Continuous Glucose Monitors

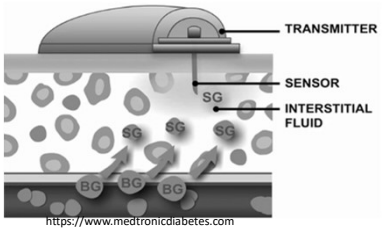
Russ Kauffman PA-C




Brief History

- History
  - 1925 – Started checking urine sugars at home (insulin 1923)
  - 1964 – First test strips for blood glucose
  - 1999 – First continuous glucose monitor
  - 2016 – First FDA-approved hybrid closed-loop system
- Organization recommendations:
  - 2010 – AACE – CGMs improve glycemic control and reduce hypoglycemia
  - 2015 – AACE / ACE Clinical Practice Guidelines:
    - CGM should be considered for patients with Type I and II diabetes on basal-bolus therapy
  - 2105 – AADE – CGM is appropriate for all patients with diabetes who are willing to wear one "regardless of age, diabetes type, or duration of diabetes"

How do they work?

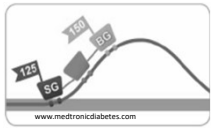


https://www.medtronicdiabetes.com

1. Sensor in interstitial fluid
2. Transmitted to transmit data
3. Receiver/Reader

- Questions:
  - Can glucose readings be correlated to blood glucose levels?
  - Lag time?
  - Laying on sensor?

Glucose in different areas



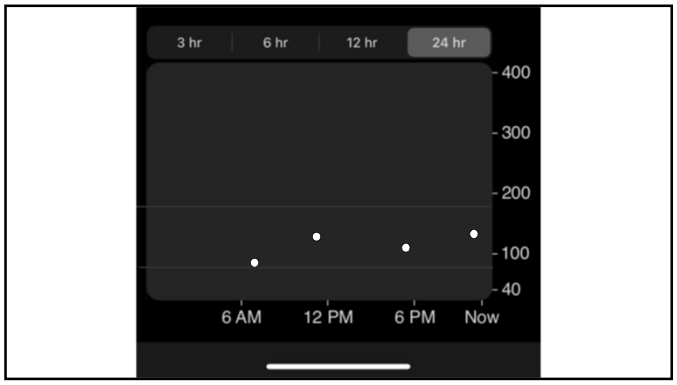
- Plasma glucose is 11% higher than whole blood glucose
  - If hematocrit is high, then
- Arterial glucose is 3-5% higher than venous glucose
  - Capillary glucose is roughly the same as arterial
- Glucose diffuses from capillary to interstitial fluid based on a concentration gradient
  - Increased blood flow → more glucose available to diffuse → decreased lag time
  - Increase cellular uptake → lower interstitial concentrations
  - Lag time (2010 study says the lag time is between 4-27 minutes)

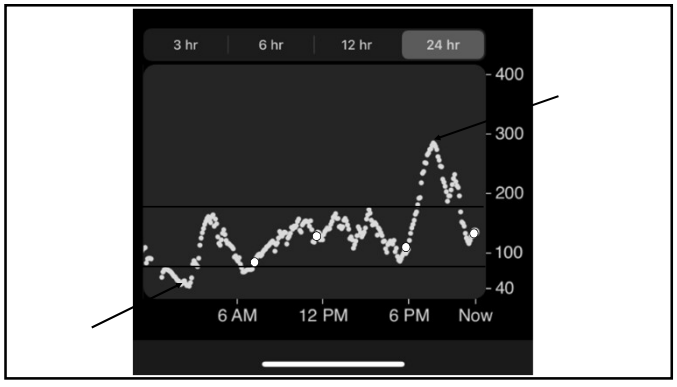
Benefits

- Huge for diabetic patients with basal-bolus management!
- Also good studies for those on oral medication management

- See trends
  - Catch more highs and lows
  - Nighttime highs and lows
- Immediate feedback
  - More than a 3-month average with A1C on how they are doing
  - See how different foods affect blood sugars
  - Feedback on the accuracy of carb counting
  - Feedback on how exercise affects blood sugars
  - Biofeedback of hyperglycemia and hypoglycemia


Back
Follow
MicahKauffman
3 mins ago
135 →
mg/dL
3 hr
6 hr
12 hr
24 hr
400
300
200
100
40
6 PM
8 PM
Now
Back
Follow
MicahKauffman
3 mins ago
135 →
mg/dL
3 hr
6 hr
12 hr
24 hr
400
300
200
100
40
6 AM
12 PM
6 PM
Now


3 hr
6 hr
12 hr
24 hr
400
300
200
100
40
6 AM
12 PM
6 PM
Now


3 hr
6 hr
12 hr
24 hr
400
300
200
100
40
6 AM
12 PM
6 PM
Now

Limitations

- Interactions
  - Vitamin C
  - Salicylic acid
  - Acetaminophen
  - Uric acid
  - L-dopa
- Dehydration
- Potential for infection or allergic reaction
- Cost (insurance)

- Accuracy
  - Lag time for decision making
  - Calibration needs?
  - Medtronic: "The system is intended to complement, not replace, information obtained from standard blood glucose monitoring devices. All therapy adjustments should be based on measurements obtained from standard blood glucose monitoring devices. All therapy adjustments should be based on measurements obtained using a home blood glucose meter and not on values provided by the system." (www.medtronicdiabetes.com)
  - FreeStyle: "If glucose alarms and readings do not match symptoms or expectations, use a fingerstick value from a blood glucose meter for treatment decisions" (www.freestyle.abbott/us-en)
  - Eversense: "Fingersticks still required for calibration and when symptoms do not match sensor glucose readings." (https://global.eversensediabetes.com/)
  - Dexcom "If your glucose alerts and readings from the G6 do not match symptoms or expectations, use a blood glucose meter to make diabetes treatment decisions." (Dexcom.com)

Impacts on Outcomes

- Randomized Clinical Trial published in 2017 and funded by Dexcom
  - 158 adults with T2DM on daily injections of insulin (Hgb A_{1C} 7.5-10%)
    - 79 in CGM group / 79 in control group (mean Hgb A_{1C} 8.5% in both groups)
  - Measured Hgb A_{1C} reduction at 24 weeks
  - Results:

	CGM Group	Control Group
Hgb A_{1C}	7.5%	7.9%
# (%) with Hgb A_{1C} <7.5	35 (45)	22 (29)
# (%) with >10% reduction in Hgb A_{1C}	44 (57)	26 (35)
# (%) with Hgb A_{1C} reduction >1%	40 (52)	25 (33)
# (%) with Hgb A_{1C} reduction >0.5%	61 (79)	38 (51)

Annals of Internal Medicine • Vol. 167 No. 6 • 19 September 2017

Impacts on Outcomes

- 2011 Study
  - 100 people with T2 DM not on prandial insulin
    - Being treated with oral medications (n=60), basal insulin (n=33), or diet/exercise alone (n=7)
    - Hgb A_{1C} >7% <12%
    - Randomized to CGM (n=50) or SMBG 4x daily (n=50)
      - CGM Group mean Hgb A_{1C} 8.4
      - SMBG Group mean Hgb A_{1C} 8.2
    - Followed for 12 weeks
  - Hgb A_{1C} Reduction Mean (± SD)
    - CGM group 1.0% (± 1.1%) – ending mean of 7.4%
    - SMBG group 0.5% (± 0.8%) – ending mean of 7.7%
  - Secondary outcomes
    - No change in weight, BP, diabetes-related stress,

J Diabetes Sci Technol 2011;5(3):668-675

Abbot

- FreeStyle Libra 2
  - Flash Glucose Monitor
  - Sensor changed every 14 days
  - FDA approved in 2020 for patients 4+ years old
  - No fingerstick calibration
  - Mean absolute relative difference (9.2%)
- FreeStyle Libra 3
  - Realtime CGM: 1-minute intervals
  - Sensor changed every 14 days
  - FDA approved in 2022 for T1/T2 DM 4+ years old
  - No fingerstick calibration
  - Mean absolute relative difference (7.9%)

https://www.freestyleprovider.abbott/us-en/freestyle-libre-3.html

Dexcom

- Dexcom G4 – 2012
- Dexcom G5 - 2016
- Dexcom G6
  - Realtime CGM: 5-minute interval
  - Sensor changed every 10 days
  - Transmitter lasts about 3 months
  - No fingerstick calibration
  - FDA approval in 2018 for diabetic patients 2+ years old
  - Mean absolute relative difference (9.0%)
  - Connects to T-slim X2 insulin pump and OmniPod 5
    - semi-closed loop systems
  - Urgent low sensor (predicts low up to 20 minutes in advance)
- Dexcom G7 – not yet FDA approved


https://www.dexcom.com/g7-ce-mark


https://www.dexcom.com/g6-cgm-system

Medtronic

- Guardian Connect (Guarding 3 sensor)
  - Realtime CGM: 5-minute interval
  - Sensor changed every 7 days
  - Rechargeable transmitter good for 1 year
  - Fingerstick calibration 3-4/day
  - FDA approval in 2018 for patients 14-75 years old
  - Mean absolute relative difference (8.7%)
  - Connects into MiniMed 770G and 630G (semi-closed loop system)
  - Predictions for highs and lows – up to 60 minutes in advance

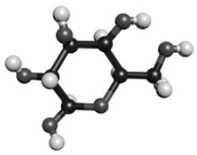

https://www.endocrinologyadvisor.com/home/topics/diabetes/insulin-pumps-cut-mortality-risk-in-diabetes/

Sensonics

- Eversense CGM - 2018
- Eversense E3
  - Realtime CGM: 5-minute intervals
  - Implanted sensor changed every 180 days
  - Removeable transmitter (backing replaced every 24 hours), needs to be recharged daily
  - No fingerstick calibration
  - FDA approved Feb 2022 for patients 18+ years old
  - Mean absolute relative difference (8.5%)

https://www.senseonics.com/

Questions ? ? ? ?



https://www.turbosquid.com/

References

- Beck, Roy W et al. "Continuous Glucose Monitoring Versus Usual Care in Patients With Type 2 Diabetes Receiving Multiple Daily Insulin Injections: A Randomized Trial." *Annals of internal medicine* 167.6 (2017): 365–. Web.
- Dexcom: https://provider.dexcom.com/products/dexcom-g6-personal-cgm-system
- Didyuk, Olesya et al. "Continuous Glucose Monitoring Devices: Past, Present, and Future Focus on the History and Evolution of Technological Innovation." *Journal of Diabetes Science and Technology* 15.3 (2021): 676–683. Web.
- Ehrhardt NM, Chellappa M, Walker MS, Fonda SJ, Vigersky RA. The Effect of Real-Time Continuous Glucose Monitoring on Glycemic Control in Patients with Type 2 Diabetes Mellitus. *Journal of Diabetes Science and Technology.* 2011;5(3):668-675. doi:10.1177/193229681100500320
- Eversense: https://www.senseonics.com/investor-relations/news-releases/2022/02-11-2022-120033959
- FreeStyle: https://www.freestyle.abbott/us-en/home.html
- Medtronic: https://www.medtronicdiabetes.com/
- Poolsup, N., Suksomboon, N., & Kyaw, A. M. (2013). Systematic review and meta-analysis of the effectiveness of continuous glucose monitoring (CGM) on glucose control in diabetes. *Diabetology & metabolic syndrome*, *5*, 39. https://doi-org.ezproxylr.med.und.edu/10.1186/1758-5996-5-39
- Solano, Laura. "Seven facts you need to know about continuous glucose monitors." Journal of the American Academy of PAs 35.9 (2022): 41-45.