UNDERSTANDING YOUR CGM DATA AND MAKING TREATMENT DECISIONS ON YOUR OWN

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Agenda

1. Overview of sensor pros and cons
2. CGM chemistry and physics
3. Real time CGM tips
4. Retrospective CGM review and tips
5. Duration of insulin action VS Bolus on Board VS Insulin action time
6,7,8…. Lots of math!

Disclosure:
- No financial disclosure

Disclaimer:
- Some information is based on individual experiences and personal experience
Ideal CGM Candidates....

Ideal CGM candidates are individuals who:
- Well educated about DM and highly motivated
  - Are prepared to see the data.
  - Are willing to make changes.
  - Are willing to wear the CGM system.
  - Frequent SMBG
Benefits for CGM

- Provides information about the direction, magnitude, duration, frequency and causes of fluctuations in blood glucose, infusion set failure
- Now approved for the use to make therapeutic decisions
- Provides trending information of multiple glucose levels with fair accuracy
  - Especially if BG is rapidly fluctuating and in the hypoglycemic ranges
  - Basal rate testing
  - Post prandial BG excursions and the subsequent adjustment of I:C
Disadvantages to CGM

- Currently, all available CGM technologies measure ISF
- Calibrations still needed to increase accuracy
- Sensitivity vs. specificity with BG alarms
  - Current CGM technologies have a ‘trade-off’ between an alarm’s sensitivity and specificity
    - Alarm at lower threshold (60mg/dl) = increased specificity, but decreased sensitivity
    - Alarm at higher threshold (100mg/dl) = increased sensitivity, but decreased specificity, which leads to more false alarms
Mechanism of Sensors – glucose diffusion across capillary wall

- **Dexcom and Medtronic**
  - Glucose oxidase technology
  - Glu+H₂O=gluconic acid+H₂O₂
  - H₂O₂ dissociates→charge is proportional to glu concentration

- **Free Style Navigator**
  - “wired enzyme” technology
  - Electrode covered with sensing element which converts glucose concentration to electrical current
## Accuracy of Difference CGM Systems

<table>
<thead>
<tr>
<th>CGM System</th>
<th>MARD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dexcom G5</td>
<td>9%</td>
</tr>
<tr>
<td>Dexcom G4</td>
<td>13%</td>
</tr>
<tr>
<td>Medtronic Enlite</td>
<td>13.6%</td>
</tr>
<tr>
<td>Abbott FreeStyle Navigator</td>
<td>11%</td>
</tr>
<tr>
<td>Abbott Freestyle Libre</td>
<td>11.4%</td>
</tr>
</tbody>
</table>
What Is Calibration?

Sensor calibration is the pairing of the fingerstick (FS) value to the sensor value from the interstitial fluid (ISF) space

- FS measures plasma-calibrated blood
- Sensor reads electrical current produced by glucose oxidase reaction
- Calibration “teaches” the sensor to recognize the glucose value that corresponds with the electrical current signal
- Calibration is how the device learns what the signals from the sensor mean

Why Is Calibration Important?

- All sensors must be calibrated for optimal performance (and with some devices, calibration is needed to continue to read glucose values)\(^1\)

- Calibration is the reference information used by the sensor algorithm to define glucose values of the sensor\(^1\)

- Proper calibration of any sensor device can lead to optimal outcomes of sensor performance\(^2\)
  - Quality of calibration may be affected by human error in the individual use of meters

DexCom Features:

- Sensor life: 7 days
- Warm Up: 2 hours
- Calibration:
  - 2 initially
  - At least once every 12 hours
  - Can be done with any BG meter
- Data Updated Every 5 Minutes
- Alerts:
  - Low and High Threshold
- Trend Data:
  - Arrows
Dexcom G5

FDA Approval 3/27/2006
Medtronic 530G/630G

- Sensor life: 6 days
- Warm Up: 2 hours
- Calibration:
  - At least once every 12 hours
- Data Updated Every 5 Minutes
- Alarms:
  - Low and High Threshold, suspend threshold
  - and predictive suspend threshold
- Trend Data:
  - Arrows
  - Immersion in up to 12 feet (3.6 meters) of water for up to 24 hours
FreeStyle Libre Flash

- 14 day use
- sensor (0.2 inches in length, about the thickness of a hair)
- factory calibrated
- fingerstick is recommended: when hypoglycemic, when glucose is changing rapidly, or when symptoms don’t match the system’s readings
- touchscreen reader device, hold it near (within 1.5 inches) the sensor patch
- real-time glucose value (e.g., 102 mg/dl), a glucose trend arrow (e.g., rising), and a trend graph showing the last eight hours of data.
- Warm up 1 hour
Tools for DATA Management

[Image: A diagram with the text: HOLY CRAP!]
Drowning in your own numbers?

- Name the few ........
- CGM – is it here to help?
- 288 readings per day
- 2.016 per week
- 4.032 per 14 days
- 8.640 per month
- How to make sense and use of the data?
Understanding the data

- The delay between the BG and the CGM is:
  
  Lag between ISF and BG + Electrochemical sensor delay

*Due to the time the reaction takes and delays in signal processing that may be used to smooth the data

Traits of Successful CGM Users

- Wear it most of the time
- Check trend line often
- They “work the lag times”
  - Food lag
  - Insulin lag
  - Sensor lag
- Not afraid to **experiment**
- Not expecting **perfection**
Preparing Yourself for CGM

- Reality of glycemic control
  - At the start, expect glucose to be within target 50% or less.

- How to utilize trend data (real-time data)
- Insulin and other medication action profiles
- Pattern recognition (retrospective analysis)
- Setting targets: pre-meal 80-130, post-meal 140-180 mg/dl
Making Use of Real time data

- Immediate blood glucose and direction it is headed
- Look at the monitor 10-12 times per day
- Use the ability to forecast where your number will be over the next 30-60 minutes

**Times to look at the monitor:**
- Bedtime
- Before the meals
- After the meals
- When you feel weird
- When your device or your dog is alerting
Dose Adjustment Based on Rate Of Change

- Use anticipated glucose value or % increase or decrease based on the arrow
- Variables to consider:

<table>
<thead>
<tr>
<th>Insulin onset, peak, duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meal composition, portion size, time</td>
</tr>
<tr>
<td>Prior exercise, duration, and intensity</td>
</tr>
<tr>
<td>Medications that raise glucose</td>
</tr>
<tr>
<td>Stress level</td>
</tr>
<tr>
<td>Illness</td>
</tr>
</tbody>
</table>
## ROC (Rate Of Change) Arrows

<table>
<thead>
<tr>
<th>Glucose Change</th>
<th>Dexcom G5 Mobile</th>
<th>Abbott Navigator II</th>
<th>Medtronic 530G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose is not increasing or decreasing &gt;1 mg/dL (0.06 mmol/L) per minute</td>
<td>Glucose is changing &lt;60 mg/dL (3.3 mmol/L) per hour</td>
<td>NOT FEATURED</td>
<td></td>
</tr>
<tr>
<td>Glucose is increasing 1-2 mg/dL (0.06-0.11 mmol/L) per minute</td>
<td>Glucose is increasing 60-120 mg/dL (3.3-6.7 mmol/L) per hour</td>
<td>NOT FEATURED</td>
<td></td>
</tr>
<tr>
<td>Glucose is increasing 2-3 mg/dL (0.11-0.17 mmol/L) per minute</td>
<td>Glucose is increasing &gt;120 mg/dL (&gt;6.7 mmol/L) per hour</td>
<td>Glucose is increasing 1-2 mg/dL (0.06-0.11 mmol/L) per minute</td>
<td></td>
</tr>
<tr>
<td>Glucose is increasing &gt;3 mg/dL (0.17 mmol/L) per minute</td>
<td>NOT FEATURED</td>
<td>Glucose is increasing ≥3 mg/dL (≥0.17 mmol/L) per minute</td>
<td></td>
</tr>
<tr>
<td>Glucose is decreasing 1-2 mg/dL (0.06-0.11 mmol/L) per minute</td>
<td>Glucose is decreasing 60-120 mg/dL (3.3-6.7 mmol/L) per hour</td>
<td>NOT FEATURED</td>
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<td>Glucose is decreasing 2-3 mg/dL (0.11-0.17 mmol/L) per minute</td>
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<td>Glucose is decreasing 1-2 mg/dL (0.06-0.11 mmol/L) per minute</td>
<td></td>
</tr>
<tr>
<td>Glucose is decreasing more than 3 mg/dL (0.17 mmol/L) per minute</td>
<td>NOT FEATURED</td>
<td>Glucose is decreasing ≥3 mg/dL (≥0.17 mmol/L) per minute</td>
<td></td>
</tr>
</tbody>
</table>
Anticipated Glucose Change – Glucose Is Not Static

Anticipated BG in 30 minutes

*Example:*
BG 202
Anticipated in 30 min – 232-262 mg/dl

*Caution:*
Avoid insulin stacking 90-120 min for insulin to peak
May work for up to 4-5 hours after injection
Bolus calculator is helpful
Case Study

- ICR 1:10, meal 40 grams of CHO
- CF 1:30
- Target 120
- **Anticipated BG in 30 min =** 147 + 30 = 177
- **Meal coverage** 40 : 10 = 4 units
- Zero active insulin
- **CF:** 177 – 120 = 57 : 30 = ~ 2 units
- **Meal injection/bolus:** 4 + 2 = ~ 6 units
Upward Trends Using Percent Increase and More Tips

- **If glucose is rising** – give insulin, do not eat, wait for glucose to stabilize, eat less carbs, increase lag time between bolus and meal
- Correction doses for upward trending require trial and error
- Wait for at least 3 hrs before repeating correction

Diagnose the problem

Early administration of prandial insulin prevents reduces post-meal spikes and need for correction dose => insulin “stacking” and delayed hypoglycemia
Prandial Doses with Down Arrows

- Calculate 30 min anticipated glucose
  - $110 - (30-60) = \sim 60-70$
  - Meal 30 grams CHO
  - ICR 1:30
  - CF 1:40

- Eat first

- Don’t give insulin till BG stabilizes or starts trending up

- Consider reducing the dose or using dual/square/extended bolus
Corrective Dose with Uptrend ROC

- Anticipated BG (2-3 mg/dl increase)
- $220 + (3 \times 30) = 310$
- CF 1:30
- Last insulin bolus 2 hours ago – 4 units
- Insulin pump user – enter anticipated BG into the calculator
- MDI user – calculate the dose
- $310 - 120$ (target) $= 210 : 30 = 7$ units
- Subtract $\frac{1}{2}$ of the previous dose ($4 - 2 = 2$ units)
- $7 - 2 = 5$ units corrective dose
- Do NOT STRESS! Do THE MATH
**Downward Trends**

- if the rate is 1 mg/dl/min – do not snack till until glucose approach the low end of target value
- Consume 15 g of CHO for low alert, 10 g for projected low alert
- Repeat SBGM in 15 min
- Discourage interrupting basal rates on the pump → set up with wide swings in BGs

<table>
<thead>
<tr>
<th>Blood Glucose (mg/dL)</th>
<th>Rate of Decrease</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;70</td>
<td>&lt;1 mg/dL/min</td>
<td>Decrease prandial insulin by 25-50% or add 15 g carbohydrates</td>
</tr>
<tr>
<td>71-90</td>
<td>&gt;1 - &lt;2 mg/dL/min</td>
<td></td>
</tr>
<tr>
<td>91-110</td>
<td>&gt;2 mg/dL/min</td>
<td></td>
</tr>
</tbody>
</table>
Algorithm for RT-CGM

- Used in most of the studies

<table>
<thead>
<tr>
<th>Glucose Trend</th>
<th>Trend Arrows</th>
<th>Change in Prandial Insulin Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rising &gt; 40 mg/dl</td>
<td>(↑↑↑)</td>
<td>Increase 20%</td>
</tr>
<tr>
<td>Rising 20-40 mg/dl</td>
<td>(↑↑)</td>
<td>Increase 10%</td>
</tr>
<tr>
<td>Rising or falling by &lt;20 mg/dl</td>
<td>(↑↓)</td>
<td>No change</td>
</tr>
<tr>
<td>Glucose falling 20-40 mg/dl</td>
<td>(↓)</td>
<td>Decrease 10%</td>
</tr>
<tr>
<td>Glucose falling by &gt; 40 mg/dl</td>
<td>(↓↓↓)</td>
<td>Decrease 20%</td>
</tr>
</tbody>
</table>
Retrospective CGM Review Benefits

- Pattern recognition or No Pattern
- More complete picture for comprehensive solutions
- Basal rate testing
- Postprandial spikes
- Nocturnal patterns
- Determine and adjust TDD
- And More …..
Available CGM Downloading Programs and Reports

- **Dexcom**
  
<table>
<thead>
<tr>
<th>Program</th>
<th>Features</th>
<th>License</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dexcom Studio</td>
<td>Patterns, daily trends, hourly stats, success report</td>
<td>Free, PC only, data shareable via e-mail</td>
</tr>
<tr>
<td>Portrait on the Web</td>
<td>Trends, patterns, insights, daily trends</td>
<td>Free, Mac only</td>
</tr>
<tr>
<td>Clarity App for G5</td>
<td>Data, trends, stats, weekly, 14 day summary</td>
<td>Free, web based</td>
</tr>
<tr>
<td>Glooko</td>
<td>Modal day, stats, daily, sorted by day of the week</td>
<td>Annual fee, apple and android</td>
</tr>
<tr>
<td>Diasend</td>
<td>Modal day, day by day</td>
<td>Requires software on the computer, web based</td>
</tr>
<tr>
<td>Tidepool</td>
<td>Stats, trends, daily, weekly</td>
<td>Web based, both CGM and pump upload</td>
</tr>
</tbody>
</table>
Dexcom

- **Dexcom Studio**
- www.dexcom.com to install
- Exclusively for Dexcom data from receiver – personal and professional
- Not web-based, PC only, no Mac
- Can be shared with health care provider by via e-mail attachment of PDF or ‘patient files’

Dexcom Portrait on the Web
For Mac
www.dexcom.com/portrait to install
- **G5 Clarity App**
  - [www.clarity.dexcom.com](http://www.clarity.dexcom.com)
  - Generate 12-digit code to share with the provider
  - Cloud based data

- **Glooko**
  - Subscription for patients and clinics
  - Integrates data from glucometers, Dexcom CGM, some pumps
  - Customized reports and data sharing

- **Tandem t-connect**
  - T-slim pump G4
Dexcom

- **Diasend**
- go to diasend.com to register and download the “uploader” software
- Web-based
- Merges data from glucometers, pumps (non-Medtronic), fitness trackers, Dexcom CGM
- Day-by-day reports (under comparison tab) combines reports from CGM and other downloaded devices

- **Tidepool Blip**
- Web-based
- Multiple devices – pumps and CGM
- Invite your provider
Medtronic Carelink Personal and Pro

- **Personal**
  - Web-based
  - [https://carelink.minimed.com](https://carelink.minimed.com)
  - Mac and PC
  - Carelink USB or Contour next link meter, no software installation, combined CGM and pump data
  - Log in and password needed for healthcare team to access data

- **Carelink Pro**
  - PC-based software package
  - More detailed views but same reports now can be generated on Personal reports
When Is The Time To Review Your Download?

- Feeling frustrated with blood sugar control and variability
- “I am doing everything I can but the numbers just don’t make sense”
- Change in lifestyle or medications
- Preparation for major life events - marriage, pregnancy
- “Why is my A1C high?”
- New Year resolutions
- “I just want to be perfect”
Data Review Pre-Planning

- **Keeping records for 1-2 weeks before upload of:**
  - Timing and content of the meal
  - Duration and nature of exercise
  - Insulin doses (in case of MDIs)
  - Noteworthy events (eating out, illness, stress, menses)
  - Basal rate testing

<table>
<thead>
<tr>
<th>Basal test</th>
<th>Eat and bolus by</th>
<th>Then no calories, boluses, or exercise until</th>
<th>Evaluate sensor data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overnight</td>
<td>6 p.m.</td>
<td>7 a.m. (no night snacks)</td>
<td>10 p.m.–7 a.m.</td>
</tr>
<tr>
<td>Morning</td>
<td>11 p.m.</td>
<td>12 noon (skip breakfast)</td>
<td>7 a.m.–12 noon</td>
</tr>
<tr>
<td>Afternoon</td>
<td>8 a.m.</td>
<td>5 p.m. (skip lunch)</td>
<td>12 noon–5 p.m.</td>
</tr>
<tr>
<td>Evening</td>
<td>1 p.m.</td>
<td>10 p.m. (late dinner)</td>
<td>5 p.m.–10 p.m.</td>
</tr>
</tbody>
</table>
Statistics

- Mean sensor glucose
- SD (standard deviation) – the lower the better, indicates stability, less than 1/3 of the mean desirable

Time spent in hypo-, hyper-glycemia, and in range

GOAL <5% in low range
Identify Patterns and Combine with Pump Data

- Stop frequent lows and optimize Total Daily Dose first
Determine TDD

- Weight based option: ~0.55 units/kg OR reduction by 5-10%

? What is the 1st step?
Stop Highs

- Use this rule for consistently high blood sugars with no or very few lows (from over-correction of highs)

Increase TDD by 5% OR by 1% for each 6 mg/dl desired decrease in mean BG (example: mean BG 200 – 140 = 60 : 6 = ~ 10% increase in TDD. Current TDD is 30 units – adjusted TDD 30 + 3 = 33 units)
More Tips on TDD

- Expected/average TDD = 0.54-0.55 u/kg/day or 0.245 u/lb/day
- Actual TDD : Expected TDD = X
- X < 1 – insulin sensitive
- X = 1 – average
- X > 1 – relative insulin resistance RIR (check sites, discuss with HCP, stress, illness, “double diabetes”, puberty/adolescence/pregnancy normal)
- Example: wt 60 kg, TDD 60 units, eTDD = 60kgx0.55 = 33 units. X = 60 : 33 = 1.8 (RIR)
Basal Insulin Dose Tips

- Basal rate testing helpful
- Over 5 basal rates per day is of little benefit
- Usually similar throughout the day (0.5-0.8 u/hr or 1-1.5 u/hr)
Basal Insulin Dose Tips

- Adjust in small steps – 0.025 – 0.1 u/hr at a time
- Change 2-3 hours before BG starts to rise or fall or 5-8 hours before high or low
- Once changed, it takes 3-5 hours to see full effect

<table>
<thead>
<tr>
<th>Basal/Bolus Balance</th>
<th>Ideal Basal/Bolus Balance Differs by Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior to puberty</td>
<td>30-45% High carbs, lower counter-regulatory hormones, honeymoon phase</td>
</tr>
<tr>
<td>Puberty</td>
<td>40-55% High carbs, mid to high counter-regulatory hormones</td>
</tr>
<tr>
<td>Adult</td>
<td>45-60% Mid carbs, mid counter-regulatory hormones</td>
</tr>
<tr>
<td>Thin elderly</td>
<td>40-50% Mid carbs, lower counter-regulatory hormones</td>
</tr>
</tbody>
</table>
Case Study

- Where do I go from here?
- Are basal rates too high or too low?

Reduce basal rate starting from 7-8 am till 7-8 PM by 0.1 u/hr
Do not suspend basal rates on lows, no benefit until 60-90 minutes later

Use temporary basal rates instead => fewer follow up highs
Assessing Postprandial Glucose Peaks

- What is wrong here?
- What are the solutions?

High GI/carb meal with an early post-prandial spike, insulin right before the meal

**Solution:** Take insulin at least 15-20 minutes before the meal, the higher the blood sugar, the longer the lag time, add 5 minutes for each 40-50 points of blood sugar over 120 mg/dl

Use Super bolus
Super Bolus Concept

- Used for high carb meals or when there is no time to pre-bolus
- Moving part of the basal insulin to the bolus

Helps for foods greater than % of your weight (lbs) in grams, ie, more than 40 gr for someone weighing 160 lbs. Max carbs/meal = Wt(lb) X 0.36 to stay in control.
Does This Look Familiar and Frustrating?

- High fat/protein → late > 3 hours postprandial spikes, especially overnight
- For high protein meals: increase insulin dose by 15-20% or use 50% of grams of protein in the carb calculator and extend the bolus
For very high fat meals (>30-40 grams), consider increasing insulin dose by 30-35% and use combo/extended bolus 50/50% split over 2-3 hours.

If on injections, take 30-35% of pre-prandial dose 1 hour after the meal.
Case Study

- Patient 47 year old with DM 1 since 5 years old, 180 lbs
- CFO of the start up company, travels frequent, under a lot of stress. Previous A1C’s ranged between 6.3 and 6.8%

Basal rates:
- Mn = 1.1
- 6AM = 1.3
- 7PM = 1.5
- I:C 1:10

Active Insulin time
- 3 hours
- CF 50

TDD 55 units
- 60% basal/40% prandial

I:C ratio: wt (lbs) x 2.6 / TDD = 180 x 2.6 / 55 = ~ 8 => under-covering carbs

Eats out – steak dinner, Chinese and Thai lunch
Solutions For Our Busy CFO Patient

- Changing I:C ratio to 1:6 (calculated 1:8 + adding 25% for high fat/protein meals) at lunch and dinner
- Using extended boluses 30-50%/70-50% with 2-3 hr extension
- Possibly reducing evening basal rates

Diabetes care must be individualized
What is the Problem Here?
Duration of Insulin Action and Bolus on Board

- Vary from person to person
- Larger doses have longer action curves
- Observe glucose pattern after typical corrective dose without the meal dose
Summary

- Be realistic
- Have **low** expectations to start
- Accept that there is a learning curve
- Use situational thinking: recent, current, impending
- Choose what you consider actionable (worth doing something about)
- PLEASE BE PATIENT
- ENJOY GOOD CONTROL!
Thank you

Questions

mbasina@stanford.edu