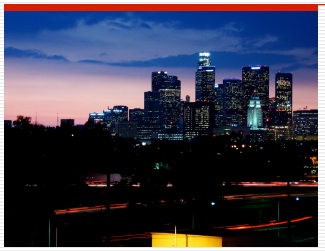
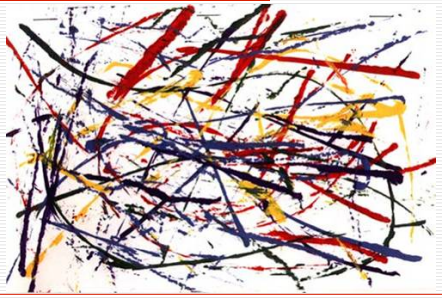
Pumps & Sensors
Practical Problem Solving



Children With Diabetes
Charlotte, NC
Sept 5, 2010

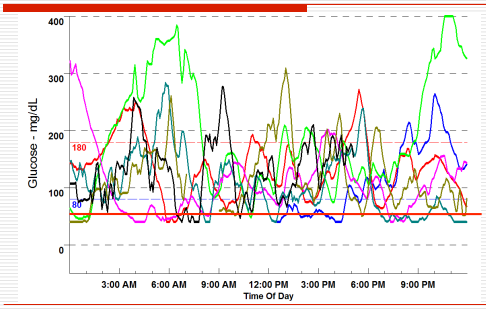
John Walsh, PA
jwalsh@diabetesnet.com
(619) 497-0900
Advanced Metabolic Care + Research
700 West El Norte Pkwy
Escondido, CA 92126
(760) 743-1431

"CGM" by Jackson Pollack



One Pollack sold for $140 million in 1996!

Make Your Own Jackson Pollack



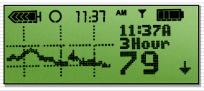
For only $1,000!

How To Read CGM Screens/Reports

Paradigm/Guardian® CGM Screens

On-Screen Reports

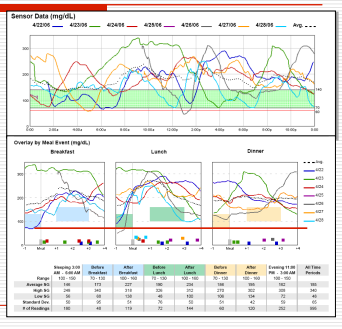
- 3 / 6 / 12 / 24-hr graphs
- Can scroll back for specific data points
- ↑↓ "direction" indicators
- Updates every 5 minutes
- Hi/Low Alerts
- Predictive Alerts (Guardian)



CareLink Online Reports

Sensor daily overlay

Sensor results by meal



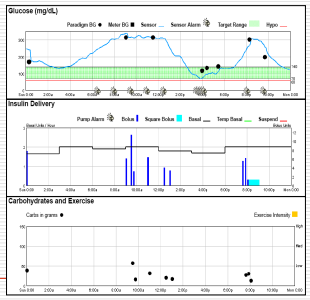
CareLink Online Reports

Daily summaries & layered reports

Sensor tracing

Basals & boluses

Carbs, exercise, etc



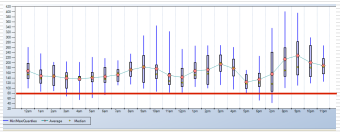
DexCom™ Seven Plus®

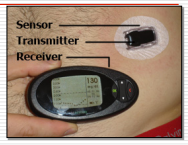
On-Screen Reports

- 1, 3, 6, 12, 24-hr graphs
- Updates every 5 minutes
- Hi/Low alerts
- Rate of Change alerts

DexCom™ 7 STS®

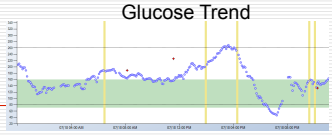
Dexcom DM2 Download Reports





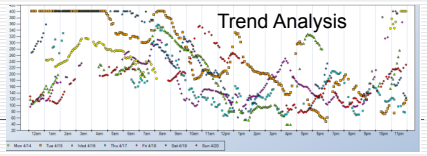
Hourly Stats

Glucose Trend



DexCom™ 7 STS®

BG Distribution



Trend Analysis

Alert Options

- Vibrate and/or beep
- Alerts for when glucose crosses specified high and low glucose thresholds
- Predictive alerts that you are likely to cross a high or low threshold (accurate up to ~20 min)
- Balance need for alerts against "nuisance factor" – Lack of sleep may raise your glucose

Where To Set The Alerts

LOW: **80 mg/dl**

Less than 90 – only for pregnancy

HIGH: **240 mg/dL** to start

Then gradually lower to 180 or less

Higher: young children, high risk jobs

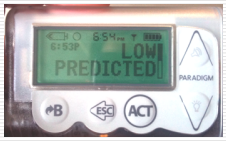
Lower: as alerts tolerated to get earlier alert for rising BG

Hi/Low thresholds are <u>not</u> BG target ranges

Adapted from: Hirsch, et al. Clinical Application of Emerging Sensor Technologies in Diabetes Management: Consensus Guidelines for CGM. Diabetes Technology & Therapeutics, 10:4, 2008, 232-244.

Predictions And Trends

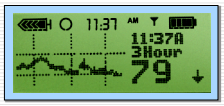
- Both help minimize highs and lows
- Good for:
  - Driving
  - Sports
  - Basal tests
  - Reducing uncertainty



Many thanks to Gary Scheiner, MS, CDE for help generating next 4 slides.

Can CGM Replace Fingersticks?

- Not right away – wait at least 12 hrs after new sensor is started
- Trust CGM only if recent calibrations are in line
- Only if you ongoing fingersticks are done to ensure accuracy



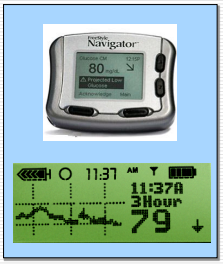
Hypoglycemia Alerts

Predictive hypo alert or hypo alert & stabilizing: less treatment

- Less than usual carbs?
- Medium G.I. food

Hypo alert & dropping: aggressive treatment

- Full or increased carbs
- High G.I. food



Check BOB for guidance!

Adjust Boluses Based on BG Direction

- 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%

How Many Grams For A Low?

If DIA time and pump settings are accurate:

1. Carbs for low itself = 8-15 grams (based on wt & BG)
2. Then add the grams needed to offset BOB:
   add. grams = BOB X CarbF
3. Example:
   If BOB = 1.5 u and CarbF = 12 g/u,
   total grams needed = 15 g + (1.5 u x 12 g/u)
   = 15+18 or 33 grams of carb for this low BG

Consider extra grams when needed for increased activity.

Help With Hypo Detection

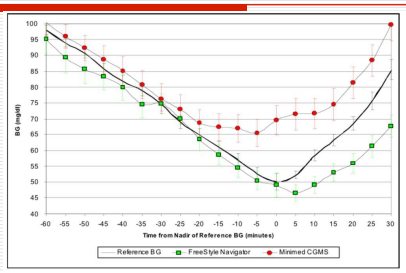


Figure 3. Accuracy assessment of CGM versus reference blood glucose.

HA Wolert: Use of Continuous Glucose Monitoring in the Detection and Prevention of Hypoglycemia Journal of Diabetes Science and Technology V1, #1, Jan 2007

Use of 2 / 3 / 6 Hr Trend Graphs

- How different foods impact BG
- How did bolus work
- Discover postprandial spikes
- Exercise effects
- Impact of stress
- Pramlintide/acarbose influence

5 Hr CGM Trend Analysis

Determine why glucose went high or low.

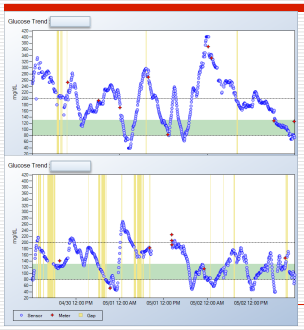
Starting BG
Can be high, low, or normal

If BG 4-5 hrs later is:	Insulin/Carbs in last 5 hrs:
Too High	Insulin too low or carbs in excess
In Target	Insulin & carbs balanced
Too Low	Excess insulin or too few carbs

Use of 6 / 12 / 24 Hr Trend Graphs

- Helps decide basal insulin doses
- Shows delayed effects of exercise, stress, high-fat foods
- Reveals overnight glucose patterns
- Lets user know when bolus action is complete

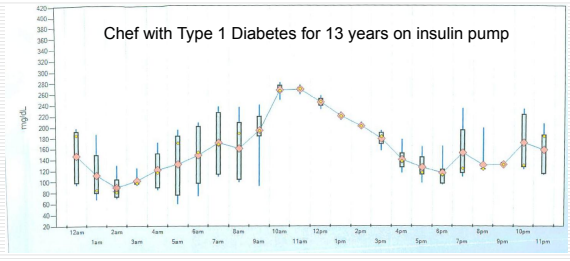
CGM As Behavior Mod Tool



- First 3 days
- Next 3 days

Type 1 x 29 yrs on pump

First Two Days On CGM



CGM Two Days Later

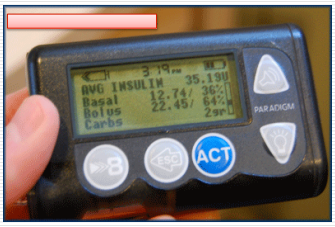
Dosing Tips

Why Use TDD To Improve Control?

- Average TDD ≈ Average BG
- Makes finding accurate basal rates, CarbF, and CorrF easy
- Right TDD and settings lead to lower and more stable BGs

Use pattern management to fine tune.

Find The TDD



TDD = 35.19 u

Low basal at 36%

2 gr of carb/day means Bolus Wizard is not used

Raise The TDD

10.6 Find Your True TDD

This table helps you find a more accurate TDD when your readings are often above 140 mg/dl (mmol) AND you are not having frequent or severe lows.
Simply find a current 14 day average TDD from your pump on the left and an average glucose from your meter (or a recent A1c) on the bottom. When they intersect provides a better estimate for your TDD.

Current TDD	14 day avg BG: 155.0	169.0	183.0	197.0	212.0	226.0	240.0	255.0	269.0
	A1c: 7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0
100 u	103.0	105.8	108.6	111.4	114.4	117.2	120.0	123.0	125.8
95 u	97.9	100.5	103.2	105.8	108.7	111.3	114.0	116.9	119.5
90 u	92.7	95.2	97.7	100.3	103.0	105.5	108.0	110.7	113.2
85 u	87.6	89.9	92.3	94.7	97.2	99.6	102.0	104.6	106.9
80 u	82.4	84.6	86.9	89.1	91.5	93.8	96.0	98.4	100.6
75 u	77.3	79.4	81.5	83.6	85.8	87.9	90.0	92.3	94.4
70 u	72.1	74.1	76.0	78.0	80.1	82.0	84.0	86.1	88.1
65 u	67.0	68.8	70.6	72.4	74.4	76.2	78.0	80.0	81.8
60 u	61.8	63.5	65.2	66.8	68.6	70.3	72.0	73.8	75.5
55 u	56.7	58.2	59.7	61.3	62.9	64.5	66.0	67.7	69.2
50 u	51.5	52.9	54.3	55.7	57.2	58.6	60.0	61.5	62.9
45 u	46.4	47.6	48.9	50.1	51.5	52.7	54.0	55.4	56.6
40 u	41.2	42.3	43.4	44.6	45.8	46.9	48.0	49.2	50.3
35 u	36.1	37.0	38.0	39.0	40.0	41.0	42.0	43.1	44.0
30 u	30.9	31.7	32.6	33.4	34.3	35.2	36.0	36.9	37.7
25 u	25.8	26.5	27.2	27.9	28.6	29.3	30.0	30.8	31.5
20 u	20.6	21.2	21.7	22.3	22.9	23.4	24.0	24.6	25.2
15 u									

For frequent highs, increase the current avg. TDD from a recent A1c or a 14 day BG average from meter.

Avg BG on pumps is 184.5 mg/dl (10.2 mmol) – most pumpers need a higher TDD

J Walsh and R Roberts: *Pumping Insulin (5th ed)*, 2011

Basal / Carb Bolus Balance

2. Optimal Insulin Use
Mean Values For Optimal Doses In Best Control Tertile

Insulin Source	% of TDD	Interquartile Range (%)
Basal	47.8%	39.6% to 54.9%
Carb Boluses	43.1%	35.6% to 51.2%
Corr Boluses	9.0%	6.2% to 11.3%
CorrF Rule Number* = 1960 mg/dl per unit (IQR = 1413 to 2151)		

* CorrF Rule Number = Avg CorrF x Avg TDD

Insulin use from best control tertile (132 of 396 pumps with avg BG of 144 mg/dl) in our Cozmo data study

Keep basal rates and carb boluses balanced

- For frequent lows, lower the higher one.
- For frequent highs, raise the lower one

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

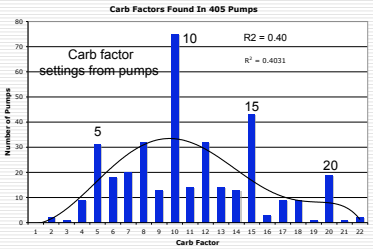
Does Your Pump Have The Right Settings?

Your Smart Pump Arrives Dumb

Your average BG and BG stability depend on:

- An accurate TDD
- Accurate basal rates (about 50% of TDD)
- An accurate CarbF
- An accurate CorrF
- An accurate DIA
- An accurate accounting of BOB*
- Appropriate correction target

Carb Factors Found in 405 Pumps[1]



Carb factors from pumps are not physiologically distributed.

Less accurate "magic" numbers – 5, 10, 15, and 20 g/unit – are preferred.

[1] J. Walsh, D. Wroblewski, and TS Bailey: Insulin Pump Settings – A Major Source For Insulin Dose Errors, Diabetes Technology Meeting 2007

Pump Setting Formulas*

Basal = ~ 48% of TDD

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

Carb factor is directly related to insulin sensitivity = average carb factor times individual's insulin sensitivity

Corr. Factor = 1960 / TDD

Correction factor is inversely related to TDD and also inversely related to avg. BG

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

Pump Settings Table

3. Estimates of Basal, CarbF, and CorrF Basal on TDD and Wt

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

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

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

How Pumps Handle BOB

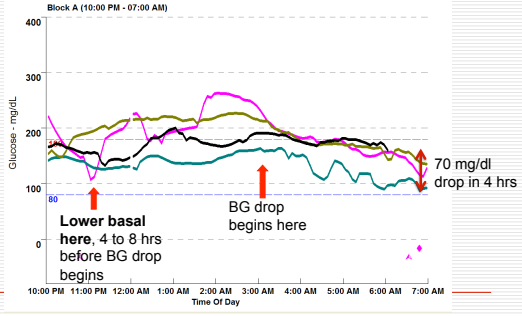
What's In the BOB & What Is It Applied Against?				
	BOB Includes This Type Of Bolus		BOB Is Subtracted From This Type Of Bolus	
	Carb	Correction	Carb	Correction
Injections	No	No	No	No
Animas Ping	Yes	Yes	No*	Yes
Deltec Cozmo	Yes	Yes	Yes	Yes
Insulet Omnipod	No	Yes	No**	Yes
Medtronic Revel	Yes	Yes	No	Yes

* Except when BG below target BG

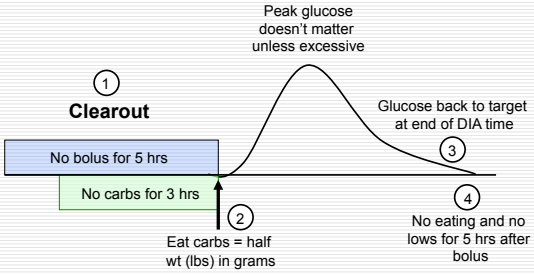
** Except when BG is below target and reverse correction is turned on

YES = Safer

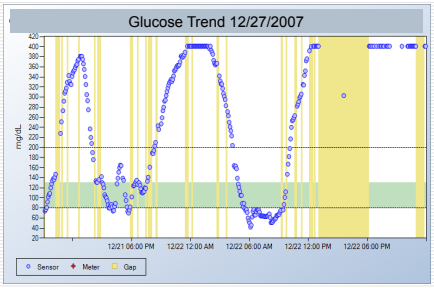
Overnight Basal Check



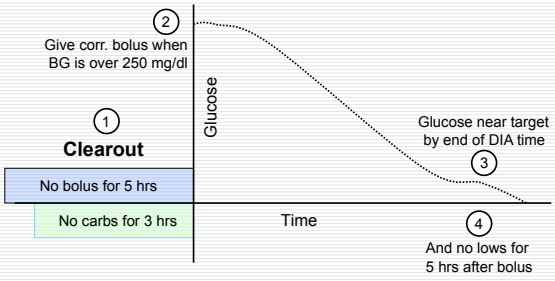
Test The Carb Factor



Is This A Carb Factor Issue?

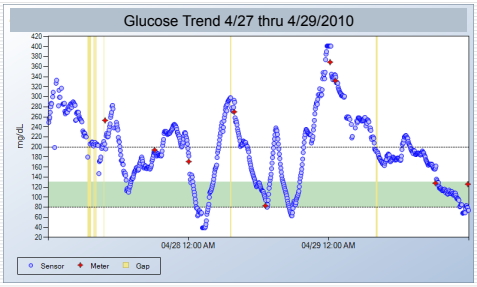


Test The Correction Factor & DIA

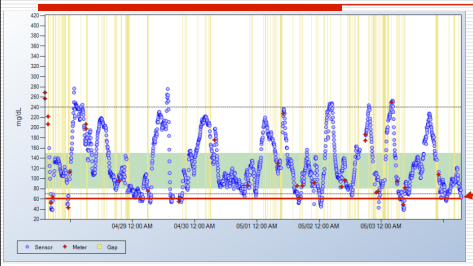


CGM helps check both correction factor and DIA time

Is This A CorrF or DIA Issue?



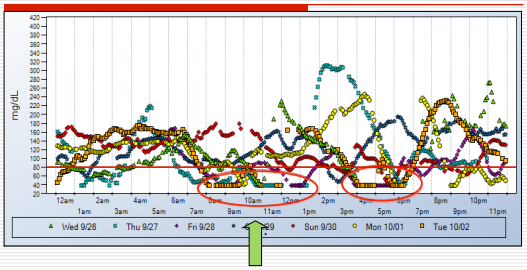
Stop Lows First



Frequent lows followed by high BGs ~2/day

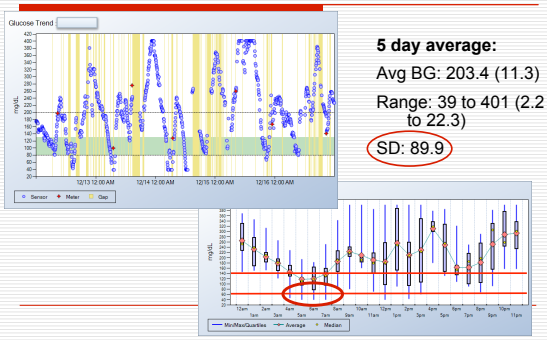
60 mg/dl (3.3 mmol)

Lower The TDD?



Need a lower TDD with new basal rates, CarbF and CorrF derived from it.

Highs And Lows – What To Do?



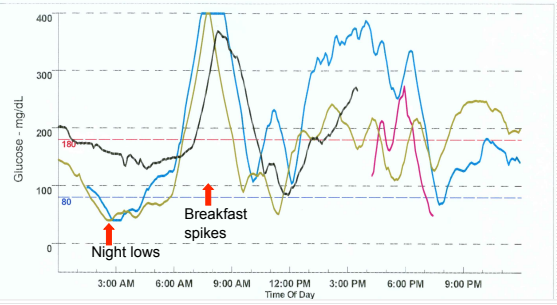
5 day average:

Avg BG: 203.4 (11.3)

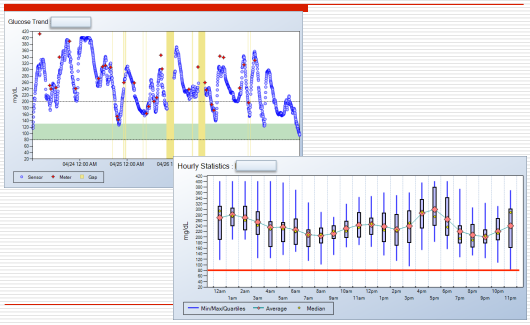
Range: 39 to 401 (2.2 to 22.3)

SD: 89.9

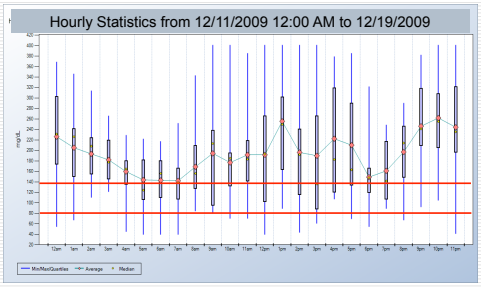
Breakfast Spikes After Night Lows



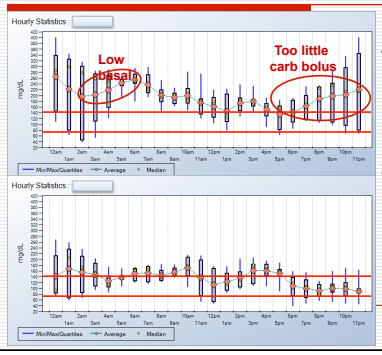
Raise The TDD?



Raise The TDD?



Before & After Insulin Adjustment



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)

Pattern Control Steps

Situation	Steps To Take
Frequent lows	Lower TDD by 5% or more
Highs and Lows (lows come first)	Lower TDD, check for short DIA
Highs and Lows (highs come first)	Check for settings that don't "fit the TDD", raise CorrF number
Mostly high	Raise TDD from table or formula
Occ. Unexplained highs	Change infusion set technique or infusion set brand, watch for association with particular food or stress, or ?

Not All High Readings Are Equal

Cause Of High	Corr. Dose Needed
Jelly on the finger	0 (wash, repeat test)
Forgot to bolus	Corr dose **only**
Infusion set failure	Corr + basal
Rebound high after release of stress hormones	Corr + stress cover. .
Ketoacidosis	2-3 X normal corr
Infection	1.5-3 X normal corr

Hyperglycemia Pearl

When you want to speed the fall with a high glucose reading:

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

– Lets BG fall faster!

– But make sure to eat carb grams in time!

Occlusions Worsen Control

BG Tertile	Low	Middle	High
Avg BG	146.6	181.6	229.3
BGs/day	4.74	4.52	4.22
Blocks/ month	1.36	3.04	3.57

Occlusions / Blockages

Should never happen!

More than once a month?

- Change brand of infusion set
- Or brand of insulin (less likely)

Never Stop Your Pump!*

- You may forget to turn it back on
- It's rarely needed
- It doesn't help when you're low

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

Never go off pump more than 1 hour without giving a bolus before disconnect to cover missing basal (max time off ~4 hrs after disconnect bolus).

* Unless hiking 7 mi. on a mountain trail after a bear ate all your food

Common Reasons For Set Failure

Unexplained highs can occur from:

- Poor design
- Use of auto-inserters
- Bent or kinked Teflon
- Not taping down the infusion line
- Bleeding (hematoma)
- Inadequate training

Don't accept "scarring" or "poor absorption" (blame shifting)

Another Source For Set Failure

Photo by Jana L'Esperance

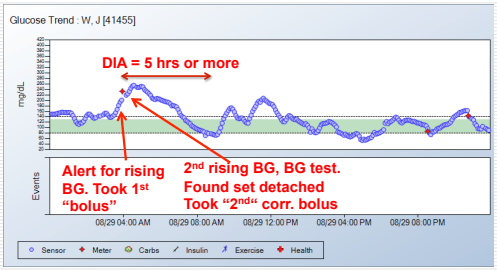
Is There An Infusion Set Problem?

- Do sites often “go bad”
- Are you experiencing “unexplained” highs?
- Do highs correct only after you change the infusion set?

Yes?

- Anchor the infusion line with tape
- Review site prep technique
- Switch to a different brand of infusion set

Night Infusion Set Failure On CGM



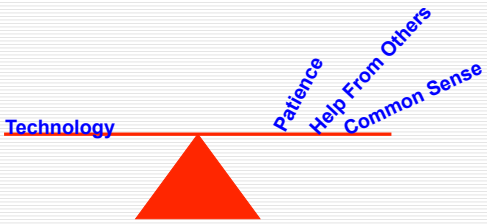
Tips For CGM

- Be patient and have realistic expectations
- Don’t panic if the meter and sensor numbers differ
- Look at trends not just individual values
- Rapid rises usually mean you need more insulin
- Expect lag time
- No Tylenol with Dexcom

More Tips For CGM

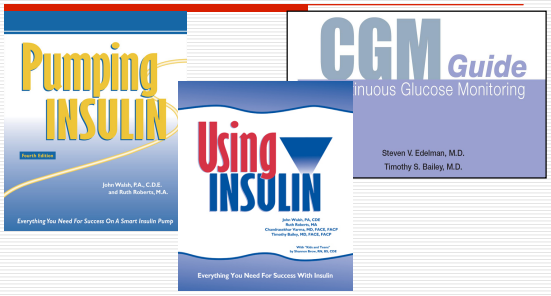
- Wear CGM at least 90% of the time
- Look at the monitor 10-20 times per day
- Don’t go from BG to BG – Get the big picture!
- Don’t over-react to data – Avoid frequent between meal corrections until pattern is clear
- Take BOB into account
- Calibrate!
- Minimize “nuisance” alarms

Technology Alone Never Enough



A pump or CGM can’t adjust your doses for exercise, heat, GI index of foods, stress, infection, circumstances around high BG, etc.

Reading – Still The Best Way To Learn



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