Insulin Pumps Secrets & Settings for Great Glucose Control
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Disclosure

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

Pump Lingo

- **TDD** – total daily dose (all basals and boluses) of insulin
- **Basal** – background insulin released around the clock
- **Bolus** – a quick release of insulin – Carb boluses cover carbs and Correction boluses lower high readings
- **Bolus Calculator (BC)** – calculates bolus recommendations
- **Correction Target** – the BG a correction bolus aims for
- **Duration of Insulin Action (DIA)** – how long a bolus lowers the BG – used to calculate residual BOB activity
- **Bolus On Board (BOB)** – bolus insulin still active from recent boluses (active insulin, insulin on board)

Outline

- Old and New Pumps & CGMs
- Pump Setup Tips
- Which DIA Do You Use?
- BOB and Insulin Stacking
- Limitations of the Bolus Calculator
- Troubleshooting the Infusion Set
- How CGMs Can Improve BGs
- Take homes

Advantages of an Insulin Pump

- Avg. A1c reduction = 0.2%¹
- Convenience
- Software calculates doses and tracks BOB
- Easier to match varying needs
- Less insulin stacking, less severe hypoglycemia, less BG variability ²
- Freedom of lifestyle
- Better data for clinicians, pumpers, and parents

21st Century Line Pumps

- Accu-Chek Aviva Combo
- Animas Ping or Vibe
- Medtronic Revel or 530G
- Asante Snap
- Tandem t:slim

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21st Century Patch Pumps

Advantages of a CGM
- Average A1c reduction = 0.7%1
- Reads glucose every 5 min
- Gives alarms for lows and highs
- Security for wearer and family
- Trend line and arrows guide bolus doses
- Lower A1c, less severe hypoglycemia, less BG variability
- Better data (clinicians, pumpers, parents)


21st Century CGM’s

CGM into Pumps and Beyond

For comparison, better BG meters have a mean average relative difference (MARD or error) of 5-6%

Dexcom G4AP (SOS), MARD 9.0%, 1-2 weeks

Medtronic 530G, MARD 13.9%, 6-10 days

Abbott Libre/Flash, MARD 11.4%, no cal, no alarms, 2 weeks use

Medtronic 330G, MARD 13.9%, 6-10 days

Available
- Medtronic
- Accu-Check
- Available Now
- Remote bolusing + data collection from multiple devices

CGM:
- Dexcom
- Animas
- Tandem
- Omnipod

APP Study – TDD, Basals, and Carbs

<table>
<thead>
<tr>
<th>Group</th>
<th>Low BG Third</th>
<th>High BG Third</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. Meter BG</td>
<td>144 mg/dL</td>
<td>227 mg/dL</td>
</tr>
<tr>
<td>BG Tests/Day</td>
<td>4.73</td>
<td>4.01</td>
</tr>
<tr>
<td>TDD</td>
<td>47.9</td>
<td>51.1</td>
</tr>
<tr>
<td>Basal %</td>
<td>47.6%</td>
<td>47.8%</td>
</tr>
<tr>
<td>CarbBolus U/d</td>
<td>26.9 u</td>
<td>19.8 u</td>
</tr>
<tr>
<td>CarbBolus/Day</td>
<td>4.07</td>
<td>4.14</td>
</tr>
<tr>
<td>CarbGram/Day</td>
<td>185.2</td>
<td>187.9</td>
</tr>
</tbody>
</table>


How To Improve Insulin Doses
APP Study – Importance of the TDD

Most people are not taking enough insulin
Find an accurate TDD first – best guide to correct pump settings
Pattern management starts AFTER TDD and settings are optimized

The TDD controls the frequency of lows, A1c, & Avg BG

Pump Setup

- Set Basals from TDD
- Set Bolus Factors from TDD
  - CarbF (carbohydrate factor)
  - CorrF (correction or “sensitivity” factor)
- Set target BG
- Set DIA (4.5 hrs or longer)
- Repeat when necessary

Use the TDD to Select Pump Settings

- Basal insulin = ~ Half of the TDD
- CarbF = 2.6 × \( \frac{\text{Wt (lbs)}}{\text{TDD}} \)
- CorrF = \( \frac{1960}{\text{TDD}} \)
  - CorrF is inversely related to TDD and to avg. BG
  - Poor control = need for a smaller CorrF

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

Bolus Calculator Settings

<table>
<thead>
<tr>
<th>This Setting</th>
<th>Helps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basal rates</td>
<td>Sound sleep</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>BG goal 4-5 hrs after bolus</td>
</tr>
<tr>
<td>DIA</td>
<td>Minimize insulin stacking</td>
</tr>
</tbody>
</table>

The average TDD determines how often highs and lows occur

Use formulas for accurate settings ⇒ far better than WAG!

Pump Settings Are Frequently Wrong

Only 40% of CarbFs have their expected value (not just the CarbF1!)
People prefer “magic” numbers – 5, 10, 15, and 20 g/unit.
Use formulas for accurate settings ⇒ far better than WAG!

Carb Factors Found in 405 Pumps

Use TDD Table to Select Pump Settings

<table>
<thead>
<tr>
<th>Units: English</th>
<th>Settings For Current BG</th>
<th>Settings For Target BG</th>
</tr>
</thead>
<tbody>
<tr>
<td>TDD 80 u/day</td>
<td>Avg Basal: 1.6 u/hr</td>
<td>Avg Basal: 1.7 u/hr</td>
</tr>
<tr>
<td>Carb Factor: 5.5 grams per unit</td>
<td>Correction Factor: 24.5 mg/dL per unit</td>
<td>Relative Insulin Sensitivity: 6%</td>
</tr>
</tbody>
</table>

Enter Your Information:

Weight: 184 lbs
Height: 68.5 feet
Avg TDD: 80 u/day
Avg Basal: 1.6 u/hr
Carb Factor: 5.5 grams per unit
Correction Factor: 24.5 mg/dL per unit
Relative Insulin Sensitivity: 6%

Or Use Decision Support Software

JD is a 20 yo college student DM1 referred to our clinic
A1c 8.4% (avg BG 194 mg/dL), Wt 184, TDD = 80 u (78-83 u/day)
- Basal: 1.8 u/hr (43.2 u/day)
- CarbF 10
- CorrF 45
- DIA 4 hrs

JD's New Pump Settings:
- Basal rate: 1.7 u/hr (originally 1.8 u/hr)
- CarbF 5.6 (10)
- CorrF 23 (45)
- DIA 5 hrs (4)
- A1c 3 mos later 6.9% (8.4%)

Which Way Do You Adjust Settings?

Frequent lows: Frequent lows: Frequency/Insulin Sensitivity:
- Basal Rates: Up
- Carb Factor: Up
- Corr Factor: Up

Frequent highs: Smaller factors = larger boluses

Common Control Issues
Common Pump User Issues
- Reactive vs proactive dosing ("The Rollercoaster")
- Too many basal rates
- Inaccurate CHO bolus / CHO counting
- Delayed boluses – high post meal BG
- Infusion site failures
- Lack of meaningful data – no pump/meter/CGM downloads
- Not adjusting pump settings
- Lack of clarity for when to override BC recommendations

Get Off The Rollercoaster
Be proactive! Don’t overtreat highs and lows. Adjust lifestyle or pump settings to improve control!

Optimal Number of Basal Rates?
Number of basal rates used per day from self-reports of hundreds of pumpers at insulin-pumpers.org
Once basal rate changes, it takes 4-5 hrs to have its full effect.*
Using more than 5 basals may have little benefit.

Basal Rates

Basal Tips – Avoid Over-Steering
- Basal rates are usually similar through day, such as between 0.5 to 0.8, or 1.0 to 1.5 u/hr
- Adjust basal rates in small steps (0.025 to 0.1 u/hr) 2 hours before BG starts to rise or fall
- Or 5-8 hours before a high or low reading typically happens
- Over 5 basals a day probably has little benefit.¹

Overnight Basal Check

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Basal/Bolus Balance

Ideal Basal/Bolus Balance Differs by Age

- **Prior to puberty**: 30-45%
  - High carbs, lower counter-regulatory hormones, honeymoon phase
- **Puberty**: 40-55%
  - High carbs, mid to high counter-regulatory hormones
- **Adult**: 45-60%
  - Mid carbs, mid counter-regulatory hormones
- **Thin elderly**: 40-50%
  - Mid carbs, lower counter-regulatory hormones

Most adults do best at 50 to 60% of TDD as basal

Temp Basal Rates

- Great for physical activity, illness, fever, menses, testing new basals
- Never suspend. Instead, use a temp basal reduction – pump restarts on time with fewer followup highs
- Don’t stop a pump for lows – provides no benefit until 60-90 min. later

Carb Bolus Types

- **Regular**
  - Taken immediately – 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 (bean burrito, steak, etc.) Test 1-2 hrs after meal.

Get Accurate Carb Boluses

- Use carb counting resources
  - CalorieKing, MyFitnessPal
- Know portion sizes
  - Measure portions or use a gram scale at home
- Base CarbF on TDD
  - CarbF = (2.6 x weight) / TDD
- Keep a record of bolus doses that work!

Stop Post Meal Spiking

- Count carbs carefully
- Bolus 15 to 30 min pre-meal
- Use combo bolus with picky eaters
- Delay eating until below 140 mg/dL
- Eat more low GI foods, complex carbs, fewer carbs
- Exercise after meals
- Use a Super Bolus
- Add fiber/psyllium/acarbose/Symlin/GLP-1 agonist
Clever Pump Trick – Bolus Early To Stop Meal Spikes

Figure shows Regular insulin injected 0, 30, or 60 min before a meal
Normal glucose profile shown in shaded area
Best glucose occurred with 60 minute bolus – but too risky to recommend!!!
Bolus 15-30 min early – the best-kept secret for better control


Bolus to Cover Protein and Maybe Fat

Protein –
- Half the grams of protein in food are converted to glucose over the next 6-8 hours
- Most meals don’t have enough protein to matter
- But when the grams of protein in a meal or snack are greater than 1/6th of your weight(lbs), cover half of these grams with an extended or square wave bolus given over a 4-5 hr period

Fat –
- Individual varieties of fats in foods differ tremendously in whether and how much they will affect the glucose
- Are hard to cover: some fats have little impact, some delay carb digestion, and some raise the BG from insulin resistance

Correction Boluses
- In the APP Study, 396 pumpers averaged 2.1 correction boluses and 5.6 correction units per day (11.6% of the TDD)
- Makes up for deficits in basal rates or carb boluses
- The better your control, the larger your CorrF becomes (to give smaller correction doses)


Insulin Adjustments for Glucose Control
- If it ain’t broke, don’t fix it!
- Mild – tweak pump settings or lifestyle
- Moderate – For patterns, use pattern management. Otherwise calculate new TDD and detune pump settings
- Severe – Reset TDD to an improved TDD (iTDD) and select new settings from this iTDD to correct the problem

Use TDD to Stop Highs and Lows
Improve Insulin Doses In Sequence

1. Stop frequent lows first
This lets you find an ideal TDD (iTDD)
2. Then correct high A1c/avg BG
3. Set & test basals from iTDD
4. Set & test CarbF from iTDD
5. Lower post meal BG’s
6. Set & test CorrF from iTDD
7. Enjoy good control or return to #1

Briale diabetes or frequent highs? Usually = the wrong pump settings

Stop Frequent Lows First

- You cannot tell how much excess insulin there is!
- Start with a 5% or 10% reduction in TDD
- Or compare current TDD to an “ideal” TDD for weight.
- Divide weight(lbs) by 4 to see what TDD a person needs if they have an average sensitivity to insulin

Example: Someone who weighs 160 lbs would be expected to have a TDD of 40 units (160/4 = 40).


Example 1 – Frequent Lows on Meter

41 yo female with A1c = 8.9%
TDD = 50.5 u/d
152 lb/4 = 38.0 u/d

Example 2 – Frequent Lows on CGM

28 yo female – Wt: 120 lbs
Current TDD = 63.8 u/day
Wt/4 (120/4) = 30.0 u/day

Hidden Hypoglycemia

Person eats when low but does not test with a meter.
Only a CGM will give a record of this!
Always tell your doctor about any hidden lows you may be having.
Clever Pump Trick –
How Many Carbs for a Low?

1. No BOB: 1 gram for each 10 lbs of weight (minimum 10 gr)
2. With BOB: Add grams = BOB* x CarbF

Example: Amy’s BG = 52 mg/dL with 2u of BOB (CarbF = 8 glu)
- At 140 lbs, she needs 14 grams of carb for the low glucose
- Plus 2u BOB x 8 gram/u = 16 grams to offset BOB
- Amy needs 14 g + 16 g = 30 grams for this low

* DIA time must be accurate

Next Stop Frequent Highs

Raise the TDD with the 5 and 6 Rules:
Raise the TDD by 5% to lower an A1c by 1%
Or by 1% to lower average BG by 6 mg/dL

Current BG – Target BG = % rise in TDD
6

Example: Amy’s avg TDD is 40 u/day, avg BG 200 mg/dL (few lows), and BG goal 140 mg/dL:
200 mg/dL – 140 mg/dL = 60 mg/dL
60 mg/dL + 6 = 10% rise in TDD
40 units x 1.10 = 44 units a day

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Example 1 – Lower Highs from A1c
27 yo male, A1c = 8.6%, TDD = 50 u/day
8.6% - 7.0% = 1.6% x 5 = an 8% increase in TDD
50u x 1.08 = 54u

Example 2 – Lower Highs from Avg BG
53 yo female
TDD = 36 u
Avg BG = 191

1. Raise basal by 0.05 u/hr all day (+1.2 u/day)
2. Lower CarbF from 1u/13g to 1u/12g (+1.8 u/day)

TDD = 39 u
8.3% increase

Jackson Pollack’s CGM
Price: $3,000,000
How Long Does a Bolus Lower the Glucose?

Insulin Action Time ≠ Duration of Action

Fig. 1 Insulin Action Time

Insulin Action Time

Duration of Insulin Action

Bedtime BG = 180 mg/dL – is there an insulin or a carb deficit?

Bolus on Board / Insulin Stacking

Bedtime BG = 180 mg/dL

Short DIA Times Hide BOB & Cause Lows

Of 201,538 boluses, 64.8% were given within 4.5 hrs of a previous bolus


With her DIA set at 3 hours, this lady (39 yo, CarbF 10) has two low BGs on Friday caused by the hidden insulin stacking.

Another low on Saturday when excess BOB was not taken away from the carb bolus of 4.5 u.

### When Is Your Bolus Calculator Just Plain Wrong?

Pump Bolus Calculators Often Recommend Excessive Boluses

<table>
<thead>
<tr>
<th>Glucose</th>
<th>Actual Units Needed</th>
<th>Other Pumps</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1: 99 mg/dL</td>
<td>0 u</td>
<td>5 u</td>
</tr>
<tr>
<td>#2: 101 mg/dL</td>
<td>0 u</td>
<td>5 u</td>
</tr>
<tr>
<td>#3: 200 mg/dL</td>
<td>2 u</td>
<td>5 u</td>
</tr>
<tr>
<td>#4: 300 mg/dL</td>
<td>4 u</td>
<td>5 u</td>
</tr>
</tbody>
</table>

43 yo man eats 50 gram dessert 2 hrs after dinner with 5u of BOB on 4 consecutive nights. Each night’s BG is shown (column 1), the actual bolus he needs (col 2), and what pumps recommend (cols 3 and 4).

CarbF = 10 gr/u; CorrF = 50 mg/dL; Target = 100; DIA = 5 hrs

### Extent of Insulin Overdose from a BC

<table>
<thead>
<tr>
<th>Time</th>
<th>BG mg/dL</th>
<th>Carbs Eaten</th>
<th>Carb Bolus</th>
<th>Total IOB</th>
<th>Carb + Corr Bolus</th>
<th>Cozmo Pump</th>
<th>Other Pumps</th>
</tr>
</thead>
<tbody>
<tr>
<td>6:54 am</td>
<td>111</td>
<td>16</td>
<td>0</td>
<td>0</td>
<td>No bolus given</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9:52 am</td>
<td>71</td>
<td>0</td>
<td>3.0 u</td>
<td>0</td>
<td>4.3 u</td>
<td>4.3 u</td>
<td></td>
</tr>
<tr>
<td>10:35 am</td>
<td>40</td>
<td>50</td>
<td>5.0 u</td>
<td>3.3 u</td>
<td>2.2 u</td>
<td>5.0 u</td>
<td></td>
</tr>
<tr>
<td>11:58 am</td>
<td>40</td>
<td>40</td>
<td>4.0 u</td>
<td>3.6 u</td>
<td>0.5 u</td>
<td>4.0 u</td>
<td></td>
</tr>
<tr>
<td>1:12 pm</td>
<td>107</td>
<td>0</td>
<td>2.3 u</td>
<td>3.3 u</td>
<td>Eat 19 g</td>
<td>No action</td>
<td></td>
</tr>
</tbody>
</table>

6.35 excess units recommended by other pumps in just 6 hours!

TDD = 38 u, carb factor = 10 gl/u, corr factor = 65 mg/dL, 65 mg/dL x 6.35 u = 413 mg/dL tail in BG if Other Pump’s advice is followed.

### Case Study – Hypoglycemia From the BC

BCs commit sins of omission –

BG is 89 mg/dL with excess BOB

BC fails to warn user they need carbs to cover this excess BOB

33 yo woman, TDD ~36 units, CarbF 10, DIA 5 hours
Case Study – Hypoglycemia From the BC

And sins of commission – BC covers carbs with a full bolus when excess BOB is present

33 yo woman, TDD ~36 units, CarbF 10, DIA 5 hours

Check BC’s Recommended Bolus

Pumps cover all carbs even when excess BOB is present

Here, 4.35u of BOB is larger than correction bolus (1.23u), Little or no bolus is needed

Ping and Vibe give correct boluses when the BG goes below target

Clever Pump Trick – Get an Accurate Bolus

1. When BOB is smaller than correction bolus, the pump’s recommended bolus is CORRECT

2. If BOB is larger than correction bolus, add carb and correction bolus, then subtract BOB

Example: Carb bolus = 2.9 u (Pump’s recommendation)
Corr bolus = 1.2 u
BOB = 4.3 u

Accurate bolus = 2.9 + 1.2 – 4.3 = –0.1 unit bolus

Troubleshooting the Infusion Set

Cannula Options

<table>
<thead>
<tr>
<th>Straight</th>
<th>Slanted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teflon</td>
<td>Teflon</td>
</tr>
<tr>
<td>6, 9 mm</td>
<td>4, 5, 6, 9 mm</td>
</tr>
<tr>
<td>3 days*</td>
<td>2 days*</td>
</tr>
<tr>
<td>3.4 days**</td>
<td>3.7 days**</td>
</tr>
<tr>
<td>Metal</td>
<td>Teflon</td>
</tr>
</tbody>
</table>


Line Disconnect Mechanisms

Motion and degree of manual dexterity required

- Twist & pull easiest
- Pinch & pull easiest
- Pinch, twist, & lift hardest
- Pinch & lift harder

Tubing lengths: 24", 32", and 43" for most sets
Auto-Inserters

- Inset 30
- Accu-Chek Link Assist
- Inset/Mio
- Omnipod
- Quick-Serter
- Cleo

Infusion Set Failure Is Common

- Most of the 16,849 adverse pump events reported to the FDA between 2006-2009 involved infusion sets.
- A 2006 review of pumps in France likewise found that most serious adverse events involved infusion sets.
- Auto-insertion devices have a high failure rate of 8.9%.

1. www.fda.gov/AdvisoryCommittees/CommitteesMeetingMaterials/MedicalDevices/ucm202779.pdf

Infusion Sets – The Achilles Heel Of Pumps

Survey of 1142 pumpers in 40 German diabetes clinics

- 54% reported an increase in glycemia for unknown reasons until their infusion set is changed
- 19% reported kinking, 12% had leakage, 12% air bubbles, and 33% had other issues
- 36% used auto-insertion devices – 72% of them reported that the device failed to work ~10% of the time


Is The Infusion Set The Problem?

- Sites “go bad”?
- “Scarring” or “poor absorption”?
- 2 or more unexplained highs in a row?
- Correction boluses don’t work?
- High BGs until set is changed?

Infusion Set Failure On CGM

Alert for rising BG. Took 1st “bolus”
2nd rising BG, confirmed with BG test. Infusion set was detached. A “2nd” corr. bolus taken after set replaced.

Infusion Set Failure

Set problem started on afternoon of May 1st and lasted until late in the day on the 2nd when the infusion set was changed.
**How Infusion Sets Fail**

- Complete pullout
- Insulin leak along Teflon to skin
- Hematoma under the skin
- Autoinserter
- Occlusion
- Loose hub
- Punctured line

**Goal:** Less than one failure a year!

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**Stop Infusion Set Problems!!!**

- Anchor Teflon infusion lines with 1” tape*
- Stops tugs and pullouts, “unexplained highs” (insulin leaks), skin irritation and “pump bumps”
- Place IV3000 or Tegaderm adhesive over metal sets
- Insert set by hand
- Review site prep and insertion technique with clinician or trainer
- Switch to a reliable set

* Transpore, Durapore, Hypafix, Micropore

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**Take Aways #1**

- Pumps and CGMs have made huge strides in options and accuracy
- Think of your TDD as a key ingredient in your control
- Stop frequent lows first
- Then lower a high A1c or avg BG with the 5 and 6 rules
- Use formulas to select optimal settings from the TDD for a pump start and to check current pump settings
- Basal often works best at ~50 to 60% of TDD, stay in basal/bolus balance, avoid too many shifts and large shifts in your basal rates
- Change basal rates 5-8 hrs before highs or lows happen
- The carb factor and other pump settings are often incorrect

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**Take Aways #2**

- For safety, subtract excess BOB from the carb dose any time BOB is greater than the correction dose (your pump will not usually do this)
- Some degree of insulin stacking happens in 2/3 of all bolus doses
- Short DIA times hide insulin stacking and cause unexplained hypoglycemia
- Infusion set problems are common but don’t have to be
  - Due to their high rate of failure, don’t use an auto-inserter unless you never have a problem with it
  - Metal sets are the easiest to use and least likely to fail – great for children, pregnancy, etc.
  - Anchor all Teflon infusion lines with 1” Transpore or other tape to prevent tugging, leaks, and pullouts
  - Apply IV3000 or Tegaderm clear adhesive over metal

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