucose

- Are "other lows" happening?
- Test when low to record the timing and degree of hypoglycemia
- Keep a written record of when and how severe these lows are

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What To Do?

**70 mg/dl (3.9 mmol)**

- Frequent lows \(\rightarrow\) lower the average TDD

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Clever Pump Trick –

**How Many Carbs Do You Need to Treat a Low?**

1. 10 grams for each 35 kg or 75 lb of weight
2. **PLUS** grams = the current BOB* \(\times\) CarbF

**Example:**

1. Amy weighs 70 kg (20 grams of carb)
2. And she has 2 units of BOB with a CarbF of 8 grams/unit
3. So, for the low she needs: 20 g + 16 g = 36 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.

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What To Do?

**Frequent highs \(\rightarrow\) raise the average TDD**

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What To Do?

**Hourly Statistics from 12/11/2009 12:00 AM to 12/19/2009**

- Frequent highs \(\rightarrow\) raise the average TDD

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Highs And Lows – But With A Pattern

- **5 day average:**
  - Avg BG: 203.4 (11.3)
  - Range: 39 to 401 (2.2 to 22.3)

- **SD: 89.9**

  - Highly variable

  - Low BGs between 5 am and 7 am

  - Frequent lows and highs \(\rightarrow\) needs slightly higher average TDD, and either a lower night basal or smaller correction boluses at night
The iTDD Table For High Avg. BGs

For frequent highs and few lows, use this table to improve (increase) the current TDD using a meter’s 14 day average BG or recent A1c.

BGs & TDD before & after Adjustment

Starting TDD = 36 u
1. Raised basal by 0.05 u/hr all day (+1.2 u/day)
2. Lowered carb factor from 1u/13g to 1u/12g (+1.8 u/day)
Ending TDD = 39 u

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 – Quick Way to Find an Improved TDD (iTDD)

When the average BG is elevated AND lows are NOT frequent with NO infusion set failures:

For each 0.33 mmol/L (6 mg/dl) you want to lower the average glucose, raise the TDD by 1%

Example: Amy’s avg TDD is 40 units/day, her avg BG is 12 mmol/L (216 mg/dl) [infrequent lows], and desired avg BG is 8 mmol/L (144 mg/dl):

12 mmol/L – 8 mmol/L = 4.0 mmol/L
4 mmol/L ÷ 3 = 1.33, or a 12% rise in TDD
TDD = 40 units x 1.12 = 44.8 units (Amy’s new iTDD)

The TDD Must Also 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

2. Optimal Insulin Use

Mean Values For Optimal Doses in Best Control Tertiary

<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>41.1%</td>
<td>33.8% to 51.2%</td>
</tr>
<tr>
<td>Corr Boluses</td>
<td>9.0%</td>
<td>6.3% to 11.3%</td>
</tr>
</tbody>
</table>

Corr Bolus Number = Avg Corr x Avg TDD

Ensure that Pump Settings “Fit the TDD”

Basal Rates

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

Accurate basal rates are needed before attempting to test and set the CarbF and CorrF.

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 4-6 basal rates a day usually makes no sense.

Basal/Carb Bolus Balance Is Important

Accurate Basal

- 50 grams
  - Bolus = 5u
  - Basal = 5u
  - Total = 10u

- 100 grams
  - Bolus = 10u
  - Basal = 5u
  - Total = 15u

Low Basal

- 50 grams
  - Bolus = 7u
  - Basal = 3u
  - Total = 10u

- 100 grams
  - Bolus = 14u
  - Basal = 6u
  - Total = 20u

Low basal rates throw the Carb Factor off, causing lows after large carb meals and mild highs after low carb meals. Reverse happens for high basal.

Don’t Always Change One Setting!

- A pumper may only change the basal rate or only the CarbF (or CorrF or DIA) to fix all control problems
- This can throw the basal/carb bolus balance out of balance
- Periodically check the basal/carb bolus balance!
Odd Settings

DIA = 3 Hrs

Your Settings:

<table>
<thead>
<tr>
<th>Units</th>
<th>Volume</th>
<th>Name</th>
<th>Age</th>
<th>Weight</th>
<th>BMB</th>
<th>Avg BG</th>
</tr>
</thead>
<tbody>
<tr>
<td>ml</td>
<td>uL</td>
<td></td>
<td></td>
<td>g</td>
<td></td>
<td>mmol/L</td>
</tr>
</tbody>
</table>

Standard (active)

<table>
<thead>
<tr>
<th>TIME</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00</td>
<td>0.00</td>
</tr>
<tr>
<td>0:30</td>
<td>0.10</td>
</tr>
<tr>
<td>0:60</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Better Practices

- From your current TDD
- TDD = 54 u
- Avg Basal = 48%
- Carb Factor = 1.1 g per unit
- Correction Factor = 3 g per unit
- Relative Insulin Sensitivity
- Insulin Distribution
- Bolus: 5.0 units per day
- Time: 15 min per day
- Correction: 0.5 units per day

Note: DIA = 3 Hrs

Unrelated to their odd pump settings, this person also had an infusion set problem that started on the afternoon of May 1st and lasted until late in the day on the 2nd when the infusion set was finally changed.

TDD = 54.2 u, Basal = 48%, Avg BG = 9.8 mmol/L +/- 4.8 mmol/L

Note how long and high their glucose was during the set failure on this CGM tracing.

Clever Pump Trick – Never Stop A Pump!

- It’s easy to forget to turn it back on
- It’s rarely needed*
- It doesn’t help a low glucose

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

To go off a pump for more than an hour, give a bolus to cover most of the missing basal before disconnecting (max time off ~4 hrs).

* Unless hiking 7 mi. out of mountain campsite after bear ate ALL your carbs

Temp Basal Reductions

- At rest, 30% of glucose is consumed by the brain
- More glucose is used during activity – physical or mental
- Temp basal reductions are helpful when a day is physically or mentally active

Carb Factor and Carb Boluses

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

CarbF = \( \frac{Wt(kg) \times 5.7}{TDD} \) or \( \frac{Wt(lb) \times 2.6}{TDD} \)
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.

APP Study – CarbF Settings In Pumps

- CarbFs actually used – calculated as bolus given for carbs in each meal
- 85% of improvement comes when the BC subtracted BOB from carb boluses or reduced carb boluses for hypoglycemia

Bolus Overrides – By BC or User?

- **Who Makes Bolus Adjustments?**
  - This pump’s bolus calculator* made most of the dose decisions!
  - HOW it calculates doses IS IMPORTANT!

<table>
<thead>
<tr>
<th>Who</th>
<th>Lowered for BOB</th>
<th>Lowered for Low BG</th>
<th>Raised for High BG</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC</td>
<td>1.4 u/day</td>
<td>0.27 u/day</td>
<td>4.18 u/day</td>
</tr>
<tr>
<td>User</td>
<td>0.09 u/day</td>
<td>0.56 u/day</td>
<td></td>
</tr>
</tbody>
</table>

* Bolus dose adjustments in the lowest glucose tertile.

Small CarbF Changes Have A Big Impact

- Small CarbF changes can make a big difference in the glucose.

  - Example: a person weighs 73 kg (160 lbs) and has a TDD of 40 units. A change in CarbF from 1 u/10 grams to 1 u/9 grams will lower the glucose
    - By an extra 1.8 mmol/L (33 mg/dl) for meals with 60 grams of carb, or
    - Or by 3.0 mmol/L (54 mg/dl) for every meal with 100 grams of carb.

Mr Great

- Avg BG = 7.0 mmol/L (126 mg/dl) +/- 2.8, Basal = 38%, TDD 34.1

Don’t fix!
CarbF and CorrF Accuracy Is Important

- Don’t use “magic” numbers for CarbFs and CorrFs
- Small changes in factors can have a big impact
- Always use formulas to select these settings

How To Get Accurate Boluses

1. Add Carb Bolus to Correction Bolus, then
2. Subtract BOB
3. For an accurate bolus!

Examples:
1. Carb bolus = 3 u, corr bolus = 1 u, BOB = 4 u
   \[3 + 1 = 4 \quad 4 - 4 = 0\ u\]  No bolus needed
2. Carb bolus = 2 u, corr bolus = 1 u, BOB = 4 u
   \[2 + 1 = 3 \quad 3 - 4 = -1\ u\]  More carbs are needed

Clever Pump Trick – Quick Way to an Accurate Bolus

1. Is BOB larger or smaller than the correction bolus?
2. If BOB is smaller, pump’s recommendation is correct
3. If BOB is larger, subtract BOB from the combined carb and correction boluses

Recommended Bolus Errors Can Be Corrected

A Paradigm user can scroll down 3 times to see active insulin, then adjust dose:

- 30 u
- 1.5 u
- 4.5 u
- 3 u bolus

Frequent Boluses Cause Stacking

- Patrice waits til her BG is high to give boluses
- This delay causes insulin to stack into the next meal
- Besides, taking 9 boluses over 4 hours creates an insulin-stacking nightmare
- No meter test was done that would mark the low

BOB’s Blind Spot

- After a carb bolus is given, it takes 90 to 120 minutes to balance the rising glucose from the carbs against the glucose-lowering effect of the carb bolus
- During this time, cover desserts or other carbs with a full carb bolus
Clever Pump Trick –
Super Bolus – Shift Basal To Bolus

Helps when eating over 30 to 40 grams of carb

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


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

Correction Boluses

- These make-up doses correct for deficits in basal rates or carb boluses
- Ideally, correction doses make up ≤ 9% of TDD

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 1800 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

Not All High Readings Are The Same

Cause Of High Reading
- Jelly on the finger
- Forgot to bolus
- Infusion set failure
- Rebound high after release of stress hormones
- Ketoacidosis or infection

Corr. Dose Needed
- None (wash, repeat test)
- Corr dose only
- Corr + basal replacement
- Corr + stress coverage
- Raise TDD (basal and bolus) by 1.5 to 3 fold + corrections until resolution

Test the Correction Factor (and the DIA)

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

Glucose near target
BG by end of DIA time

Clemout

No bolus for 5 hrs

Glucose

Time

NO LOWS for at least 5 hrs after bolus

Clemout helps check both correction factor and DIA time

Measure Insulin Sensitivity

Insulin Sensitivity = Wt(kg) x 0.53 or Wt(lb) x 0.24
TDD

Or use a person’s iTDD for even better accuracy!

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

Not All BGs Are Created Equal!

Level of a BG’s risk depends on its trend

Greater Risk Going Down

Less Risk Going Up

3.6 mmol/L

Clever Pump Trick – Fast Correction

To lower a high glucose faster:
- Take usual correction dose
- Add to this a certain amount of carb coverage, say 10 or 20 grams
- Take correction + carb bolus but wait to eat
  - Lowers glucose faster and pumper knows about how many carbs they’ll need to offset the extra BOB!
  - Eat carbs in time!

Don’t use with HU or an aggressive doser
DIA, BOB, & 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

Terms
- **TDD** – total daily dose (all basals and boluses) of insulin
- **Basal** – background insulin released slowly through the day
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- **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

Rapid insulin lowers the glucose for 4.5 to 6.5 hrs.
This DOES NOT CHANGE in the body when DIA time is changed in a pump!

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

Typical Carb Digestion Times

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

Take Home: Choose combo foods to lengthen carb digestion time
Clever Pump Trick –
Bolus Early To Stop Meal Spiking
Figure shows rapid 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

A Short DIA Hides Insulin Stacking
3 hours after a 10 unit bolus, this shows how much BOB a pump will think is left with each DIA time:

<table>
<thead>
<tr>
<th>Estimate Of Insulin On Board Remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>For a DIA setting =</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>3 hr</td>
</tr>
<tr>
<td>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

Short DIAs Cause Problems
A short DIA hides active BOB and leads to
- Unexplained lows
- Incorrect adjustments in basal rates, carb factors, and correction factors to compensate for excess boluses
- Pump wearer ignoring their "smart" pump's advice

Insulin Action Time From GIR* Studies
After insulin injection in healthy person, Insulin Action Time starts (C) and ends (D) with the IV glucose infusion.
Often quoted as "3 to 5 hours" in insulin handouts.
Glucose infusion (curved line) from C to D does not include the time it takes for injected insulin to suppress or to recover the normal basal insulin output from a healthy pancreas.

Duration of Insulin Action for Pumps
DIA Time is measured from the time a pump bolus is given (A) to when the bolus insulin action ends (B) while basal insulin is also delivered from an insulin pump.

Does Dose Size Really Change DIA?
Glucose infusion rate studies are imprecise themselves. When done in healthy humans, they can make small insulin doses appear faster and insulin appear more variable than they really are.


© 2012, Pumping Insulin, 5th ed
**Recommended DIA Times**

Set DIA to 4.25 to 6.25 hrs for accurate calculation of BOB and bolus doses.

**DIA Tips**
- Current research suggests that DIA times are NOT different between children and adults.
- If the pump does not "give enough bolus insulin", do NOT shorten the 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

**Bolus On Board (BOB)**

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!*

**Insulin Stacking**
- Happens when 2 or more boluses overlap
- Measured as bolus on board (BOB, IOB, active insulin)
- Used in bolus calculation IF a glucose is entered
- **BOB has a Blind Spot** – The impact of a bolus cannot be measured accurately with a glucose test until about 90 to 120 minutes after a bolus is given.

**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*

**Insulin Stacking**

Bedtime BG = 10 mmol/L (180 mg/dl) – is there an insulin or a carb deficit?

**Recommended DIA Times**

- Set DIA to 4.25 to 6.25 hrs for accurate calculation of BOB and bolus doses.

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**Insulin Stacking**

Bedtime BG = 10 mmol/L (180 mg/dl) – is there an insulin or a carb deficit?
What Would You Do?

Your daughter’s glucose is 6.7 mmol/L (120 mg/dl) at bedtime and she wants a 40 gram snack and has 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?

Pumps Differ in How They 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>Ideal</td>
<td>Carb Correction</td>
<td>Carb Correction</td>
</tr>
<tr>
<td>0</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>0</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>0</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>0</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Omnipod prior to 2012 in U.S.</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Medtronic</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No*</td>
</tr>
</tbody>
</table>

* Except when BG is below target BG

YES = Safer

Example: Boluses Recommended by 2 Different Pumps on One Morning

<table>
<thead>
<tr>
<th>How Bolus Recommendations Differ between 2 Pumps</th>
<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>No bolus</td>
<td>0</td>
<td>0</td>
<td></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</td>
<td></td>
</tr>
<tr>
<td>10:35 am</td>
<td>140 (7.6)</td>
<td>50</td>
<td>5.0 u</td>
<td>5.0 u</td>
<td>2.15 u</td>
<td>2.86 u</td>
<td></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>
<td></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>
<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

The Correction Target

<table>
<thead>
<tr>
<th>Where In Correction Target Range Does The Pump Aim?</th>
<th>Animas</th>
<th>Medtronic</th>
<th>Omnipod</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle</td>
<td></td>
<td>Top and Bottom</td>
<td>Middle</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). *
What To Do

Lower basal to stop night lows, lower CarbF to stop spiking

Clever Pump Trick – Stop Post Meal Spikes

- Count carbs carefully
- Bolus 15 to 30 min before meals if 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
Infusion Set Issues

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June 22, 2012
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Fallbrook, CA 92028
(760) 743-1431

View slides at www.diabetesnet.com/presentations/

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Glucoses Following A Set Change

- Change in the average glucose during each 6 hr interval following (and just before) the infusion set is changed in 396 insulin pumps.

Infusion Set Failure – Patrice

- Infusion Set Failure On CGM
  - Glucose Trend: **\( W \) [8/15/15]
  - **DIA > 5 hrs or more**
  - Notice rising BG, Took 1st “bolus”
  - 2nd rising BG, BG test. Found set detached. Took a corr. bolus

Why Infusion Sets & Patch Pumps Fail:
- Leaking from site (or hub)
- Not taping down the infusion line (tugging)
- Auto-inserters → bent or kinked Teflon
- Detachment
- Bleeding (hematoma)
- Clogging, blockage, occlusion

Why Infusion Sets & Patch Pumps Fail:
- Leaking from site (or hub)
- Not taping down the infusion line (tugging)
- Auto-inserters → bent or kinked Teflon
- Detachment
- Bleeding (hematoma)
- Clogging, blockage, occlusion
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

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>Avg BG</td>
<td>146.6</td>
<td>181.6</td>
<td>229.3</td>
</tr>
<tr>
<td>BGs/day</td>
<td>4.74</td>
<td>4.52</td>
<td>4.22</td>
</tr>
<tr>
<td>Blocks/month</td>
<td>1.36</td>
<td>3.04</td>
<td>3.57</td>
</tr>
</tbody>
</table>

Oclusions / Blockages

Should not happen!
More than once a month?
- Change infusion set type
- Or brand of insulin (rare)

More Reliable Infusion Sets

ALWAYS anchor the Sof-Set with the Sof-Set Adhesive Patch, and the Silhouette infusion line with 1” tape. These steps minimize site irritation and reduce tugging that can cause leaks.

Cost Savings When Budgets Matter

- Most savings come from extended use of sets or sensors
- Risks versus rewards
- Staph carriers are at much higher risk of infection – try to identify these individuals
- Emphasize sterile technique with extended use
- Use lower cost metal infusion sets
- Do not use auto-inserters (close to 10% failure rate)
CGMs For Better Control

St. Michael’s Hospital
Toronto, ON
June 22, 2012

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(915) 745-1431

View slides at www.diabetesnet.com/presentations/

CGM by Jackson Pollack

One Pollack painting sold for $140 million in 1996!

Make Your Own Jackson Pollack

Only $1,000!

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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

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

**Trends And Predictions**

- Both help minimize highs and lows
- Good for:
  - Driving
  - Sports
  - Basal tests
  - Reducing uncertainty
  - Overriding bolus recommendations

*Picture from Scott Hanselman at [http://www.hanselman.com](http://www.hanselman.com)*

**Hypoglycemia Alerts**

Hypo or predictive alert, relatively stable BG, and little BOB: mild treatment
- Fewer carbs
- Medium G.I. food

Hypo or predictive alert, dropping BG, + BOB: aggressive treatment
- Full or increased carbs
- High G.I. food

*Check BOB for guidance on # of carbs needed!*

*Pictures from Scott Hanselman at [http://www.hanselman.com](http://www.hanselman.com)*

**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 High: Bolus too small</td>
</tr>
<tr>
<td></td>
<td>In Target: Bolus in balance</td>
</tr>
<tr>
<td></td>
<td>Too Low: Bolus too large</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: excellent readings!

An Ideal Pump

Long-Lasting Implanted CGMs

- Few disposables
- Minor surgery
- Funded as rental?

CGM – Implanted Fluorescent

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

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