Insulin Pump Secrets & Settings for Great Glucose Control

John Walsh, PA, CDTC Saturday, March 7, 2015

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, Halozyme
- Pump Trainer – Accu-Chek, Animas, Medtronic, Omnipod, Tandem
- Web Advertising – Sanofi-Aventis, Sooil, Tandem Diabetes Medtronic, Animas, Accu-Chek, Abbott, 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
- Why the TDD Is So Important
- Which DIA Do You Use?
- BOB and Insulin Stacking
- Limitations of the Bolus Calculator

Advantages of an Insulin Pump

- Average 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 (clinicians, pumpers, parents)

*

[1] Hsin-Chieh Y, et al: Ann Intern Med. 2012;157(5):336-347.

[2] Pickup JC, Sutton AJ: Diabet Med 2008 Jul;25(7):765-74.

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20th Century Pumps

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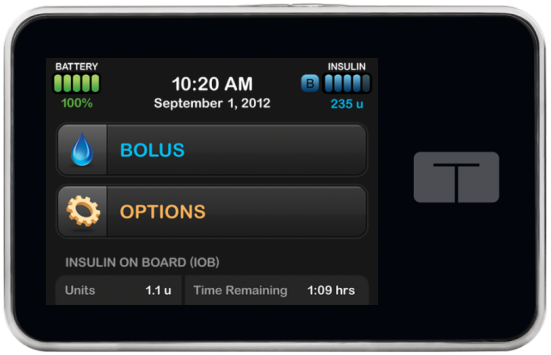
21st Century Line Pumps

Accu-Chek Aviva Combo

Animas Ping or Vibe

Medtronic Revel or 530G



Tandem t:slim

Asante Snap

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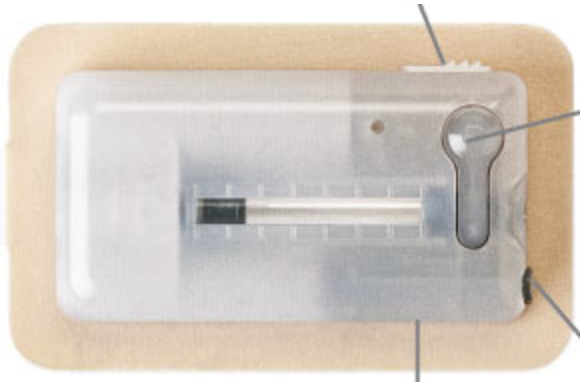
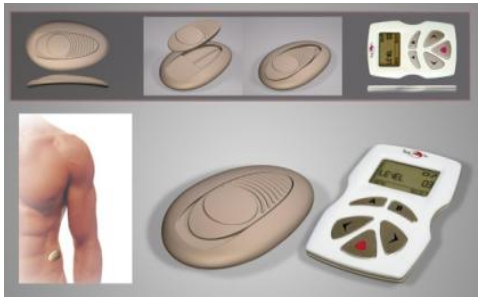
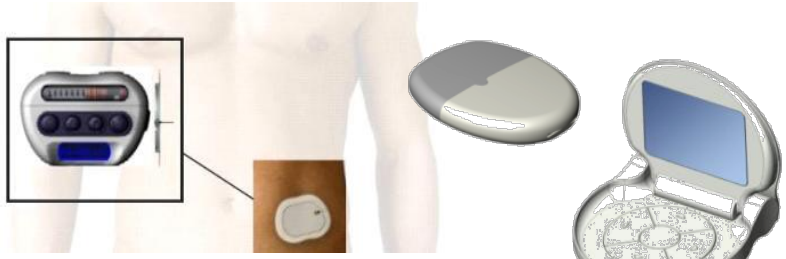
21st Century Patch Pumps







Remote Control + Meter

Animas Ping

Accu-Chek Combo

Omnipod

- Integrated glucose meters improve bolus accuracy
- Give carb and correction boluses conveniently and discreetly (Omnipod remote must be present to bolus)
- Basal adjustments can be made with some remotes
- Smartphone connectivity will do the same

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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)

[1] Y Hsin-Chieh et al: Ann Intern Med. 2012;157(5):336-347.

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Cygnus Glucowatch (GW)

- First FDA approved real time device (2001)
  - MARD 24.5%
- Reverse iontophoresis
  - through intact skin
- Significant Limitations
  - Poor performance
  - 13h duration
  - high hassle factor
  - skin irritation
  - discomfort limited use

Cygnus Glucowatch Package insert (2001)

Current CGM's

2014 Dexcom G4 Platinum (505)
MARD 9.0%, 1-2 week use

Medtronic Enlight
MARD 13.9%, 6-10 days use

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

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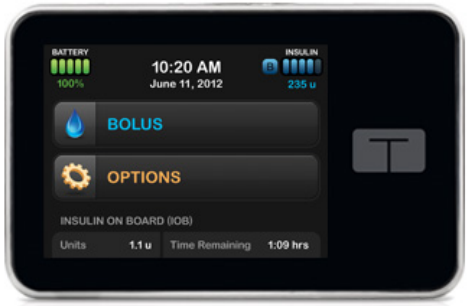
CGM into Pump and Beyond

CGM:		Pump:	Available
Dexcom	⟷	Animas	Now
	⟷	Tandem	2015?
	⟷	Omnipod	2015?
Medtronic	⟷	Medtronic	Now
Accu-Check	⟷	Accu-Check	2016?
Connectivity via Bluetooth Low Energy			2015?



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Dexcom G4 and G5 – Animas, Asante, Omnipod, Tandem

- High contrast color screens
- 1-2 week Dexcom G4 sensor
- Internet access via Diasend, t:connect, Tidepool, iHealth
- Share with Share App for iPhone and iPod
- Nightscout remote readings on Android
- Predictive glucose suspend in development

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Dexcom G4AP vs Enlite Accuracy

Dexcom G4AP with 505 upgrade

- MARD = 9.0%[1]
- For BGs < 70 mg/dL (3.9 mmol/L), MARD was 6.4 mg/dL
- 73% of sensors had MARD <10%
- 92.4% of readings were in Clarke error grid zone A

Enlite

- MARD = 13.6%[2]

1. Bailey TS, Chang A, Mark Christiansen M: *J Diabetes Sci Technol November 3, 2014*
2. Bailey TS, Ahmann A, Mark Christiansen M, et al.: Diabetes Tech Therap. 2014, 16(5): 277-283

Pump Setup Tips

Bolus Calculator Settings

This Setting	Helps
Basal rates	Sound sleep
CarbF or I:C ratio	Cover carbs well
CorrF or ISF	Lower highs safely
Target glucose	BG goal 4-5 hrs after bolus
DIA	Minimize insulin stacking

The average TDD determines how often highs and lows occur

Which Way Do You Adjust Settings?

12.6 Which Way Do You Change Your Pump Settings?			
If you are having:	This is the direction to change your:		
	Basal Rates	Carb Factor	Corr Factor
Frequent lows	↓	↑	↑
Frequent highs	↑	↓	↓

Smaller factors = larger boluses

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Pump Setup

- Educate
- **Determine TDD** (Total Daily Dose)
- 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

APP Study – TDD, Basals, and Carbs

Glucose, Insulin and Carb Data				
Group:	All 396 Pumps	Low Third	Mid Third	High Third
Avg. Meter BG	184 mg/dL	144 mg/dL	181 mg/dL	227 mg/dL
BG Tests/Day	4.38	4.73	4.41	4.01
TDD	49.4	47.9	49.1	51.1
Basal %	47.6%	47.6%	47.2%	47.8%
CarbBolus U/d	20.4 u	20.9 u	20.4 u	19.8 u
CarbBolus/Day	4.14	4.07	4.20	4.14
CarbGram/Day	189.9	185.2	196.3	187.9

1. J Walsh, R Roberts, T Bailey: J Diab Science & Technology 2010, Vol 4, #5, Sept 2010

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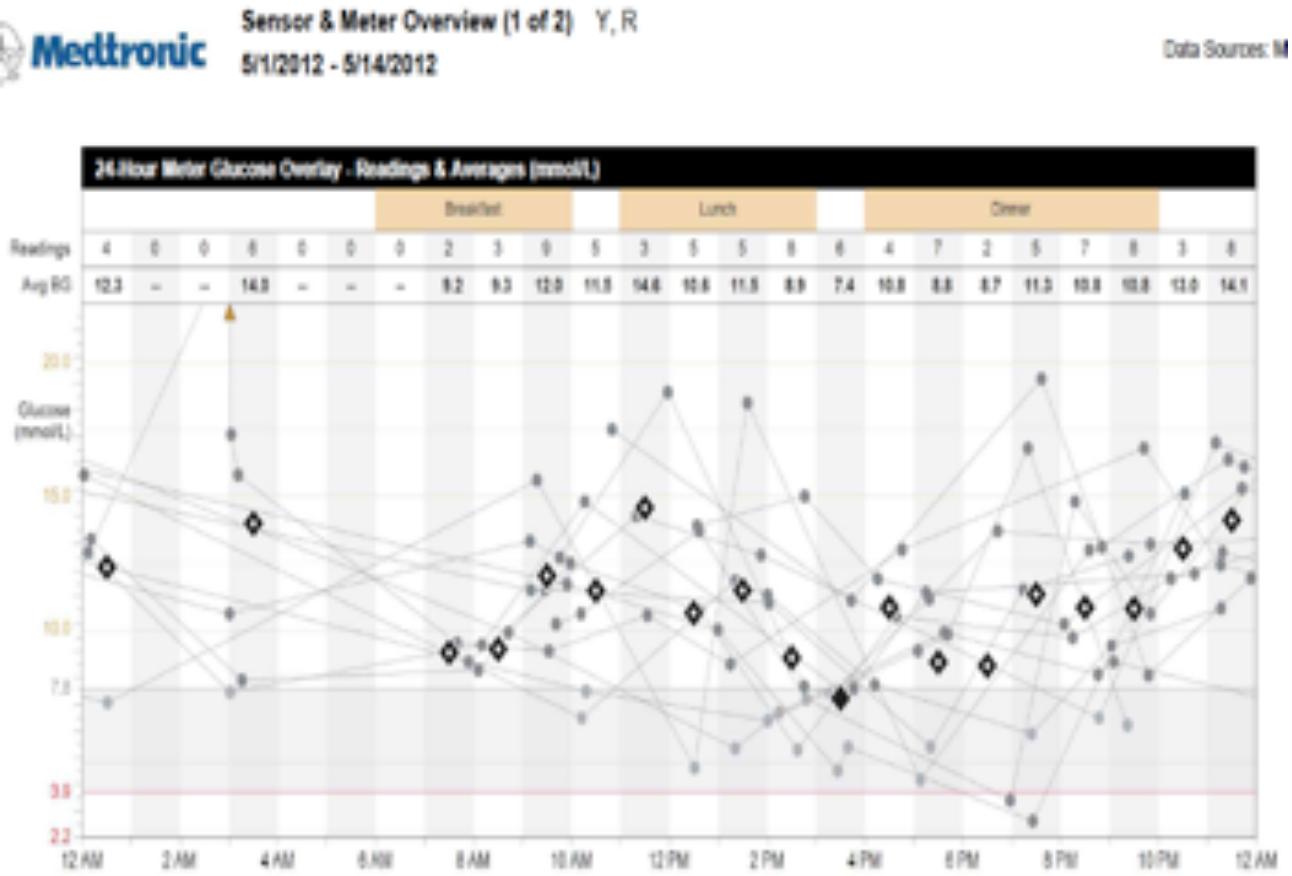
APP Study – Major Finding



- Find an accurate TDD first
- TDD is best guide to correct pump settings
- Start pattern management AFTER the TDD and settings are optimized

TDD controls frequency of lows and A1c/avg BG

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

Use the TDD to Optimize Pump Settings[1]

Basal insulin = ~ Half of the TDD

CarbF = $2.6 \times \frac{\text{Wt(lbs)}}{\text{TDD}}$

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/

[1]J Walsh, R Roberts, T Bailey: J Diab Science & Technology 2010, Vol 4, #5, Sept 2010

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Use TDD to Optimize Pump Settings

9.5 Master List for Bolus Calculator Settings: Find Your Basal Rates, CarbF, and CorrF from Your TDD (or iTDD) and Weight

TDD or iTDD u/day	Basal [1] u/day	Basal u/hr	Carb Factor[2] in grams/u									CorrF[3] (mg/dl) / u
			100 lbs 45.4 kg	110 lbs 49.9 kg	120 lbs 54.4 kg	130 lbs 60.0 kg	140 lbs 63.5 kg	150 lbs 68.0 kg	160 lbs 72.6 kg	170 lbs 77.1 kg	180 lbs 81.6 kg	
16	7.7	0.32	16.3	17.9	19.5	21.1	22.8					122
20	9.6	0.40	13.0	14.3	15.6	16.9	18.2	19.5	20.8			98.0
24	11.5	0.48	10.8	11.9	13.0	14.1	15.2	16.3	17.3	19.5	21.7	81.7
28	13.4	0.56	9.3	10.2	11.1	12.1	13.0	13.9	14.9	16.7	18.6	70.0
32	15.4	0.64	8.1	8.9	9.8	10.6	11.4	12.2	13.0	14.6	16.3	61.3
36	17.3	0.72	7.2	7.9	8.7	9.4	10.1	10.8	11.6	13.0	14.4	54.4
40	19.2	0.80	6.5	7.2	7.8	8.5	9.1	9.8	10.4	11.7	13.0	49.0
45	21.6	0.90	5.8	6.4	6.9	7.5	8.1	8.7	9.2	10.4	11.6	43.6
50	24.0	1.00	5.2	5.7	6.2	6.8	7.3	7.8	8.3	9.4	10.4	39.2
55	26.4	1.10	4.7	5.2	5.7	6.1	6.6	7.1	7.6	8.5	9.5	35.6
60	28.8	1.20	4.3	4.8	5.2	5.6	6.1	6.5	6.9	7.8	8.7	32.7
65	31.2	1.30	4.0	4.4	4.8	5.2	5.6	6.0	6.4	7.2	8.0	30.2
70	33.6	1.40	3.7	4.1	4.5	4.8	5.2	5.6	5.9	6.7	7.4	28.0
80	38.4	1.60	3.3	3.6	3.9	4.2	4.6	4.9	5.2	5.9	6.5	24.5
90	43.2	1.80	2.9	3.2	3.5	3.8	4.0	4.3	4.6	5.2	5.8	21.8
100	48.0	2.00	2.6	2.9	3.1	3.4	3.6	3.9	4.2	4.7	5.2	19.6

[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 opensourcediabetes.org

J Walsh and R Roberts: Pumping Insulin (5th ed), 2012

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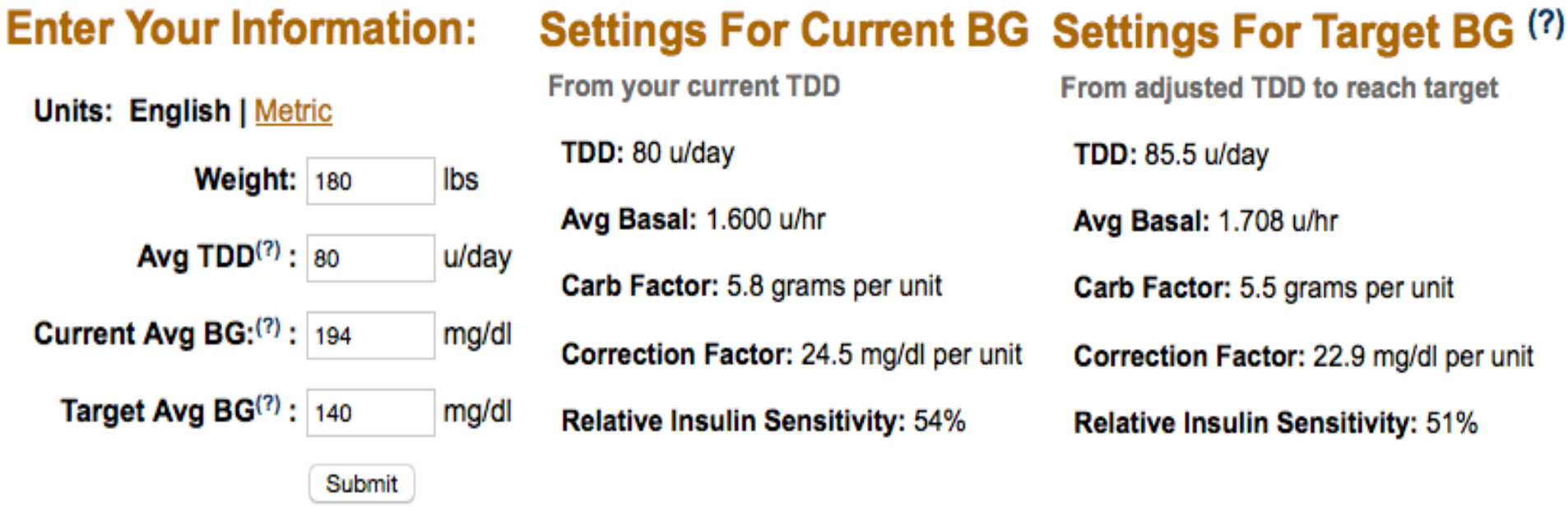
Or Use Decision Support Software

- 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

Use Decision Support Software



Enter Your Information:

Units: English | Metric

Weight: 180 lbs

Avg TDD(?) : 80 u/day

Current Avg BG:(?) : 194 mg/dl

Target Avg BG(?) : 140 mg/dl

Submit

Settings For Current BG

From your current TDD

TDD: 80 u/day

Avg Basal: 1.600 u/hr

Carb Factor: 5.8 grams per unit

Correction Factor: 24.5 mg/dl per unit

Relative Insulin Sensitivity: 54%

Settings For Target BG (?)

From adjusted TDD to reach target

TDD: 85.5 u/day

Avg Basal: 1.708 u/hr

Carb Factor: 5.5 grams per unit

Correction Factor: 22.9 mg/dl per unit

Relative Insulin Sensitivity: 51%

http://www.diabetesnet.com/diabetes_tools/pumpsettings/

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From Decision Support Suggestions

- 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%)

opensourcediabetes.org

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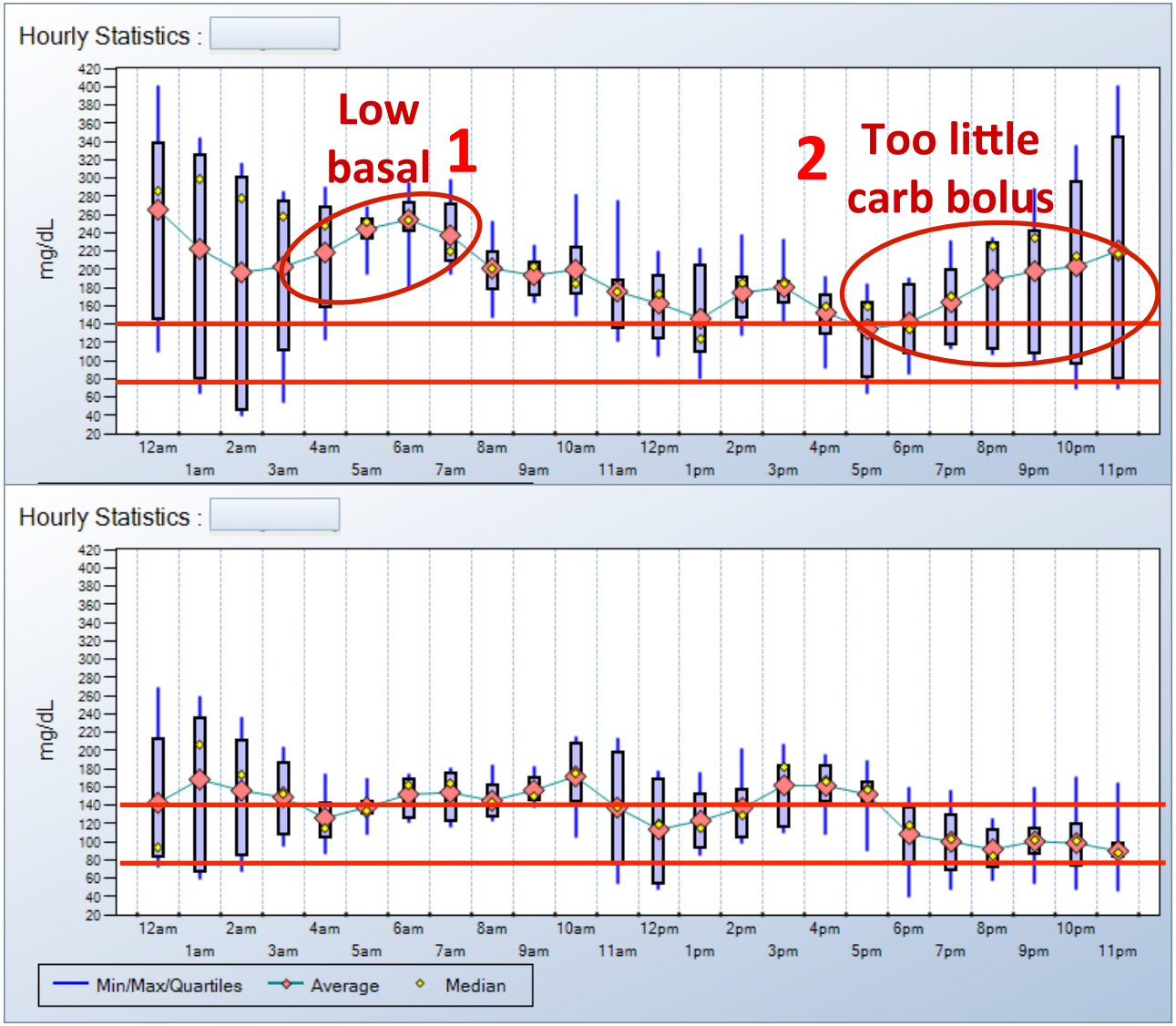
BGs & TDD Before & After Adjustment



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

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Common Pump User Issues

- Reactive vs proactive dosing ("The Rollercoaster") (Next talk)
- Too many basal rates
- Inaccurate CHO bolus / CHO counting
- Delayed boluses – high post meal BG
- Infusion site failures (Next talk)
- Lack of meaningful monitoring data – no pump/meter/sensor downloads
- Lack of clarity for when to override BC recommendations (Next talk)

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]

[1] Heinemann L, Nosek L, Kapitza C, et. al. Changes in basal insulin infusion: time until a change in metabolic effect is induced in patients with type 1 diabetes. Diabetes Care. 2009;32(8):1437–1439.

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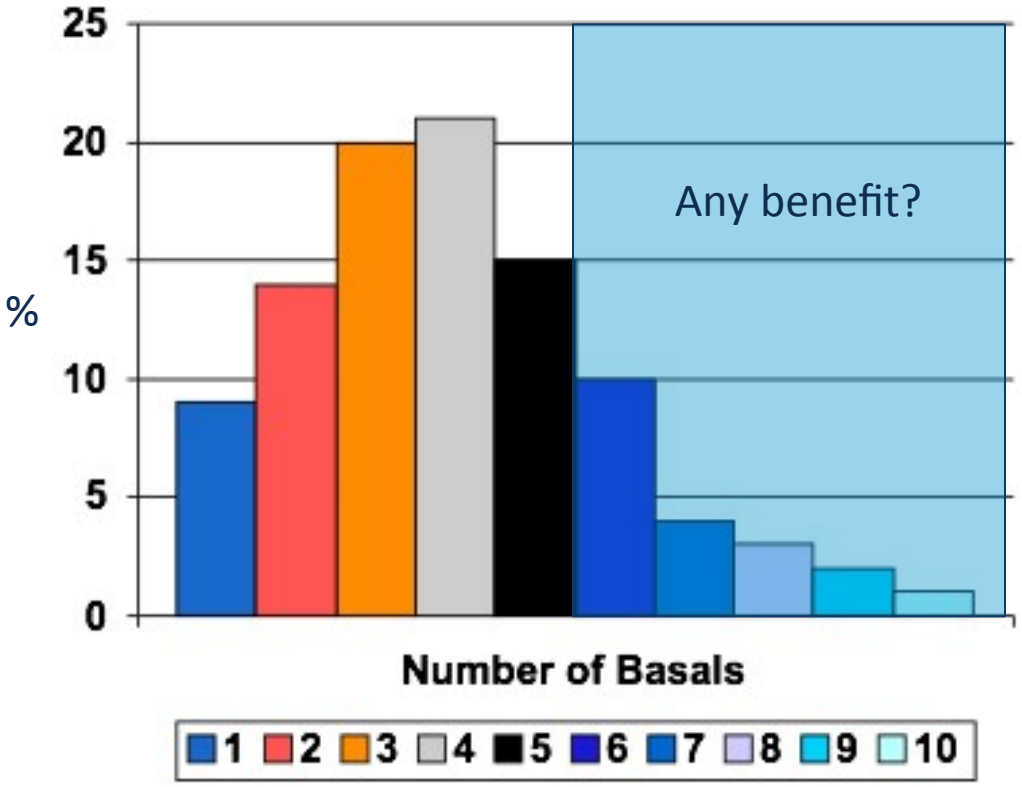
Optimal Number of Basal Rates?



Number of basal rates used per day from self-reports of hundreds of pumpers at insulin-pumpers.org

Once basal rate changes, it takes 3-5 hrs to have its full effect.*

Using more than 5 basals may have little benefit.

* Heinemann L, Nosek L, Kapitza C, et. al. Changes in basal insulin infusion: time until a change in metabolic effect is induced in patients with type 1 diabetes. Diabetes Care. 2009;32(8):1437–1439.

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Check the Basals

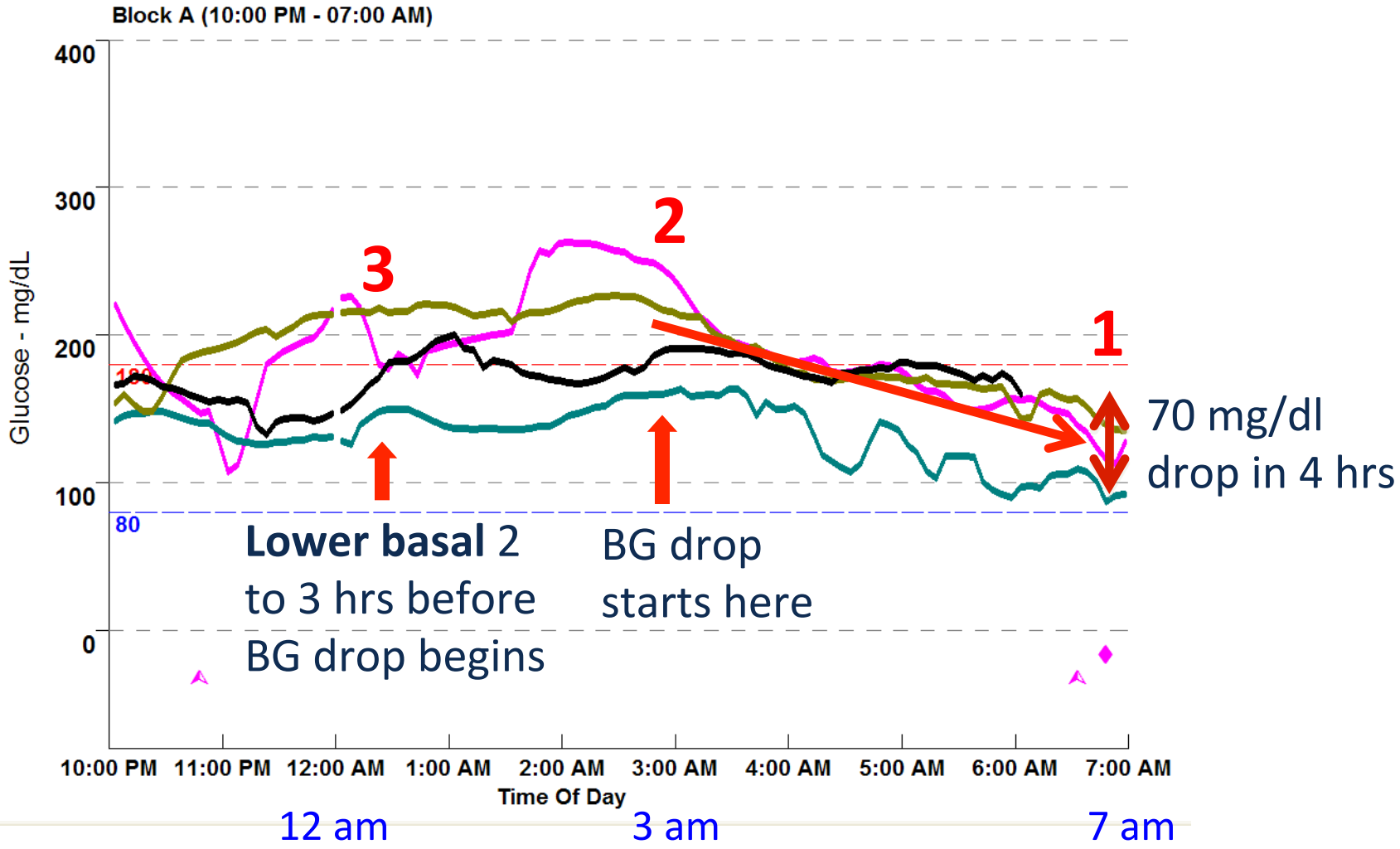
Basal profiles

Program: 1

	Start	Rate
1	00:00:00	0.250
2	04:30:00	0.550
3	08:00:00	0.300
4	13:30:00	0.150
5	17:30:00	0.475
6	22:00:00	0.300

Sum: 8.037 U

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

Temp Basal Rates

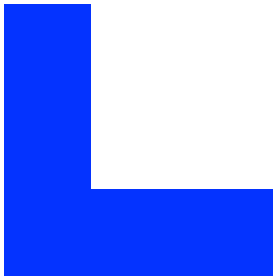
- Temp basals are great for physical activity, illness, fever, menses, testing new basals
- Don't stop a pump for lows – provides no benefit until 60-90 min. later
- Never suspend. Instead, use a temp basal reduction – pump restarts on time, fewer followup highs

Carb Boluses

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.

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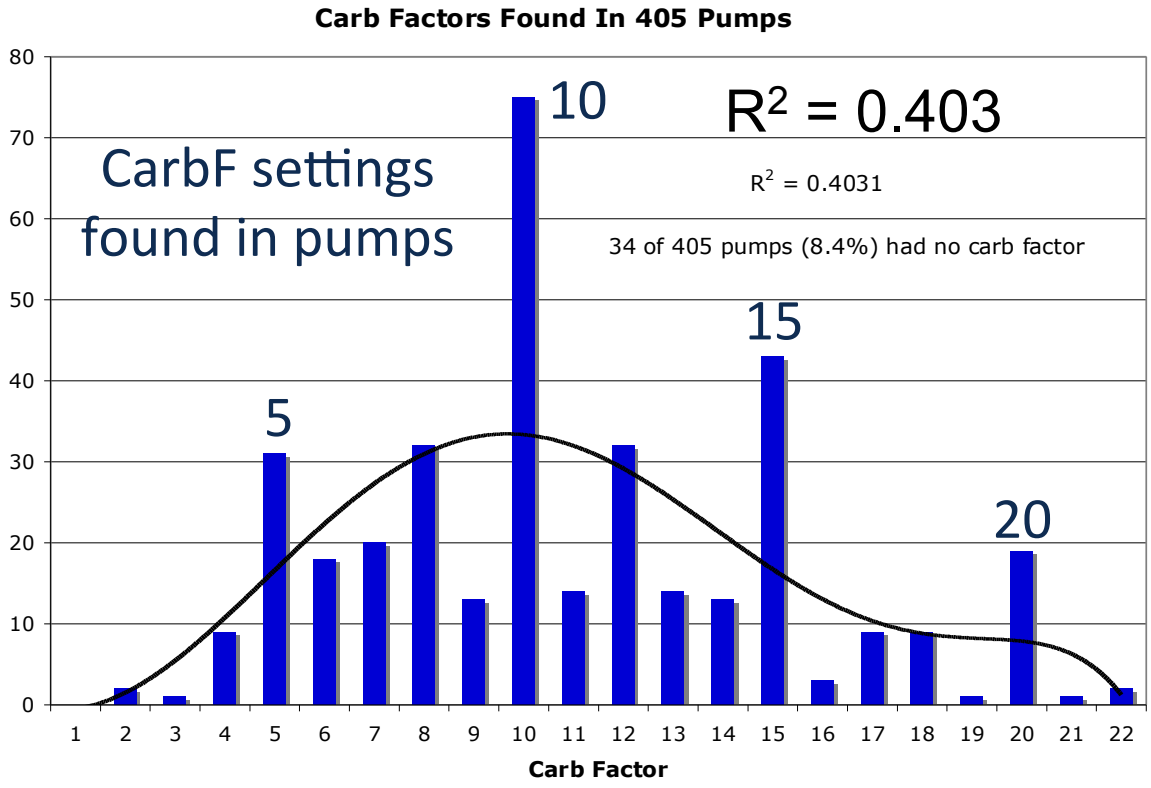
Get More Accurate Carb Boluses

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

Carb Factors Are Often Incorrect [1,2]



Don't use "magic" numbers!

CarbFs are not evenly distributed.

People prefer "magic" numbers – 5, 10, 15, and 20 g/unit.

Formulas provide accurate settings –> better than WAG!

1. J Walsh, R Roberts, T Bailey: J Diab Science & Technology 2010, Vol 4, #5, Sept 2010
2. J. Walsh, D. Wroblewski, and TS Bailey: Insulin Pump Settings – A Major Source For Insulin Dose Errors, Diabetes Technology Meeting 2007

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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

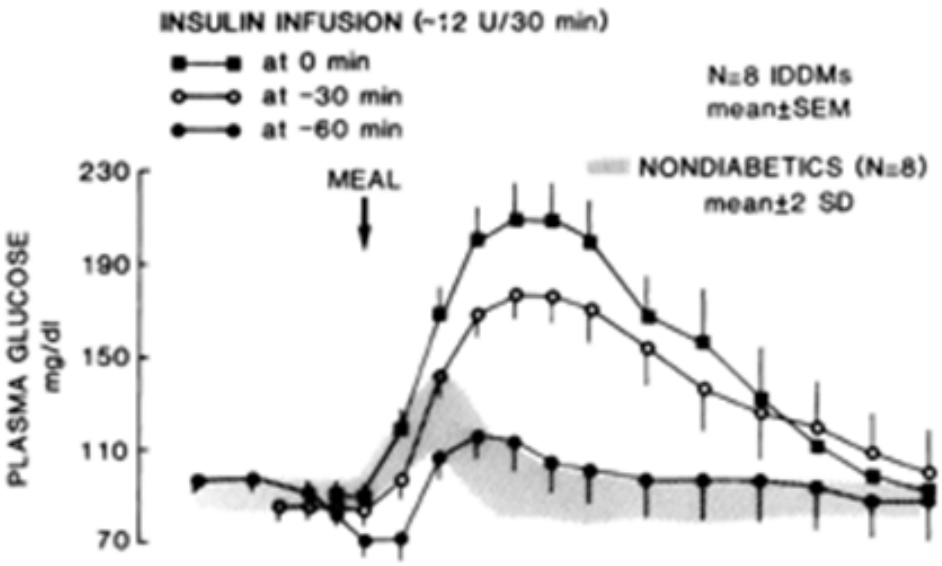

Figure shows Regular insulin injected 0, 30, or 60 min before a meal

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

GD Dimitriadis and JE Gerich: Importance of Timing of Preprandial Subcutaneous Insulin Administration in the Management of Diabetes Mellitus.Diabetes Care 6:374-377, 1983.

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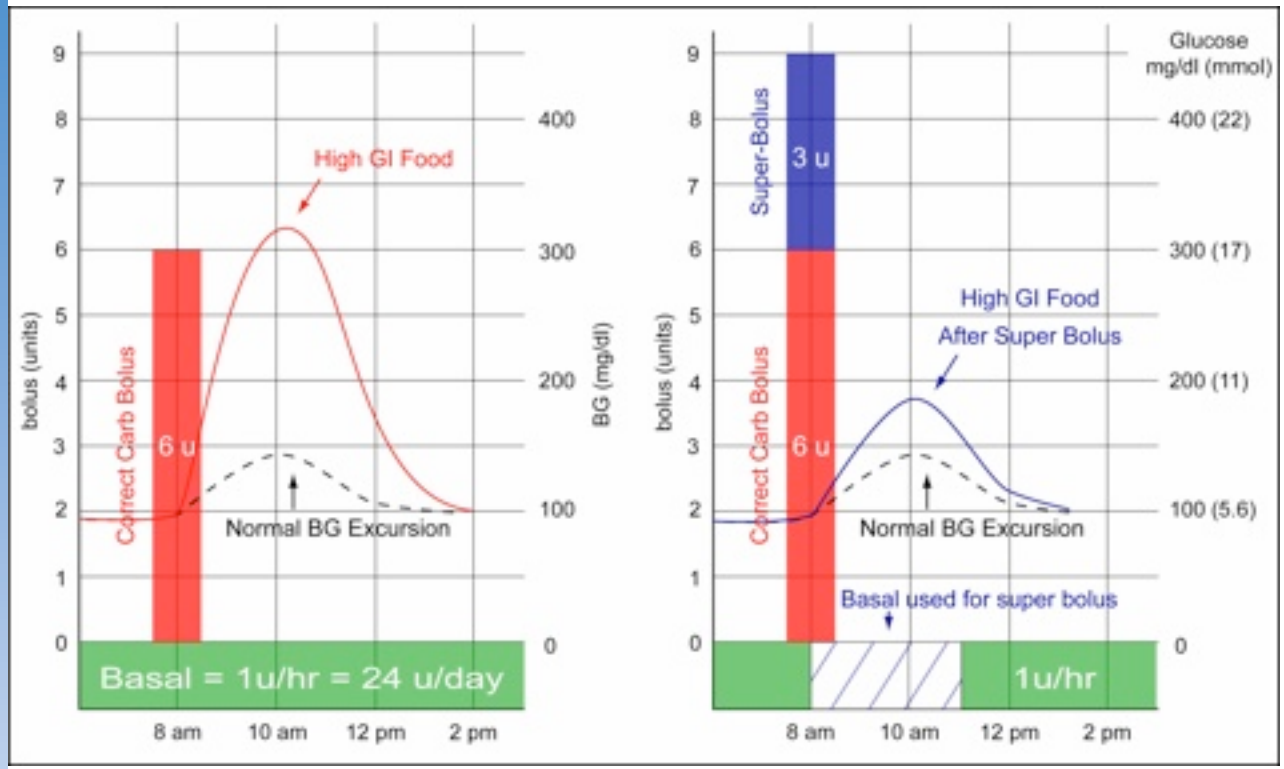
Clever Pump Trick –
Super Bolus – Shift Basal into Bolus



Helps when eating more than ¼ of your weight(lbs) in grams

Ie, more than 40 grs for someone weighing 160 lbs

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

A 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]

[1] J. Walsh: http://www.diabetesnet.com/diabetes_presentations/super-bolus.html September, 2004

[2] J. Bondia, E. Dassau, H. Zisser, R. Calm. J. Vehí, L. Jovanovic, F.J. Doyle III, Coordinated basal-bolus for tighter postprandial glucose control in insulin pump therapy. JDST, 3(1), 89-97, 2008

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)
- Make up for deficits in basal rates or carb boluses
- The smaller the deficit (better BGs), the larger the CorrF becomes (smaller correction doses)

1. J Walsh, R Roberts, T Bailey: J Diab Science & Technology 2010, Vol 4, #5, Sept 2010

How Long Does a Bolus Lower the Glucose?

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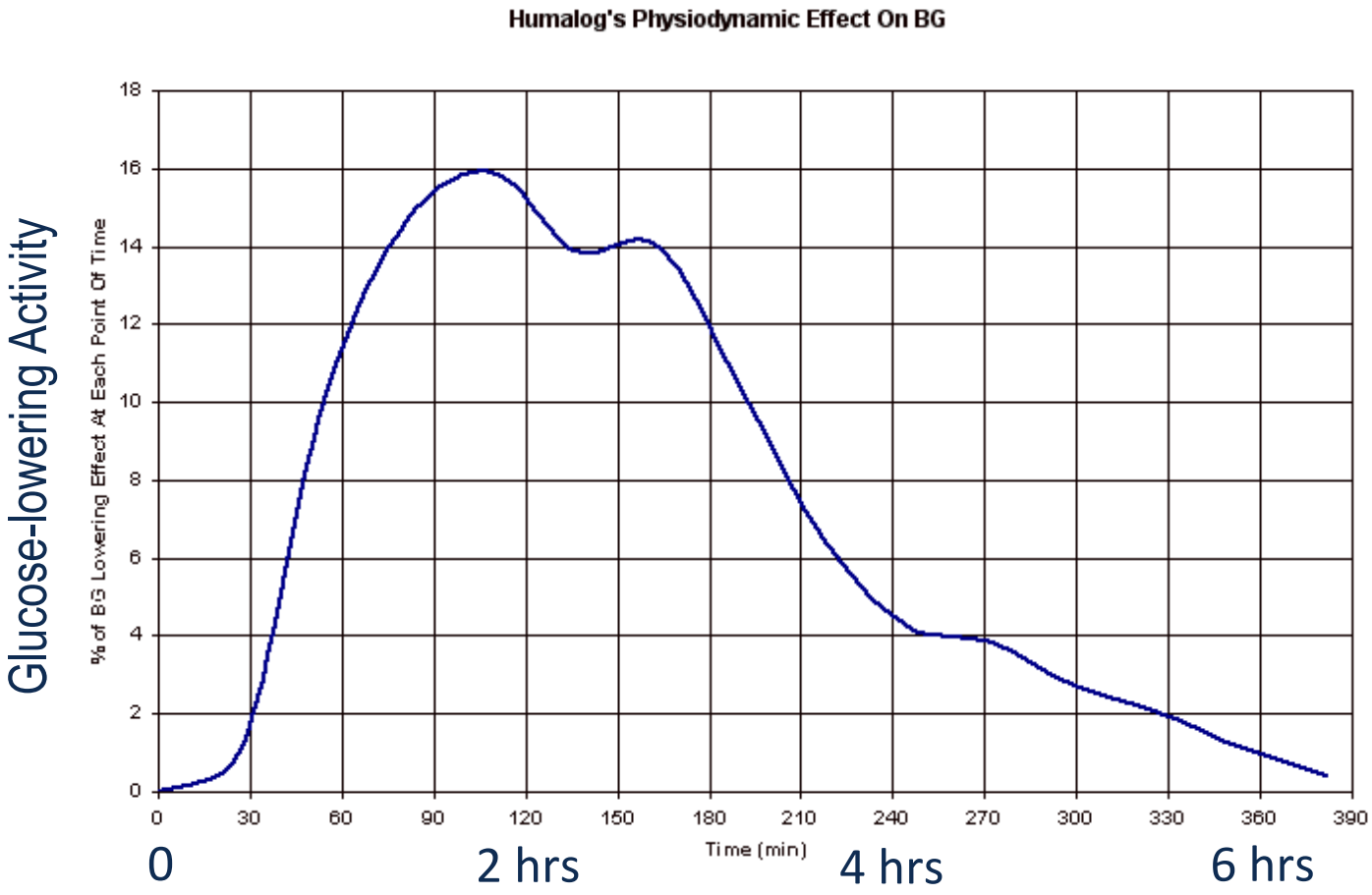
Duration Of Insulin Action

Accurate boluses require an accurate DIA



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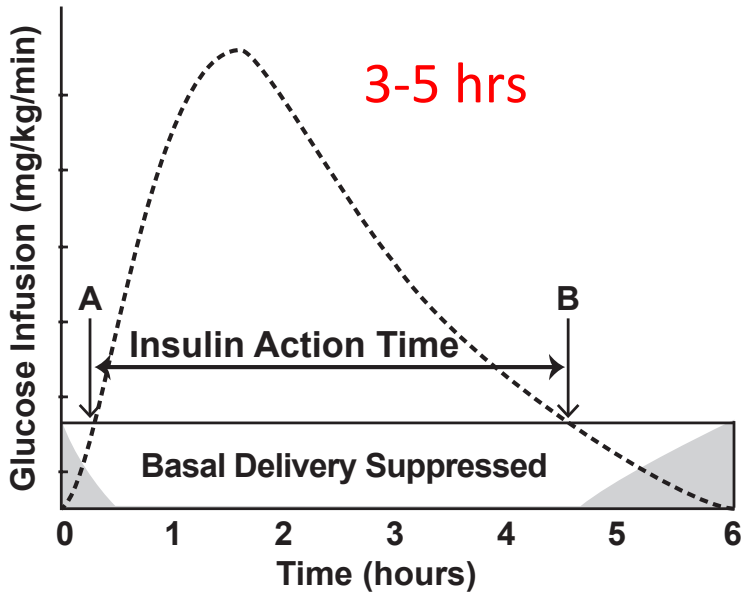
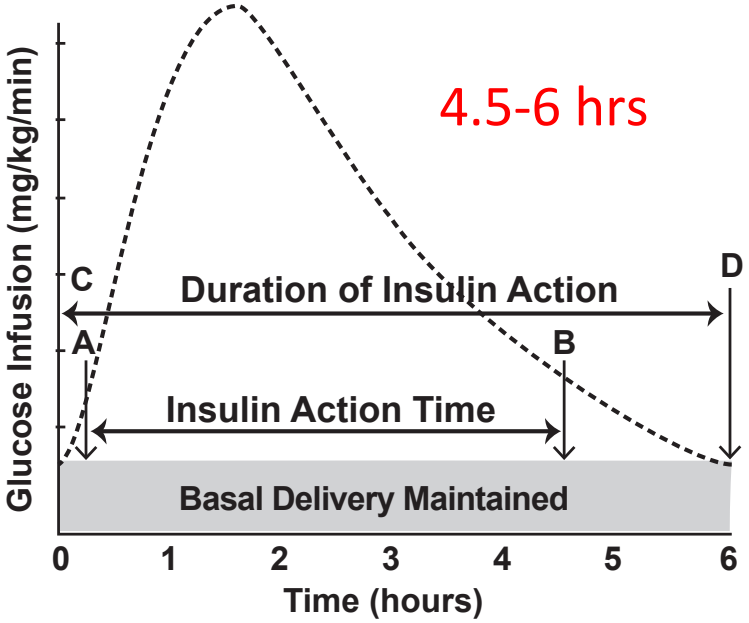
Insulin Action Time ≠ Duration of Action

Fig. 1 Insulin Action Time



IAT is measured between points A and B, and involves suppression of basal delivery.

Fig. 2 Duration of Insulin Action



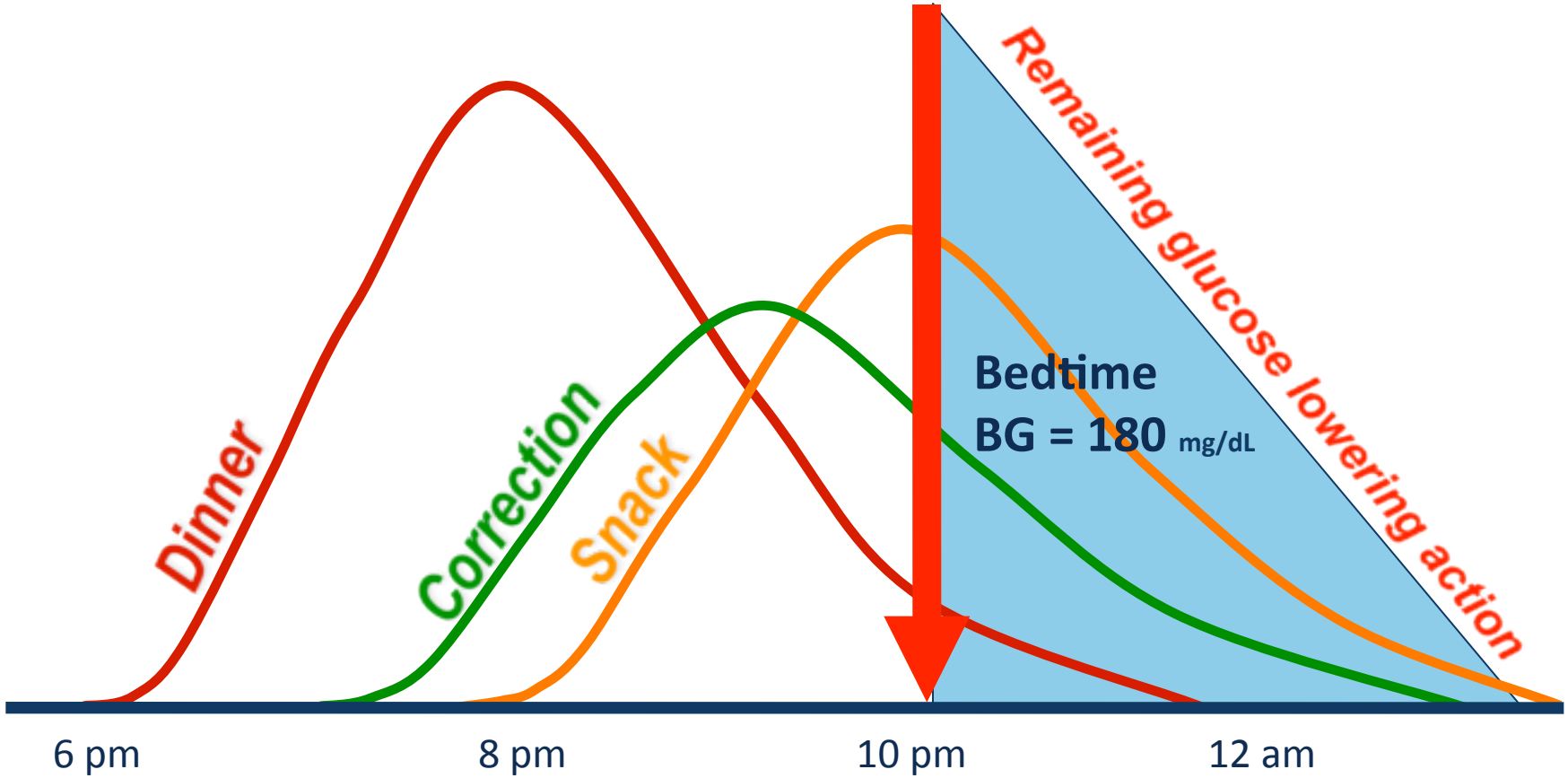
DIA is measured between points C and D. Once basal delivery is maintained, the PD of a bolus insulin can be directly measured.

J Walsh, R Roberts, L Heinemann. Confusion Regarding Duration of Insulin Action A Potential Source for Major Insulin Dose Errors by Bolus Calculators. *J Diabetes Sci Technol January 2014 vol. 8 no. 1 170-178.*

JDRF typeonenation

Bolus on Board / Insulin Stacking

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



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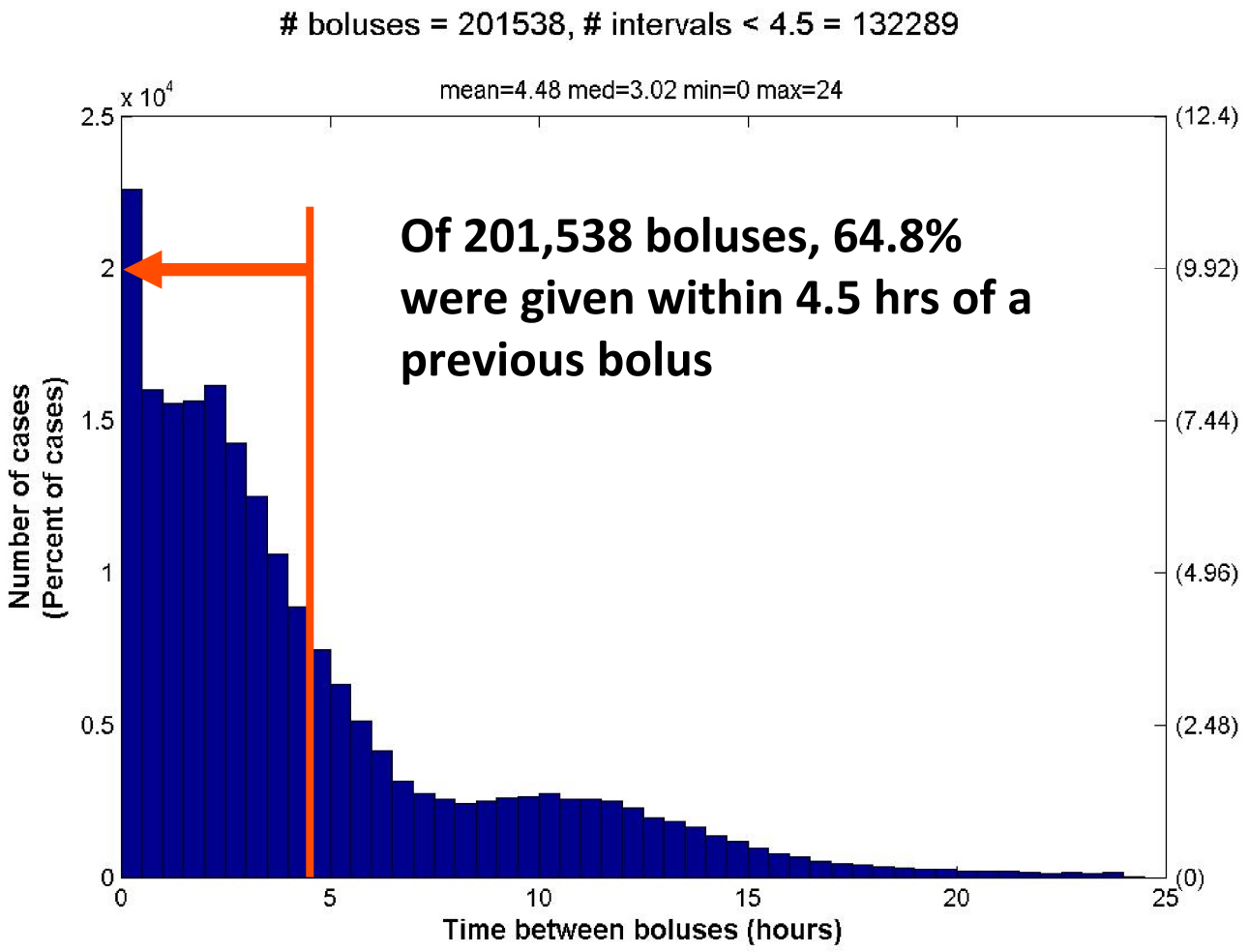
Insulin Stacking Is Common



J Walsh, D Wroblewski, T Bailey. Disparate Bolus on Board Recommendations in Insulin Pump Therapy. Poster 2007 AACE Meeting

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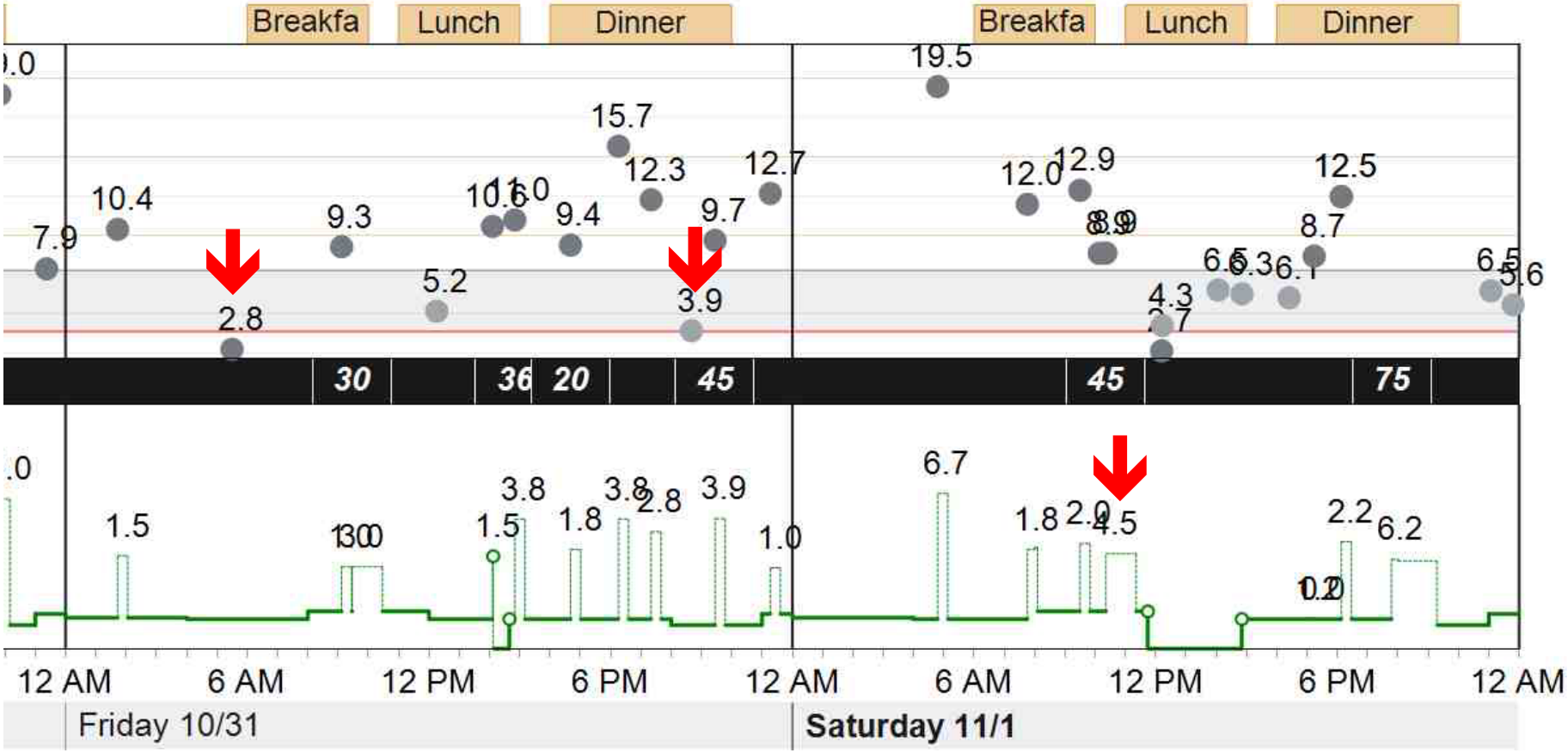
Short DIA Times Hide BOB & Cause Lows

How much BOB a pump thinks is left 3 hours after a 10 unit bolus for these DIA times:				
	Pump's estimate of Insulin On Board			
If DIA is set to:	3 hr	4.5 hr	5.0 hr	5.5 hr
Estimated BOB is:	0 u	2.5 u	3.4 u	4.0 u

Short DIA Times Cause Lows



This lady (39 yo, CarbF 10) has two lows on Friday caused by insulin stacking from her short DIA time (3 hrs)

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

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Clever Pump Trick –
How Many Carbs for a Low?

1. 1 gram for each 10 lbs of weight (minimum 10 gr)
2. Plus grams = BOB* x CarbF

Example: Amy's BG = 52 mg/dL with 2u of BOB (CarbF = 8 g/u)

- 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**

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When Is Your Bolus Calculator Just Plain Wrong?

Tuning and Taming the Bolus Calculator

The BC should help the user find bolus recommendations that better match their carb intake and current glucose while minimizing insulin stacking

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Pump Bolus Calculators Often Recommend Excessive Boluses

Recommended Bolus from BC			
Glucose	Units Needed	Animas	Other Pumps
#1: 99 mg/dL	0 u	0 u	5 u
#2: 101 mg/dL	0 u	5 u	5 u
#3: 200 mg/dL	2 u	5 u	5 u
#4: 300 mg/dL	4 u	5 u	5 u

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

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Extent of Insulin Overdose from a BC

Bolus Recommendations Differ between Pumps						
Time	BG mg/dL	Carbs Eaten	Carb Bolus	Total IOB	Carb + Corr Bolus	
					Cozmo Pump	Other Pumps
6:54 am	111	16	0	0	No bolus given	
9:52 am	174	0	3.0 u	0	4.3 u	4.3 u
10:35 am	140	50	5.0 u	3.3 u	2.2 u	5.0 u
11:58 am	117	40	4.0 u	3.6 u	0.5 u	4.0 u
1:12 pm	137	0	0	2.3 u	Eat 19 g	No action

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

TDD = 38 u, carb factor = 10 g/u, corr factor = 65 mg/dl, 65 mg/dL x 6.35 u = 413 mg/dl fall in BG if Other Pump's advice is followed

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Check BC's Recommended Bolus

4.35 u of BOB remain from a bolus given 3 hrs earlier – would you give 2.9 more units for a bedtime snack?

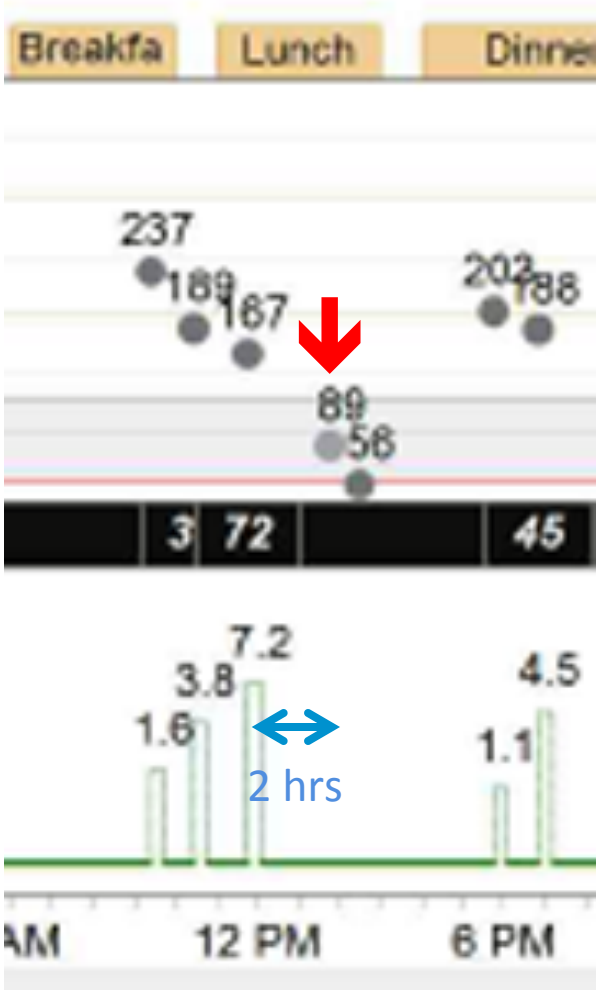
Bolus on board (IOB) = glucose-lowering activity that remains from recent boluses

Pumps cover all carbs even when excess BOB is present

BOB of 4.35u is larger than correction bolus (1.23u), so consider reducing recommended bolus

Ping and Vibe give correct bolus once the BG is below target

Case Study – Hypoglycemia From the BC



By omission:

Pump BC fails to warn user that they need carbs to cover their excessive BOB

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

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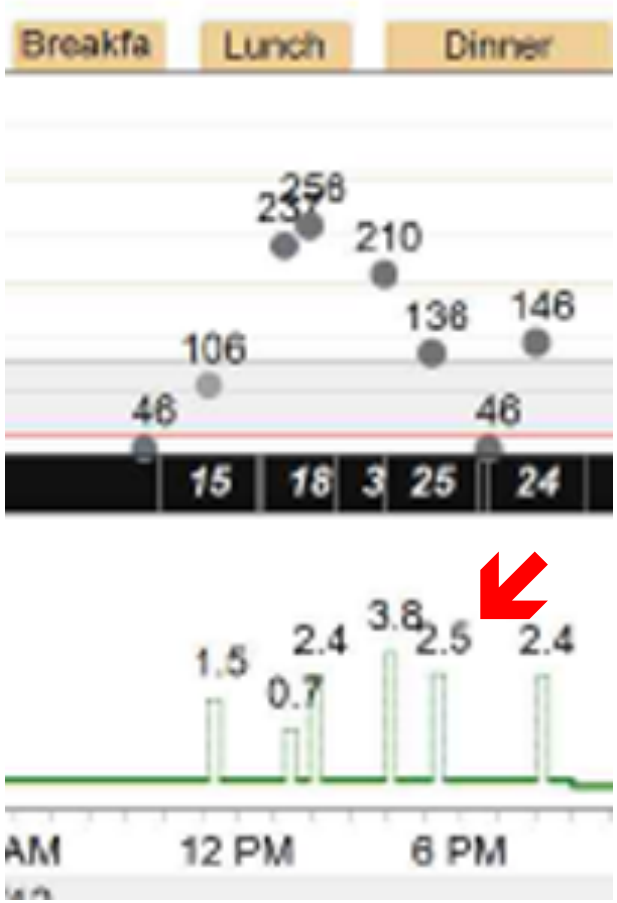
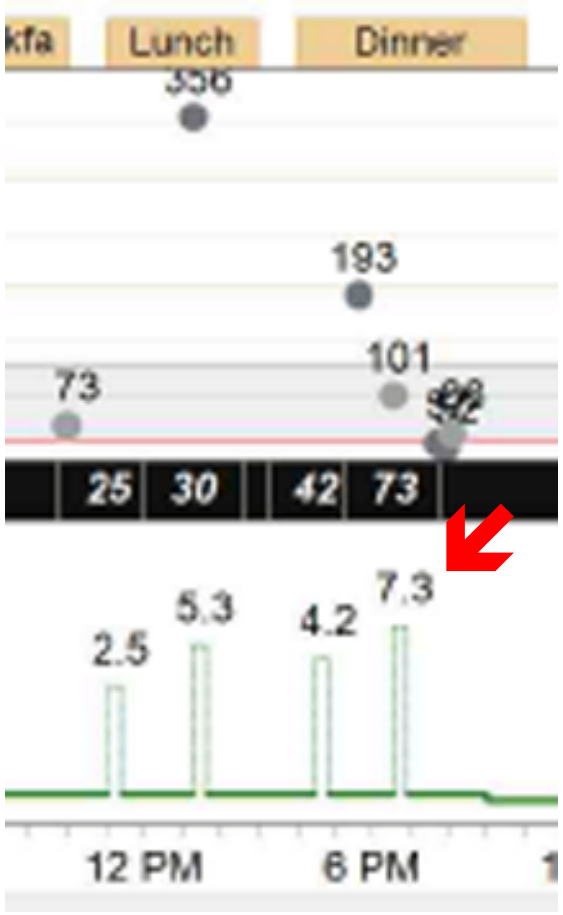
Case Study – Hypoglycemia From the BC





By commission:

Pump BC covers carbs with a full bolus even when excessive BOB is present

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

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Clever Pump Trick – Get an Accurate Bolus

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

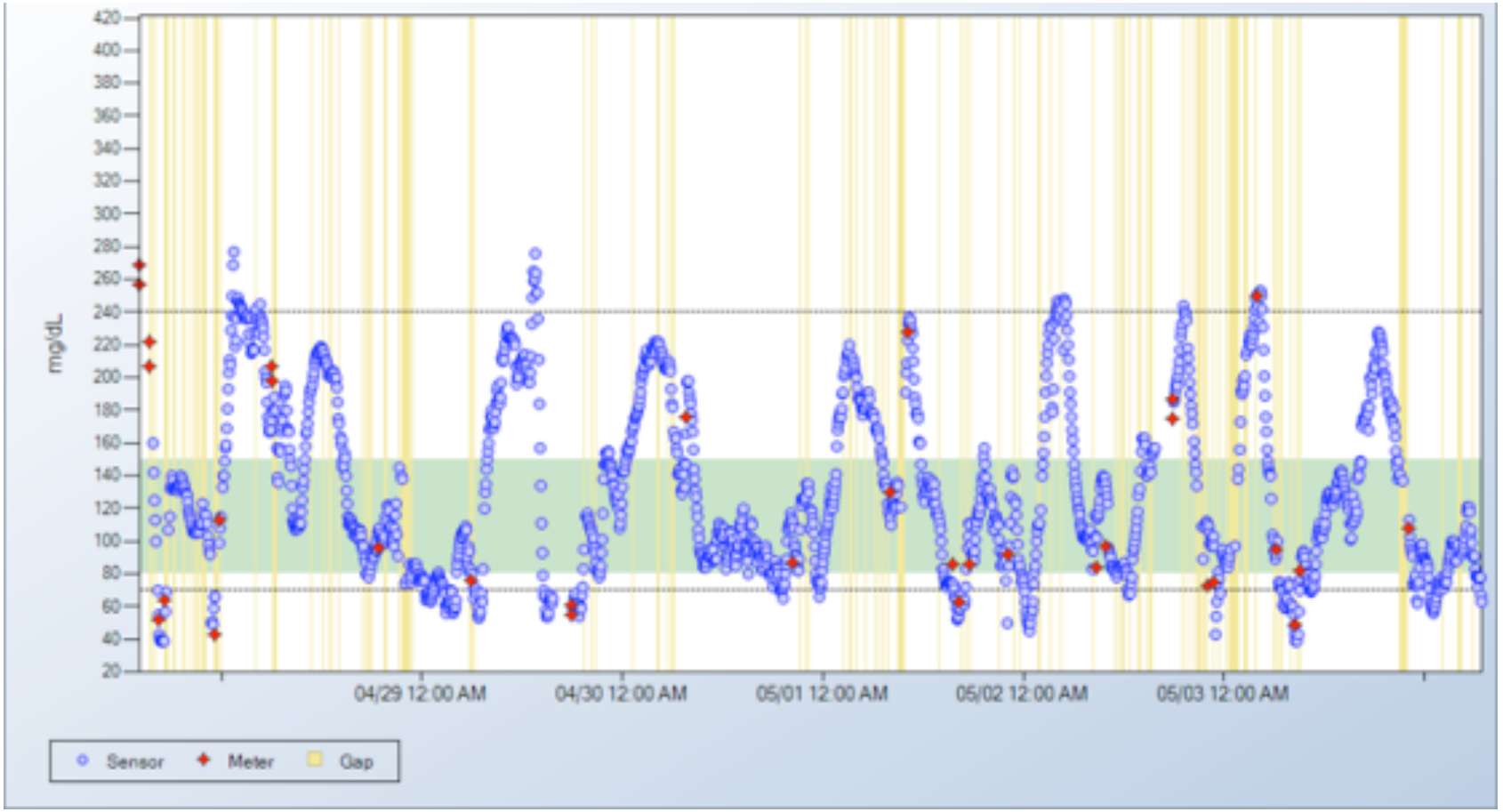
} **BOB larger than Corr bolus**

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

Get Off The Rollercoaster

Be proactive! Don't overtreat highs and lows.

Instead, adjust lifestyle or pump settings for great control!



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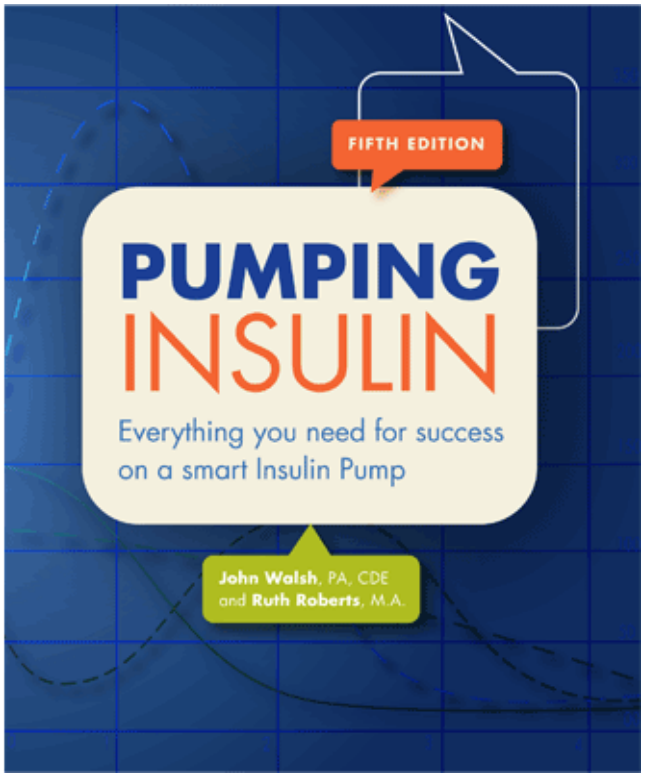
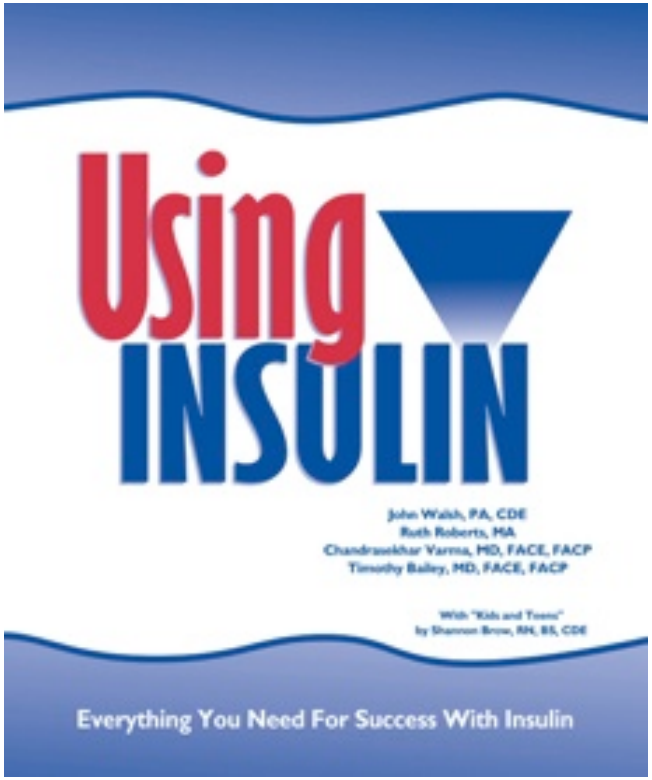
Life Is Better When You Know More!





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